Master thesis

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Mining concept for a bauxite deposit

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Finally I want to thank all the other people who encouraged me during the development of this thesis, especially to Dipl. Ing. Christoph Stranzl.

Affidavit

I declare in lieu of oath,
that I wrote this thesis
and performed the associated research myself,
using only literature cited in this volume.

Natascha Groll

Leoben, Januar 2009

Kurzfassung

Der RHI Konzern plant den Kauf einer Bauxitlagerstätte in Brasilien. Die gegenständliche Diplomarbeit zielte darauf ab, für diese Lagerstätte mögliche Konzepte für eine tagebaumäßige Gewinnung zu erstellen und die verschiedenen möglichen Abbauvarianten hinsichtlich ihrer Vor- und Nachteile zu bewerten. Die Ausgangsbasis für die Arbeit bildeten Daten über die Geometrie und Quantität der Lagerstätte. Die Datenlage kann als grob aber weitgehend ausreichend für eine Konzeptstudie betrachtet werden. Im Rahmen der Diplomarbeit unterschiedliche Abbaumethoden entwickelt und diese sodann hinsichtlich ihrer Wirtschaftlichkeit betrachtet. Weiters erfolgten Investitionsberechnungen für die Erschließung, den laufenden Betrieb sowie für den Transport zur vorgesehenen Weiterverarbeitung.

Abstract

The company RHI is planning to buy a bauxite deposit in Brazil. The aim of this thesis was to develop various concepts for mining of the bauxite deposit in an open pit and to compare the possible concepts with respect to their technical and economical advantages and disadvantages. The basis for the work was the data available about the deposit geometry and the bauxite resources. The available data is rough but sufficient in terms of developing a first open pit mining concept. In the frame of this master thesis various mining methods were planned and evaluated in economical and technical terms. The capital costs for access, infrastructure and mine development were determined as well. In addition the mine operating costs including transport to the processing plant were calculated.

Table of content

1 Task

RHI is planning to buy a bauxite deposit in Brazil. So far there are calculations done by the owner of the prospecting licence for shape and volume of the deposit. The calculations are very rough but good enough to start with the planning of the mining activities.

Within the master thesis various mining methods should be planned and evaluated. The investments for the various methods have to be shown. Additionally the mining costs of the various mining methods (incl. transport to the mineral processing plant) have to be calculated at the end of the master thesis.

The foundation of this thesis is a report named Projeto Bauxitia Refratària JARI subsequently abbreviated with Jari-report. This report was obtained in Portuguese and has been translated to German. The entire report can be found in appendix E.

The master thesis should – as the result – propose a mining method to RHI and argue the advantages and disadvantages of this method. A time schedule for the realisation should be included.

2 Summary

Within this paper 6 different mining methods, respectively mining options were developed, discussed and interpreted from an economical point of view.

The final statement of this thesis is that the mining method described as option 6, using dipper shovels and mining trucks for overburden handling and pulls shovel excavators in combination with dumpers for extraction the bauxite ore, is the one to prefer during the first 5 years of the mine's 14-year-lifetime. In year 6 an additional cost effectiveness analysis is recommended to consider a redesign of the method and the efficiency of the installation of a belt conveyor system.

3 Company Profil RHI

"RHI is a globally operating industrial group with nearly 100 production sites and service offices on five continents. The group's headquarters is based in Vienna, Austria. The RHI share is listed on the Prime Market of the Vienna Stock Exchange (ATX).

RHI employs 7,800 people worldwide; consolidated revenue amounts to about € 1.5 billion. After the restructuring of the group portfolio RHI now exclusively focuses on refractories as core competence.

RHI is the world's leading supplier of high-grade ceramic refractory products and services. The Group produces 2 million tons of raw materials and refractory products per year. As a reliable and competent partner for such key industries as iron & steel, cement, lime, glass, nonferrous, environment protection, energy, chemicals and petrochemicals, RHI has the constant objective to offer refractory systems solutions with the best price/performance ratio. Consequently, this will enable all RHI customers to add value to their production processes.

RHI is not only the market leader. RHI is also the global technology leader. The daily implementation of the company values – power of innovation, frankness and reliability – ensures continuous development and expansion of this position. The RHI brand comprises a large number of successfully established trade marks – Veitscher, Didier, Radex, Refel, Dolomite Franchi, Interstop, Monofrax –, which combine tradition with innovative technology and highest quality standards.

Speaking of tradition: the company's roots go back to the 19th century. They were characterized by the European refractories pioneers who played a decisive role in the industrial development of the company:

In 1834, Friedrich Ferdinand Didier, acquired a brick and lime firing plant near Stettin, then Prussia, and established the factory "Chamottefabrik F. Didier in Podejuch". Didier thus became one of the first manufacturers of refractory bricks in Germany.

In 1881, Carl Spaeter discovered and developed a magnesite deposit near the village of Veitsch in Styria, Austria, and started mining operations in September of the same year. Five years later, the first company to process magnesite started its business operations. Finally, in 1899, "Veitscher Magnesitwerke Aktien-Gesellschaft" was founded.

In 1908, the mining engineer Josef Hörhager discovered a magnesite deposit at Millstätter Alpe in Carinthia, Austria. A German-American, Emil Winter, acquired the mining rights and founded the "Austro-American Magnesite Company", which would later become Radex Austria.

In 1919, Attilio Franchi, a pioneer in the iron and steel industry in northern Italy, set up mining operations at Lake Iseo near Brescia (Marone, Italy) and established a production facility for sintered dolomite, "Dolomite Franchi", nearby.

In 1959/60, the research and development institute was founded in the university town of Leoben, amidst the three locations operated by Veitscher Magnesitswerke at the time. Refractories know-how and especially understanding of refractories in application processes were gradually enhanced. Today, group-wide R&D activities are concentrated at the Technology Center Leoben.

In 1987, Radex Heraklith Industriebeteiligungs AG emerged from the management buyout of General Refractories Co. Following a successful IPO, Radex-Heraklith shares were admitted to trading on the Vienna Stock Exchange. The core business unit of the globally operating group is Refractories. In 1993, the company acquired a majority holding in Dolomite Franchi.

In 1993, the two renowned Austrian companies Veitscher Magnesitwerke Aktien-Gesellschaft and Radex Austria AG also merged to form Veitsch-Radex AG, today a wholly-owned subsidiary of RHI as Veitsch-Radex GmbH & Co.

In 1995, Radex Heraklith Industriebeteiligungs AG acquired a majority holding in Didier-Werke AG and established itself as the largest refractories supplier in the world market.

In 1998, the company changed its name to RHI AG.

In 1999, the leading market position was extended further by acquiring a majority holding in the US company Global Industrial Technologies Inc. and the integration of their refractories subsidiary Harbison-Walker.

Economic problems in North America, triggered by a recession, the US steel crisis and especially the soaring number of asbestos-related claims, required a radical restructuring concept which, among other things, entailed the complete deconsolidation of all US investments by the end of the year 2001. The objective was to break away from less profitable dealings and to concentrate activities in the refractory sector - RHI's core business. Therefore the entire Engineering Group was dispensed with in 2002. The reorientation of the group and the focusing on the refractory division was finally completed with the sale of the insulation sector Heraklith in 2006.

By taking over the renowned refractory companies Monofrax (USA) and Clasil (India) at the end of 2006 a strategically important step had been taken towards the further development of RHI's leading position as a global full-line supplier of refractories.

Today, RHI operates 34 production facilities on four continents. Production at the individual locations is geared to product groups and the demands of modern logistics. Production procedures are optimized through continuous comprehensive investments, thus ensuring the production of high-quality products and systems based on state-of-the-art technologies. The products and production methods of RHI meet all essential internationally recognized quality and environmental standards worldwide.

The technology leadership of RHI is based on established, successful research and development activities which are centered at the Technology Center in Leoben, Austria. At the Technology Center, a highly motivated, competent and creative team of international experts works on product innovations and developments in close contact with research institutes in Austria and abroad, internationally renowned universities and important key customers, networked via common competence centers and in nationally and internationally funded projects. Moreover, within its wide range of functions (quality management, logistics, procurement, raw materials), the Technology Center supports the sales and marketing departments. Sales and Marketing employ technically experienced, highly qualified experts who can operate worldwide and, as central link between customer requirements and highly specialized products and systems, act as an important strategic interface. A total of more than 200 refractory specialists work in Leoben.

The highest quality standards apply not only to all products but also to the services of RHI. Technical know-how and international orientation of the employees, state-of-the-art machinery and a tight global sales and service network guarantee all partners quick availability, best possible service and optimal product application. Partnership cooperation also requires comprehensive on-site support of customers. For this purpose RHI has a large number of refractory experts who do not only think in terms of the group's product range but also in terms of the customers' processes. Having been active and employed throughout the world, these RHI service technicians have acquired extensive experience and the competence to solve problems.

Close cooperation and the jointly developed and realized projects between RHI and its customers build mutual trust and enable new and efficient forms of partnership. Full Line Service is the furthest-reaching partnership. "Full Line Service" means efficient and specific refractories management on site, an outsourcing concept, which guarantees the customers optimized costs in the value-added chain and gives them the opportunity to concentrate on their own core competencies. Full Line Service solutions include the development of economical lining concepts, the selection and supply of the best suited refractory products, installation, servicing during operations, necessary infrastructure (machines, stock-keeping), efficient logistics concept and provision of qualified staff." [12]

4 History of Bauxite mining, world wide

"The extraction of bauxite started in France in the eighteen-fifties, mainly for the production of aluminous chemicals. Even with the development of the aluminium industry, world production remained throughout the 19th century at some thousand tons per annum. It increased steadily in the first decade of the 20th century and reached its first peak during World War I, in 1917. The end of the war brought a strong drop in demand for bauxite, from which production recovered slowly, to reach a second peak in 1929. The years of great economic depression produced a new decrease with a minimum in 1932. A slow increase followed as World War II approached and a new peak was reached during the war, in 1943. World production dropped again after the end of the war, but began to rise steadily from 1946, the growth lasting until 1980. The average annual growth was 2.5 Mt during production seems to have stabilized at around 86 Mt, with both annual increases and decreases. Further development cannot be expected before the nineties.

We have indicated not only the annual world production, but also for each year the three leading bauxite-producing countries. France was the leading producer from the beginning until 1914. Bauxite mining started in the USA, in Arkansas, in 1896 and production there soon reached second place after France. A now completely forgotten producer, Northern Ireland (U.K.), occupied the third place before World War I; bauxite production had started there as early as 1873 (Bracewell, 1962).

World War I saw a change in the order of the main bauxite-producing countries, as the USA considerably increased its production and took the lead from 1915 to 1923. A new and important bauxite-producing country appeared in 1917; Guyana, started production in 1922 and reached the third place behind France and the USA. Suriname started production in 1922 and reached the third place in 1929. Karst-bauxite production started in Yugoslavia at the end of World War I and in Hungary in 1926. Production in Hungary increased considerably and the country was among the leading bauxite-producing countries from 1934 to 1942.

The demands for aluminium during World War II propelled the production of the USA to new peaks and to the first place, which it held from 1941 to 1946, followed by

Suriname and Guyana. The production of the European countries diminished considerably as a result of war damage.

After the end of the war, Suriname became the leading producer from 1947 to 1956. A new country started producing karst bauxite as from 1952; Jamaica. A spectacular rise in production brought that island to first place in 1957, a position that it occupied until 1970. Another major change came with the rise of bauxite production in Australia, where mining started in 1927. However, it remained at a level of a few thousand tons until 1962, when mining started in the newly discovered large deposits in the north and west of the country. Production increased rapidly and Australia took the lead in 1971, a position that it occupies up to the present. With 32,2 Mt produced (calculated on a crude-ore basis), Australia provided 37% of the world production in 1985.

Two further new bauxite-producing countries of major importance should be mentioned: Guinea and Brazil. Production started in Guinea in the forties, increasing slowly during the fifties and sixties and the country reached third place in 1976 and second place in 1981. Bauxite mining started in Brazil in 1936, but it remained at a low level until the discovery of the large deposits in the Amazon Basin. Brazil's production increased considerably in the eighties and in 1985 Brazil was the fourth world producer.

The above outline development demonstrates how the role of the European countries and the USA decreased in favour of the tropical and subtropical territories.

The 1987 production values, based on the data of "World Metals Statistics", are presented. The values for China and the USSR are estimated. In the case of USSR, we have taken into account the estimated proportion of nepheline concentrate and alunite-ore production, as indicated by Patterson et al. (1986). The original values of the "World Metals Statistics" have been corrected correspondingly. The value for China includes the ca. 200.000 tons of bauxite produced for refractories. For Australia the production value has been recalculated to a crude-ore basis.

Although twenty-two countries took part in the 1985 world production, the bulk of the bauxite came from three countries – Australia, Guinea and Jamaica – furnishing together more than 60% of the world production.

We have also calculated the sum of the bauxite production by the different countries since the beginning of their production until the end of 1987. The results are presented. Almost 2000 million tons have been extracted since the beginning of bauxite mining. This enormous quantity represents only 5% of the bauxite reserves or 4% of the total world bauxite resources. A further instructive point in this table is that countries that became leading producers only after the sixties, such as Australia, Jamaica and Guinea, have already produced more bauxite than ancient producing countries such as the USA, France, Guyana and Suriname. On the other hand, countries like Hungary, Greece and Yugoslavia have produced much bauxite in relation to their small area.

In some countries, e.g., Austria, Dominican Republic, Federal Republic of Germany, Haiti, and Northern Ireland, the production seems to have ended definitively.

In others, like Italy, it came to a temporary stop, but will be resumed as a result of new discoveries. It is very probable that in the coming decade Cameroon, Venezuela and Vietnam will become bauxite-producing countries. The appearance of other countries as smaller producers may be expected.

The majority of the bauxite has been produced by open-pit mining. Underground mining started in France and the USA. Underground mining developed since the twenties in Hungary, Yugoslavia, Greece, Italy, China, the USSR, Romania, Austria, Northern Ireland and Spain. At present, underground mining accounts for less than 10% of the world production. Higher production costs, underground-water hazards and environmental problems (mainly in the industrialized countries) represent strong limitations on underground bauxite mining. It remains competitive only where the deposits are close to an established aluminium industry and where a given country is far from the main bauxite-producing countries. Open-pit mining is considerably cheaper, this is the reason why even buried bauxite deposits are operated with open-pit methods, with stripping rations up to 13:1; e.g., Guyana, Suriname, Amazon, Basin, etc.

The further development of bauxite mining depends in the first place on the future demands of the world aluminium industry, and not on the present mining capacities, as these capacities can be increased in the main producing areas without substantial capital investments. However, the establishment of completely new mining centres in remote tropical areas is a very costly business and it risks exercising a negative pressure on world Al prices. Unfortunately, ambitions towards autarky in some countries seem to disregard the world price and supply situation.

The main producers of refractory- and chemical-grade bauxites are Guyana, Suriname and the People's Republic of China. Abrasive-grade bauxite is produced in Australia (Weipa), Suriname and Guinea. Other countries producing bauxite for non-metallurgical purposes are the USSR, Greece, Yugoslavia, France, Hungary, Turkey, and the USA. The world production of special-grade bauxite for abrasives, cement, chemicals, refractories and other non-metallurgical purposes is at present in the range of 2 to 3 Mt per year, according to our estimate and data from Everts."[7]

The world production of bauxite in the year 2006 was 178.000.000 tons.

Bauxite production 2006 [t]	
Australia	62.307.000
Brazil	21.000.000
China	21.000.000
Guinea	15.200.000
Jamaica	14.851.000
India	12.732.000
Russia	6.600.000
Venezuela	5.500.000
Kazakhstan	4.800.000
Suriname	4.750.000
Greece	2.450.000
Indonesia	1.502.000
Guyana	1.400.000

Bauxite reserves 2006 [t]	
Guinea	8.600.000.000
Australia	7.900.000.000
Brazil	2.500.000.000
Jamaica	2.500.000.000
China	2.300.000.000
India	1.400.000.000
Guyana	900.000.000
Greece	650.000.000
Suriname	600.000.000
Kazakhstan	450.000.000
Venezuela	350.000.000
Russia	250.000.000

[10]

5 General Geology Bauxite

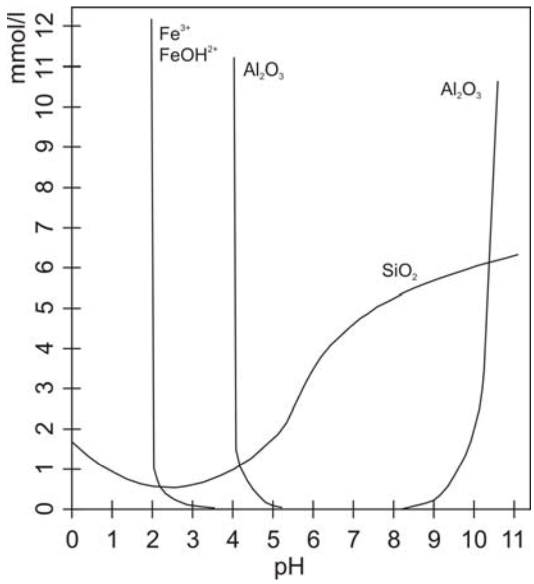
"Classification

The main classification of bauxites used by Patterson et al (1986) is the division into two major types; the karst bauxites and laterite-types. Laterite-types form mostly deposits with a great extend and a layered shape, whereas the karst-deposits are mainly restricted to karst-depressions. But there are also some deposits with a worldwide distribution which consist of transported material, where the parent rocks are unknown, and so the division into laterite-type for silicate rocks and karst-type for carbonatic rocks, used by Patterson et al (1986) does not work any more. There are many classifications used, but another one should be mentioned; the classification based on shapes and occurrences, used by Harder and Greig (1960). They divided into three types, Blanket deposits, Interlayer deposits and Pocket deposits. The Blanket deposits occur as layers near the surface, as residuals without transportation. Most of them occur on plateaus with long lasting geological stability. The second group of Interlayer deposits are mainly remnants of previous Blanket deposits which were covered by younger rocks. Due to there genesis they often show discontinuous shapes with separated beds and lenses. The Pocket deposits can be likened to the karst-deposits, described before, as they occur in depressions formed in carbonatic rocks.

Origin

Many theories have been proposed for the origin of bauxites, but the mostly agreed one is the thesis of weathering under conditions where alumina is detained and the other elements are favourable leached. The principal agents for chemical weathering are indicated by Patterson et al (1986), as descending surface water together with organic constituents, influencing the water-chemistry. Those waters leach the soluble elements and add hydroxyl groups, oxygen or carbon dioxide. The mechanical weathering is caused, according to Patterson et al (1986), by the interaction of penetrating roots, breaking the structures and shrinking due to solar energy. Similar processes are named by P.J. Ball & R.J. Gilkes (1987) as isovolumetric weathering, where the primary minerals were replaced by aggregates of secondary minerals, whereas the bauxites are generated in well-drained morphological positions of the Pocos de Caldas bauxite deposits. For the Mount Saddleback bauxite deposit Valeton I. & Schumann A (1997) describe the isovolumetrically weathering of a dense alkaline parent rock to "spongy" bauxite.

The illustration of the solubility of the main bauxite constituents (Harders & Kienow; 1960) describes the conditions best, where alumina is a remnant and the other elements are preferentially leached away. When the pH-value of the penetrating water is compared to the solubility, you may see that SiO_2 is under acidic conditions poorly, but in contact to basic solutions, well soluble. Al_2O_3 shows an amphoteric behaviour, as it is under strongly acidic and strongly basic conditions, excellent soluble but between pH five and eight practically insoluble. The Fe_2O_3 components are only leached under strongly acidic conditions, in a pH region below two, which causes the strong impact of the parental material on the iron contents.



The alkali and alkaline earth metals have a much higher solubility than the three mentioned elements and therefore they are leached earlier. Kronberg et al. (1982) as well as Sen & Guha (1987) give some weathering reactions from feldspar to gibbsite, as follows:

$4KAlSi_3O_8 + 22H_2O \rightarrow 4K^+ + 4OH^- + 8Si(OH)_{4aq} + Al_4Si_4O_{10}(OH)_8$

K-feldspar kaolinite

$Al_4Si_4O_{10}(OH)_8 + 10H_2O \rightarrow 4Al(OH)_3 + 4Si(OH)_{4aq}$

kaolinite gibbsite

The differences in the molar volumes between K-feldspar and gibbsite are varying around a loss of 70 percent (Kronberg et al., 1982), so isovolumetrically weathering (Valeton I. & Schumann A, 1997) may take place due to the obtained, high porosity, if no compaction occurs.

Parent material

Bauxite deposits may be derived, under appropriate conditions, from nearly each kind of rock containing alumina. Two examples for extraordinary low alumina concentrations of the parent rocks may be given. The first one for bauxites with silicic parent material is the deposit of Weipa, described by Loughnan & Bayliss (1965). The kaolinitic sandstones, overlain by the bauxite horizons only contain around 4 percent of alumina but the bauxite zone, described as concretionary laterite type varies in thickness up to 15 feet (ca. 4.6 m). The second example is described by MacLean et al. (1997) for the karst bauxites of the Olmedo bauxite deposits of Sardinia, where 25 to 50 m of argillaceous limestone was required to form only one meter of pure alumina of the bauxite zone. To describe the variety a list of parent materials of the worldwide bauxite deposits may be delineated: greenstone, kaolinitic sandstones, alkaline magmatic rocks, tinguaite / phonolithe, mottled clay, schistose sandstones, schistous clay with some incorporated dolerites, basalt, sandstone, charnockites, marls and carbonates, sediments derived from mafic rocks, kaolin deposits and arkosic sand, andesite and andesitic tuff, granulites and feldspathic gneisses.

Element behaviour under weathering conditions

As discussed before, the weathering action causes on the one hand strong depletion in soluble elements and a relative enrichment in the dissoluble ones. Valeton and Schumann (1997) point out a strong depletion of Mg, Ca, Na, K., Si, Ni, Co, Cu, Zn, Rb, Ba, Sr, Y and REE for the Pocos de Caldas bauxite deposits Kronberg et al., (1982) observed for Paragominas bauxite deposits, enrichment for B, Sc, Zr, Nb, Sn, Sb, I, Hf and Th and differences in concentration patterns for some refractory metals (Al, Ti, Zr, Hf, etc.) which lead to the suggestion that some (e.g., Ti, Zr, Hf) of these metals may be participating in biological reactions. MacLean et al. (1997) showed with correlation plots, that Al, Ti, Zr, Nb, Th, Cr and V were immobile and mass changes pointed to large net removal of Si, Mg and K from the system."[15]

Bauxite minerals:

Mineral:	Chem. formula:	[%] Al_2O_3 theor.:	Density [g/cm^3]:
Gibbsit	γ.-$Al(OH)_3$	65	2,4
Böhmit	γ-AlOOH	85	3,0
Diaspor	α-AlOOH	85	3,4
Alunit	$KAl_3[(OH)_6/(SO_4)_2]$	37	2,7
Nephelin	$KNa_3[AlSiO_4]_4$	36	2,6

Bauxite (named after Les Baux in southern France) is a rock formed of following minerals in varying proportions: gibbsite, diaspore, boehmite, caolinite, quartz, hematite, goethite, rutile and anatase. Alunite and nepheline can be sweeters for apatite mining. During the leaching process according to the Bayer-Process the gibbsite rich bauxite is readily soluble, the diaspore rich bauxite on the other hand is of low solubility.

About 95% of the bauxite mined world wide is used for production of metallic aluminium. The rest is goes into the refractory, abrasives, cement, ceramics, glass or chemical industry.

In the Earth's crust, aluminium is the most abundant (8% by weight) metallic element and the third most abundant of all elements but mineable deposits occur rarely. The enrichment happens through alteration under humid-tropical conditions.
Alumosilicates (primary Al2O3 carrier, e.g.: feldspar) form kaolinite and later on colloidal aluminium hydroxide and colloidal silica.

$$4KAlSi_3O_8 + 22H_2O \rightarrow 4K^+ + 4OH^- + 8Si(OH)_{4aq} + Al_4Si_4O_{10}(OH)_8$$

(K-feldspar) (kaolinite)

$$Al_4Si_4O_{10}(OH)_8 + 10H_2O \rightarrow 4Al(OH)_3 + 4Si(OH)_{4aq}$$

(kaolinite) (gibbsite)

Changing tropic climate conditions are necessary, because rising ground water is alkaline during dry season and dissolves SiO_2. During the rain season the falling ground water level conducts the SiO_2 and the readily soluble alkali Na, K and Ca. The forming of bauxite requires low pH/Eh conditions, to gain a low grade of iron. In the end diagenesis forms out of colloidal aluminium hydroxide the minerals: gibbsite, boehmite and diaspore.

There are 3 major types of bauxite deposits:

- Tikhvin Type: This type of deposit consists of so called transferred bauxite embedded in aged sediments. These appearances can be found in former courses of rivers, i.e. in the area of the Moscow Basin. The ore is composed of gibbsite, boehmite, caolinite and calcite; characteristic values of Al_2O_3 are between 35% and 49%, SiO_2 can reach about 18%. Approximately 0, 5% of the known reserves rank among the Tikhvin type of deposits.

- Karst Bauxite: Karst bauxite is a matter of fillings of karstdepressions like dolines, caves and canyons, which result in very irregular boundaries. Host rocks are karst-able carbonates. The bauxite development in karst depressions is associated with aeolian and fluviatile sedimentation of material, unlike discussed in former theories about being an insoluble residuum of carbonates. In terms of mineralogy this type of bauxite is formed of boehmite and diaspore. Representative examples occur around the Mediterranean Sea, as well as Hungary and Romania, in Caribbean (Jamaica), Ural, Vietnam and China. Bauxite appearances in Austria are also part of this type of deposits. Karst bauxite represents about 9, 5 % of the know bauxite deposits world wide.

- Lateritic bauxite: The third type of bauxite occurs as vast surface areas and stratiform formations with a thickness from some meters to several tens of meters (Figure 1). In theory, if the needed climate conditions prevail, the bauxite creation is still in progress. An important criterion is the presence of an Al_2O_3 bearing host rock. A very frequent characteristic of rock like: granite, basalt, dolerite, sandstone, shale, phyllite, greenschist, gneiss, etc. In the Jari region the source rock was unconsolidated sediment.

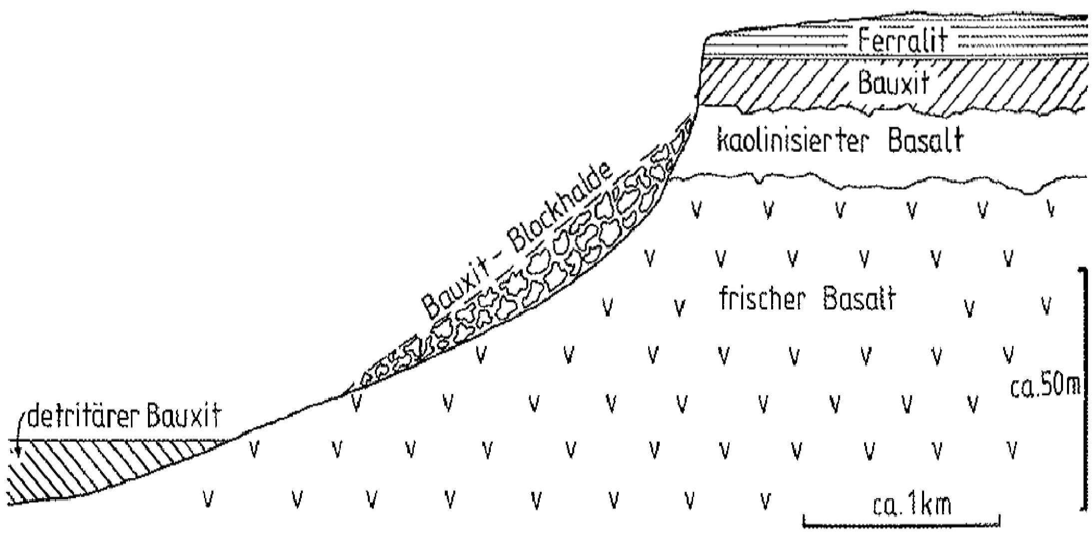


Figure 1: Lateritic Bauxite in the hanging wall of a volcanic source rock

The geochemical character of the source rock can be found in the formed bauxite; i.e. Indian or western-Australian bauxites show high grades if Fe2O3 and TiO2, which can be traced back to volcanic sources. Possible adjoining rocks are laterite, (kaolinite) clay, (smectite) clay and weathered source rocks. Caused by erosion bauxite often appear as discontinuous plateaus. At the edges of the plateaus relocated bauxite can occur, which normally is aligned with much lower qualities. Lateritic bauxite deposits can be found in India, Australia, Guinea, Ghana, Sierra Leone, Surinam, Guyana and Brazil. The remaining 90% of bauxite deposits are represented by this type. [13]

6 Deposit

6.1 Geographical position

Figure 2: Geographical map of Brazil

In general the known bauxite deposits extend over the states of Pará and Amapá. The deposit of Serra do Almerim is located in the state of Pará only.

As shown in Figure 2 the region is located in the estuary of the Amazon River, some degrees south of the equator and can be reached by plane from Belém in about 1, 5 hours. The area covered with tropical rain forest and shows just a minor relief.

Plateaus and table lands on an average elevation of 240m to 250m are the topographic characteristics of this area.

Important aspects are the weather conditions which consist of rainy and dry seasons. The temperature is typically for the rain forest and is always between 22°C and 34°C degrees. The periodic precipitation chart of the Town of Monte Dourado, shown in Figure 3 was taken to evaluate the conditions at the site. As you can see there is a dry season from July to December, followed by a period of heavy rainfalls from January until June. Local flooding triggered by these rainfalls often complicate the transportation of man, equipment and supply material on dirt roads as well as on the uncommon highways. Even under dry conditions there is still the risk of accidents caused by line-of-sight obstruction due to heavy dust formation. In summary the trip from Monte Dourado to the site, which is a one hour’s drive under perfect conditions, can pass into extreme delays or even into total cancellation.

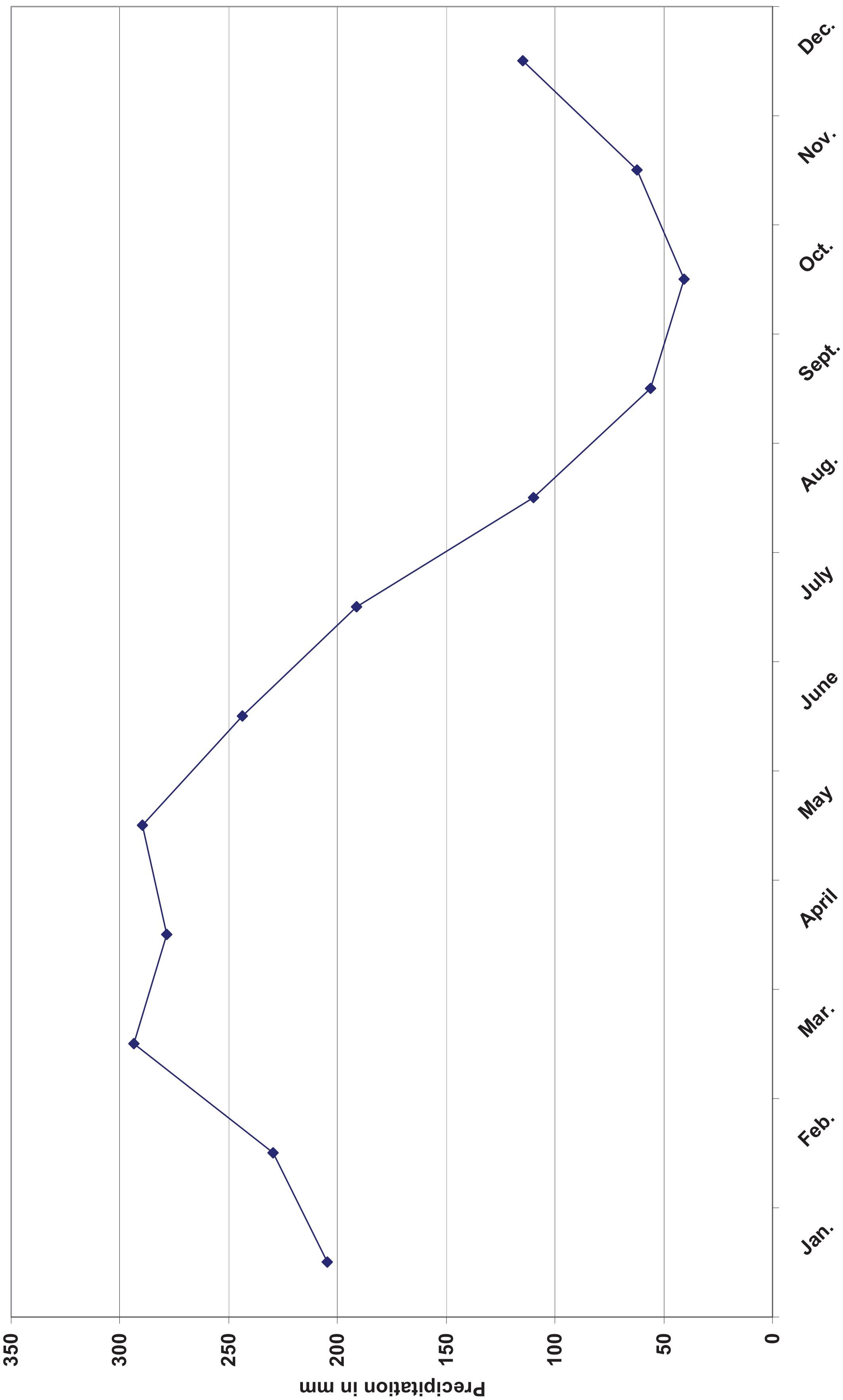


Figure 3: Precipitation chart of the Town of Monte Dourado

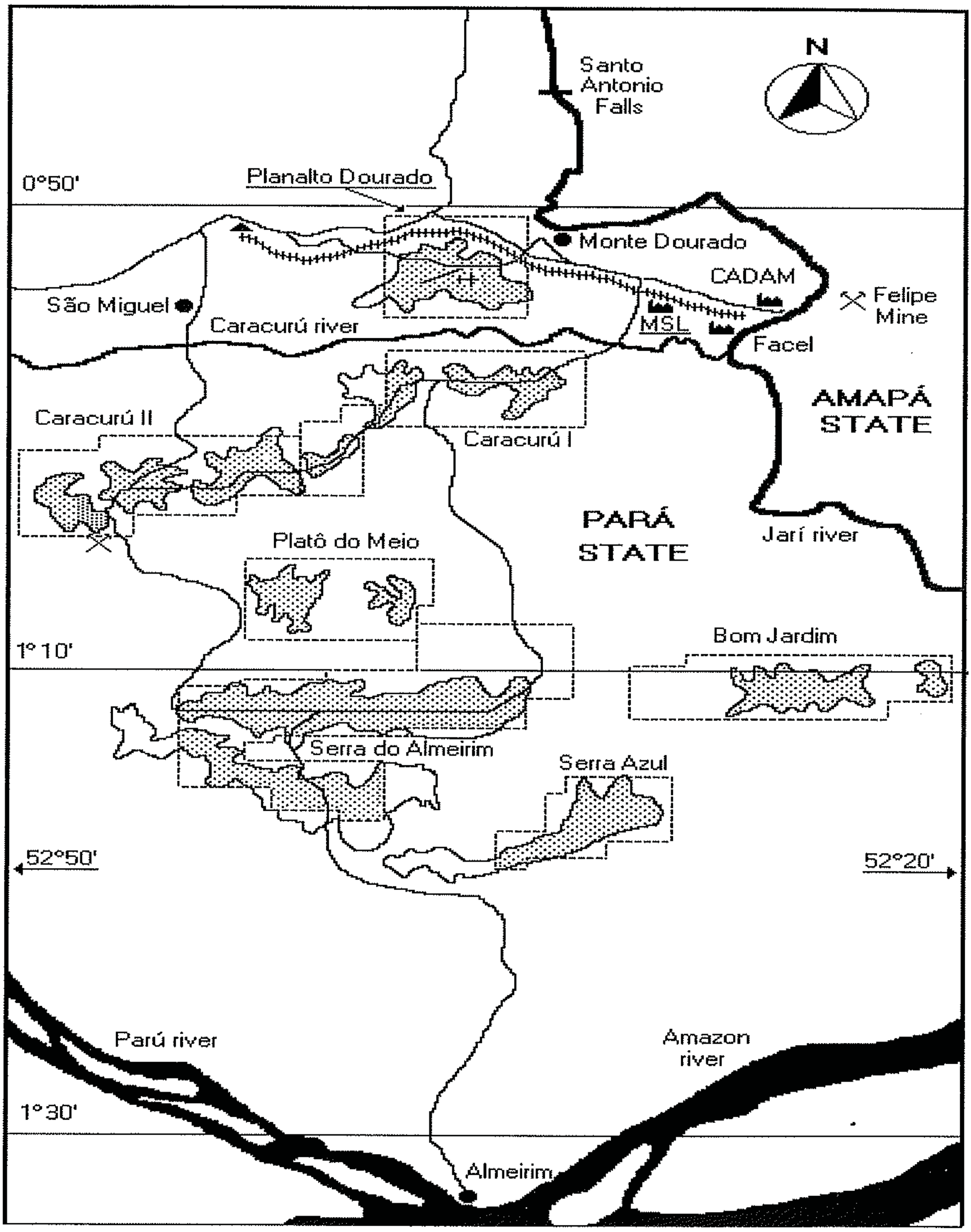


Figure 4: Geographical map of Para

Many different mining companies acquired a mining licence in the considered area. Most of them are for refractory bauxite but there are some for aluminium or kaolin as well.

In the following the licence holding companies in the area of Almeirim in addition with relevant information are listed:

- Msl Minerais S A

DNPM Nr.	first entry	responsible person	commodity	area [ha]
806.566/1971	13.05.1971		bauxite	10.000,00
850.290/1980	25.02.1980	Alves,carlos Alberto	bauxite	4.431,78
850.354/1979	18.06.1979	Jaci Ferreira de Sousa	bauxite	2.586,67
850.440/1979	29.06.1979	Jaci Ferreira de Sousa	bauxite	7.970,00

Table 1: Mining licenses of Msl Minerais S A

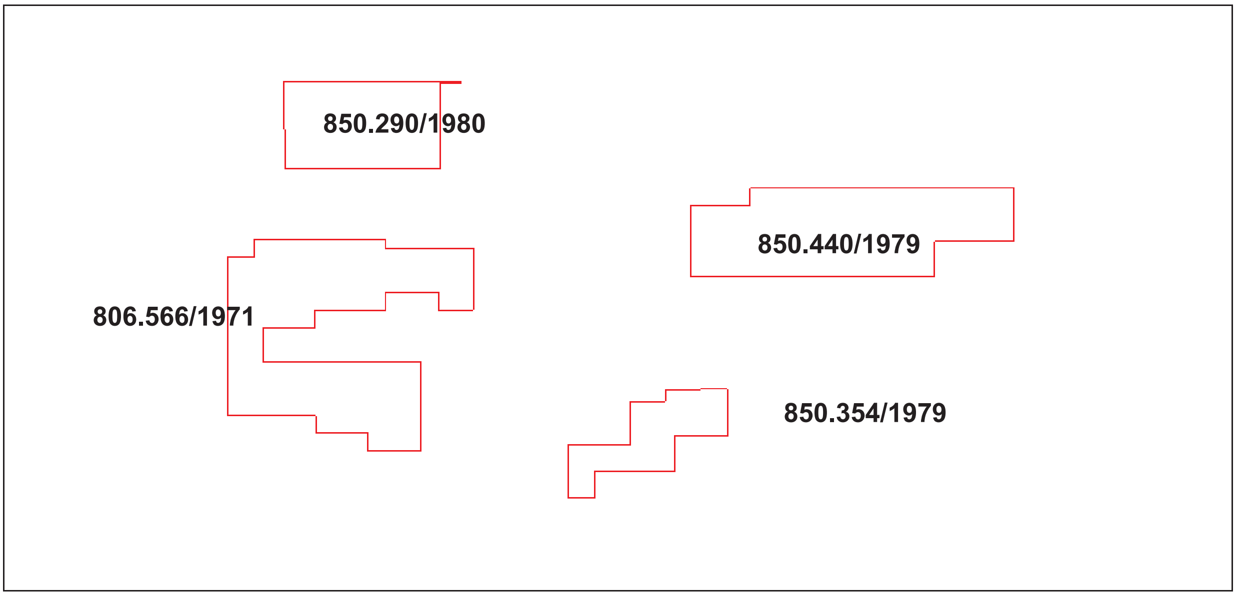


Figure 5: Map of the mining licenses of Msl Minerais S A

- Orsa Produtos e Materiais de Mineração Ltda.

DNPM Nr.	first entry	responsible person	commodity	area [ha]
850.134/2007	26.02.2007	Alcidio Pinheiro Ribeiro	bauxite, kaolinite	1.946,90
850.302/2003	11.07.2003	Alcidio Pinheiro Ribeiro	bauxite, kaolinite	9.609,99
850.806/2004	16.12.2004	Alcidio Pinheiro Ribeiro	bauxite, kaolinite	3.475,00
850.808/2004	16.12.2004	Alcidio Pinheiro Ribeiro	bauxite, kaolinite	8.843,91
850.809/2004	16.12.2004	Alcidio Pinheiro Ribeiro	bauxite, kaolinite	703,47

Table 2: Mining licenses of Orsa Produtos e Meteriais de Mineracao Ltda.

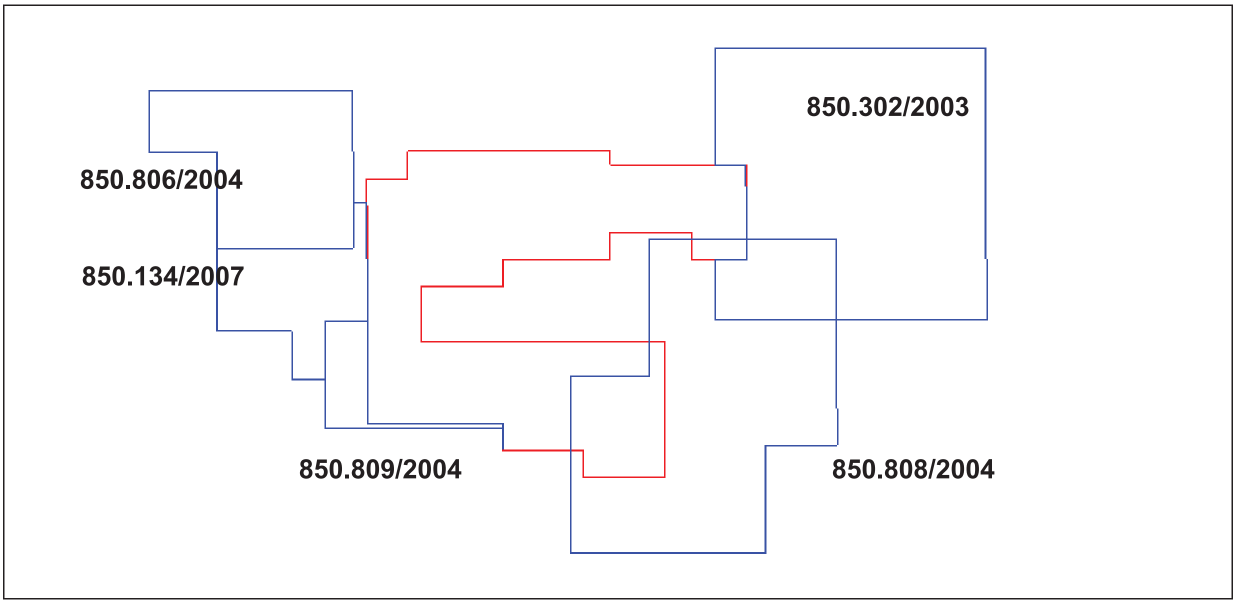


Figure 6: Map of the mining licenses of Orsa Produtos e Meteriais de Mineracao Ltda.

The exploration shafts and the bigger part of the drill-holes done by Orsa are situated in 850.302/2003.

- Jari Celulose S.a.

DNPM Nr.	first entry	responsible person	commodity	area [ha]
850.129/2008	29.02.2008	Samuel Ferreira Setton	construction material	50,00
850.130/2008	29.02.2008	Samuel Ferreira Setton	construction material	46,55
850.321/2003	18.07.2003	Alcidio Pinheiro Ribeiro	construction material	50,00
850.349/2007	28.05.2007	Samuel Ferreira Setton	construction material	50,00
850.350/2007	28.05.2007	Samuel Ferreira Setton	construction material	50,00

Table 3: Mining licenses of Jari Celulose S.a.

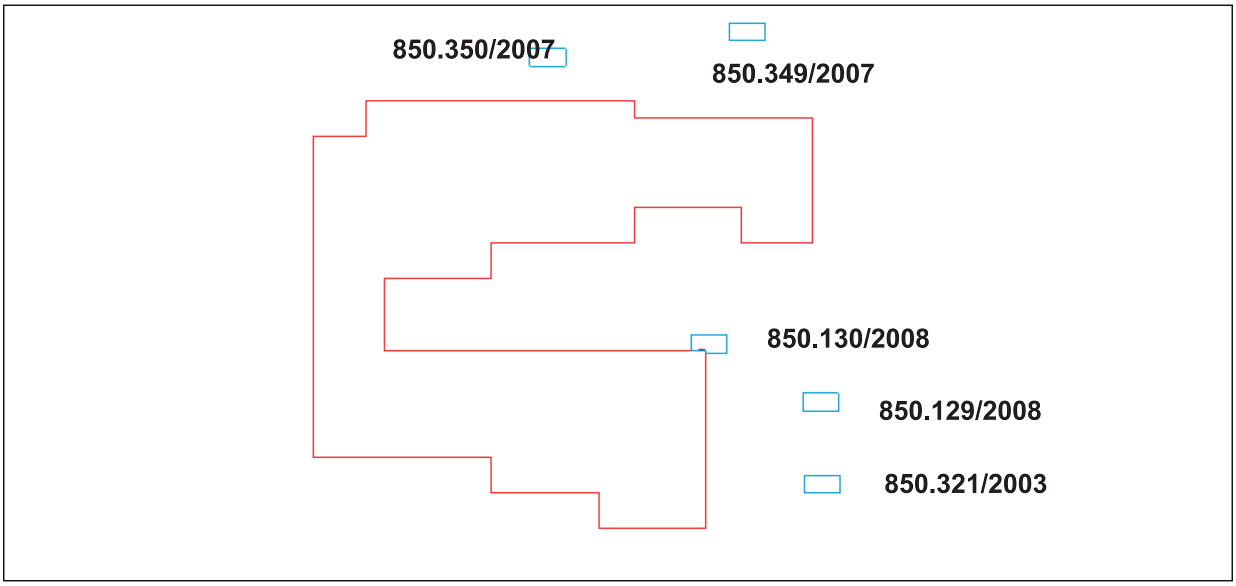


Figure 7: Map of the mining licenses of Jari Celulose S.a.

- Keystone Ltda.

DNPM Nr.	first entry	responsible person	commodity	area [ha]
850.243/2004	07.06.2004	Helio Terutoshi Ikeda	bauxite	9.682,29

Table 4: Mining licenses of Keystone Ltda.

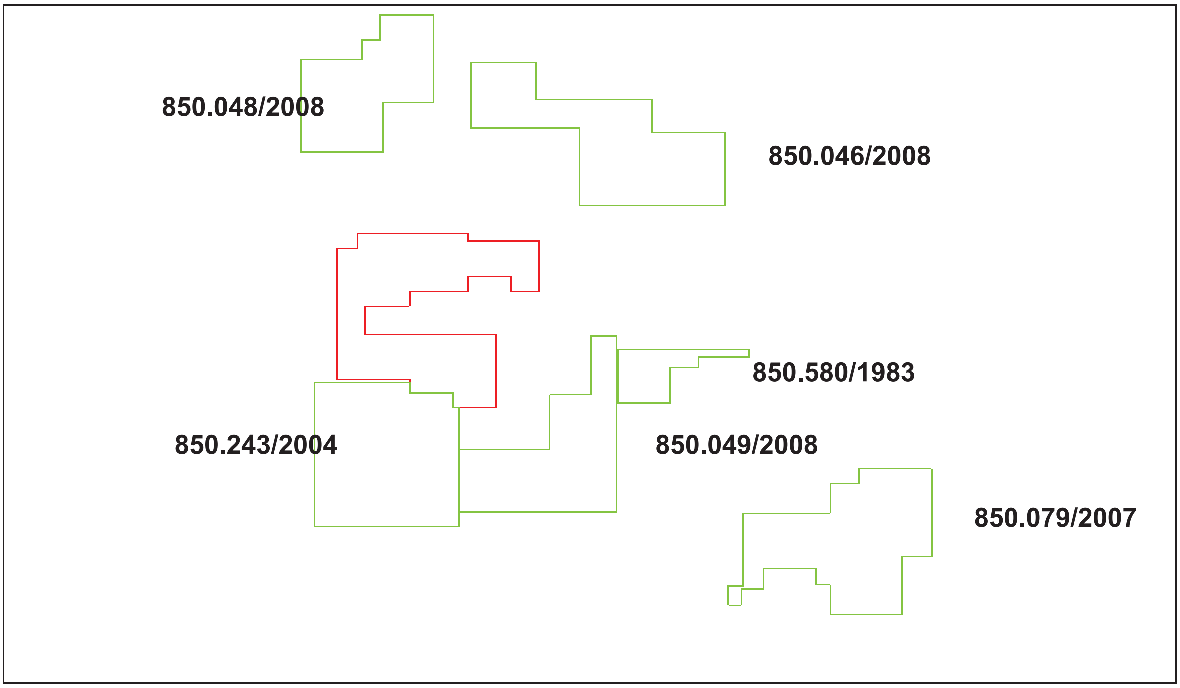


Figure 8: Map of the mining licenses of Keystone Ltda.

- Metal Data S.a

DNPM Nr.	first entry	responsible person	commodity	area [ha]
850.046/2008	24.01.2008	Aldo Ferreira Lopes Filho	aluminum ore	8.775,00
850.048/2008	24.01.2008	Aldo Ferreira Lopes Filho	aluminum ore	5.935,00
850.049/2008	24.01.2008	Aldo Ferreira Lopes Filho	aluminum ore	7.155,00

Table 5: Mining licenses of Metal Data S.a

- Mineração Tacuma Ltda

DNPM Nr.	first entry	responsible person	commodity	area [ha]
850.580/1983	14.06.1983	Porto,mario Olinto F	aluminum	1.726,37

Table 6: Mining licenses of Mineração Tacuma Ltda

- Rio Tinto Desenvolvimentos Minerais Ltda

DNPM Nr.	first entry	responsible person	commodity	area [ha]
850.079/2007	31.01.2007	Zander Leite Castro	aluminum ore	8.737,53

Table 7: Mining licenses of Rio Tinto Desenvolvimentos Minerais Ltda

Further license areas of Msl Minerais S A in the region:

DNPM Nr.	first entry	responsible person	commodity	area [ha]
808.116/1973	11.06.1973		bauxite	5.687,50
810.413/1974	27.08.1974		bauxite	5.936,37
850.470/1979	11.07.1979		bauxite	7.225,00
950.121/1988	17.06.1988	Carlos Babsky Neves	bauxite	???

Table 8: Mining licenses of Msl Minerais S A

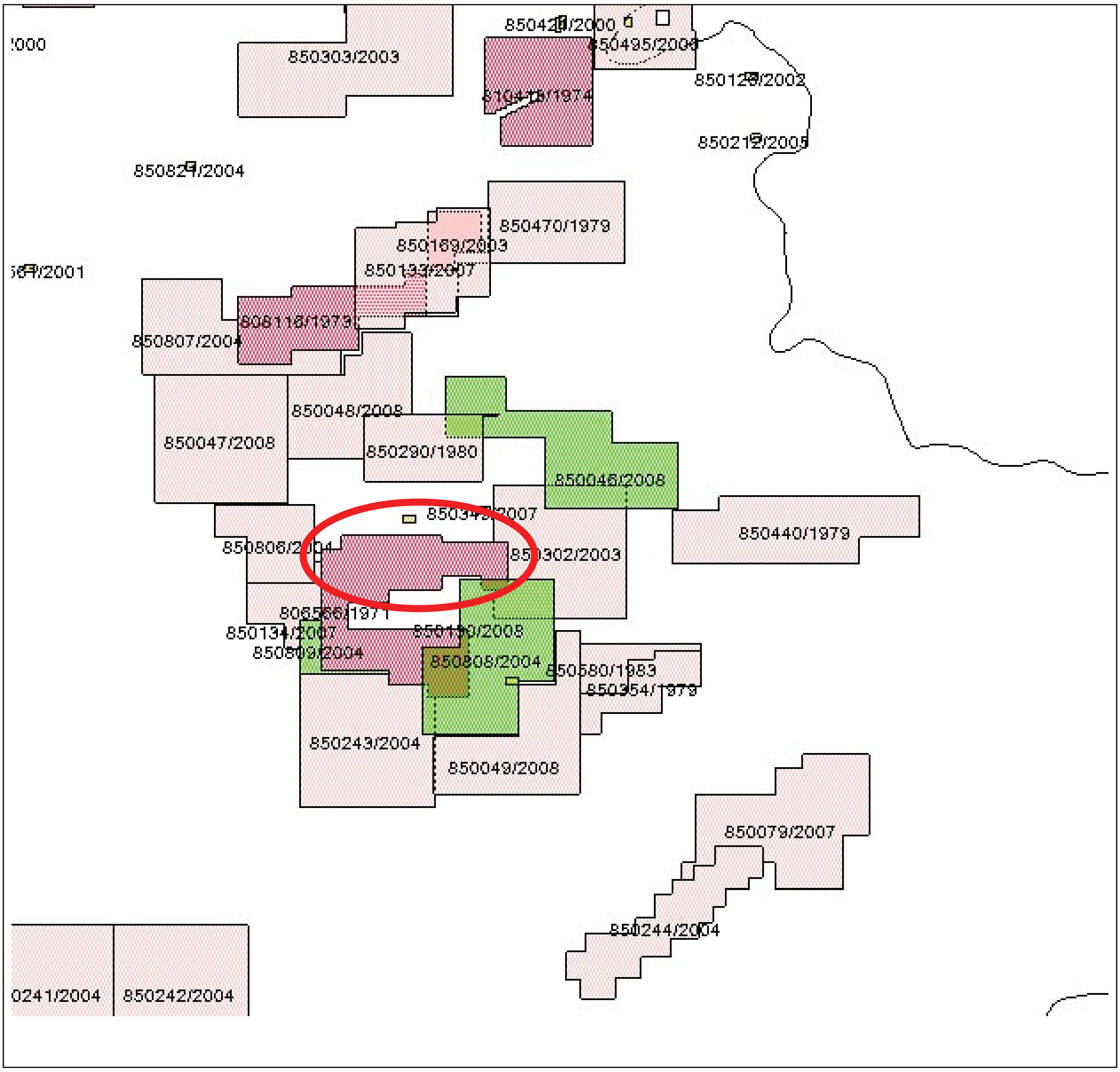


Figure 9: Map of all mining licenses in the region

The deposit, which is subject of this thesis, is marked in red in figure XX and can be found within the boundaries of the licence area with the DNPM number 806.566/1971. The origin licence holder was the company Msl Minerais S A, which is part of Companhia Vale Do Rio Doce today. It has to be mentioned that the area of interest is the northern part of this C-shaped property only.

6.2 Geology

Almeirím District

"This district includes an area on both sides of the Amazon River, from the town of Santarém, where the Rio Tapajós joins the Amazon, downstream to just past the confluence with the Rio Jarí, a distance of ca. 350 km.

Little has been published on these deposits or their geology. Towse and Vinson (1959) gave the first short description, based on the exploration activities in the fifties for Kayser Aluminium Co. Aleva has been in the area several times, stating in the late sixties.

Klammer (1971) gave a drillhole-section with little further detail. Dennen and Norton (1977) published a short geological description with considerable geochemical data, based on the most easterly hills (Serra do Acapuzal).

The following paragraphs summarize the available data deposit by deposit, from west to east.

Almeirím

North of the town of this name is the extensive Almeirím or Berenice Plateau. The development of the weathering profile closely resembles that from the Trombetas district. Detailed exploration by the Compania Vale de Rio Doce (CVRD) established, besides the metal-grade bauxite reserve, also a reserve of refractory-grade bauxite (low in iron and silica). The low iron content in this bauxite is clearly the result of iron removal after the bauxite profile – with its iron-rich horizon – had been established. The remaining iron is largely present in vertical ellipsoid bodies, 0,5 – 1 dm in diameter and 2 – 5 dm in length, which seem to be relicts of an originally columnar structure. Because the remaining iron is concentrated in such discrete bodies, beneficiation after crushing, e.g., by an optical method, is an economically feasible process.

Carucaru

Halfway between Almeirím and the Monte Dourado on the bank of Rio Jarí, there are a number of plateau hills, which have been explored during the seventies, resulting in deposits of refractory-grade bauxite. The Carucaru deposit might be developed in the near future.

Serra do Acapuzal

This is a large complex of plateau hills dissected by a very young eastward-draining creek system, although the western part of the hill complex forms the bank of the Rio Jarí. The publications of Towse and Vinson (1959), Klammer (1971) and Dennen and Norton (1977) are based on work in this area. The latter authors give the following profile description, which may serve as the type section for the district.

The exploration experience in the area is that the horizons between the Belterra clay horizon and the kaolin substrate are highly variable in thickness; the average thickness values are usually less than half the above indicated spread. Our impression is that considerable resilication of the bauxite horizon took place.

Interesting to note is the occurrence of a commercial kaolin deposit, the Morro do Filipe deposit, at the central west side of the Serra do Acapuzal. Here the gibsitic horizons together are reduced to ca. one metre and the underlying, up to 20 m thick, kaolinitic clay can be beneficiated (mainly by removal of all hard relict minerals such as quartz, zircon, rutile, etc.) to be sold as paper-grade kaolin. Microscopic study has shown that this kaolinitic clay is the in-situ weathering product of clastic feldspar grains (Padraic Partridge, pers. comm., 1979).

Klammer (1978) observed that the surface morphology of the top of the 50 – 60 m lower underlying sandstone, only with much reduced relief: the thickness of the kaolinitic and gibbsitic sediments is 15 m over the sandstone culminations and 55 m over valleys in the sandstone surface. Klammer concludes that both the sandstone relief and the Belterra surface are depositional surfaces and not planation surfaces.

Monte Dourado

A plateau hill on the west bank of the Rio Jarí, almost opposite the Serra do Acapuzal; the weathering profiles are comparable. Here also the bauxite horizon is thin and irregular and evidently of no commercial interest, as the plateau has been used to accommodate the air strip of Jarí Company."[7]

Local geology

The bauxite district can be described as a 200 km wide band located between the river of Parù and Jari. Layers of bauxite are covered with homogeneous, compact Belterra clays. These clays are a result of erections and erosions of lateritic zones.

Deposit characteristics

Due to the high clay contents, bauxite deposits in this region are classified as refractory bauxites. Speaking of mineralogy they are composed of gibbsite ($Al_2O_3.3H_2O$), limonite, titan oxide, silica, different clay minerals and impurities. Alkalis occur in traces only.

Lithologic features of the bauxite profile

1. clay covering
2. gibbsite (pea-like)
3. gibbsite concretion
4. pink bauxite
5. crystallised gibbsite
6. ferro-laterite
7. china clay bauxite
8. china clay

[14]

Further details regarding geology and mineralogy are mentions in the Jari-report which can be found in appendix E.

7 Reserves calculation

Mining licences, owned by MSL Minerais S.A. are located in the Almeirim district in the state of Prá. The table shows a rough calculation of raw bauxite within this area:

Area	Thousand tons
Caracuru II*	6766
S. Almeirim	35951
Planalto Dourado	38062
Caracuru I	1569
Bom Jardim	8176
Plateau do Meio	4616
Serra Azul	5319
Total	100459

(*) without Plateau VI

Table 9: Tons of raw bauxite, 1974 - 1977

1-Analysis 1974 to 1977

First estimations, done between 1974 and 1977, lead to a tonnage of 8 176 500 t of raw bauxite.
An area of about 2 000 ha has been surveyed using diamond drilling and geophysical methods. This was done in a 500 m pattern which was changed to a 250 m patter after gaining positive results.
The cut off for the first calculations was set at 80% Al_2O_3 and a Fe_2O_3 grad of 2, 5% or less. Additionally only bauxite layers thicker than 1 m were considered to be ore and influenced the calculation of the tonnage mentioned above.

2-Analysis 1995 – 1999

The target of this analysis was re-evaluation of the former estimations to define a consistent and economically mineable deposit as a basis for further feasibility studies. Ore parameters gained during mining of Plateau VI of Caracuru II, demands on the market as well as new gathered information in terms of mining costs and profits were considered. The Plateau of Serra de Almeirim, with a special focus on the grade of AL_2O_3 and Fe_2O_3, was re-drilled in a 250 m pattern to achieve a reasonable image of the deposit.

Method

Each sample (every 0,5 m of a drill core) underwent assays regarding values like moisture, specific gravity, porosity, LOI value, as well as grades of aluminium (Al_2O_3), iron (Fe_2O_3), silica(SiO_2) and titanium (TiO_2).
[14]

Basic information is shown in Table 10. Furthermore, more details results and more extensive descriptions regarding the reserve calculation can be found in the Jari report in appendix E.

Analysis 1997 to 1999	upper deposit		lower deposit
	measured	indicated	measured
Area of the deposit	800 ha	275 ha	75 ha
waste	74,313.000 m³	26,156.000 m³	594.000 m³
Thickness waste	9,3 m	9,5 m	0,8 m
Ore (ROM)	21,325.000 t	8,523.000 t	1,603.000 t
Thickness ore layer	1,6 m	1,8 m	1,3 m
moisture	13,94 %	13,04 %	15,1 %
recovery	30,40 %	32,05 %	28,20 %
Raw bauxite	5,186.240 t	2,185.297,2 t	361.636,8 t
MEA	2,36 g/cm³	2,19 g/cm³	2,11 g/m³
PA	8,7 %	9,5 %	12,8 %
LOI	29,23 %	29,40 %	28,82 %
SiO_2	8,64 %	7,90 %	10,61 %
Fe_2O_3	1,75 %	1,89 %	1,66 %
Al_2O_3	59,12 %	59,57 %	57,35 %
TiO_2	1,25 %	1,24 %	1,56 %

Table 10: Deposit parameters achieved during analysis 1997 - 1999

8 Former open pit

In the area of Caracuru II, Bauxite was already mined. Because of non-profit earnings the open pit got closed in the year 2003.
The technique of the mining methods in Caracuru II is described below.

The mine layout was based on the results obtained by the analysis of the samples taken during the diamond drilling exploration program in a 250 m pattern.

The extraction of bauxite was done in an open pit operation using an internal dump for the removed overburden. The major steps of this method are listed below:

- Construction of access to property

- Construction of main road on property

- Clearing / uprooting

- Final clearing and cleaning with hydraulic excavators

- Removing of overburden
  Scrapers in combination with pushing units removed the 10 – 12 m thick layer of overburden. This material was dumped in areas which have been mined out already. Soil, previously dumped separately was put back on the dumping area and used to form a reasonable topography in order to full fill the reclamation plan.

- Extraction and transportation of ore
  The exposed layer of bauxite was mined with hydraulic excavator in combination with 8 m³ dumpers for the transport to the processing plant. This

method was carried out in mining block of 25 x 25 meters with a thickness of 1 -3 meters, which were introduced after additional drilling and sampling in a 50m pattern. [14]

This listing is just a rough overview of the former mining operation extracted from the Jari-report which is attached to this thesis in appendix E.

9 Target

The internal targets for the JARI project were following masses of refractory final goods.

Step 1: Production of 150.000 tons per year calzined Bauxite with a quality level of Minimum 86 % Al_2O_3, Maximum 2 % Fe_2O_3, Bulk density of minimum 3,15 g/cm³

Step 2: Production of 40.000 tons per year Mullit with grades of 45 – 70 % Al_2O_3

Production of additional 75.000 tons per year calzined Bauxite with a quality level of Minimum 86 % Al_2O_3, Maximum 2 % Fe_2O_3, Bulk density of minimum 3,15 g/cm³

Step 3: Production of 30.000 tons Brown Fused Alumina per year with a quality level of 95 % Al_2O_3

Production of additional 75.000 tons per year calzined Bauxite with a quality level of Minimum 86 % Al_2O_3, Maximum 2 % Fe_2O_3, Bulk density of minimum 3,15 g/cm³

After tree years of production the next step should be realized.

The numbers of the final goods are building the foundation for all following calculations. [16]

10 Reserves of the deposit

At the time of the development of the present thesis the only data available was, as mentioned above, the reserves estimated by the company MSL.

The basis for all the upcoming calculations the following numbers were used:

ROM = 21,325.000 t

Area of the deposit in plan view = 800 ha

10.1 Deposit model

Since there was no deposit model, with the help of the responsible geologists, the available data from MSL and the coordinates of licence area, the following geometry was established and used for further calculations:

Geometry:

Thickness of overburden:	10 m
Thickness of bauxite deposit:	1,6 m
Length of deposit:	15.000 m
Latitude of deposit:	570 m

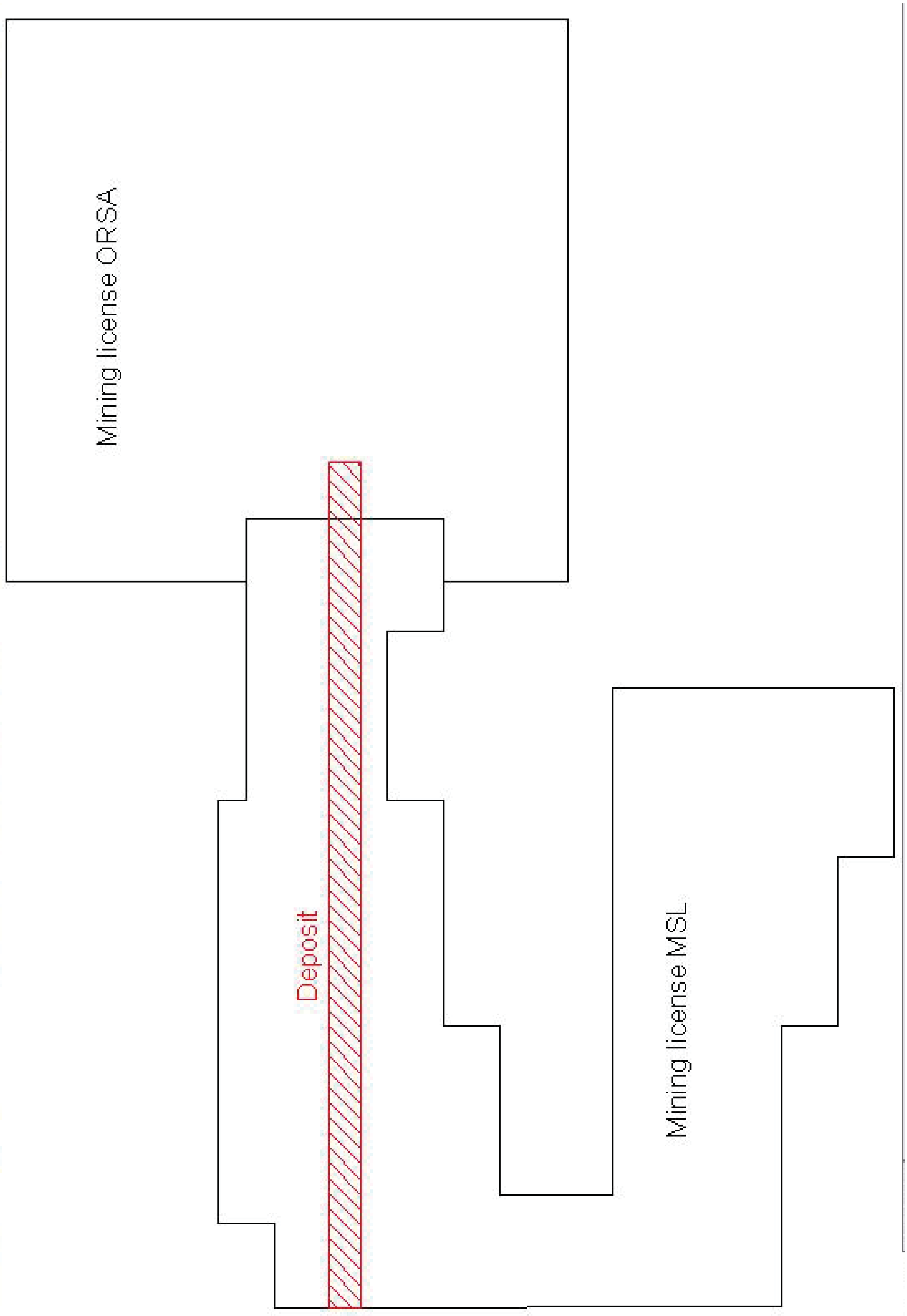


Figure 10: Map of the deposit and the related mining licenses

11 Mine planning

11.1 Geometry

The rectangular shape of the bauxite deposit provides a range of possibilities in terms of mining methods. Before I start to describe the ideas concerning the mining direction it has to be mentioned that the processing plant is going to be right in the middle of either the northern or southern long side of the deposit. The orientation doesn't affect the calculation of transportation and travelling distance.

The location of the plant on the other hand was used as the base point for the estimation of the travelling and transportation distance of haul trucks which are going to carry the ore from the loading point back to the plant.

In this chapter the focus is on the distances for ore handling only, overburden related calculations will be discussed later on.

In total there were 4 different basic directions of mining to be considered:

1. Mining the deposit from one side to the other.

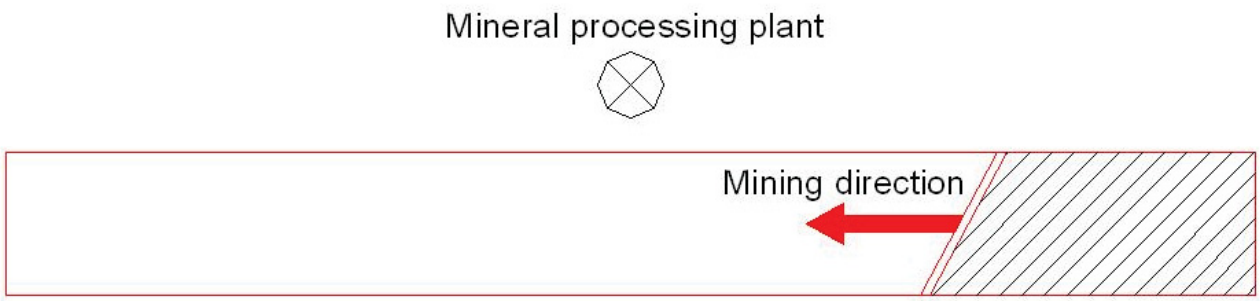


Figure 11: Geometry of mining direction, possibility 1

2. Starting to mine in the middle, excavating one half of the deposit until it is mined out, replacing the equipment back to the middle and repeat the procedure for the second half.

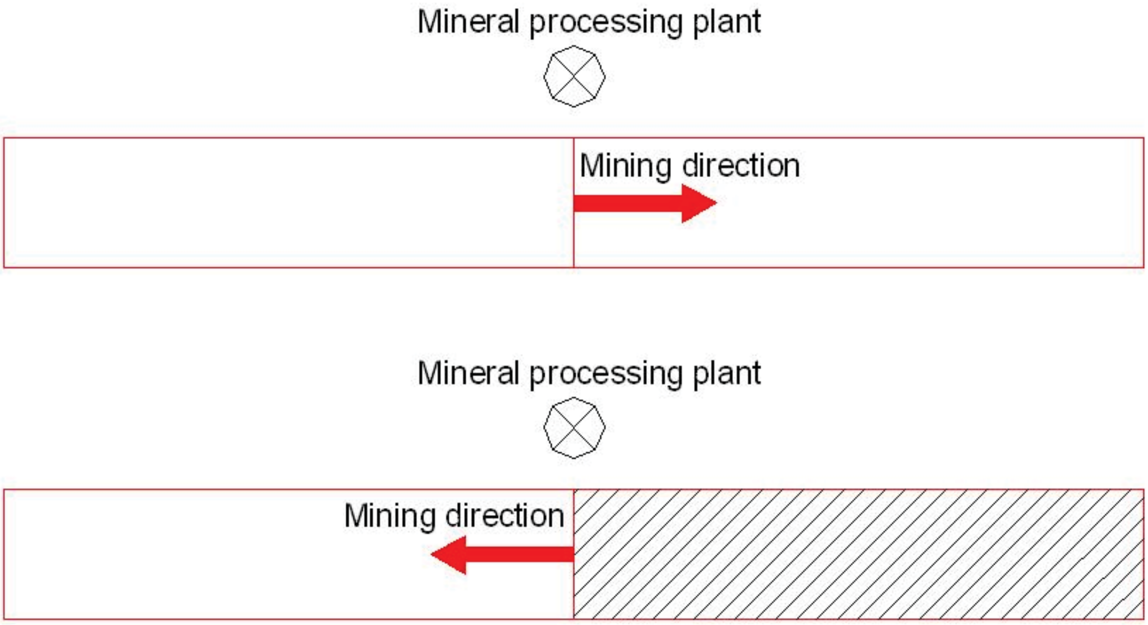


Figure 12: Geometry of mining direction, possibility 2

3. Starting to mine the deposit in the middle, excavating ore in both directions at the same time by replacing the equipment from one side to the other after mining a certain section.

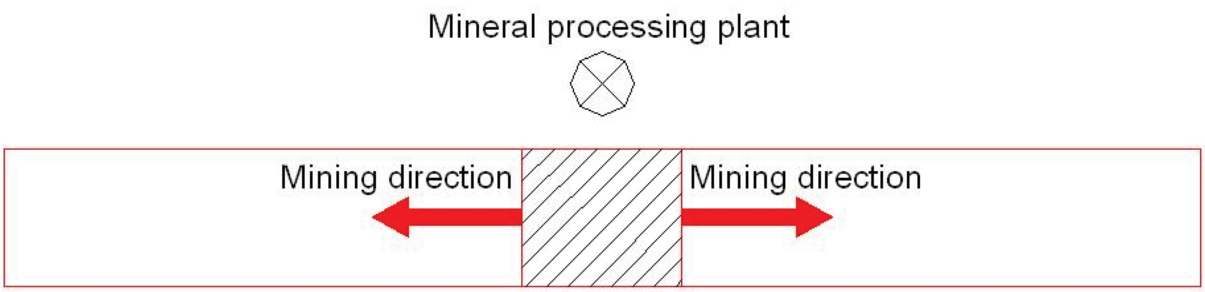


Figure 13: Geometry of mining direction, possibility 3

4. Dividing the deposit in 4 sections and mining each section to the end of the deposit, similar to the sequence described in the first option.

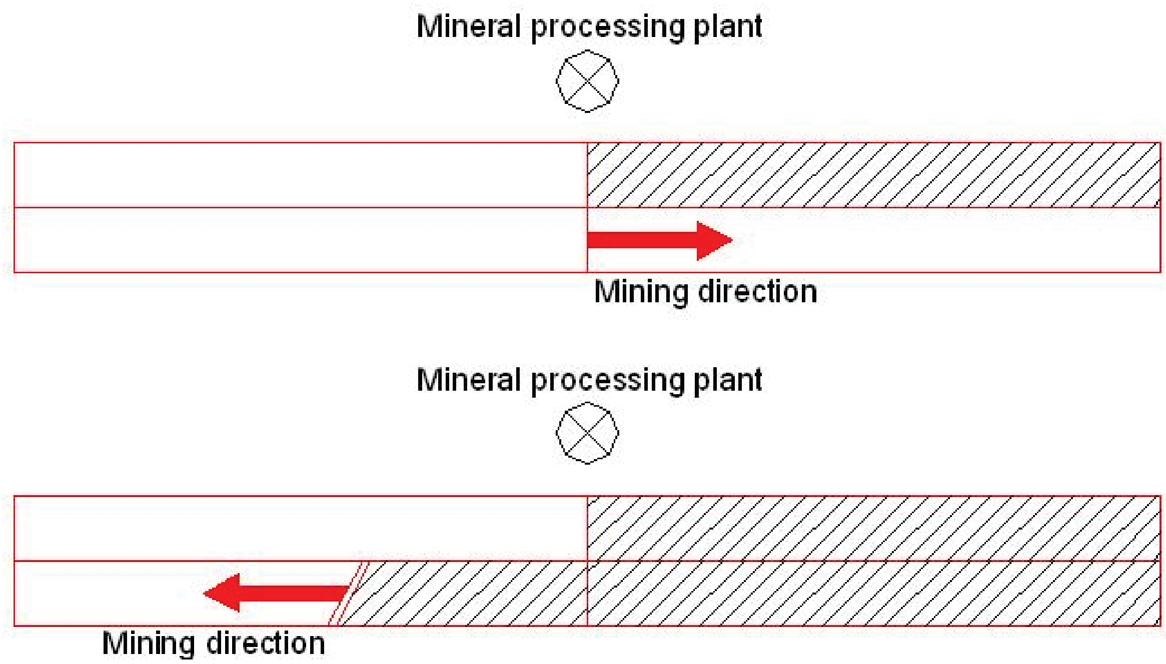


Figure 14: Geometry of mining direction, possibility 4

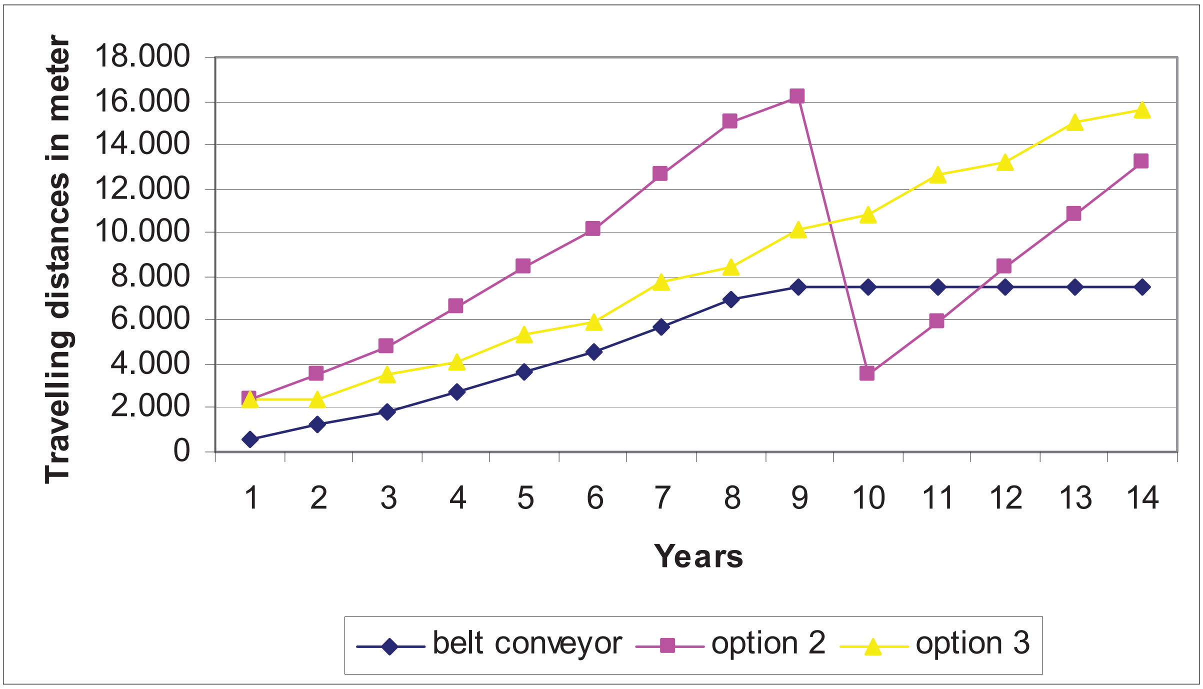


Figure 15: Travelling distances against mining years for the possibilities 2 and 3

During a detailed discussion, option 1 and 4 were rejected and estimations were done for option 2 and 3. Figure 15 shows the comparison between the length of a belt conveyer (blue) and the travelling distances of haul trucks in option 2 (pink) and 3 (yellow).

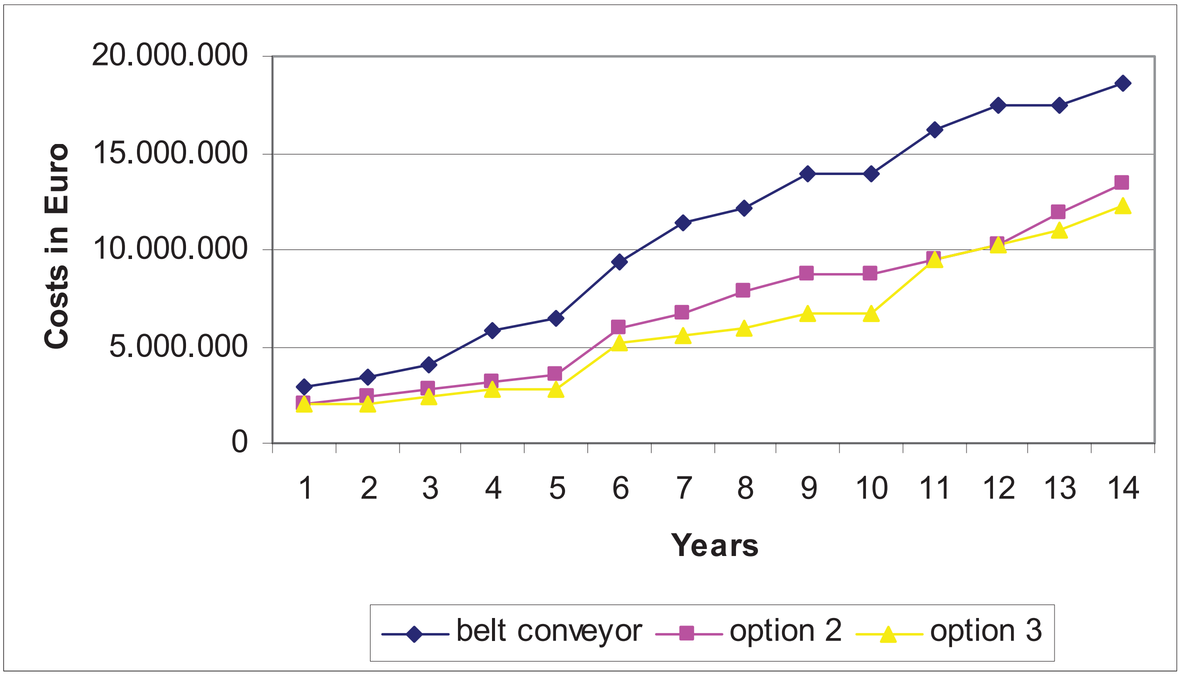


Figure 16: Total costs against mining years for the possibilities 2 and 3

After identifying the distances, it was possible to figure out a rough structure of total costs which can be seen in Figure 16 over a period of 14 years.
As a result of the costs and the number of possibly needed equipment the mining method described as option 2 was chosen. Still there is no final choice and a cost effective analysis is done in upcoming chapters to compare the ore transportation by truck and belt conveyer.
Furthermore it is important to know that no data related to quality distribution was available, which means the discussed mining direction will probably need some adaptation in the case more detailed date will collected. Detailed calculations are shown in appendix A.

Having decided what kind of mining direction is to be preferred, the basic development of the mine will be discussed:

The total width of 570 m is divided into 3 sections, each about 190 m wide. Thereby 3 mining faces are created which provide the possibility to handle quality fluctuations in a more flexible way and come with a cost reduction due to the potential of keeping travelling distances on a lower level.

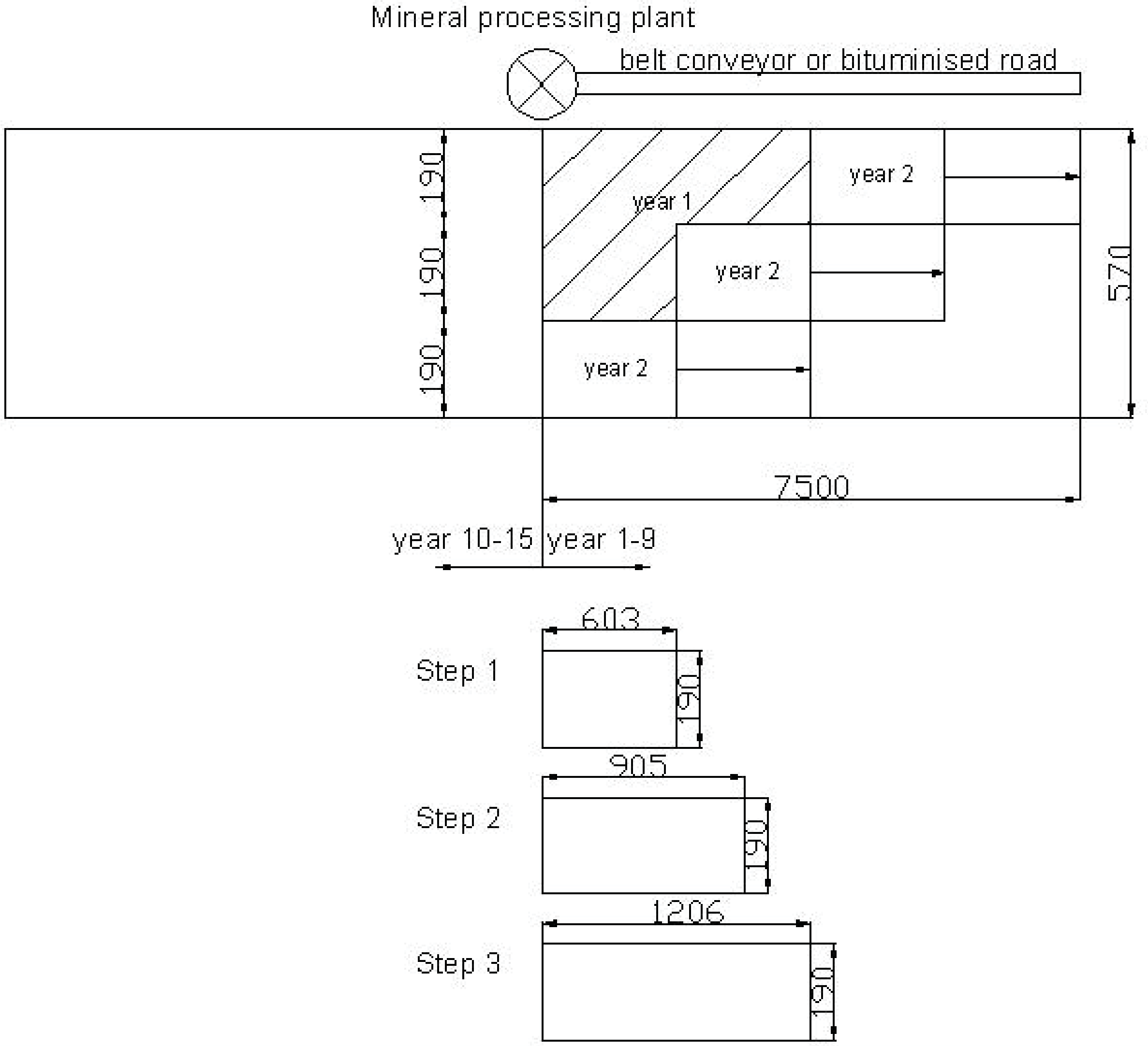


Figure 17: Size of each mining part for each Step

The stripped overburden in front of each mining section is transferred to the rear end of this section which at this time has been mined out already. A common principle called internal dump. The mined ore on the other hand is either transported to the processing plan directly or is loaded onto the conveyor system as shown in Figure 17.

The different mining section, their geometry and the schedule for mining these sections are drafted in Figure 17 as well.

Not shown in this draft is the area at the end of the conveyor, respectively road designated to become a stock yard for different ore qualities which again will guarantee a consistent feed for the processing plant in terms of volumes and qualities. Estimations and further discussion is not useful within this thesis because no information about the configuration of the plan or different bauxite qualities are available.

12 Mining methods

The determination of the mining direction was the first step, followed by the evaluation of the actual mining method.
A couple of ideas and options came up, but in the end there were 6 different ways to be discussed more specifically.

12.1 Produktion rate Determination

First of all the tonnage of ore, delivered to the processing plant annually, the ROM respectively, was given by Dipl. Ing. Georg Egger who is responsible for the processing and shipping of the processed bauxite to the RHI factories according to the targets mentioned in chapter 8. [16]

ROM according to Egger	**[t]**	**1.100.000**				
Density according to geologist	[t/m³]	2,00		1,50	[t/m³]	bulk density according to geologist
Mean volume	[m³]	550.000		733.333	[m³]	Mean bulk volume
Mean thickness	[m]	1,6				

Table 11: Results regarding ore volumes for Step 1

Density overburden according to JARI report	[t/m³]	1,91
surface of ore that has to be mined per year	[m²]	343.750
Mean thickness overburden	[m]	10
Mean volume	[m³]	3.437.500
Tonnage per year	**[t]**	**6.565.625**

Table 12: Results regarding over burden volumes for Step 1

ROM according to Egger	**[t]**	**1.650.000**				
Density according to geologist	[t/m³]	2,00		1,50	[t/m³]	bulk density according to geologist
Mean volume	[m³]	825.000		1.100.000	[m³]	Mean bulk volume
Mean thickness	[m]	1,6				

Table 13: Results regarding ore volumes for Step 2

Density overburden according to JARI report	[t/m³]	1,91
surface of ore that has to be mined per year	[m²]	515.625
Mean thickness overburden	[m]	10
Mean volume	[m³]	5.156.250
Tonnage per year	**[t]**	**9.848.438**

Table 14: Results regarding over burden volumes for Step 2

ROM according to Egger	**[t]**	**2.200.000**				
Density according to geologist	[t/m³]	2,00		1,50	[t/m³]	bulk density according to geologist
Mean volume	[m³]	1.100.000		1.466.667	[m³]	Mean bulk volume
Mean thickness	[m]	1,6				

Table 15: Results regarding ore volumes for Step 3

Dichte Abraum laut JARI Bericht	[t/m³]	1,91
Fläche des Wertminerals die pro Jahr abgebaut werden muss	[m²]	687.500
Durchschnittliche Mächtigkeit Abraum	[m]	10
Durchschnittliche m³ für Jahresförderung	[m³]	6.875.000
Tonnage pro Jahr	**[t]**	**13.131.250**

Table 16: Results regarding over burden volumes for Step 3

Summary:

	Ore	Over burden
Step 1	1.100.000 [t/a]	6.565.625 [t/a]
Step 2	1.650.000 [t/a]	9.848.438 [t/a]
Step 3	2.200.000 [t/a]	13.131.250 [t/a]

The high ratio between the volumes of ore and overburden, leads to the conclusion that the use of mining and production equipment for burden handling will not be the most effective way. As a result an economic equipment choice has to be made for striping ore and waste separately.

12.2 Land use planning

On the basis of the annual production of ore and the assumed geometry of the deposit the claimed area for each of the 3 steps was calculated:

Claimed area:

	Ore	Over burden	Area
Step 1	1.100.000 [t/a]	6.565.625 [t/a]	343.750 [m²/a]
Step 2	1.650.000 [t/a]	9.848.438 [t/a]	515.625 [m²/a]
Step 3	2.200.000 [t/a]	13.131.250 [t/a]	687.500 [m²/a]

The claimed area again forms the data needed for equipment rating as well as for the estimation of travelling distances.

12.3 Rain season

As mentioned in chapters above, there are basically two seasons. The rain and the dry season last about six month each. Information provided by former mining activities says that their effect on the mining performance is worth mentioning. Details discussions and new gathered information about the weather conditions in this particular area made it possible to point out some major impacts:

Bauxit ore
Ore excavating activities are not influenced by a rainfall, which means bauxite production can be carried out the whole year.

Overburden – Soil
During the first stages of the thesis the available data proved that there will be no possibility for striping waste and soil due to the heavy rain. A fact that would have had a huge impact on the number and size of equipment needed for removing over burden. Fortunately new and more accurate information was collected, which lead to the assumption that stripping of waste can be performed at least for a period of 8 month. This period was used as a basis for the equipment rating later on.
Furthermore a trip to Brazil in November 2008 and the inspection of the site showed that the mentioned period of 8 month still was a pessimistic assumption. The over burden handling units will be able to be operated during the whole year with but with a performance cut back of 50% during the 4 month of heavy rainfalls.

The major problem caused by rainfalls is the maceration of the soil. Tyres will penetrate the surface too far and this leads again to lower performance and much higher operation costs of every kind of equipment or in the worst case even total subsidence. The construction of proper roads within the stripping area will not be economical due to the high volume of waste and the quite fast moving mining face.
On the other hand, equipment used for mining the layer of bauxite underneath the soil will be designed way smaller and create a slower mining face for which reason

the construction of proper roads in this area of the pit has to be considered. In any case the smaller equipment will not be effected by wet ground conditions in the same range as the bigger units.

12.4 Mining methods

The following 6 mining methods are discussed in this thesis:

1. Scraper; Pull shovel excavator, dumper and belt conveyor
2. Scraper; Pull shovel excavator and dumper
3. Bucket wheel excavator; pull shovel excavator, dumper and belt conveyor
4. Bucket wheel excavator; pull shovel excavator and dumper
5. Dipper shovel and mining truck; pull shovel excavator, dumper and bet conveyor
6. Dipper shovel and mining truck; pull shovel excavator and dumper

12.5 Equipment rating

It is important to mention that the detailed discussion regarding the choice of equipment shown in the following chapters are for Step 1 and year 1 only. Results for the next two steps are just summed up. Considerations and detailed results of the ratings for Step 2 and year 4 and Step 3 and year 7 can be found in appendix C. The targets and facts of each step can be found in chapter 8.

12.5.1 Scraper

The scraper's biggest advantage is the fact that it combines the five steps of material handling, which means excavation, loading, transport, unloading and compaction.
The downside of this wide range of use is that a certain amount of know-how is needed to operate this kind of equipment efficiently. Furthermore scraper comes with high acquisition costs and needs a steady eye on its economical application. Factors related to that are travelling distance, excavated material, ground conditions, inclination, training level of the operating team, weather conditions and synchronisation with other units of the fleet. [4]

In general the arguments listed above sound daunting, but scrapers were used in the former bauxite mining operation Caracuru II, which is the reason why a closer look at its use is taken in the following paragraphs.
It was a difficult task to gather current information an experiences within the German-speaking Europe about the usage of scrapers. Only in Gammelsdorf (Germany), a bentonite mining site and a clay mining operation in Hennersdorf (Austria) are currently using this kind of machine. To round off collected data the operation in Germany was visited and the gained experience was used in the considerations.
The conclusion at the German site was quite a negative one. Especially the operators expressed their concern regarding driving safety during wet periods and on moist underground. Due to the more severe rainfall in Brazil this statement may cause an even bigger problem at the bauxite site. Today the mine in Gammelsdorf already

changed its mining method to excavation by pull shovel excavators combined with dumpers, an option that will be discussed in this thesis as well.

For this particular deposit the scraper arrangement, called push-pull was chosen.
This kind of method doesn't need an extra dozer for pushing the scraper because every two of them are pushing / pulling each other. The only adaptation in terms of extra features mounted on the machine is a special hook at the rear end and a push-block at its front end as well as a clip on both ends. In addition the missing dozer provides more flexibility.
Push-pull scrapes always come as twin-engine scrapers. A material with clay-like parameters is a very important factor for the use of scrapers. Otherwise the friction contact between the tyres and the ground won't be high enough to excavate the soil or will be too high and shorten the durability of the tyres. The push-pull action end at the moment when both scrapers are fully loaded, then they unhook and drive to the unloading area. A loading cycle in general takes about 1, 5 minutes.
A common value for an economical travelling distance is approximately 1 200 m. To reach these parameters a well trained operator team is essential. [4]

Advices for the use of scrapers

1. Organizing

The installation of a skilled and experienced supervisor for the entire processes recommended.
Fields of responsibilities are to be arranged.
Extraction: Supervisor or pusher operator
Haul roads: Supervisor or grader operator
Dumping area: Supervisor
A high value on operator training is to be set. Knowledge about operating features, service and basic maintenance is insufficient. The scraper mining method has to be part of the trained skills. Ability to work as a team is essential. Uncoordinated processes will lead to inefficient and uneconomic results.

2. Performance

a) Extraction

- Working on downhill slopes as far as possible
- Provide adequate space for handling of equipment
- Do not open to large areas (rainfall)
- Maintain an even mining surface
- Mine in offset tracks (load material on a track after extracting material on the tracks adjacent to it)
- Operate with high engine rpm to keep up high hydraulic performance; keep revolutions low in hard surface to avoid wheel spins
- Try to fill scraper bowl to optimum limit, instead of maximum limit
- Avoid sharp turns with fully loaded scrapers; straight roads are to be preferred
- If suspension system is in place on scraper, turn it off during loading process

b) Haul road

- Maintain smooth and even surface with motor graders
- Construct wide roads (~3 times width of scraper), bank turns and ensure safety at crossings
- Organize a right of way system (loaded scrapers have right of way)
- Install a draining system for roads

c) Dumping area

- If compaction is not necessary, unload in downhill slopes
- Unload in even and thin layers to make compaction easier
- Slow down scraper before start of unloading process
- Organize a drainage system to avoid muddy conditions after rainfalls [4]

Figure 18: CAT 637G Wheel Tractor Scraper

Type: CAT 637G Wheel Tractor Scraper

Engine

Tractor Engine	CAT C18 ACERT
Net Power	373 kW
Scraper Engine	CAT C9 ACERT
Net Power	211 kW

Scraper Bowl

Heaped Capacity	23, 7 m³ (in this case approximately 15 t)
Rated Load	37.285 kg

Calculation of the resistance to rolling

$$RW_k = 20\frac{kg}{t}$$

$$RW_s = 6\frac{kg}{t} procm\,\mathrm{Re}\,ifeneindringung$$

$$RW_g = (RW_k + RW_s) * Einsatzgewicht$$

Due to poor road conditions a penetration of 20 cm is assumed.

$$RW_s = 6 * 20 = 120\frac{kg}{t}$$

$$RW_g = (20 + 120) * 52 = 7280kg$$

Every single percent of inclination creates a resistance of rolling in the range of 10kg per tonne of equipment weight.

1 cm of Penetration = 6 kg/t resistance of rolling

As a result the resistance of rolling equals to 7.280 kg, which would be the same as a scraper facing an inclination of 7% after being fully loaded.

CAT 637 G			Resistance of rolling	20	[kg/t]
capacity loosely	23,7	[lm³]	Resistance of rolling	120	[kg/t]
Fill factor	0,90	[%]	RR total	7.280	[kg]
Bulking factor	1,25	[%]	inclination	7	[%]
Scraper capacity	**17**	**[fm³]**	**26**	**[t]**	
payload	34	[t]			
Efficiency factor	50	[min/h]	83	[%]	

Table 17: Calculation of scraper payload

Transport time 1		loaded				
		Distance	0,19	[km]		1,14
		Velocity	10	[km/h]		1,90
Transport time 2		loaded				
		Distance	0,1	[km]		0,40
		Velocity	15	[km/h]		0,67
Transport time 3		loaded				
		Distance	0,503	[km]		1,51
		Velocity	20	[km/h]		2,52
Return time 1		empty				
		Distance	0,19	[km]		1,14
		Velocity	10	[km/h]		1,90
Return time 2		empty				
		Distance	0,1	[km]		0,30
		Velocity	20	[km/h]		0,50
Return time 3		empty				
		Distance	0,503	[km]		0,86
		Velocity	35	[km/h]		1,44

Table 18: Calculation of travelling speed, distance and duration

Rim pull Diagram

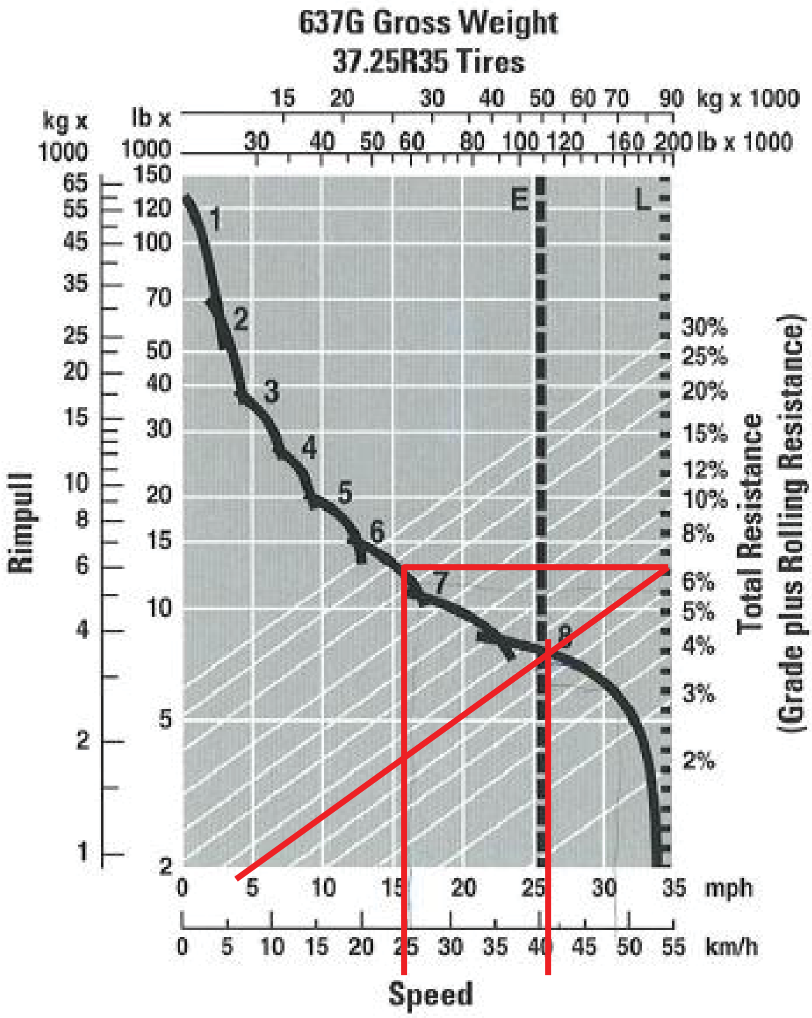


Figure 19: Rim pull Diagram CAT 637G Wheel Tractor Scraper

The estimated speed of 41 km/h as given in the Rim pull Diagram doesn't seem to be plausible, considering the short distances and the poor road conditions. As a result the speed was reduced to a more reasonable value.

Scraper loading time	0,70	[min]
Transport time 1	1,14	[min]
Transport time 2	0,40	[min]
Transport time 3	1,51	[min]
Discharging time	0,70	[min]
Return time 1	1,14	[min]
Return time 2	0,30	[min]
Return time 3	0,86	[min]
	6,75	[min]

Table 19: Summary of one loading – unloading cycle

Theoretical maximum production		60 min - hour and availability 100 %
Scraper in 60 min	9	
Output	227	[t/h]
Numbers of Scraper	**11**	
Numbers of dozers	2	
11 Scraper in 60 min	98	
Output	2.502	[t/h]

Table 20: Estimation of needed amount of scrapers assuming 100% availability

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	1.595	t/h

Table 21: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	244	d	8 month mining possible			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	4.758	h/y				
Availability Scraper	90,0%		available hours		4.282	h
utilisation Scraper	100,0%		utilised hours		4.282	h
long term production	**6.830.880**	**t/y**				

Table 22: Estimation of long term production assuming reductions caused by holiday, unforeseen events and scraper availability

Summary:

To achieve the given volume of over burden, 6.565.625 t per year, a number of 11 scrapers, model CAT 637 G, are needed. In theory this amount of units will be able to handle about 6.830.880 tonnes per year.

12.5.2 Dipper shovel excavator and mining truck

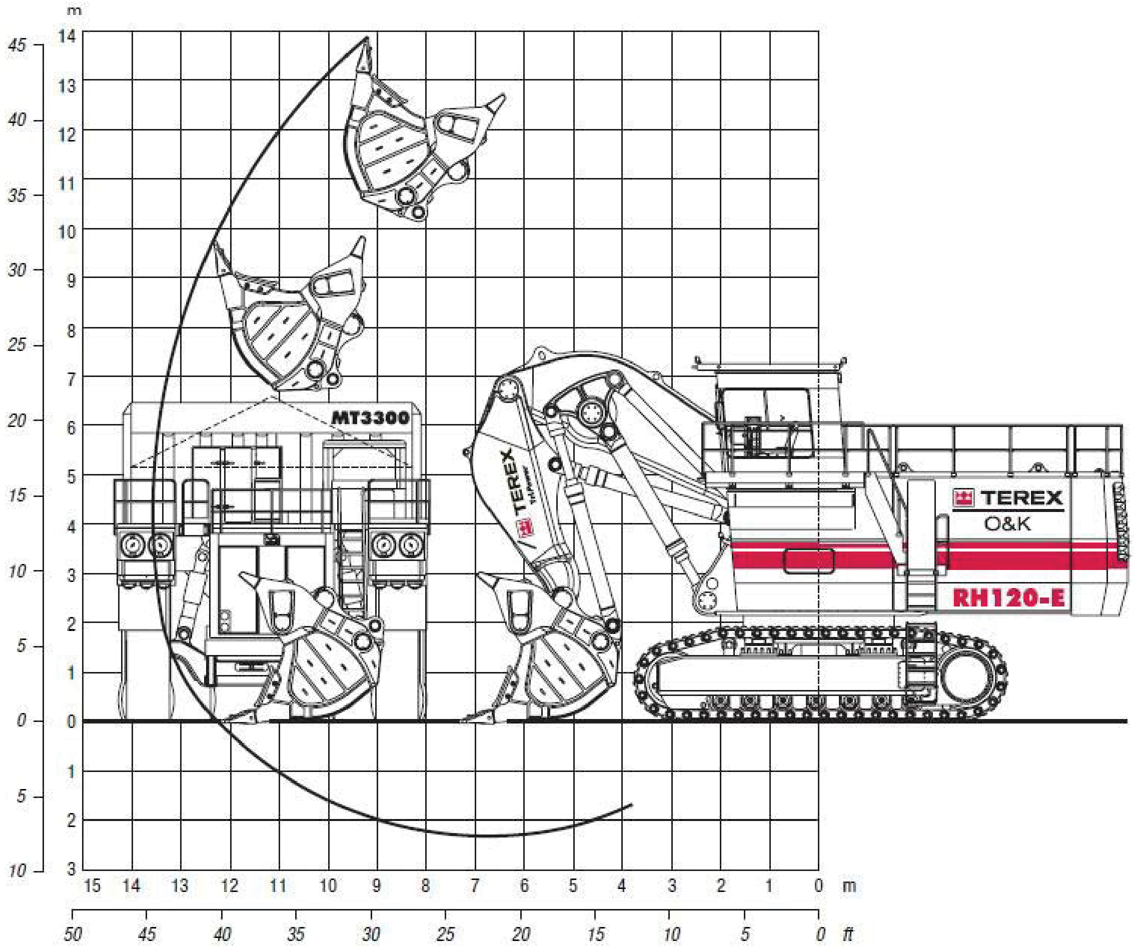


Figure 20: TEREX O&K RH 120-E dipper shovel excavator

Type: TEREX O&K RH 120-E

Engine 1008 kW

Shovel volume 15 – 17 m³

Operating weight 284 t

Figure 21: CAT 777 F mining truck

Type: CAT 777F

Net power 699 kW 951 hp

Max. Speed 60, 4 km/h

Payload 96 t

Bucket 60 m³

Operating weight 161 t

Shovel volume	14,00	[m³]
Shovel filling factor	110	[%]
Working circle time	0,5	[min]
Availability factor	50	[min]
Loading cycle	4	
Bucket volume	62	[m³]
loaded tonnage	92	[t]

Table 23: Estimation of the shovel volume, loading cycle and resulting load of the mining truck

Resistance of rolling	20	[kg/t]
Resistance of rolling	90	[kg/t]
RR total	17.710	[kg]
inclination	18	[%]

Table 24: Estimation of the resistance of rolling and resulting inclination

Transport time 1		loaded			
		Distance	0,19	[km]	1,90
		Velocity	6	[km/h]	3,17
Transport time 2		loaded			
		Distance	0,1	[km]	0,60
		Velocity	10	[km/h]	1,00
Transport time 3		loaded			
		Distance	0,5	[km]	3,02
		Velocity	10	[km/h]	5,03
Return time 1		empty			
		Distance	0,19	[km]	1,14
		Velocity	10	[km/h]	1,90
Return time 2		empty			
		Distance	0,1	[km]	0,27
		Velocity	22	[km/h]	0,45
Return time 3		empty			
		Distance	0,5	[km]	1,37
		Velocity	22	[km/h]	2,29

Table 25: Calculation of travelling speed, distance and duration

Rim pull Diagram

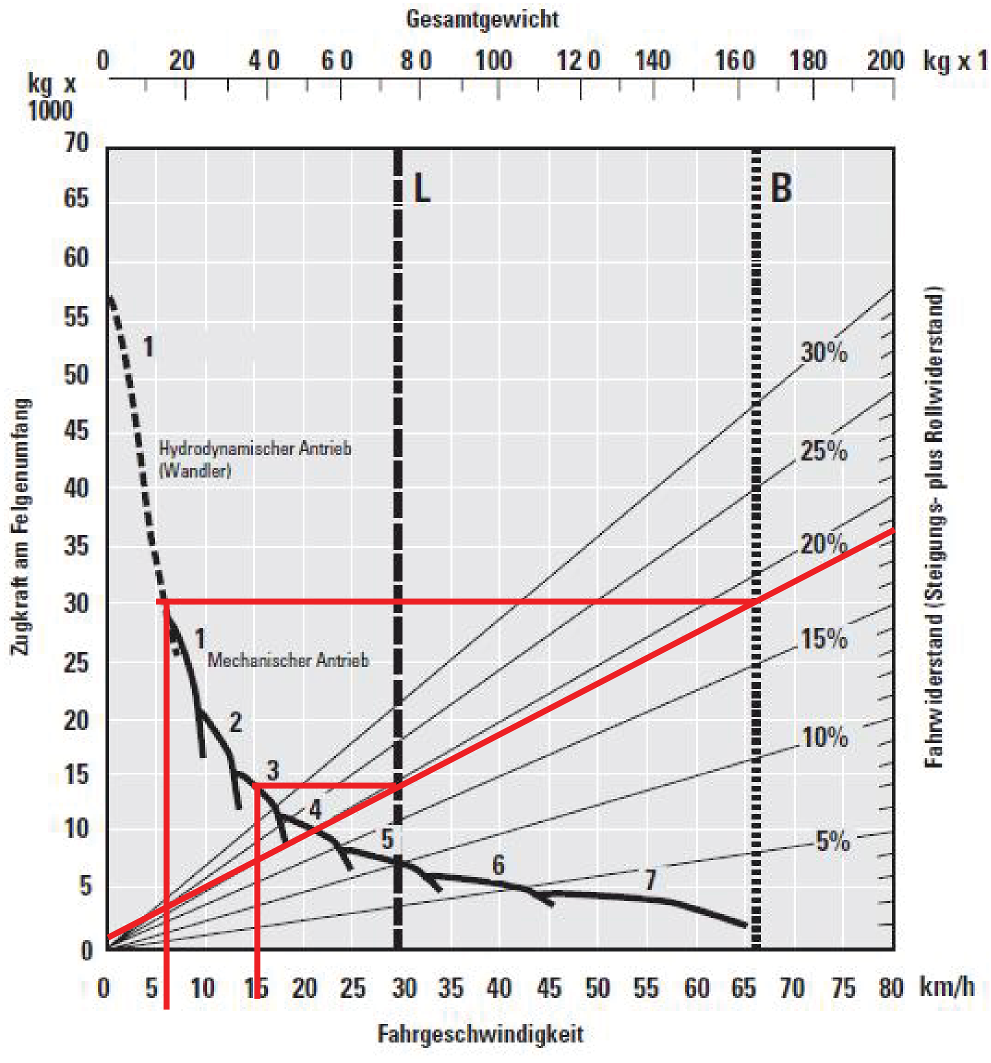


Figure 22: Rim pull Diagram CAT 777 F mining truck

According to the Rim pull Diagram shown in Figure 22 the maximum travelling speed of the mining truck is 8 km/h under loaded condition, respectively 15 km/h unloaded. The eye-catching slow speeds are the result of the worst case assumptions regarding tyre penetration, road conditions and resistance of rolling. For further calculation the values were changed to 10 km/h and 22 km/h.

loading time	2,00	[min]
Manoeuvre time	0,30	[min]
Transport time 1	1,90	[min]
Transport time 2	0,60	[min]
Transport time 3	3,02	[min]
Discharging time	1,20	[min]
Return time 1	1,14	[min]
Return time 2	0,27	[min]
Return time 3	1,37	[min]
	11,80	[min]
Required trucks	**6**	

Table 26: Estimation of one loading-unloading cycle and required number of mining trucks

Theoretical maximum production		60 min - hour and availability 100 %
Trucks in 60 min	30	
Output	2.772	[t/h]

Table 27: Estimation of theoretical production assuming 100% truck utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	1.767	t/h

Table 28: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	244	d	8 month mining possible			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	4.758	h/y				
Availability excavator	90,0%		available hours		4.282	h
Utilisation excavator	90,0%		utilised hours		3.854	h
long term production	6.810.561	t/y				

Table 29: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To achieve the given target of stripping 6.565.625 tonnes of overburden per year, one dipper shovel excavator, type RH 120-E combined with 6 mining trucks of the model CAT 777 F will be required.

12.5.3 Bucket wheel excavator

"Continuous open pit

Soft rock mining systems

A continuous rock process starts with a bucket wheel excavator. The mined material, overburden or other material, such as lignite, is then transported from the pit on conveyors. Overburden material is typically dumped on the other side of the pit across from the mine face.

Sandvik has a long history as a leading supplier of soft rock mining systems. We supply a multitude of different machines, with various purposes and capabilities to facilitate the continuous process. Our engineering and mining experts design the correct system for each specific mine, using one of the two following techniques.

Around the pit system

In this technique, the conveyor system transports the material along three sides of the pit. Because each mine operation in unique, Sandvik´s engineering and mining experts design the correct system for each specific operation.

The bucket wheel excavator, through an installed conveyor system, discharges overburden into the receiving chute of a hopper car. To minimize distance and height issues, a belt wagon can work as a mobile link to the mobile hopper offering greater flexibility. A conveyor system, specially adapted to the topographic conditions, transfers the material aroud the pit to a crawler-mouted spreader whith discharges the waste material in the dumping area. Sandvik´s around the pit system:

- Adapt to different mining and deposit conditions
- Provide shift able or mobile conveyors
- Accommodate long distances between mines and dump areas

Cross pit system

In this specialized system, to be used as an across the pit conveyor, the excavator extracts overburden material and feeds it via conveyors to a spreader. The spreader conveys the waste material directly across the open pit and onto the developing dumping area. Sandvik´s cross pit systems:

- Produce the shortest distance and time for conveying material
- Mines deeper reserves economically
- Meet requirements of certain geographical conditions at the dump site." [18]

In this case the cross pit system is used.
The bucket wheel excavator is going to be designed for Step 3.
The excavator will run 24-7 whereas one shift will be to be used for maintenance what brings the production shifts per day down to two.
In this case the tonnes per hour are 2.242 but for bucket wheel excavators the volume is relevant. So for rating the excavator the most important parameter is 1.174 m³ per hour.
Discussions with Dipl. Ing. Landsmann from GKB showed that the listed values of m³ provided by manufacturers are theoretical estimations, for the long term production calculations just 1/3 of the listed m³ are assumed. [19]

A fact that forced us to multiply the value of 1.761 m³ with the factor 3 which equals 3.522 m³, which is the crucial value for the final excavator rating.

Figure 23: PE 100-700/1x15 Sandvik

PE 100-700/1x15

Key Specifications

Material to be handled	overburden, coal
Nominal capacity	3.500 m³/h
Bucket capacity	700 l
Block height	15 m
Length of bucket wheel boom	16 m

Figure 24: PA 200-1200/35+50 Sandvik

PA 200-1200/35+50

Key Specifications

Material to be handled	overburden
Nominal capacity	3.500 m³/h
Receiving boom length	35 m
Discharge boom length	50 m
Belt width	1.200 mm

12.5.4 Pull shovel excavator and dumper

Figure 25: CAT 365C L pull shovel excavator

Type: CAT 365C L

Net power 302 kW 411 hp

Max. Dig Depth 9, 5 m

Max. Long Stick 14, 1 m

Shovel volume 2, 5 – 5, 0 m³

Operating weight 67,8 – 71,6 Tons

Max. Speed 4,1 km/h

Max. Drawbar Pull 462 kN

Figure 26: CAT 725 dumper

Type: CAT 725

Net power 277 kW 309 hp

Max. Speed 51, 3 km/h

Payload 23, 6 t

Bucket volume 14, 3 m³

Operating weight 22, 8 t

Shovel volume	3,20	[m³]
Shovel filling factor	110	[%]
Working circle time	0,38	[min]
Availability factor	50	[min]

Table 30: Estimation of the shovel volume and the degree of filling

Loading cycle	4	
Bucket volume	14	[m³]
loaded tonnage	21	[t]

Table 31: Estimation of one loading-unloading cycle and the resulting load of the dumper

Resistance of rolling	20	[kg/t]
Resistance of rolling	120	[kg/t]
RR total	3.192	[kg]
inclination	3	[%]

Table 32: Estimation of the resistance of rolling and the resulting inclination

Design without the usage of a belt conveyor

loaded			
Distance	0,57	[km]	
Velocity	10	[km/h]	3,42
Distance	0,603	[km]	
Velocity	30	[km/h]	1,21
empty			
Distance	0,603	[km]	
Velocity	35	[km/h]	1,03
Distance	0,57	[km]	
Velocity	12	[km/h]	2,85

Table 33: Calculation of travelling speed, distance and duration

loading time	1,52	[min]
Manoeuvre time	0,30	[min]
Transport time	4,63	[min]
Discharging time	1,20	[min]
Return time	3,88	[min]
	11,53	[min]
Required trucks	8	

Table 34: Estimation of one loading-unloading cycle and required number of mining trucks

Design with the use of a belt conveyor

loaded		
Distance	0,57	[km]
Velocity	10	[km/h]
		3,42
empty		
Distance	0,57	[km]
Velocity	12	[km/h]
		2,85

Table 35: Calculation of travelling speed, distance and duration

loading time	1,52	[min]
Manoeuvre time	0,30	[min]
Transport time	3,42	[min]
Discharging time	1,20	[min]
Return time	2,85	[min]
	9,29	[min]
Required trucks	6	

Table 36: Estimation of one loading-unloading cycle and required number of mining trucks

Rim Pull Diagram

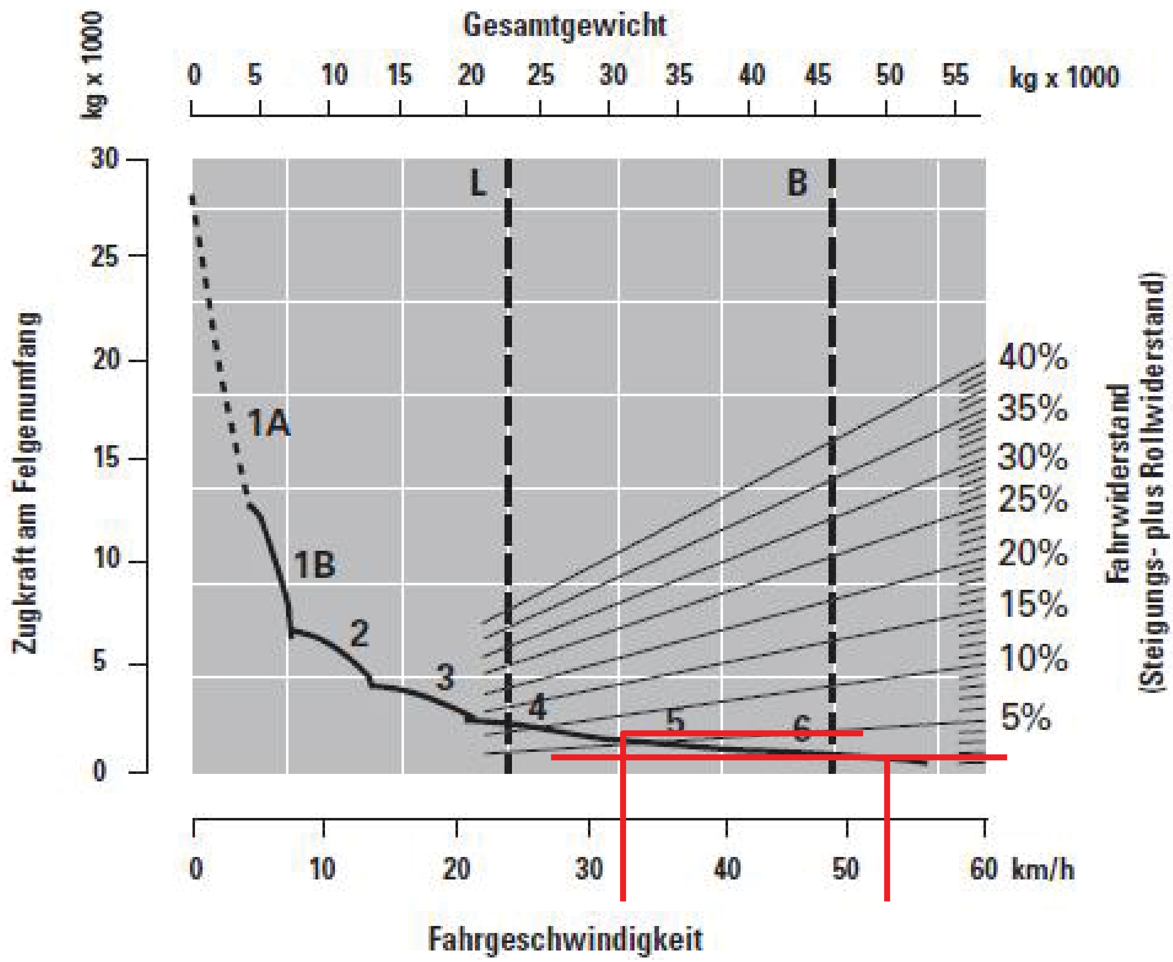


Figure 27: Rim Pull Diagram CAT 725 dumper

As shown in the Rim Pull Diagram above, the maximum speed for a fully loaded dumper will be approximately 32 km/h and under unloaded conditions 52 km/h. During the visit of the mining operation in Gammelsdorf, the experience was gained that this kind of haul truck will travel significantly slower under these poor conditions, which is why the estimated speeds were reduced as you can see in Table 33 and Table 35.

Theoretical maximum production		60 min - hour and availability 100 %
Trucks in 60 min	39	
Output	834	[t/h]

Table 37: Estimation of theoretical production assuming 100% truck utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	531	[t/h]

Table 38: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	200	d	5 days per week			
	5					
Shifts per day	2					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	2.535	h/y				
Availability excavator	90,0%		available hours		2.282	h
Utilisation excavator	90,0%		utilised hours		2.053	h
long term production	1.091.301	[t/y]				

Table 39: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To achieve the given target of mining 1.100.000 tonnes of bauxite per year, one pull shovel excavator, type CAT 365C L combined with 8 mining trucks of the model CAT 725 will be required. In the case a belt conveyor is used to transport the mined ore to the plant, the distances will be short and as a result the needed amount of dumpers decreases to 6, which will represent a capacity 1.091.301 tonnes per year.

12.5.5 Belt conveyor

The design of the belt conveyor was done by the company Binder & Co. The results and additional information can be found in the appendix B.

12.5.6 Additional Equipment

Diamond drill rig

Figure 28: Atlas Copco Christensen C S10

Atlas Copco Christensen C S10

Basic data	
Depth capacity (NO)	800 m
Drill rod size, wire line	B-P
Main hoist	53,5 kN
Lift capacity, feed	90 kN
Feed length	1,83 m
Rod pull length	6 m

For concomitant exploration and determining qualities during the mining process a small type of diamond drill rig is needful. The rating of this unit is based on data provided by the former mining operation of Caracuru II, where a rig similar to the chosen one was used to gather information about the ore body by drilling a 250 x 250 pattern. Since there was no diamond drilling done at time this thesis was developed, the meters drilled on the Caracuru II property were used to get a rough calculation regarding the drill rig.

There might be the possibility the set up an ideal drilling schedule in order to avoid drilling through the entire thickness of the overburden by removing it first to a certain point. This happened to be done at the Caracuru II site, and will allow saving time and money at this point.

Track – Type – Tractor

Figure 29: CAT D8 T track - type - tractor

Track – Type – Tractor D8T

Engine

Engine Model	CAT C15 ACERT
Gross Power	259 kW
Flywheel Power	231 kW

Weights

Operating Weight	38.488 kg
Shipping Weight	29.553 kg

A dozer will be used to manage the unloaded overburden at the dump and for performing the necessary compaction work. Especially the mining options which are using the dipper shovel excavator and mining trucks or the bucket wheel excavator will require a dozer handling stripped material.

The use of scrapers will not necessarily exclude the need of a dozer because it could become a very useful unit for pulling stuck equipment out of wet ground conditions.

Motor grader

Figure 30: CAT M14 motor grader

Motor Grader M14

CAT C13 ACERT VHP

Base Power (1st gear) Net	193 kW
VHP Range – Net	193 – 204 kW
VHP Plus Range – Net	193 – 219 kW

Gross Vehicle Weight – base

Total	21.379 kg
Front axle	5.720 kg
Rear axle	15.659 kg

Moldboard

Blade Width	4,3 m

As mentioned in the chapter about the use of scapers, a motor grader is an essential part of a scraper fleet. The adequate motor grade for a scraper of the model CAT 637 G will be the model M14 by Caterpillar with a blade width of 4,3 m.

Figure 31: CAT M16 motor grader

Motor Grader M16

CAT C13 ACERT VHP

Base Power (1st gear) Net	221 kW
VHP Range – Net	221 – 233 kW
VHP Plus Range – Net	221 – 248 kW

Gross Vehicle Weight – base

Total	26.060 kg
Front axle	7.112 kg
Rear axle	18.948 kg

Moldboard

Blade Width	4,9 m

In case the stripping option, using the CAT 777 F trucks will be the most economic one, a slightly bigger motor grade will be necessary for road maintenance.

There is no need for a motor grade in case of the bucket wheel excavator option.

Wheel loader

Figure 32: CAT 980 H wheel loader

Type: CAT 980 H

Net power 232 kW 315 hp

Static Tipping Load, Full turn 19.580 kg

Breakout force 233 kN

Bucket capacity 5, 4 m³

Operating weight 29, 8 t

As mentioned in chapter 10 some kind of stock pile is constructed next to the processing plant. To manage this stock yard a wheel loader was added to the equipment rating. This would be a very basic method to handle the material transported to and stored at this area as well as to guarantee a consistent feed of ore for the plant in terms of volumes and qualities.

Shovel volume	5,40	[m³]
Shovel filling factor	100	[%]
Working circle time	1,33	[min]
Bucket volume	5	[m³]
loaded tonnage	8	[t]

Table 40: Estimation of the shovel capacity and the degree of filling

Resistance of rolling	20	[kg/t]
Resistance of rolling	30	[kg/t]
RR total	1.490	[kg]
inclination	1	[%]

Table 41: Estimation of the resistance of rolling and the resulting inclination

Distance	75	[m]
loading time	0,50	[min]
Transport time	0,45	[min]
Return time	0,38	[min]
	1,33	[min]

Table 42: Calculation of the duration of travelling and a loading cycle

Theoretical maximum production		60 min - hour and availability 100 %
Wheel loader in 60 min	45	
output	365	[t/h]

Table 43: Estimation of theoretical production assuming 100% loader utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	233	[t/h]

Table 44: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	300	d	5 days per week			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	5.850	h/y				
Availability wheel loader	90,0%		available hours		5.265	h
Utilisation wheel loader	100,0%		utilised hours		5.265	h
long term production	1.226.488	[t/y]				

Table 45: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To feed the processing plant with the required amount of ore, 1 wheel loader of the type CAT 980 H is sufficient to handle the given amount of 1.100.000 tonnes of ore.

12.6 Result equipment rating

ROM	1.100.000	[t]				
Overburden	6.565.625	[t]				
Scraper	Model	CAT 637 G	numbers	11		4 shifts
Overburden excavator & truck	Model	RH 120-E	numbers	1		4 shifts
	Model	CAT 777F	numbers	6		
excavator & truck & belt conveyor	Model	CAT 365C L	numbers	1		2 shifts
	Model	CAT Dumper 725	numbers	6		
excavator & truck	Model	CAT 365C L	numbers	1		2 shifts
	Model	CAT Dumper 725	numbers	11		

Table 46: Results of the equipment rating for step 1 and year 1

ROM	1.650.000	[t]				
Overburden	9.848.438	[t]				
Scraper	Model	CAT 637 G	numbers	19		4 shifts
Overburden excavator & truck	Model	RH 90-C	numbers	2		4 shifts
	Model	CAT 777F	numbers	12		
excavator & truck & belt conveyor	Model	CAT 365C L	numbers	1		2 shifts
	Model	CAT Dumper 725	numbers	9		
excavator & truck	Model	CAT 365C L	numbers	1		2 shifts
	Model	CAT Dumper 725	numbers	27		

Table 47: Results of the equipment rating for step 2 and year 4

ROM	2.200.000	[t]				
Overburden	13.131.250	[t]				
Scraper	Model	CAT 637 G	numbers	30		4 shifts
Overburden excavator & truck	Model	RH 120-E	numbers	2		4 shifts
	Model	CAT 777F	numbers	17		
excavator & truck & belt conveyor	Model	CAT 365C L	numbers	1		2 shifts
	Model	CAT Dumper 725	numbers	8		
excavator & truck	Model	CAT 365C L	numbers	1		2 shifts
	Model	CAT Dumper 725	numbers	32		

Table 48: Results of the equipment rating for step 3 and year 7

12.7 Shift model

The assumptions regarding the working hours of the rated equipment lead to the evaluation and planning of shift schedules for stripping the waste and for producing the asked amounts of bauxite ore separately.

Overburden

Talking about the arrangement of shift work for removing overburden, the described weather conditions have to be considered. Due to the 8-month stripping period a twenty-four-seven schedule is useful. This could be managed by introducing 4 shifts:
A morning shift from 6:00 -14:00, an afternoon shift from 14:00 – 22:00 and a night shift from 22:00 – 6:00; the fourth shift is off, but a back-up for unforeseen events as well. A rotation of these shifts takes place after every week.
This 4-shift system will allow handling the overburden in each of the 3 steps of the mining progress.

Bauxite ore

On the other hand mining of the ore is happened during the entire year and is in theory not affected by rainfalls. Hence it is not necessary to set up a twenty-four-seven schedule in the first place.
The claimed tonnages of bauxite in step 1 and step 2 can be mined in 2 shifts, 5 days a week. A common solution in this case is a morning shift and an afternoon shift.
As specified in chapters before, the bauxite production increases significantly in step 3. This increase can be managed by adding a third shift to the 2 existing ones on each of the 5 ore production days.

13 Cost effectiveness study

13.1 Static cost effectiveness study

- Cost caparison method
- Profit comparison method
- Payback period rule
- ROI reporting

The static method used in this thesis is the Cost comparison method:

$$K = \frac{(AW - RW)}{n} + \frac{(AW + RW) * i}{2} + BK$$

AW	Anschaffungswert
RW	Restwert
n	Nutzungsdauer
$\frac{(AW - RW)}{n}$	kalk. Abschreibung
$\frac{(AW - RW) * i}{2}$	kalk. Zinsen

[3]

For each piece of equipment the costs generated during all the years have to be determined and assigned to the specific year. To achieve this task a closer look at the following factors is required:

- Acquisition value
- Salvage value (assumed 0 in this case)
- Useful economic life (calculated with the help of values given by the manufacturers and the estimated period of use per year)
- Rate of interest (fixed internal RHI value is 10%)
- Overheads

- Fuel consumption per hour, according to Caterpillar Performance Handbook Edition 37, combined with Brazilian fuel prices (1 lit. diesel approximately 0,70 €);
- Labour costs, considering the shift schedule for the relevant piece of equipment as well as the Brazilian average operator salary of 1000 Real (1 Real = 0,4 €);
- Service costs, Caterpillar provides a Full-Service-Rate for each of its machines;
- Maintenance costs, Caterpillar suggests to estimate the maintenance costs in the range of 90% of the equipment's acquisition costs over the years of the unit's lifetime; these values were converted to costs per operation hour;

All shown calculation refer to year 1

425.000	AW	Acquisition value				
0	RW	Salvage value				
3	n	Useful economic life				
151.258	(AW-RW)/n	Amortisation				
136.132	BK	Overhead costs				
21.250	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
308.639	K	**costs**				
Useful life	20.000	Operation hours	**7.118**	h/y	lifetime	**3**
Fuel consumption	25,5 - 30,5	per hour		**28**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	27.760	**3,9**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	108.372	**15,23**	per hour			

Table 49: Calculation of costs generated by wheel loader 980 H per year

650.000	AW	Acquisition value				
0	RW	Salvage value				
5	n	Useful economic life				
140.833	(AW-RW)/n	Amortisation				
268.723	BK	Overhead costs				
32.500	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
442.056	K	**costs**				
Useful life	12.000	Operation hours	**2.600**	h/Jahr	lifetime	**5**
Fuel consumption	67,5 - 74,0	per hour		**70,75**	lit/ h	
Labour costs	**2**	Operator	per hour	12,5	Real	
Service costs	12.870	**4,95**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	113.880	**43,80**	per hour			

Table 50: Calculation of costs generated by pull shovel excavator 365C L per year

3.800.000	AW	Acquisition value				
0	RW	Salvage value				
9	n	Useful economic life				
401.787	(AW-RW)/n	Amortisation				
909.693	BK	Overhead costs				
190.000	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
1.501.480	K	**costs**				
Useful life	45.000	Operation hours	**4.758**	h/Jahr	lifetime	**9**
Fuel consumption	140 - 160	per hour		**150**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	73749	**15,5**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	287.859	**60,50**	per hour			

Table 51: Calculation of costs generated by dipper shovel excavator RH 120-E per year

395.000	AW	Acquisition value				
0	RW	Salvage value				
5	n	Useful economic life				
83.444	(AW-RW)/n	Amortisation				
119.047	BK	Overhead costs				
19.750	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
222.240	K	**costs**				
Useful life	12.000	Operation hours	**2.535**	h/Jahr	lifetime	**5**
Fuel consumption	14,8 - 20,8	per hour		**17,8**	lit/ h	
Labour costs	**2**	Operator	per hour	12,5	Real	
Service costs	12.168	**4,8**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	62.931	**24,83**	per hour			

Table 52: Calculation of costs generated by dumper 725 with belt conveyor per year

395.000	AW	Acquisition value				
0	RW	Salvage value				
5	n	Useful economic life				
85.583	(AW-RW)/n	Amortisation				
122.099	BK	Overhead costs				
19.750	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
227.432	K	**costs**				
Useful life	12.000	Operation hours	**2.600**	h/Jahr	lifetime	**5**
Fuel consumption	14,8 - 20,8	per hour		**17,8**	lit/ h	
Labour costs	**2**	Operator	per hour	12,5	Real	
Service costs	12.480	**4,8**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	64.545	**24,83**	per hour			

Table 53: Calculation of costs generated by dumper 725 without belt conveyor per year

1.900.000	AW	Acquisition value				
0	RW	Salvage value				
5	n	Useful economic life				
401.787	(AW-RW)/n	Amortisation				
627.213	BK	Overhead costs				
95.000	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
1.124.000	K	**costs**				
Useful life	22.500	Operation hours	**4.758**	h/Jahr	lifetime	**5**
Fuel consumption	56,3 - 75,0	per hour		**65,65**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	37.350	**7,85**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	324.258	**68,15**	per hour			

Table 54: Calculation of costs generated by mining truck 777 F per year

1.300.000	AW	Acquisition value				
0	RW	Salvage value				
4	n	Useful economic life				
309.270	(AW-RW)/n	Amortisation				
625.494	BK	Overhead costs				
65.000	(AW+RW)*i/2	Calc. interest				
0	i	Rate of interest				
999.764	K	**costs**				
Useful life	20.000	Operation hours	**4.758**	h/Jahr	lifetime	**4**
Fuel consumption	87 - 93	per hour		**90**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	33781,8	**7,1**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	244.561	**51,40**	per hour			

Table 55: Calculation of costs generated by scraper 637 G per year

750.000	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
53.571	(AW-RW)/n	Amortisation				
223.232	BK	Overhead costs				
37.500	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
314.303	K	**costs**				
Useful life		Operation hours	**4.758**	h/Jahr	lifetime	
Fuel consumption	33,7 - 43,5	per hour		**38,6**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	25.693	**5,4**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	22.521	**4,73**	per hour			

Table 56: Calculation of costs generated by dozer D8T per year

550.000	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
39.286	(AW-RW)/n	Amortisation				
159.806	BK	Overhead costs				
27.500	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
226.592	K	**costs**				
Useful life		Operation hours	**4.758**	h/Jahr	lifetime	
Fuel consumption	21,0 - 26,0	per hour		**23,5**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	25217,4	**5,3**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	10.140	**2,13**	per hour			

Table 57: Calculation of costs generated by motor grader M14 per year

800.000	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
57.143	(AW-RW)/n	Amortisation				
192.622	BK	Overhead costs				
40.000	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
289.765	K	**costs**				
Useful life		Operation hours	**4.758**	h/Jahr	lifetime	
Fuel consumption	25,0 - 32,0	per hour		**28,5**	lit/ h	
Labour costs	**4**	Operator	per hour	25	Real	
Service costs	33781,8	**7,1**	Euro per operation hour			
Repairing costs	90	[%]	Mr. Specht; Sum repairing and service costs			
	17.647	**3,71**	per hour			

Table 58: Calculation of costs generated by motor grader M16 per year

6.875.000	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
491.071	(AW-RW)/n	Amortisation				
443.500	BK	Overhead costs				
343.750	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
1.278.321	K	**costs**				
Useful life		Operation hours	**3.200**	h/y	lifetime	
Consumption of electricity	**175**	per hour	**0,1**	Euro per hour		
Labour costs	**6**	Operator	per hour	37,5	Real	
maintenance	**350.000**	Euro/y				

Table 59: Calculation of costs generated by belt conveyor per year

215.900	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
15.421	(AW-RW)/n	Amortisation				
92.050	BK	Overhead costs				
10.795	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
118.266	K	**costs**				
Useful life		Operation hours	**2.600**	h/y	lifetime	
Fuel consumption	25	per hour		**25**	lit/ h	
Labour costs	**2**	Operator	per hour	12,5	Real	
maintenance	**13**	Euro/h				

Table 60: Calculation of costs generated by drill rig per year

2.000.000	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
142.857	(AW-RW)/n	Amortisation				
570.662	BK	Overhead costs				
100.000	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
813.519	K	**costs**				
		Operation hours	**5.840**	h/y		
Consumption of electricity	**175**	per hour	**0,1**	Euro per hour		
Labour costs	**12**	Operator	per hour	75	Real	
maintenance	**300.000**					

Table 61: Calculation of costs generated by belt conveyor for the bucket wheel excavator per year

5.000.000	AW	Acquisition value				
0	RW	Salvage value				
14	n	Useful economic life				
357.143	(AW-RW)/n	Amortisation				
664.954	BK	Overhead costs				
250.000	(AW+RW)*i/2	Calc. interest				
0,10	i	Rate of interest				
1.272.097	K	**costs**				
		Operation hours	**5.840**	h/y		
Consumption of electricity	**700**	per hour	**0,1**	Euro per hour		
Labour costs	**4**	Operator	per hour	25	Real	
maintenance	**200.000**					

Table 62: Calculation of costs generated by stacker per year

10.000.000	AW	Acquisition value		
0	RW	Salvage value		
14	n	Useful economic life		
714.286	(AW-RW)/n	Amortisation		
1.096.308	BK	Overhead costs		
500.000	(AW+RW)*i/2	Calc. interest		
0,10	i	Rate of interest		
2.310.593	K	**costs**		
		Operation hours	**5.840**	h/y
Consumption of electricity	**1000**	per hour	**0,1**	
Labour costs	**8**	Operator	per year	50
maintenance	**400.000**			

Table 63: Calculation of costs generated by bucket wheel excavator per year

The following tables show the resulting costs of each piece of equipment during the different years. By multiplying the estimated amount of units for each option regarding the mining method, a value representing the total costs for each year came up. These sums of costs are used for comparing and interpreting the different options during the years.

Costs per object in euro	Numbers of objects		
		option 1	
118.266	1	118.266	Drill rig
999.764	12	11.997.168	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
222.240	7	1.580.538	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		16.991.967	
		option 2	
118.266	1	118.266	Drill rig
999.764	12	11.997.168	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
227.432	9	1.952.584	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		16.085.691	
		option 3	
118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
222.240	7	1.580.538	Dumper 725 with belt conveyor
442.056	1	442.056	Excavator 365C L
1.278.321	1	1.278.321	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		9.478.719	
		option 4	
118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	9	1.952.584	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		8.572.443	
		option 5	
118.266	1	118.266	Drill rig

1.124.000	7	7.757.030	Mining truck 777F
1.501.480	1	1.501.480	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
222.240	7	1.580.538	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		14.316.481	

option 6

118.266	1	118.266	Drill rig
1.124.000	7	7.757.030	Mining truck 777F
1.501.480	1	1.501.480	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
227.432	9	1.952.584	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		13.410.206	

Table 64: Comparison of costs for the first year

year	option 1	option 2	option 3	option 4	option 5	option 6
1	16.991.967	16.085.691	9.478.719	8.572.443	14.316.481	13.410.206
2	17.028.892	16.420.812	9.515.644	8.907.564	14.353.407	13.745.327
3	17.028.892	16.755.932	9.515.644	9.242.684	14.353.407	14.080.447
4	26.724.327	28.086.751	10.213.203	11.575.627	23.351.827	24.714.252
5	26.724.327	29.118.918	10.213.203	12.607.794	23.351.827	25.746.418
6	26.724.327	29.923.652	10.213.203	13.412.528	23.351.827	26.551.153
7	39.725.861	45.441.712	11.217.569	16.933.421	31.228.943	36.944.794
8	39.725.861	46.780.231	11.217.569	18.271.939	31.228.943	38.283.312
9	39.725.861	48.459.397	11.217.569	19.951.105	31.228.943	39.962.479
10	39.725.861	39.739.308	11.217.569	11.231.016	31.228.943	31.242.389
11	39.725.861	41.418.474	11.217.569	12.910.182	31.228.943	32.921.556
12	39.725.861	42.756.992	11.217.569	14.248.701	31.228.943	34.260.074
13	39.725.861	44.436.159	11.217.569	15.927.867	31.228.943	35.939.241
14	39.725.861	45.774.677	11.217.569	17.266.385	31.228.943	37.277.759
15	39.725.861	47.113.195	11.217.569	18.604.903	31.228.943	38.616.277

Table 65: Arrangement of all cost for each mining option per year

All this numbers come form appendix D.

Figure 33 shows the data provided in Table 65. As you can see the no-belt-conveyor mining methods are to be favoured during the first 3, 5 years, but after this period the installation of a conveyor will create fewer costs. Further graphs for the no-belt-conveyor methods show a decline between the year 9 and 10, a fact that can be ascribed to the relocation of the mining front back to the middle of the deposit. This situation is accompanied by shorter travelling distances which end in fewer costs.

In general during the first 3, 5 years is the removal of overburden is with the help of a bucket wheel excavator and ore extraction by pull shovel excavators in combination with dumpers is recommended. After the 4^{th} year the installation of a belt-conveyor for ore transportation will form a less cost intense method.

It is important to keep in mind that this static cost effectiveness study uses average values instead of periodic values. It does not account for new acquisitions, respectively investments caused by exceeding a machine's lifetime or breakdowns.

Furthermore this method is not able to provide any information about profit, rate of return or payback period.

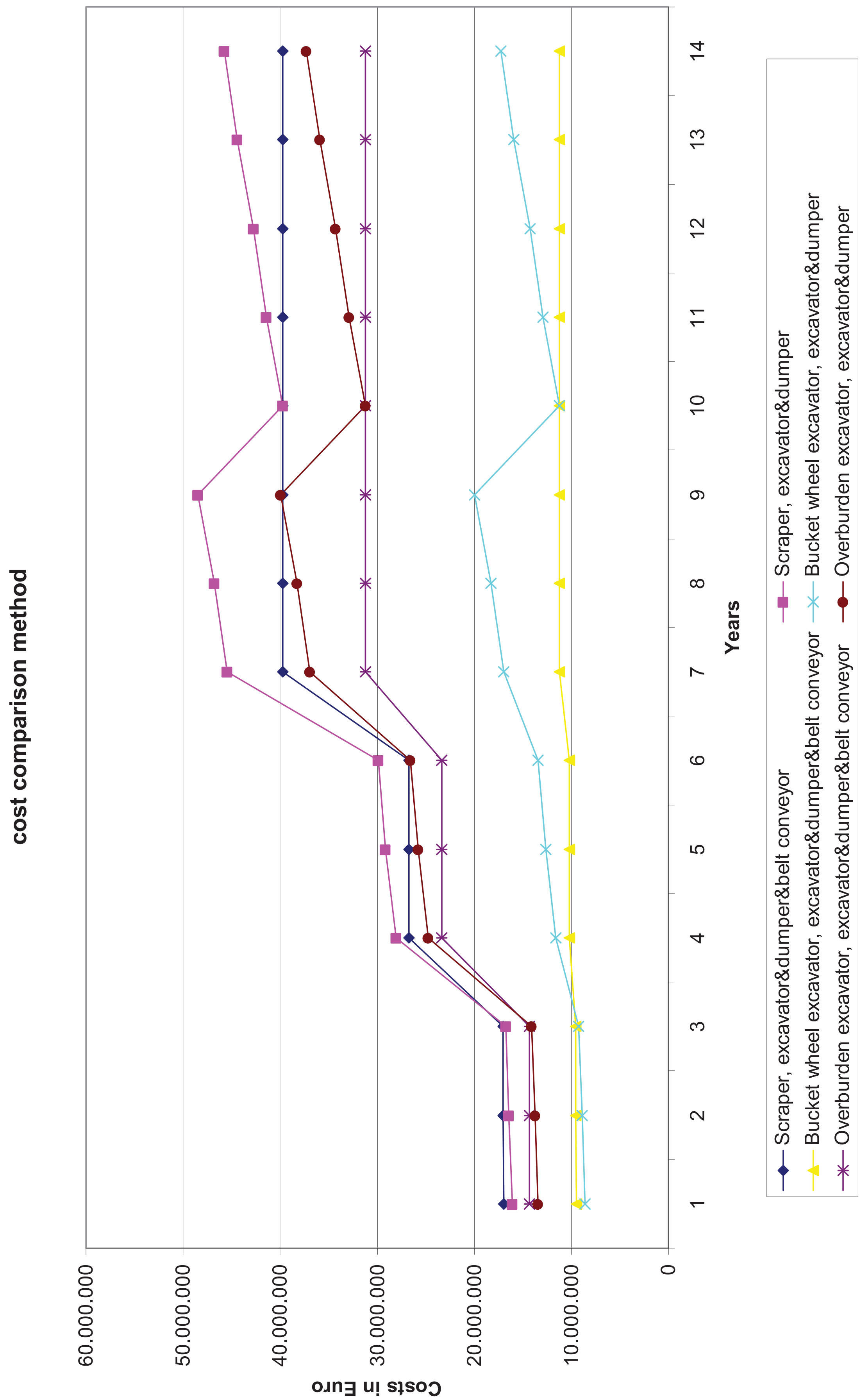


Figure 33: Cost caparison method

13.2 Dynamic cost effectiveness study

- Net present value method
- Internal rate of return method
- Dynamic payback period calculation
- Annuity method

To start with dynamic cost effectiveness studies all investments and operating costs have to be identified on an annual basis. This is shown in a very detailed way in the following two tables:

year	Numbers of needed objects	AC for 1 object	Useful life	Numbers of objects to buy	Acquisition costs per year
Scraper 637 G					
1	12	1.300.000	4	12	15.600.000
2	12	1.300.000	4	0	0
3	12	1.300.000	4	0	0
4	21	1.300.000	4	9	11.700.000
5	21	1.300.000	4	12	15.600.000
6	21	1.300.000	4	0	0
7	33	1.300.000	4	12	15.600.000
8	33	1.300.000	4	9	11.700.000
9	33	1.300.000	4	12	15.600.000
10	33	1.300.000	4	0	0
11	33	1.300.000	4	12	15.600.000
12	33	1.300.000	4	9	11.700.000
13	33	1.300.000	4	12	15.600.000
14	33	1.300.000	4	0	0
15	33	1.300.000	4	12	15.600.000
Wheel loader 980 H					
1	2	425.000	3	2	850.000
2	2	425.000	3	0	0
3	2	425.000	3	0	0
4	2	425.000	3	2	850.000
5	2	425.000	3	0	0
6	2	425.000	3	0	0
7	2	425.000	3	2	850.000
8	2	425.000	3	0	0
9	2	425.000	3	0	0
10	2	425.000	3	2	850.000
11	2	425.000	3	0	0
12	2	425.000	3	0	0
13	2	425.000	3	2	850.000
14	2	425.000	3	0	0
15	2	425.000	3	0	0
Excavator 365C L					

1	1	450.000	5	1	450.000
2	1	450.000	5	0	0
3	1	450.000	5	0	0
4	1	450.000	5	0	0
5	1	450.000	5	0	0
6	1	450.000	5	1	450.000
7	1	450.000	5	0	0
8	1	450.000	5	0	0
9	1	450.000	5	0	0
10	1	450.000	5	0	0
11	1	450.000	5	1	450.000
12	1	450.000	5	0	0
13	1	450.000	5	0	0
14	1	450.000	5	0	0
15	1	450.000	5	0	0
Excavator 120-E					
1	1	3.800.000	9	1	3.800.000
2	1	3.800.000	9	0	0
3	1	3.800.000	9	0	0
4	2	3.800.000	9	1	3.800.000
5	2	3.800.000	9	0	0
6	2	3.800.000	9	0	0
7	2	3.800.000	9	0	0
8	2	3.800.000	9	0	0
9	2	3.800.000	9	0	0
10	2	3.800.000	9	1	3.800.000
11	2	3.800.000	9	0	0
12	2	3.800.000	9	0	0
13	2	3.800.000	9	1	3.800.000
14	2	3.800.000	9	0	0
15	2	3.800.000	9	0	0
Mining truck 777 F					
1	7	1.900.000	5	7	13.300.000
2	7	1.900.000	5	0	0
3	7	1.900.000	5	0	0
4	13	1.900.000	5	6	11.400.000
5	13	1.900.000	5	0	0
6	13	1.900.000	5	7	13.300.000
7	19	1.900.000	5	6	11.400.000
8	19	1.900.000	5	0	0
9	19	1.900.000	5	6	11.400.000
10	19	1.900.000	5	0	0
11	19	1.900.000	5	7	13.300.000
12	19	1.900.000	5	6	11.400.000
13	19	1.900.000	5	0	0
14	19	1.900.000	5	6	11.400.000
15	19	1.900.000	5	0	0
725 with belt conveyor					
1	7	395.000	5	7	2.765.000
2	7	395.000	5	0	0
3	7	395.000	5	0	0
4	10	395.000	5	3	1.185.000
5	10	395.000	5	0	0
6	10	395.000	5	7	2.765.000

7	9	395.000	5	0	0
8	9	395.000	5	0	0
9	9	395.000	5	3	1.185.000
10	9	395.000	5	0	0
11	9	395.000	5	6	2.370.000
12	9	395.000	5	0	0
13	9	395.000	5	0	0
14	9	395.000	5	3	1.185.000
15	9	395.000	5	0	0
725 without belt conveyor					
1	9	395.000	5	9	3.555.000
2	10	395.000	5	1	395.000
3	12	395.000	5	2	790.000
4	22	395.000	5	10	3.950.000
5	26	395.000	5	4	1.580.000
6	30	395.000	5	13	5.135.000
7	29	395.000	5	0	0
8	33	395.000	5	6	2.370.000
9	38	395.000	5	15	5.925.000
10	13	395.000	5	0	0
11	18	395.000	5	0	0
12	22	395.000	5	1	395.000
13	27	395.000	5	11	4.345.000
14	30	395.000	5	18	7.110.000
15	34	395.000	5	4	1.580.000
Dozer D8T					
1	1	750.000	14	1	750.000
2	1	750.000	14	0	0
3	1	750.000	14	0	0
4	1	750.000	14	0	0
5	1	750.000	14	0	0
6	1	750.000	14	0	0
7	1	750.000	14	0	0
8	1	750.000	14	0	0
9	1	750.000	14	0	0
10	1	750.000	14	0	0
11	1	750.000	14	0	0
12	1	750.000	14	0	0
13	1	750.000	14	0	0
14	1	750.000	14	0	0
15	1	750.000	14	0	0
Motor grader M 14					
1	1	550.000	14	1	550.000
2	1	550.000	14	0	0
3	1	550.000	14	0	0
4	1	550.000	14	0	0
5	1	550.000	14	0	0
6	1	550.000	14	0	0
7	1	550.000	14	0	0
8	1	550.000	14	0	0
9	1	550.000	14	0	0
10	1	550.000	14	0	0
11	1	550.000	14	0	0
12	1	550.000	14	0	0
13	1	550.000	14	0	0

14	1	550.000	14	0	0
15	1	550.000	14	0	0
Motor grader M 16					
1	1	800.000	14	1	800.000
2	1	800.000	14	0	0
3	1	800.000	14	0	0
4	1	800.000	14	0	0
5	1	800.000	14	0	0
6	1	800.000	14	0	0
7	1	800.000	14	0	0
8	1	800.000	14	0	0
9	1	800.000	14	0	0
10	1	800.000	14	0	0
11	1	800.000	14	0	0
12	1	800.000	14	0	0
13	1	800.000	14	0	0
14	1	800.000	14	0	0
15	1	800.000	14	0	0
Belt conveyor					
1	1	6.875.000	14	1	6.875.000
2	1	6.875.000	14	0	0
3	1	6.875.000	14	0	0
4	1	6.875.000	14	0	0
5	1	6.875.000	14	0	0
6	1	6.875.000	14	0	0
7	1	6.875.000	14	0	0
8	1	6.875.000	14	0	0
9	1	6.875.000	14	0	0
10	1	6.875.000	14	0	0
11	1	6.875.000	14	0	0
12	1	6.875.000	14	0	0
13	1	6.875.000	14	0	0
14	1	6.875.000	14	0	0
15	1	6.875.000	14	0	0
Drill rig					
1	1	215.900	14	1	215.900
2	1	215.900	14	0	0
3	1	215.900	14	0	0
4	1	215.900	14	0	0
5	1	215.900	14	0	0
6	1	215.900	14	0	0
7	1	215.900	14	0	0
8	1	215.900	14	0	0
9	1	215.900	14	0	0
10	1	215.900	14	0	0
11	1	215.900	14	0	0
12	1	215.900	14	0	0
13	1	215.900	14	0	0
14	1	215.900	14	0	0
15	1	215.900	14	0	0
Belt conveyor bucket wheel excavator					
1	1	2.000.000	14	1	2.000.000
2	1	2.000.000	14	0	0
3	1	2.000.000	14	0	0

4	1	2.000.000	14	0	0
5	1	2.000.000	14	0	0
6	1	2.000.000	14	0	0
7	1	2.000.000	14	0	0
8	1	2.000.000	14	0	0
9	1	2.000.000	14	0	0
10	1	2.000.000	14	0	0
11	1	2.000.000	14	0	0
12	1	2.000.000	14	0	0
13	1	2.000.000	14	0	0
14	1	2.000.000	14	0	0
15	1	2.000.000	14	0	0
spreader					
1	1	5.000.000	14	1	5.000.000
2	1	5.000.000	14	0	0
3	1	5.000.000	14	0	0
4	1	5.000.000	14	0	0
5	1	5.000.000	14	0	0
6	1	5.000.000	14	0	0
7	1	5.000.000	14	0	0
8	1	5.000.000	14	0	0
9	1	5.000.000	14	0	0
10	1	5.000.000	14	0	0
11	1	5.000.000	14	0	0
12	1	5.000.000	14	0	0
13	1	5.000.000	14	0	0
14	1	5.000.000	14	0	0
15	1	5.000.000	14	0	0
Bucket wheel excavator					
1	1	10.000.000	14	1	10.000.000
2	1	10.000.000	14	0	0
3	1	10.000.000	14	0	0
4	1	10.000.000	14	0	0
5	1	10.000.000	14	0	0
6	1	10.000.000	14	0	0
7	1	10.000.000	14	0	0
8	1	10.000.000	14	0	0
9	1	10.000.000	14	0	0
10	1	10.000.000	14	0	0
11	1	10.000.000	14	0	0
12	1	10.000.000	14	0	0
13	1	10.000.000	14	0	0
14	1	10.000.000	14	0	0
15	1	10.000.000	14	0	0

Table 66: Acquisition costs

year	Labour costs	Fuel costs	Service costs	Repairing costs	Sum
Scraper 637 G					
1	548.122	3.597.048	405.382	2.934.734	7.485.286
2	548.122	3.597.048	405.382	2.934.734	7.485.286
3	548.122	3.597.048	405.382	2.934.734	7.485.286
4	959.213	6.294.834	709.418	5.135.785	13.099.250
5	959.213	6.294.834	709.418	5.135.785	13.099.250
6	959.213	6.294.834	709.418	5.135.785	13.099.250
7	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
8	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
9	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
10	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
11	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
12	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
13	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
14	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
15	1.507.334	9.891.882	1.114.799	8.070.520	20.584.535
Wheel loader 980 H					
1	136.666	279.026	55.520	216.814	688.026
2	136.666	279.026	55.520	216.814	688.026
3	136.666	279.026	55.520	216.814	688.026
4	136.666	279.026	55.520	216.814	688.026
5	136.666	279.026	55.520	216.814	688.026
6	136.666	279.026	55.520	216.814	688.026
7	136.666	279.026	55.520	216.814	688.026
8	136.666	279.026	55.520	216.814	688.026
9	136.666	279.026	55.520	216.814	688.026
10	136.666	279.026	55.520	216.814	688.026
11	136.666	279.026	55.520	216.814	688.026
12	136.666	279.026	55.520	216.814	688.026
13	136.666	279.026	55.520	216.814	688.026
14	136.666	279.026	55.520	216.814	688.026
15	136.666	279.026	55.520	216.814	688.026
excavator 365C L					
1	12.480	128.765	13.000	74.750	228.995
2	12.480	128.765	13.000	74.750	228.995
3	12.480	128.765	13.000	74.750	228.995
4	12.480	128.765	13.000	74.750	228.995
5	12.480	128.765	13.000	74.750	228.995
6	12.480	128.765	13.000	74.750	228.995
7	28.080	193.148	19.500	112.125	352.853
8	28.080	193.148	19.500	112.125	352.853
9	28.080	193.148	19.500	112.125	352.853
10	28.080	193.148	19.500	112.125	352.853
11	28.080	193.148	19.500	112.125	352.853
12	28.080	193.148	19.500	112.125	352.853
13	28.080	193.148	19.500	112.125	352.853
14	28.080	193.148	19.500	112.125	352.853
15	28.080	193.148	19.500	112.125	352.853
Excavator 120-E					
1	45.677	499.590	73.749	577.145	1.196.161
2	45.677	499.590	73.749	577.145	1.196.161
3	45.677	499.590	73.749	577.145	1.196.161
4	91.354	999.180	147.498	1.154.291	2.392.322

5	91.354	999.180	147.498	1.154.291	2.392.322
6	91.354	999.180	147.498	1.154.291	2.392.322
7	91.354	999.180	147.498	1.154.291	2.392.322
8	91.354	999.180	147.498	1.154.291	2.392.322
9	91.354	999.180	147.498	1.154.291	2.392.322
10	91.354	999.180	147.498	1.154.291	2.392.322
11	91.354	999.180	147.498	1.154.291	2.392.322
12	91.354	999.180	147.498	1.154.291	2.392.322
13	91.354	999.180	147.498	1.154.291	2.392.322
14	91.354	999.180	147.498	1.154.291	2.392.322
15	91.354	999.180	147.498	1.154.291	2.392.322
Mining truck 777 F					
1	319.738	1.530.577	262.784	2.269.804	4.382.903
2	319.738	1.530.577	262.784	2.269.804	4.382.903
3	319.738	1.530.577	262.784	2.269.804	4.382.903
4	593.798	2.842.501	488.028	4.215.350	8.139.677
5	593.798	2.842.501	488.028	4.215.350	8.139.677
6	593.798	2.842.501	488.028	4.215.350	8.139.677
7	867.859	4.154.424	713.272	6.160.896	11.896.451
8	867.859	4.154.424	713.272	6.160.896	11.896.451
9	867.859	4.154.424	713.272	6.160.896	11.896.451
10	867.859	4.154.424	713.272	6.160.896	11.896.451
11	867.859	4.154.424	713.272	6.160.896	11.896.451
12	867.859	4.154.424	713.272	6.160.896	11.896.451
13	867.859	4.154.424	713.272	6.160.896	11.896.451
14	867.859	4.154.424	713.272	6.160.896	11.896.451
15	867.859	4.154.424	713.272	6.160.896	11.896.451
725 with belt conveyor					
1	87.360	226.772	87.360	451.906	853.398
2	87.360	226.772	87.360	451.906	853.398
3	87.360	226.772	87.360	451.906	853.398
4	124.800	323.960	124.800	645.580	1.219.140
5	124.800	323.960	124.800	645.580	1.219.140
6	124.800	323.960	124.800	645.580	1.219.140
7	252.720	437.346	168.480	871.533	1.730.079
8	252.720	437.346	168.480	871.533	1.730.079
9	252.720	437.346	168.480	871.533	1.730.079
10	252.720	437.346	168.480	871.533	1.730.079
11	252.720	437.346	168.480	871.533	1.730.079
12	252.720	437.346	168.480	871.533	1.730.079
13	252.720	437.346	168.480	871.533	1.730.079
14	252.720	437.346	168.480	871.533	1.730.079
15	252.720	437.346	168.480	871.533	1.730.079
725 without belt conveyor					
1	107.145	278.131	107.145	554.252	1.046.673
2	125.534	325.866	125.534	649.378	1.226.313
3	143.923	373.601	143.923	744.504	1.405.953
4	271.940	705.911	271.940	1.406.724	2.656.515
5	328.579	852.936	328.579	1.699.710	3.209.803
6	372.737	967.564	372.737	1.928.139	3.641.177
7	827.938	1.432.792	551.958	2.855.235	5.667.924
8	938.273	1.623.734	625.515	3.235.739	6.423.262
9	1.076.689	1.863.269	717.792	3.713.080	7.370.830

10	357.883	619.336	238.589	1.234.198	2.450.006
11	496.298	858.872	330.865	1.711.539	3.397.575
12	606.634	1.049.813	404.422	2.092.043	4.152.912
13	745.049	1.289.349	496.699	2.569.384	5.100.481
14	855.384	1.480.290	570.256	2.949.888	5.855.819
15	965.720	1.671.232	643.813	3.330.392	6.611.157
Dozer D8T					
1	45.677	128.561	25.693	62.520	262.451
2	45.677	128.561	25.693	62.520	262.451
3	45.677	128.561	25.693	62.520	262.451
4	45.677	128.561	25.693	62.520	262.451
5	45.677	128.561	25.693	62.520	262.451
6	45.677	128.561	25.693	62.520	262.451
7	45.677	128.561	25.693	62.520	262.451
8	45.677	128.561	25.693	62.520	262.451
9	45.677	128.561	25.693	62.520	262.451
10	45.677	128.561	25.693	62.520	262.451
11	45.677	128.561	25.693	62.520	262.451
12	45.677	128.561	25.693	62.520	262.451
13	45.677	128.561	25.693	62.520	262.451
14	45.677	128.561	25.693	62.520	262.451
15	45.677	128.561	25.693	62.520	262.451
Motor grader M 14					
1	45.677	78.269	25.217	39.491	188.655
2	45.677	78.269	25.217	39.491	188.655
3	45.677	78.269	25.217	39.491	188.655
4	45.677	78.269	25.217	39.491	188.655
5	45.677	78.269	25.217	39.491	188.655
6	45.677	78.269	25.217	39.491	188.655
7	45.677	78.269	25.217	39.491	188.655
8	45.677	78.269	25.217	39.491	188.655
9	45.677	78.269	25.217	39.491	188.655
10	45.677	78.269	25.217	39.491	188.655
11	45.677	78.269	25.217	39.491	188.655
12	45.677	78.269	25.217	39.491	188.655
13	45.677	78.269	25.217	39.491	188.655
14	45.677	78.269	25.217	39.491	188.655
15	45.677	78.269	25.217	39.491	188.655
Motor grader M 16					
1	45.677	94.922	33.782	60.331	234.712
2	45.677	94.922	33.782	60.331	234.712
3	45.677	94.922	33.782	60.331	234.712
4	45.677	94.922	33.782	60.331	234.712
5	45.677	94.922	33.782	60.331	234.712
6	45.677	94.922	33.782	60.331	234.712
7	45.677	94.922	33.782	60.331	234.712
8	45.677	94.922	33.782	60.331	234.712
9	45.677	94.922	33.782	60.331	234.712
10	45.677	94.922	33.782	60.331	234.712
11	45.677	94.922	33.782	60.331	234.712
12	45.677	94.922	33.782	60.331	234.712
13	45.677	94.922	33.782	60.331	234.712
14	45.677	94.922	33.782	60.331	234.712
15	45.677	94.922	33.782	60.331	234.712

Drill rig					
1	12.480	45.500	13.000	20.800	91.780
2	12.480	45.500	13.000	20.800	91.780
3	12.480	45.500	13.000	20.800	91.780
4	12.480	45.500	13.000	20.800	91.780
5	12.480	45.500	13.000	20.800	91.780
6	12.480	45.500	13.000	20.800	91.780
7	28.080	68.250	19.500	31.200	147.030
8	28.080	68.250	19.500	31.200	147.030
9	28.080	68.250	19.500	31.200	147.030
10	28.080	68.250	19.500	31.200	147.030
11	28.080	68.250	19.500	31.200	147.030
12	28.080	68.250	19.500	31.200	147.030
13	28.080	68.250	19.500	31.200	147.030
14	28.080	68.250	19.500	31.200	147.030
15	28.080	68.250	19.500	31.200	147.030

Belt conveyor	Labour costs	Electricity costs	Repairing costs	Rebuilding costs	Sum
1	46.080	56.000	350.000	0	452.080
2	46.080	56.000	350.000	0	452.080
3	46.080	56.000	350.000	0	452.080
4	46.080	56.000	350.000	0	452.080
5	46.080	56.000	350.000	0	452.080
6	46.080	56.000	350.000	0	452.080
7	103.680	84.000	350.000	0	537.680
8	103.680	84.000	350.000	0	537.680
9	103.680	84.000	350.000	3.437.500	3.975.180
10	103.680	84.000	350.000	0	537.680
11	103.680	84.000	350.000	0	537.680
12	103.680	84.000	350.000	0	537.680
13	103.680	84.000	350.000	0	537.680
14	103.680	84.000	350.000	0	537.680
15	103.680	84.000	350.000	0	537.680

Belt conveyor bucket wheel excavator	Labour costs	Electricity costs	maintenance	Sum
1	168.192	102.200	300.000	570.392
2	168.192	102.200	300.000	570.392
3	168.192	102.200	300.000	570.392
4	168.192	102.200	300.000	570.392
5	168.192	102.200	300.000	570.392
6	168.192	102.200	300.000	570.392
7	168.192	102.200	300.000	570.392
8	168.192	102.200	300.000	570.392
9	168.192	102.200	300.000	570.392
10	168.192	102.200	300.000	570.392
11	168.192	102.200	300.000	570.392
12	168.192	102.200	300.000	570.392
13	168.192	102.200	300.000	570.392
14	168.192	102.200	300.000	570.392
15	168.192	102.200	300.000	570.392
Stacker				
1	56.064	408.800	200.000	664.864
2	56.064	408.800	200.000	664.864
3	56.064	408.800	200.000	664.864
4	56.064	408.800	200.000	664.864

5	56.064	408.800	200.000	664.864
6	56.064	408.800	200.000	664.864
7	56.064	408.800	2.700.000	3.164.864
8	56.064	408.800	200.000	664.864
9	56.064	408.800	200.000	664.864
10	56.064	408.800	200.000	664.864
11	56.064	408.800	200.000	664.864
12	56.064	408.800	200.000	664.864
13	56.064	408.800	200.000	664.864
14	56.064	408.800	200.000	664.864
15	56.064	408.800	200.000	664.864
Bucket wheel excavator				
1	112.128	584.000	400.000	1.096.128
2	112.128	584.000	400.000	1.096.128
3	112.128	584.000	400.000	1.096.128
4	112.128	584.000	400.000	1.096.128
5	112.128	584.000	400.000	1.096.128
6	112.128	584.000	400.000	1.096.128
7	112.128	584.000	5.400.000	6.096.128
8	112.128	584.000	400.000	1.096.128
9	112.128	584.000	400.000	1.096.128
10	112.128	584.000	400.000	1.096.128
11	112.128	584.000	400.000	1.096.128
12	112.128	584.000	400.000	1.096.128
13	112.128	584.000	400.000	1.096.128
14	112.128	584.000	400.000	1.096.128
15	112.128	584.000	400.000	1.096.128

Table 67: Operating Costs

Year	1	2	3	4	5	6
Option 1						
Acquisition costs	28.055.900	0	0	13.735.000	15.600.000	3.215.000
Operating costs	10.250.670	10.250.670	10.250.670	16.230.377	16.230.377	16.230.377
	38.306.570	10.250.670	10.250.670	29.965.377	31.830.377	19.445.377
Option 2						
Acquisition costs	21.970.900	395.000	790.000	16.500.000	17.180.000	5.585.000
Operating costs	9.991.865	10.171.505	10.351.145	17.215.672	17.768.960	18.200.334
	31.962.765	10.566.505	11.141.145	33.715.672	34.948.960	23.785.334
Option 3						
Acquisition costs	29.655.900	0	0	2.035.000	0	3.215.000
Operating costs	5.170.565	5.170.565	5.170.565	5.536.307	5.536.307	5.536.307
	34.826.465	5.170.565	5.170.565	7.571.307	5.536.307	8.751.307
Option 4						
Acquisition costs	23.570.900	395.000	790.000	4.800.000	1.580.000	5.585.000
Operating costs	4.911.760	5.091.400	5.271.040	6.521.603	7.074.891	7.506.264
	28.482.660	5.486.400	6.061.040	11.321.603	8.654.891	13.091.264
Option 5						
Acquisition costs	29.805.900	0	0	17.235.000	0	16.515.000
Operating costs	8.390.507	8.390.507	8.390.507	13.709.184	13.709.184	13.709.184
	38.196.407	8.390.507	8.390.507	30.944.184	13.709.184	30.224.184
Option 6						
Acquisition costs	23.720.900	395.000	790.000	20.000.000	1.580.000	18.885.000

Operating costs	8.131.702	8.311.341	8.490.981	14.694.479	15.247.767	15.679.141
	31.852.602	8.706.341	9.280.981	34.694.479	16.827.767	34.564.141

Year	7	8	9	10	11	12
Option 1						
Acquisition costs	16.450.000	11.700.000	16.785.000	850.000	18.420.000	11.700.000
Operating costs	24.491.309	24.491.309	27.928.809	24.491.309	24.491.309	24.491.309
	40.941.309	36.191.309	44.713.809	25.341.309	42.911.309	36.191.309
Option 2						
Acquisition costs	16.450.000	14.070.000	21.525.000	850.000	16.050.000	12.095.000
Operating costs	27.891.474	28.646.811	29.594.380	24.673.556	25.621.124	26.376.462
	44.341.474	42.716.811	51.119.380	25.523.556	41.671.124	38.471.462
Option 3						
Acquisition costs	850.000	0	1.185.000	850.000	2.820.000	0
Operating costs	13.811.954	6.311.954	9.749.454	6.311.954	6.311.954	6.311.954
	14.661.954	6.311.954	10.934.454	7.161.954	9.131.954	6.311.954
Option 4						
Acquisition costs	850.000	2.370.000	5.925.000	850.000	450.000	395.000
Operating costs	17.212.119	10.467.456	11.415.025	6.494.201	7.441.769	8.197.107
	18.062.119	12.837.456	17.340.025	7.344.201	7.891.769	8.592.107
Option 5						
Acquisition costs	12.250.000	0	12.585.000	4.650.000	16.120.000	11.400.000
Operating costs	18.241.604	18.241.604	21.679.104	18.241.604	18.241.604	18.241.604
	30.491.604	18.241.604	34.264.104	22.891.604	34.361.604	29.641.604
Option 6						
Acquisition costs	12.250.000	2.370.000	17.325.000	4.650.000	13.750.000	11.795.000
Operating costs	21.641.769	22.397.107	23.344.676	18.423.851	19.371.420	20.126.758
	33.891.769	24.767.107	40.669.676	23.073.851	33.121.420	31.921.758

Year	13	14	15
Option 1			
Acquisition costs	16.450.000	1.185.000	15.600.000
Operating costs	24.491.309	24.491.309	24.491.309
	40.941.309	25.676.309	40.091.309
Option 2			
Acquisition costs	20.795.000	7.110.000	17.180.000
Operating costs	27.324.031	28.079.369	28.834.706
	48.119.031	35.189.369	46.014.706
Option 3			
Acquisition costs	850.000	1.185.000	0
Operating costs	6.311.954	6.311.954	6.311.954
	7.161.954	7.496.954	6.311.954
Option 4			
Acquisition costs	5.195.000	7.110.000	1.580.000
Operating costs	9.144.676	9.900.014	10.655.351
	14.339.676	17.010.014	12.235.351
Option 5			
Acquisition costs	4.650.000	12.585.000	0
Operating costs	18.241.604	18.241.604	18.241.604
	22.891.604	30.826.604	18.241.604
Option 6			
Acquisition costs	8.995.000	18.510.000	1.580.000
Operating costs	21.074.326	21.829.664	22.585.002
	30.069.326	40.339.664	24.165.002

Table 68: Summary of acquisition and operating cost for each year

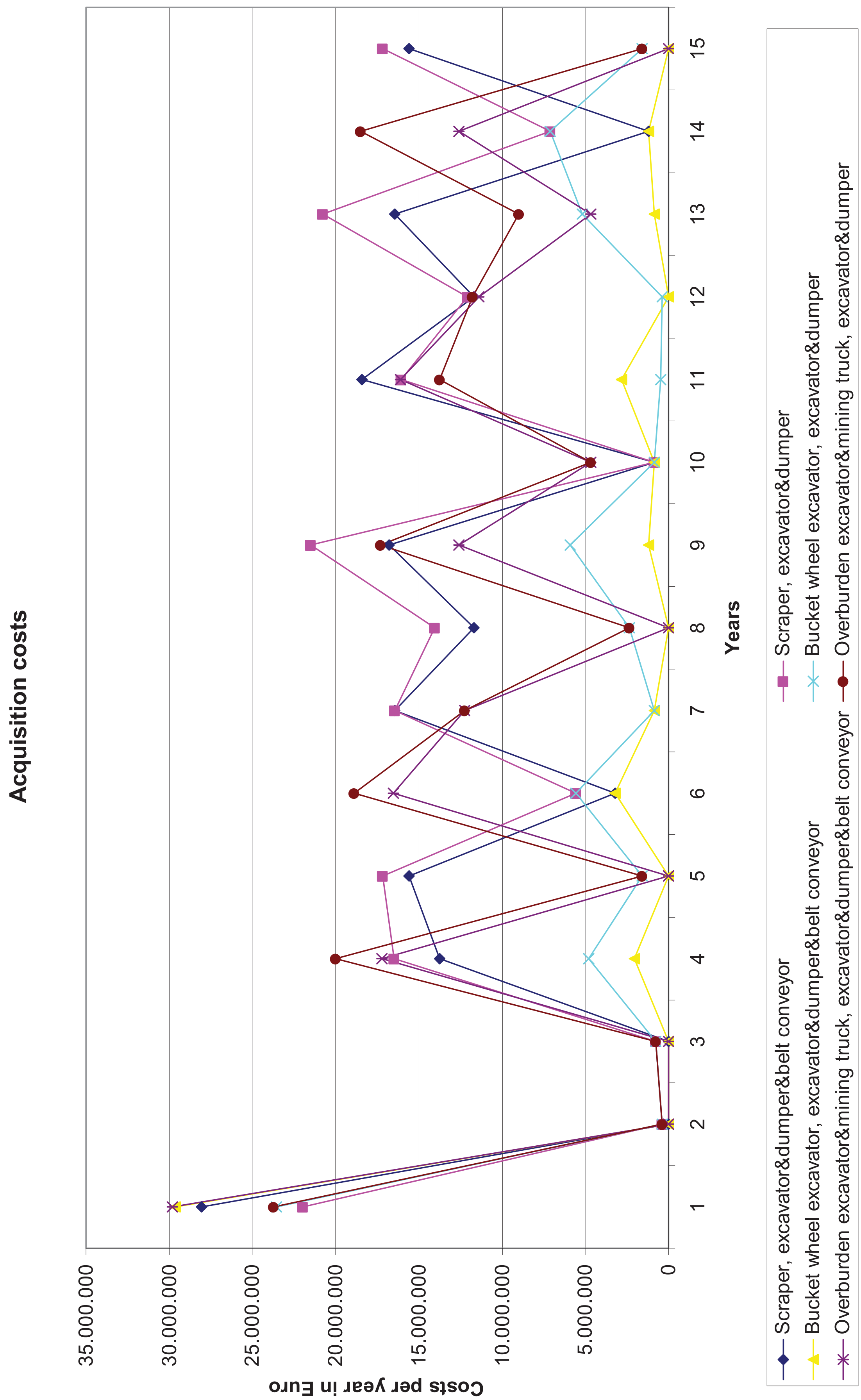


Figure 34: Acquisition costs per year

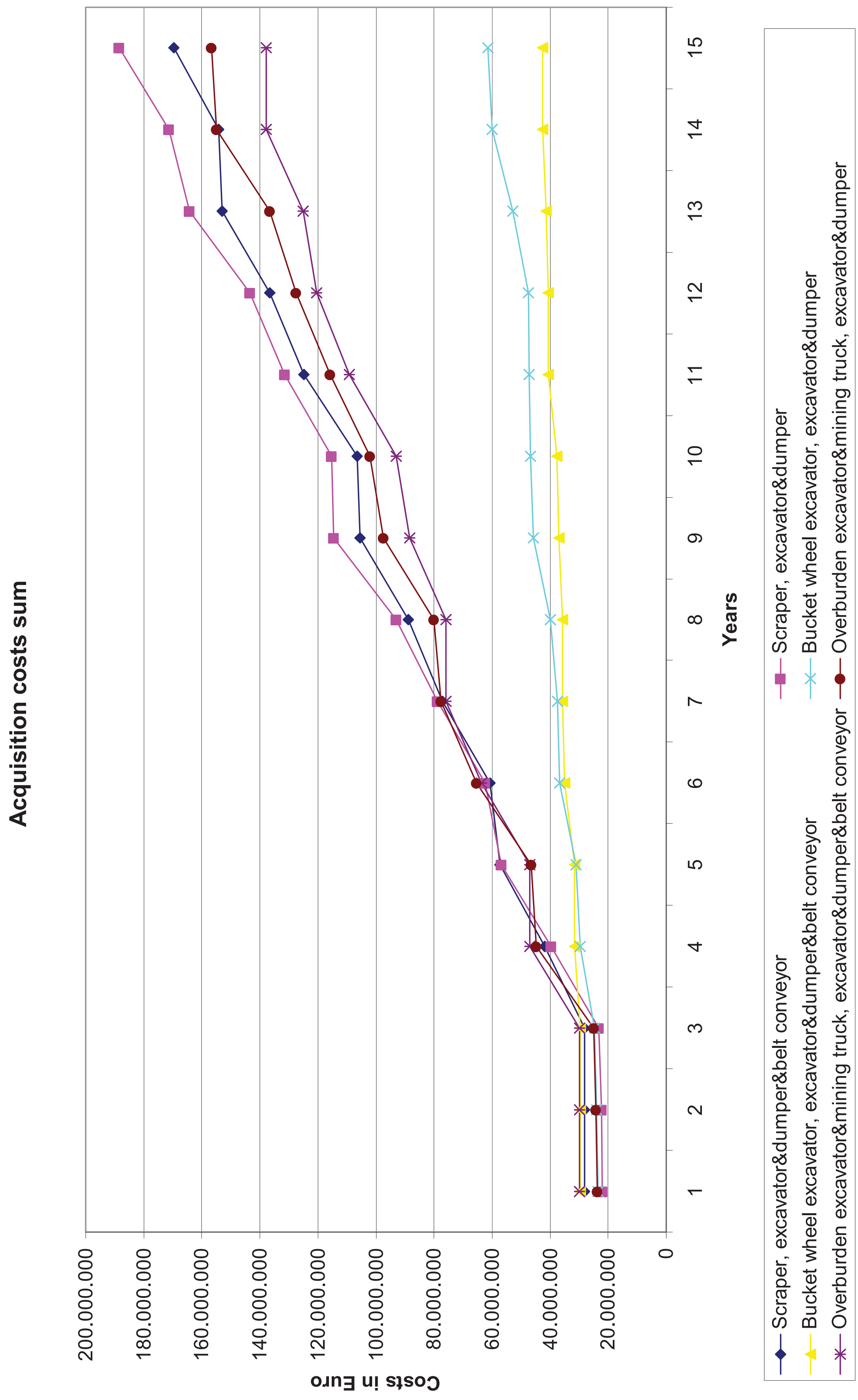


Figure 35: Sum of all Acquisition costs

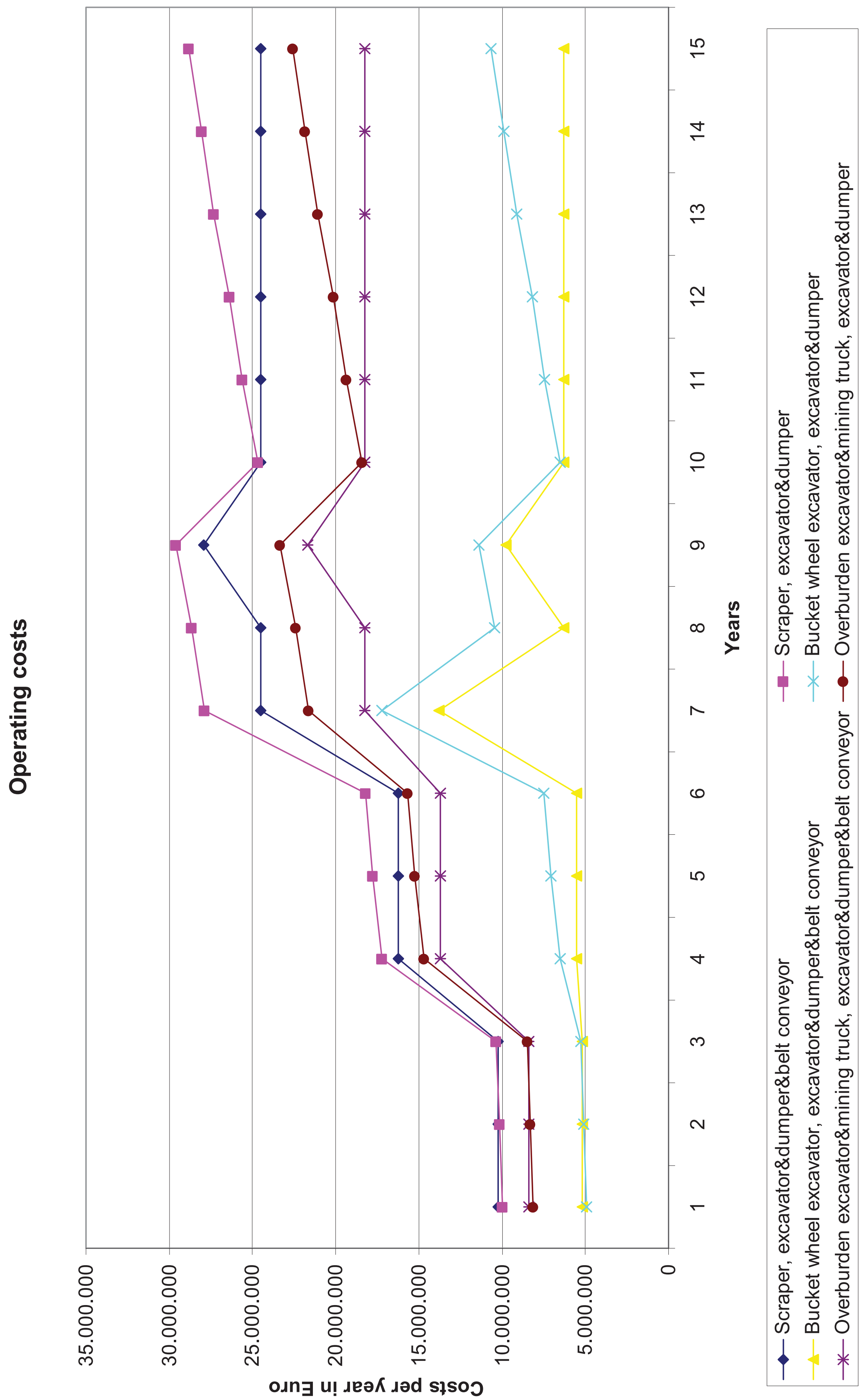


Figure 36: Operating costs per year

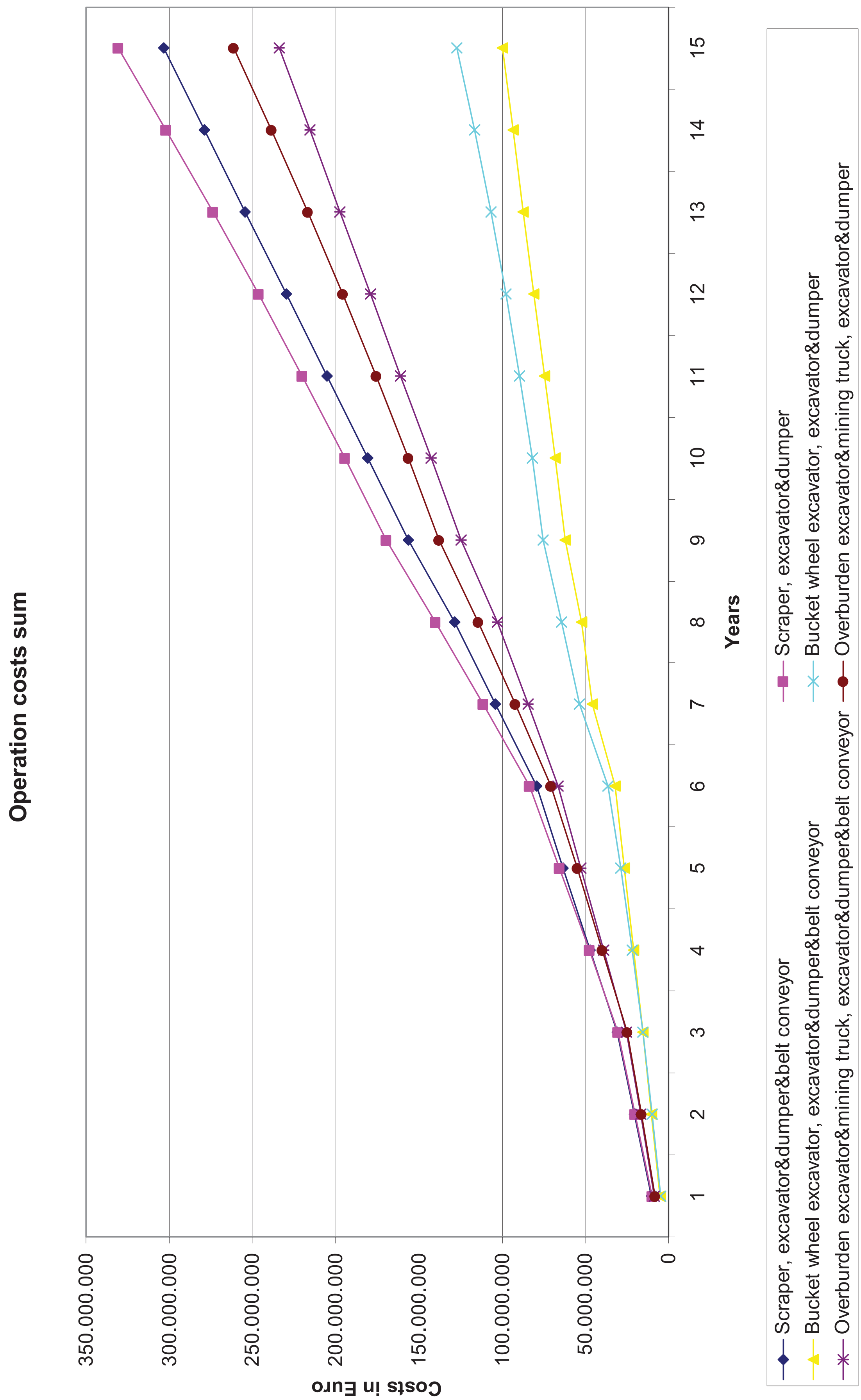


Figure 37: Sum of all Operating costs

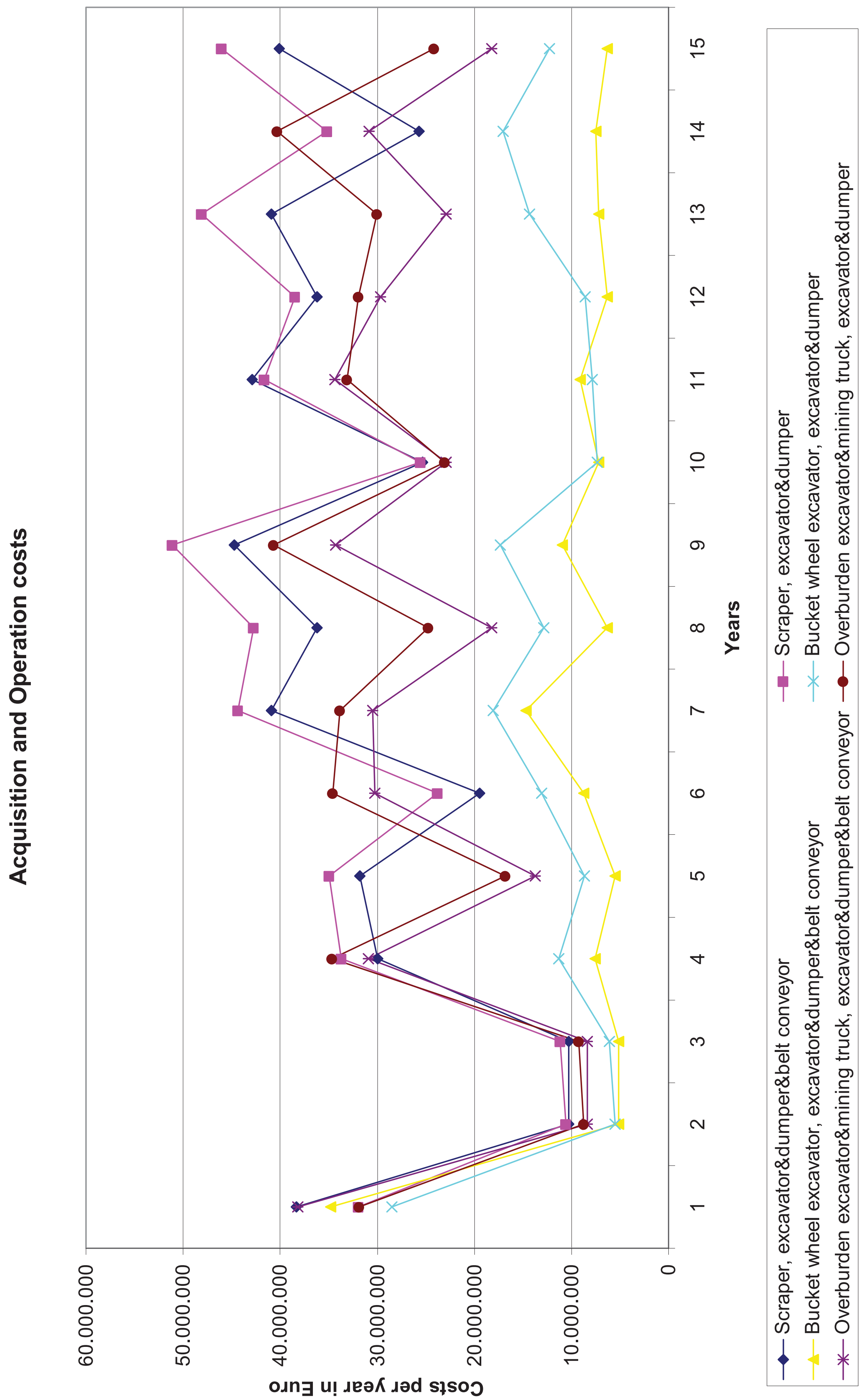


Figure 38: Acquisition costs and Operating costs per year

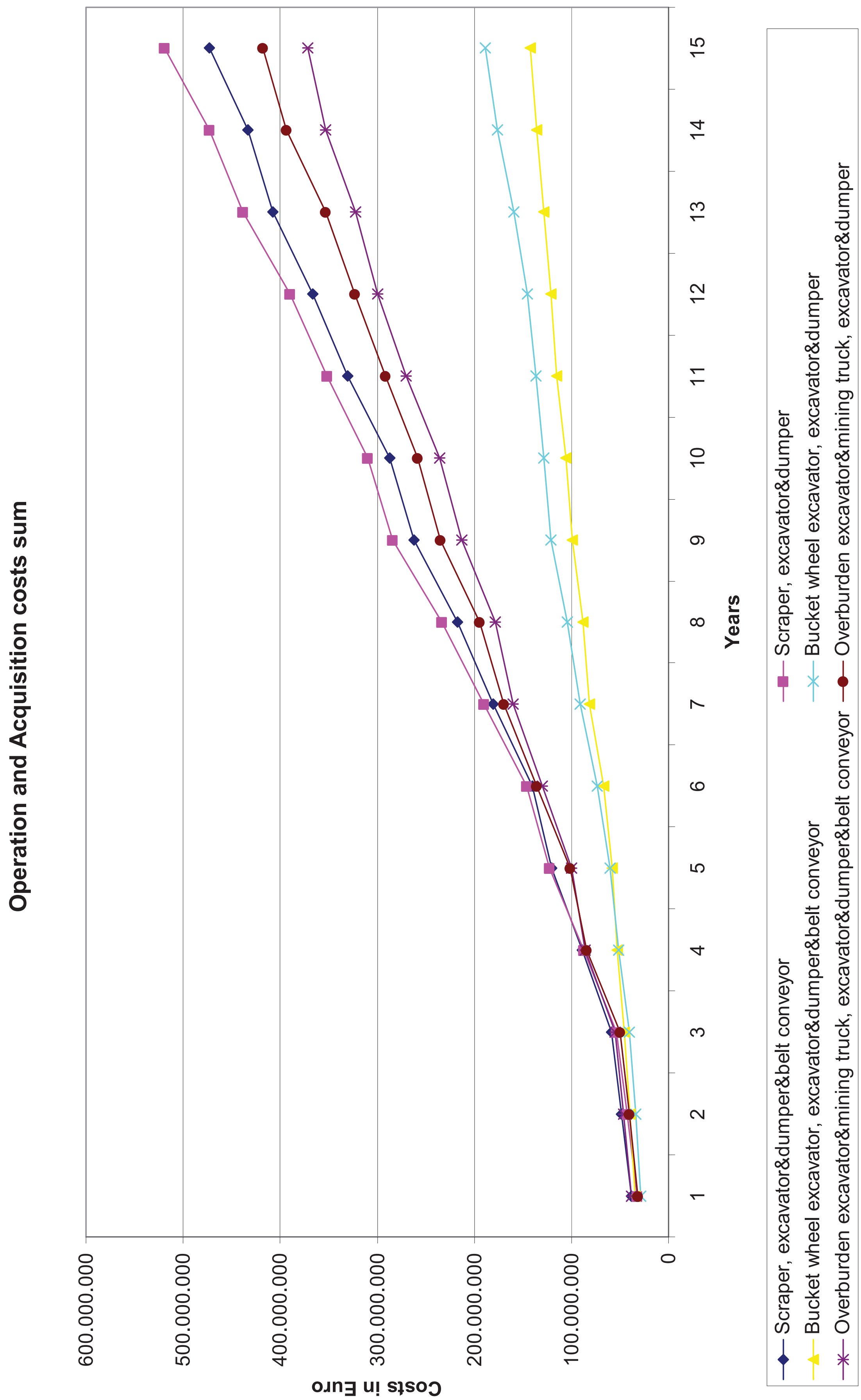


Figure 39: Sum of all Acquisition costs and Operating costs

Year	1	2	3	4	5	6
Option 1	34,82	9,32	9,32	18,16	19,29	11,79
Option 2	29,06	9,61	10,13	20,43	21,18	14,42
Option 3	31,66	4,70	4,70	4,59	3,36	5,30
Option 4	25,89	4,99	5,51	6,86	5,25	7,93
Option 5	34,72	7,63	7,63	18,75	8,31	18,32
Option 6	28,96	7,91	8,44	21,03	10,20	20,95
Year	7	8	9	10	11	12
Option 1	18,61	16,45	20,32	11,52	19,51	16,45
Option 2	20,16	19,42	23,24	11,60	18,94	17,49
Option 3	6,66	2,87	4,97	3,26	4,15	2,87
Option 4	8,21	5,84	7,88	3,34	3,59	3,91
Option 5	13,86	8,29	15,57	10,41	15,62	13,47
Option 6	15,41	11,26	18,49	10,49	15,06	14,51
Year	13	14	15			
Option 1	18,61	11,67	18,22			
Option 2	21,87	16,00	20,92			
Option 3	3,26	3,41	2,87			
Option 4	6,52	7,73	5,56			
Option 5	10,41	14,01	8,29			
Option 6	13,67	18,34	10,98			

Table 69: Costs per tonne depended on the mining method for each year

	mean costs per ton in euro
Option 1	**16,94**
Option 2	**18,30**
Option 3	**5,91**
Option 4	**7,27**
Option 5	**13,69**
Option 6	**15,04**

Table 70: Average costs per tonne for each mining method

The data listed above was used to feed the RHI owned calculation sheets for dynamic cost effectiveness studies. These sheets are for internal use only and are not published in this paper. The results on the other hand are mentioned and interpreted in the following paragraphs.

	Option 1	Option 2
Costs per ton in euro	16,94	18,30
Selling price per ton in euro	16,94	18,30
discounted cash flow	**14.438**	**6.772**
internal rate of return	**29,49%**	**28,62%**
payback period	**4,33**	**4,01**
benefit cost ration	1,68	1,30
	Option 3	Option 4
Costs per ton in euro	5,91	7,27
Selling price per ton in euro	5,91	7,27
discounted cash flow	**109.544**	**101.703**
internal rate of return	**92,40%**	**129,11%**
payback period	**1,39**	**0,89**
benefit cost ration	7,43	10,46
	Option 5	Option 6
Costs per ton in euro	13,69	15,04
Selling price per ton in euro	13,69	15,04
discounted cash flow	**40.182**	**32.291**
internal rate of return	**48,25%**	**58,82%**
payback period	**2,92**	**1,36**
benefit cost ration	2,96	2,68

Table 71: Listing of results of the dynamic cost effectiveness analysis methods

At first view the results seem to be very promising, but a critical look at it and some explanations about the dynamic calculations method are required at this point.

The aim of the dynamic calculation method is to compare two different situations or investments, i.e. to decide if site A is more economical as site B. In this case a second bauxite producing site is missing. RHI was buying the needed amounts of processed bauxite on the open market. The only way to apply this kind of calculations is to compare the planned mine in Brazil with the present situation of buying the resource from other companies. However this kind of application is a bit unorthodox.

There are no official prices for raw bauxite available, which were needed due to the consideration of setting up a new mine excluding the processing plant. Therefore the determined production costs per tonne were used to solve this problem.

Another critical aspect is the focus on the investments regarding the open pit only. A common way would be to include the processing plant representing the consumer of the mine as well. The last mentionable facet is that the RHI calculation sheets are

not able to perform their tasks for longer periods than 10 year, a fact that is not applicable for this mine which has a planned lifetime for at least 14 years.
All these reasons may have caused the very good results.

On the other hand all the basis parameters are similar for all 6 mining options, a fact that allows at least a good comparison among each other.
The graph of the discounted cash flow (Figure 40) shows, despite a positive DCF value in general, a consistent drop below 0 in option 1 and 2.
Due to the short payback period and the high DCF as well as the remarkable internal rate of return, the construction and operation of a bauxite mine, instead of purchasing the ore, is recommended.
The value 'benefit cost ration' is for RHI internal use only and not part of the estimations developed in this paper.

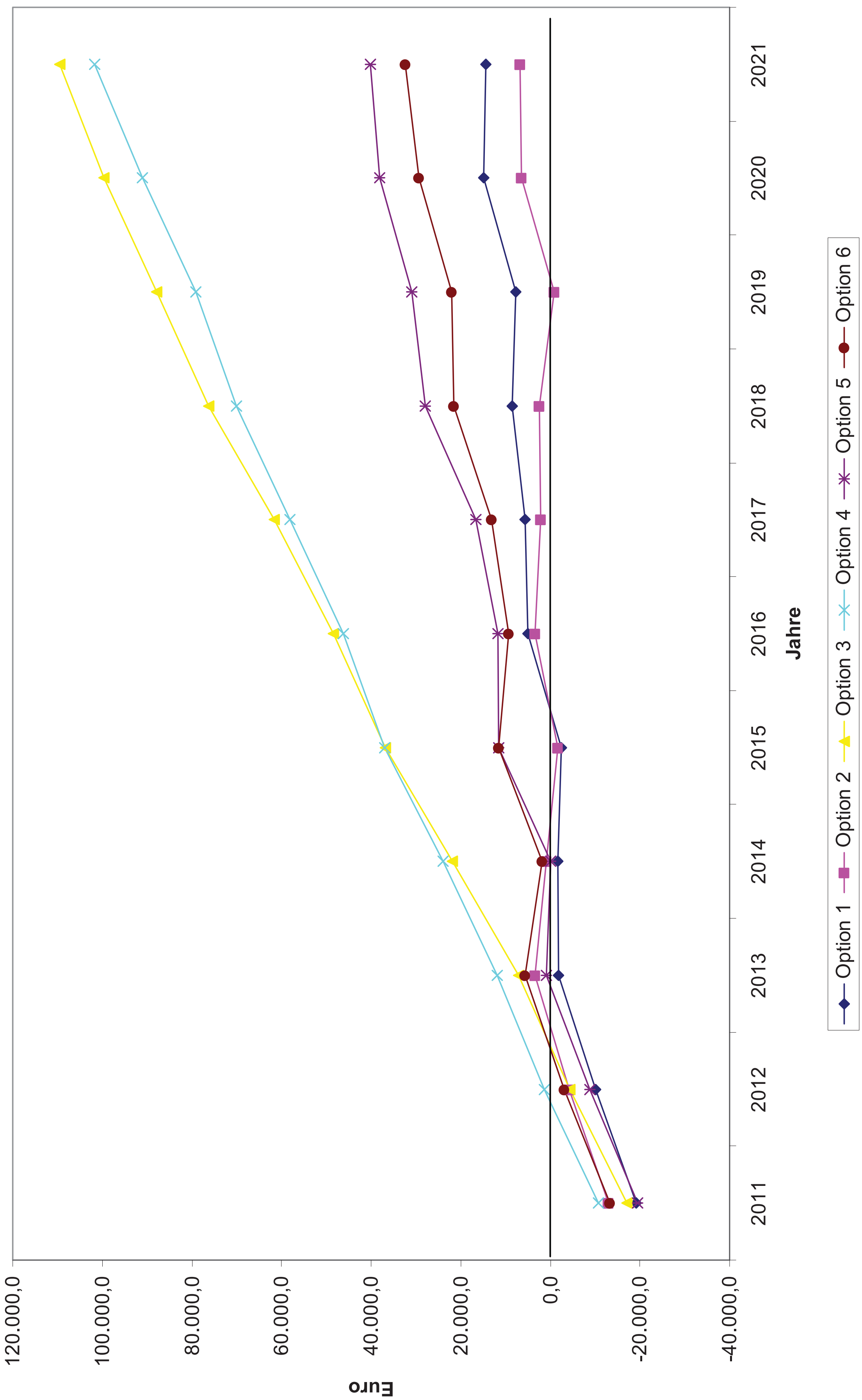


Figure 40: Development of DCF against operating years

14 Conclusion

A look at the results of the cost effectiveness studies shows that the stripping of overburden can be done most efficiently with a bucket wheel excavator.

If the bauxite transportation with a belt conveyor will be the most effective option in terms of economic aspects is not as easy to tell.

The obtained values show that option 3, the mentioned transportation of ore with a belt conveyor, reaches the highest DCF. Option 4 on the other hand is more preferable talking about the results regarding payback period and internal rate of return. Further the graph in Figure 40 demonstrated that option 4 has got a higher DCF during the first 5, 5 years, but option 3 will perform more profitable after this period.

Nevertheless there are arguments against the use of a bucket wheel excavator. Figure 34 and Figure 35 for instance proves the high acquisition costs of this kind of machine compared to the equipment rated for the rest of the options. A quite important aspect thinking of the fact that capital costs should be kept at the lowest possible level. Furthermore there are also arguments against it with no reference to costs, like the lack of experience with bucket wheel excavators and the related risk of misjudgements and false economic assumptions. This means, data used in the calculations are provided by manufacturers only without any chance of verifying based on RHI experience. Additionally there is no chance of testing a machine like this under these conditions. Unpredictable events like blocking of the buckets caused by the sticky and moist overburden characteristics or a total breakdown what will affect the entire production, not just the stripping of waste, create very risky circumstances. In this case it is impossible to have a back-up system for the removal of overburden to keep up the production rate of ore.

The two scraper using options are rejected as a result of the cost calculations and the discussed disadvantages. Whereas the required know-how to operate a scraper fleet at its optimum level can be seen is the most important one. It be too cost intensive to build up and maintain the needed amount of knowledge and experience in this area of Brazil. The same goes for the recruiting of skilled operators in other areas or even other countries.

Positive aspects are the existing knowledge about the usability of scraper in this specific area, because they were already used in the former bauxite mine of Caracuru II to remove the layer of overburden and investing costs for the first year, which are the lowest of all 6 options.

Hence the remaining options for handling the overburden are the ones with a dipper shovel excavator in combination with mining trucks. In comparison to the scraper options these options show significantly better results obtained in the cost effectiveness calculations. Looking at the DCF value of option 5, it seems to be the one to go with whereupon option 6 delivers as well better results during the first 5 years as lower capital cost for the first year.

Still there is the risk of being dependent on the performance of one single piece of equipment, but according to the 3 mining steps a second excavator will be installed in the 4^{th} year, a risk reducing point of this mining method. Another positive facet of the use of the excavators is the possibility to create two different mining faces which can help to manage the occurrence of quality fluctuations.

The final statement of this thesis is that the mining method described as option 6, using dipper shovels and mining trucks for overburden handling and pulls shovel excavators in combination with dumpers for extraction the bauxite ore, is the one to prefer during the first 5 years. In year 6 an additional cost effectiveness analysis is recommended to consider a redesign of the method and the efficiency of the installation of a belt conveyor system.

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16 Table of figures

17 List of tables

18 Appendix A

Appendix A - Table 1: Calculation of the driving distances and the needed trucks for each year

Year 1:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	0,603	[km]	Distance	0,57	[km]
Transport time	4,63	[min]	Velocity	30	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		1,21			3,42	
Return time	3,88	[min]	Empty					
	12,32	[min]	Distance	0,603	[km]	Distance	0,57	[km]
			Velocity	35	[km/h]	Velocity	12	[km/h]
Needed trucks	5			1,03			2,85	

Year 2:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	1,21	[km]	Distance	0,57	[km]
Transport time	5,43	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		2,01			3,42	
Return time	4,24	[min]	Empty					
	13,48	[min]	Distance	1,21	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	6			1,39			2,85	

Year 3:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	1,81	[km]	Distance	0,57	[km]
Transport time	6,44	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		3,02			3,42	
Return time	4,94	[min]	Empty					
	15,18	[min]	Distance	1,81	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	7			2,09			2,85	

Year 4:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	2,71	[km]	Distance	0,57	[km]
Transport time	7,94	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		4,52			3,42	

Return time	5,98	[min]	Empty					
	17,73	[min]	Distance	2,71	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	8			3,13			2,85	

Year 5:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	3,62	[km]	Distance	0,57	[km]
Transport time	9,45	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		6,03			3,42	
Return time	7,03	[min]	Empty					
	20,29	[min]	Distance	3,62	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	9			4,18			2,85	

Year 6:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	4,52	[km]	Distance	0,57	[km]
Transport time	10,96	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		7,54			3,42	
Return time	8,07	[min]	Empty					
	22,84	[min]	Distance	4,52	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	10			5,22			2,85	

Year 7:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	5,73	[km]	Distance	0,57	[km]
Transport time	12,97	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		9,55			3,42	
Return time	9,46	[min]	Empty					
	26,24	[min]	Distance	5,73	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	11			6,61			2,85	

Year 8:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	6,94	[km]	Distance	0,57	[km]
Transport time	14,98	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		11,56			3,42	
Return time	10,85	[min]	Empty					
	29,64	[min]	Distance	6,94	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	13			8,00			2,85	

Year 9:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	7,50	[km]	Distance	0,57	[km]
Transport time	15,92	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		12,50			3,42	
Return time	11,50	[min]	Empty					
	31,23	[min]	Distance	7,50	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	14			8,65			2,85	

Year 10:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	1,21	[km]	Distance	0,57	[km]
Transport time	5,43	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		2,01			3,42	
Return time	4,24	[min]	Empty					
	13,48	[min]	Distance	1,21	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	6			1,39			2,85	

Year 11:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	2,41	[km]	Distance	0,57	[km]
Transport time	7,44	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		4,02			3,42	
Return time	5,63	[min]	Empty					
	16,88	[min]	Distance	2,41	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	7			2,78			2,85	

Year 12:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	3,62	[km]	Distance	0,57	[km]
Transport time	9,45	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		6,03			3,42	
Return time	7,02	[min]	Empty					
	20,28	[min]	Distance	3,62	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	9			4,17			2,85	

Year 13:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	4,82	[km]	Distance	0,57	[km]
Transport time	11,46	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		8,04			3,42	
Return time	8,42	[min]	Empty					
	23,69	[min]	Distance	4,82	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	10			5,57			2,85	

Year 14:

Loading time	2,31	[min]	Loaded					
Maneuver time	0,30	[min]	Distance	6,03	[km]	Distance	0,57	[km]
Transport time	13,47	[min]	Velocity	36	[km/h]	Velocity	10	[km/h]
Discharging time	1,20	[min]		10,05			3,42	
Return time	9,81	[min]	Empty					
	27,09	[min]	Distance	6,03	[km]	Distance	0,57	[km]
			Velocity	52	[km/h]	Velocity	12	[km/h]
Needed trucks	12			6,96			2,85	

Appendix A - Table 2: Calculation of the costs caused by belt conveyor for each year

Year	Conveyor length		920 Euro per meter Conveyor costs	Distance Dumper	needed Dumper	Dumper buy	Costs dumper	Costs per year	Costs in total
1	603	603	554.760	1.140	6	6	2.370.000	2.924.760	2.924.760
2	1.206	603	554.760	1.140	6	0	0	554.760	3.479.520
3	1.809	603	554.760	1.140	6	0	0	554.760	4.034.280
4	2.714	654	601.680	1.140	9	3	1.185.000	1.786.680	5.820.960
5	3.619	654	601.680	1.140	9	0	0	601.680	6.422.640
6	4.524	654	601.680	1.140	9	6	2.370.000	2.971.680	9.394.320
7	5.730	872	802.240	1.140	12	3	1.185.000	1.987.240	11.381.560
8	6.936	872	802.240	1.140	12	0	0	802.240	12.183.800
9	7.500	564	518.880	1.140	12	3	1.185.000	1.703.880	13.887.680
10	7.500	0	0	1.140	12	0	0	0	13.887.680
11	7.500	0	0	1.140	12	6	2.370.000	2.370.000	16.257.680
12	7.500	0	0	1.140	12	3	1.185.000	1.185.000	17.442.680
13	7.500	0	0	1.140	12	0	0	0	17.442.680
14	7.500	0	0	1.140	12	3	1.185.000	1.185.000	18.627.680
				15.960					

Appendix A - Table 3: Calculation of the costs caused trucks for each year, geometry 2

Year	distance Dumper	needed Dumper	Dumper buy	Cost per year	Costs in total
1	2.346	5	5	1.975.000	1.975.000
2	3.552	6	1	395.000	2.370.000
3	4.758	7	1	395.000	2.765.000
4	6.568	8	1	395.000	3.160.000
5	8.378	9	1	395.000	3.555.000
6	10.188	10	6	2.370.000	5.925.000
7	12.600	11	2	790.000	6.715.000
8	15.012	13	3	1.185.000	7.900.000
9	16.140	14	2	790.000	8.690.000
10	3.552	6	0	0	8.690.000
11	5.964	7	2	790.000	9.480.000
12	8.376	9	2	790.000	10.270.000
13	10.788	10	4	1.580.000	11.850.000
14	13.200	12	4	1.580.000	13.430.000
	121.422				

Appendix A - Table 4: Calculation of the costs caused trucks for each year, geometry 3

Year	distance Dumper	needed Dumper	Dumper buy	Cost per year	Costs in total
1	2.346	5	5	1.975.000	1.975.000
2	2.346	5	0	0	1.975.000
3	3.552	6	1	395.000	2.370.000
4	4.156	7	1	395.000	2.765.000
5	5.362	7	0	0	2.765.000
6	5.966	8	6	2.370.000	5.135.000
7	7.774	9	1	395.000	5.530.000
8	8.378	9	1	395.000	5.925.000
9	10.186	10	2	790.000	6.715.000
10	10.790	10	0	0	6.715.000
11	12.598	11	7	2.765.000	9.480.000
12	13.202	12	2	790.000	10.270.000
13	15.010	13	2	790.000	11.060.000
14	15.614	14	3	1.185.000	12.245.000
	117.280				

19 Appendix B

Pos. 1 Gurtförderer bico-TEC

Aufgabenstellung:			
Aufgabegut			
Aufgabeleistung	380	[t/h]	
Schüttgewicht	1,3	[t/m³]	
Korngröße	-	[mm]	Annahme: max. 200 mm
Technische Daten:			
Gurtbreite	800	[mm]	
Achsabstand	7500	[m]	
Hubhöhe	15	[m]	
max. Bandneigung	18	[°]	
Bandgeschwindigkeit	2,62	[m/s]	
Antriebsleistung	3x200	[kW]	
Ausführung:			
ANTRIEBSSTATION			
Gerüsttyp			Stahlkonstruktion
Antriebstrommel	Ø1000	[mm]	mit Gummi-Reibbelag, SN-Lagergehäuse
Anlegerolle,-trommel	Ø504	[mm]	mit Weichbelag
Abwurfhaube	1	[Stk]	mit Prallblech
Antriebseinheit	3	[Stk]	Aufsteckgetr. mit Rücklaufsp./elas. Kuppl./Frequenzumr.
	3	[Stk]	E-Motor 400V/50Hz/IP54/Isol. Kl. F
Gurtreinigung	1	[Stk]	Lamellenabstreifer Fabr. BINDER inkl. Rosta-Element
SPANNSTATION			
Typ			gew.-bel. Untergurtstation/Spannkorb/Spannturm/Schutz
Spanntrommel	Ø800	[mm]	SN-Lagergehäuse
Umlenktrommel	Ø216	[mm]	SN-Lagergehäuse
Knicktrommeln	Ø504	[mm]	SN-Lagergehäuse
Gurtreinigung	4	[Stk]	Pflugabstreifer
	1	[Stk]	Lamellenabstreifer Fabr. BINDER inkl. Rosta-Element
MULDENSTATION			
Aufgaberollen	Ø89/133x315	[mm]	mit Pufferringen, Abstand 0,4 m; 3-tlg
Tragrollen	Ø108x315	[mm]	Abstand 1,25 m; 3-tlg
Rücklaufrollen	Ø108/159x465	[mm]	mit Stützringen, Abstand 2,5 m; 2-tlg
bico-TEC Rücklaufro.	Ø89/133	[mm]	vollbesetzt mit Pufferringen
Tragkonstruktion			bico-TEC/UNP-Längsprofil
Fördergurt	15020	[m]	ST 2000 6+4, hochabriebfest, offen
Schurre(n)	1	[Stk]	Stahlblechkonstruktion, mit HARDOX-Schleißauskleidung
Aufgabegosse	10	[m]	ohne Abdeckung/HARDOX-Schleißauskleidung
Sicherheitseinricht.	300	[Stk]	Seilzugnotschalter AEG NSR12/beidseitige Reißleine
	1	[Stk]	Drehzahlwächter Telemecanique XSA-V11373
	68	[Stk]	Schieflaufwächter KIEPE-VG-133/6
Unterstützungskonstr.	3	[Stk]	Pendelstütze H = 15m
	1	[Stk]	Feststütze H = ca. 0,5m
Gittertr./Bandbrücken	1	[Stk]	Bandbrücke(n) L/B/H = 100/2,5/2,8m
Verkleidung/Bandbrücken			Wand und Dach vollverkleidet

Key specifications belt conveyor

20 Appendix C

20.1 Equipment rating Step 2 year 4

20.1.1 Scraper

Transport time 1		loaded				
		Distance	0,19	[km]		1,14
		Velocity	10	[km/h]		
Transport time 2		loaded				
		Distance	0,1	[km]		0,30
		Velocity	20	[km/h]		
Transport time 3		loaded				
		Distance	0,81	[km]		2,42
		Velocity	20	[km/h]		
Return time 1		empty				
		Distance	0,19	[km]		1,14
		Velocity	10	[km/h]		
Return time 2		empty				
		Distance	0,1	[km]		0,30
		Velocity	20	[km/h]		
Return time 3		empty				
		Distance	0,81	[km]		1,38
		Velocity	35	[km/h]		

Appendix C - Table 1: Calculation of travelling speed, distance and duration

Scraper loading time	0,70	[min]
Transport time 1	1,14	[min]
Transport time 2	0,30	[min]
Transport time 3	2,42	[min]
Discharging time	0,70	[min]
Return time 1	1,14	[min]
Return time 2	0,30	[min]
Return time 3	1,38	[min]
	8,08	[min]

Appendix C - Table 2: Summary of one loading – unloading cycle

Theoretical maximum production		60 min - hour and availability 100 %
Scraper in 60 min	7	
Output	190	[t/h]
Numbers of Scraper	19	
Numbers of dozers	10	
19 Scraper in 60 min	141	
Output	3.614	[t/h]

Appendix C - Table 3: Estimation of needed amount of scrapers assuming 100% availability

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	2.304	t/h

Appendix C - Table 4: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	244	d	8 month mining possible			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	4.758	h/y				
Availability Scraper	90,0%		available hours		4.282	h
utilisation Scraper	100,0%		utilised hours		4.282	h
long term production	9.864.647	t/y				

Appendix C - Table 5: Estimation of long term production assuming reductions caused by holiday, unforeseen events and scraper availability

Summary:

To achieve the given volume of over burden, 9.848.438 t per year, a number of 19 scrapers, model CAT 637 G, are needed. In theory this amount of units will be able to handle about 9.864.647 tonnes per year.

20.1.2 Dipper shovel excavator and mining truck

Shovel volume	10,00	[m³]
Shovel filling factor	110	[%]
Working circle time	0,5	[min]
Availability factor	50	[min]
Loading cycle	5	
Bucket volume	55	[m³]
loaded tonnage	83	[t]

Appendix C - Table 6: Estimation of the shovel volume, loading cycle and resulting load of the mining truck

Transport time 1		loaded			
		Distance	0,19	[km]	1,90
		Velocity	6	[km/h]	
Transport time 2		loaded			
		Distance	0,1	[km]	0,60
		Velocity	10	[km/h]	
Transport time 3		loaded			
		Distance	0,805	[km]	4,83
		Velocity	10	[km/h]	
Return time 1		empty			
		Distance	0,19	[km]	1,14
		Velocity	10	[km/h]	
Return time 2		empty			
		Distance	0,1	[km]	0,27
		Velocity	22	[km/h]	
Return time 3		empty			
		Distance	0,805	[km]	2,20
		Velocity	22	[km/h]	

Appendix C - Table 7: Calculation of travelling speed, distance and duration

loading time	2,50	[min]
Manoeuvre time	0,30	[min]
Transport time 1	1,90	[min]
Transport time 2	0,60	[min]
Transport time 3	4,83	[min]
Discharging time	1,20	[min]
Return time 1	1,14	[min]
Return time 2	0,27	[min]
Return time 3	2,20	[min]
	14,94	[min]
Required trucks	6	

Appendix C - Table 8: Estimation of one loading-unloading cycle and required number of mining trucks

Theoretical maximum production		60 min - hour and availability 100 %
Trucks in 60 min	24	
Output	1.980	[t/h]

Appendix C - Table 9: Estimation of theoretical production assuming 100% truck utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	1.262	t/h

Appendix C - Table 10: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	244	d	8 month mining possible			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ..)			
Production time	4.758	h/y				
Availability excavator	90,0%		available hours		4.282	h
Utilisation excavator	90,0%		utilised hours		3.854	h
long term production	4.864.686	t/y				

Appendix C - Table 11: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To achieve the given target of stripping 9.848.438 tonnes of overburden per year, two dipper shovel excavator, type RH 120-E combined with 12 mining trucks of the model CAT 777 F will be required.

20.1.3 Pull shovel excavator and dumper

Shovel volume	5,00	[m³]
Shovel filling factor	110	[%]
Working circle time	0,38	[min]
Availability factor	50	[min]

Appendix C - Table 12: Estimation of the shovel volume and the degree of filling

Loading cycle	2,5	
Bucket volume	14	[m³]
loaded tonnage	21	[t]

Appendix C - Table 13: Estimation of one loading-unloading cycle and the resulting load of the dumper

Design without the usage of a belt conveyor

loaded			
Distance	0,57	[km]	3,42
Velocity	10	[km/h]	
Distance	2,714	[km]	5,43
Velocity	30	[km/h]	
empty			
Distance	2,714	[km]	4,65
Velocity	35	[km/h]	
Distance	0,57	[km]	2,85
Velocity	12	[km/h]	

Appendix C - Table 14: Calculation of travelling speed, distance and duration

loading time	0,95	[min]
Manoeuvre time	0,30	[min]
Transport time	8,85	[min]
Discharging time	1,20	[min]
Return time	7,50	[min]
	18,80	[min]
Required trucks	20	

Appendix C - Table 15: Estimation of one loading-unloading cycle and required number of mining trucks

Design with the use of a belt conveyor

loaded		
Distance	0,57	[km]
Velocity	10	[km/h]
		3,42
empty		
Distance	0,57	[km]
Velocity	12	[km/h]
		2,85

Appendix C - Table 16: Calculation of travelling speed, distance and duration

loading time	0,95	[min]
Manoeuvre time	0,30	[min]
Transport time	3,42	[min]
Discharging time	1,20	[min]
Return time	2,85	[min]
	8,72	[min]
Required trucks	9	

Appendix C - Table 17: Estimation of one loading-unloading cycle and required number of mining trucks

Theoretical maximum production		60 min - hour and availability 100 %
Trucks in 60 min	63	
Output	1.303	[t/h]

Appendix C - Table 18: Estimation of theoretical production assuming 100% truck utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	830	t/h

Appendix C - Table 19: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	200	d	5 days per week			
Shifts per day	2					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	2.600	h/y				
Availability excavator	90,0%		available hours		2.340	h
Utilisation excavator	90,0%		utilised hours		2.106	h
long term production	1.748.881	t/y				

Appendix C - Table 20: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To achieve the given target of mining 1.650.00 tonnes of bauxite per year, one pull shovel excavator, type CAT 365C L combined with 20 mining trucks of the model CAT 725 will be required. In the case a belt conveyor is used to transport the mined ore to the plant, the distances will be short and as a result the needed amount of dumpers decreases to 9, which will represent a capacity 1.748.881 tonnes per year.

20.2 Equipment rating Step 3 year 7

20.2.1 Scraper

Transport time 1		loaded				
		Distance	0,19	[km]		1,14
		Velocity	10	[km/h]		1,90
Transport time 2		loaded				
		Distance	0,1	[km]		0,30
		Velocity	20	[km/h]		0,50
Transport time 3		loaded				
		Distance	1,106	[km]		3,32
		Velocity	20	[km/h]		5,53
Return time 1		empty				
		Distance	0,19	[km]		1,14
		Velocity	10	[km/h]		1,90
Return time 2		empty				
		Distance	0,1	[km]		0,30
		Velocity	20	[km/h]		0,50
Return time 3		empty				
		Distance	1,106	[km]		1,90
		Velocity	35	[km/h]		3,16

Appendix C - Table 21: Calculation of travelling speed, distance and duration

Scraper loading time	0,70	[min]
Transport time 1	1,14	[min]
Transport time 2	0,30	[min]
Transport time 3	3,32	[min]
Discharging time	0,70	[min]
Return time 1	1,14	[min]
Return time 2	0,30	[min]
Return time 3	1,90	[min]
	9,49	[min]

Appendix C - Table 22: Summary of one loading – unloading cycle

Theoretical maximum production		60 min - hour and availability 100 %
Scraper in 60 min	6	
Output	162	[t/h]
Numbers of Scraper	30	
Numbers of dozers	15	
30 Scraper in 60 min	190	
Output	4.853	[t/h]

Appendix C - Table 23: Estimation of needed amount of scrapers assuming 100% availability

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	3.094	t/h

Appendix C - Table 24: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	244	d	8 month mining possible			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	4.758	h/y				
Availability Scraper	90,0%		available hours		4.282	h
utilisation Scraper	100,0%		utilised hours		4.282	h
long term production	13.247.762	t/y				
	13.131.250					

Appendix C - Table 25: Estimation of long term production assuming reductions caused by holiday, unforeseen events and scraper availability

Summary:

To achieve the given volume of over burden, 13.131.250 t per year, a number of 30 scrapers, model CAT 637 G, are needed. In theory this amount of units will be able to handle about 13.247.762 tonnes per year.

20.2.2 Dipper shovel excavator and mining truck

Shovel volume	14,00	[m³]
Shovel filling factor	110	[%]
Working circle time	0,5	[min]
Availability factor	50	[min]
Loading cycle	4	
Bucket volume	62	[m³]
loaded tonnage	92	[t]

Appendix C - Table 26: Estimation of the shovel volume, loading cycle and resulting load of the mining truck

Transport time 1		loaded			
		Distance	0,19	[km]	1,90
		Velocity	6	[km/h]	3,17
Transport time 2		loaded			
		Distance	0,1	[km]	0,60
		Velocity	10	[km/h]	1,00
Transport time 3		loaded			
		Distance	1,11	[km]	6,64
		Velocity	10	[km/h]	11,06
Return time 1		empty			
		Distance	0,19	[km]	1,14
		Velocity	10	[km/h]	1,90
Return time 2		empty			
		Distance	0,1	[km]	0,27
		Velocity	22	[km/h]	0,45
Return time 3		empty			
		Distance	1,11	[km]	3,02
		Velocity	22	[km/h]	5,03

Appendix C - Table 27: Calculation of travelling speed, distance and duration

loading time	2,00	[min]
Manoeuvre time	0,30	[min]
Transport time 1	1,90	[min]
Transport time 2	0,60	[min]
Transport time 3	6,64	[min]
Discharging time	1,20	[min]
Return time 1	1,14	[min]
Return time 2	0,27	[min]
Return time 3	3,02	[min]
	17,07	[min]
Required trucks	9	

Appendix C - Table 28: Estimation of one loading-unloading cycle and required number of mining trucks

Theoretical maximum production		60 min - hour and availability 100 %
Trucks in 60 min	30	
Output	2.772	[t/h]

Appendix C - Table 29: Estimation of theoretical production assuming 100% truck utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	1.767	t/h

Appendix C - Table 30: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	244	d	8 month mining possible			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	4.758	h/y				
Availability excavator	90,0%		available hours		4.282	h
Utilisation excavator	90,0%		utilised hours		3.854	h
long term production	6.810.561	t/y				

Appendix C - Table 31: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To achieve the given target of stripping 13.131.250 tonnes of overburden per year, two dipper shovel excavator, type RH 120-E combined with 18 mining trucks of the model CAT 777 F will be required.

20.2.3 Pull shovel excavator and dumper

Shovel volume	4,50	[m³]
Shovel filling factor	110	[%]
Working circle time	0,38	[min]
Availability factor	50	[min]

Appendix C - Table 32: Estimation of the shovel volume and the degree of filling

Loading cycle	3	
Bucket volume	15	[m³]
loaded tonnage	22	[t]

Appendix C - Table 33: Estimation of one loading-unloading cycle and the resulting load of the dumper

Design without the usage of a belt conveyor

loaded			
Distance	0,57	[km]	3,42
Velocity	10	[km/h]	
Distance	5,73	[km]	11,5
Velocity	30	[km/h]	
empty			
Distance	5,73	[km]	9,82
Velocity	35	[km/h]	
Distance	0,57	[km]	2,85
Velocity	12	[km/h]	

Appendix C - Table 34: Calculation of travelling speed, distance and duration

loading time	1,14	[min]
Manoeuvre time	0,30	[min]
Transport time	14,88	[min]
Discharging time	1,20	[min]
Return time	12,67	[min]
	30,19	[min]
Required trucks	26	

Appendix C - Table 35: Estimation of one loading-unloading cycle and required number of mining trucks

Design with the use of a belt conveyor

loaded		
Distance	0,57	[km]
Velocity	10	[km/h]
		3,42
empty		
Distance	0,57	[km]
Velocity	12	[km/h]
		2,85

Appendix C - Table 36: Calculation of travelling speed, distance and duration

loading time	1,14	[min]
Manoeuvre time	0,30	[min]
Transport time	3,42	[min]
Discharging time	1,20	[min]
Return time	2,85	[min]
	8,91	[min]
Required trucks	8	

Appendix C - Table 37: Estimation of one loading-unloading cycle and required number of mining trucks

Theoretical maximum production		60 min - hour and availability 100 %
Trucks in 60 min	53	
Output	1.172	[t/h]

Appendix C - Table 38: Estimation of theoretical production assuming 100% truck utilization

calculatory average production (realistic)		
Utilisation of operational hours	75	[%]
Operator performance	85	[%]
Utilisation factor	64	[%]
average production	747	t/h

Appendix C - Table 39: Estimation of production assuming utilization reductions regarding operational hours and operator performance

long term production						
Working days per year	200	d	5 days per week			
Shifts per day	3					
Hours per shift	8	h				
Loss of time per shift	1,5	h	(breaks, refuelling, start up time, ...)			
Production time	3.900	h/y				
Availability excavator	90,0%		available hours		3.510	h
Utilisation excavator	90,0%		utilised hours		3.159	h
long term production	2.360.989	t/y				

Appendix C - Table 40: Estimation of long term production assuming reductions caused by holidays, unforeseen events and excavator availability and utilization

Summary:

To achieve the given target of mining 2.200.00 tonnes of bauxite per year, one pull shovel excavator, type CAT 365C L combined with 26 mining trucks of the model CAT 725 will be required. In the case a belt conveyor is used to transport the mined ore to the plant, the distances will be short and as a result the needed amount of dumpers decreases to 8, which will represent a capacity 1.091.301 tonnes per year.

21 Appendix D

Appendix D - Table 1: Comparison of costs for the 2nd year

Costs per object in euro	Numbers of objects		
	option 1		
118.266	1	118.266	Drill rig
999.764	12	11.997.168	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	7	1.617.463	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		17.028.892	
	option 2		
118.266	1	118.266	Drill rig
999.764	12	11.997.168	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
227.432	10	2.287.704	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L

517.361	2	1.034.722	Wheel loader 980H
		16.420.812	

option 3

118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	7	1.617.463	Dumper 725 with belt conveyor
442.056	1	442.056	Excavator 365C L
1.278.321	1	1.278.321	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		9.515.644	

option 4

118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	10	2.287.704	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		8.907.564	

option 5

118.266	1	118.266	Drill rig
1.124.000	7	7.757.030	Mining truck 777F
1.501.480	1	1.501.480	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	7	1.617.463	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		14.353.407	

option 6

118.266	1	118.266	Drill rig
1.124.000	7	7.757.030	Mining truck 777F
1.501.480	1	1.501.480	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
227.432	10	2.287.704	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		13.745.327	

Appendix D - Table 2: Comparison of costs for the 3rd year

Costs per object in euro	Numbers of objects		
		option 1	
118.266	1	118.266	Drill rig
999.764	12	11.997.168	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	7	1.617.463	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		17.028.892	
		option 2	
118.266	1	118.266	Drill rig
999.764	12	11.997.168	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
227.432	12	2.622.825	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		16.755.932	
		option 3	
118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	7	1.617.463	Dumper 725 with belt conveyor
442.056	1	442.056	Excavator 365C L
1.278.321	1	1.278.321	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		9.515.644	
		option 4	
118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	12	2.622.825	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		9.242.684	
		option 5	
118.266	1	118.266	Drill rig
1.124.000	7	7.757.030	Mining truck 777F

1.501.480	1	1.501.480	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	7	1.617.463	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		14.353.407	

option 6

118.266	1	118.266	Drill rig
1.124.000	7	7.757.030	Mining truck 777F
1.501.480	1	1.501.480	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
227.432	12	2.622.825	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		14.080.447	

Appendix D - Table 3: Comparison of costs for the 4th year

Costs per object in euro	Numbers of objects		

option 1

118.266	1	118.266	Drill rig
999.764	21	20.995.044	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	10	2.315.022	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		26.724.327	

option 2

118.266	1	118.266	Drill rig
999.764	21	20.995.044	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
227.432	22	4.955.768	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		28.086.751	

option 3

118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	10	2.315.022	Dumper 725 with belt conveyor
442.056	1	442.056	Excavator 365C L
1.278.321	1	1.278.321	Belt conveyor

314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		10.213.203	

option 4

118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	22	4.955.768	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.575.627	

option 5

118.266	1	118.266	Drill rig
1.124.000	13	14.556.412	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	10	2.315.022	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		23.351.827	

option 6

118.266	1	118.266	Drill rig
1.124.000	13	14.556.412	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
227.432	22	4.955.768	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		24.714.252	

Appendix D - Table 4: Comparison of costs for the 5th year

Costs per object in euro	Numbers of objects		
		option 1	
118.266	1	118.266	Drill rig
999.764	21	20.995.044	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	10	2.315.022	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		26.724.327	
		option 2	
118.266	1	118.266	Drill rig
999.764	21	20.995.044	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
227.432	26	5.987.934	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		29.118.918	
		option 3	
118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	10	2.315.022	Dumper 725 with belt conveyor
442.056	1	442.056	Excavator 365C L
1.278.321	1	1.278.321	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		10.213.203	
		option 4	
118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	26	5.987.934	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		12.607.794	
		option 5	
118.266	1	118.266	Drill rig
1.124.000	13	14.556.412	Mining truck 777F

1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	10	2.315.022	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		23.351.827	

option 6

118.266	1	118.266	Drill rig
1.124.000	13	14.556.412	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
227.432	26	5.987.934	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		25.746.418	

Appendix D - Table 5: Comparison of costs for the 6th year

Costs per object in euro	Numbers of objects		

option 1

118.266	1	118.266	Drill rig
999.764	21	20.995.044	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	10	2.315.022	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		26.724.327	

option 2

118.266	1	118.266	Drill rig
999.764	21	20.995.044	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
227.432	30	6.792.668	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		29.923.652	

option 3

118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	10	2.315.022	Dumper 725 with belt conveyor
442.056	1	442.056	Excavator 365C L
1.278.321	1	1.278.321	Belt conveyor

314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		10.213.203	

option 4

118.266	1	118.266	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
227.432	30	6.792.668	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		13.412.528	

option 5

118.266	1	118.266	Drill rig
1.124.000	13	14.556.412	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.278.321	1	1.278.321	Belt conveyor
442.056	1	442.056	Excavator 365C L
227.432	10	2.315.022	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		23.351.827	

option 6

118.266	1	118.266	Drill rig
1.124.000	13	14.556.412	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
227.432	30	6.792.668	Dumper 725 without belt conveyor
442.056	1	442.056	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		26.551.153	

Appendix D - Table 6: Comparison of costs for the 7th year

Costs per object in euro	Numbers of objects		
		option 1	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	
		option 2	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	29	10.044.008	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		45.441.712	
		option 3	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	
		option 4	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	29	10.044.008	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		16.933.421	
		option 5	
173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F

1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	29	10.044.008	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		36.944.794	

Appendix D - Table 7: Comparison of costs for the 8th year

Costs per object in euro	Numbers of objects		

option 1

173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	

option 2

173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	33	11.382.526	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		46.780.231	

option 3

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor

314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	

option 4

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	33	11.382.526	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		18.271.939	

option 5

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	33	11.382.526	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		38.283.312	

Appendix D - Table 8: Comparison of costs for the 9th year

Costs per object in euro	Numbers of objects		
		option 1	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	
		option 2	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	38	13.061.693	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		48.459.397	
		option 3	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	
		option 4	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	38	13.061.693	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		19.951.105	
		option 5	
173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F

1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	38	13.061.693	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		39.962.479	

Appendix D - Table 9: Comparison of costs for the 10th year

Costs per object in euro	Numbers of objects		

option 1

173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	

option 2

173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	13	4.341.604	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		39.739.308	

option 3

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor

314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	

option 4

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	13	4.341.604	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.231.016	

option 5

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	13	4.341.604	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		31.242.389	

Appendix D - Table 10: Comparison of costs for the 11th year

Costs per object in euro	Numbers of objects		
		option 1	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	
		option 2	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	18	6.020.770	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		41.418.474	
		option 3	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	
		option 4	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	18	6.020.770	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		12.910.182	
		option 5	
173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F

1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	18	6.020.770	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		32.921.556	

Appendix D - Table 11: Comparison of costs for the 12th year

Costs per object in euro	Numbers of objects		
		option 1	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	
		option 2	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	22	7.359.288	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		42.756.992	
		option 3	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor

314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	

option 4

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	22	7.359.288	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		14.248.701	

option 5

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	22	7.359.288	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		34.260.074	

Appendix D - Table 12: Comparison of costs for the 13th year

Costs per object in euro	Numbers of objects		
		option 1	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	
		option 2	
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	27	9.038.455	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		44.436.159	
		option 3	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	
		option 4	
173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	27	9.038.455	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		15.927.867	
		option 5	
173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F

1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	27	9.038.455	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		35.939.241	

Appendix D - Table 13: Comparison of costs for the 14th year

option 1

Costs per object in euro	Numbers of objects		
173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		39.725.861	

option 2

173.666	1	173.666	Drill rig
999.764	33	32.992.212	Scraper
314.303	1	314.303	Dozer D8T
226.592	1	226.592	Motor grader 14H
340.649	30	10.376.973	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		45.774.677	

option 3

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	9	3.003.085	Dumper 725 with belt conveyor
656.209	1	656.209	Excavator 365C L
1.325.071	1	1.325.071	Belt conveyor

314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		11.217.569	

option 4

173.666	1	173.666	Drill rig
2.310.593	1	2.310.593	Becket wheel excavator
340.649	30	10.376.973	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
314.303	2	628.607	Dozer D8T
517.361	2	1.034.722	Wheel loader 980H
1.272.097	1	1.272.097	Stacker
813.519	1	813.519	Belt conveyor bucket wheel excavator
		17.266.385	

option 5

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
1.325.071	1	1.325.071	Belt conveyor
656.209	1	656.209	Excavator 365C L
340.649	9	3.003.085	Dumper 725 with belt conveyor
517.361	2	1.034.722	Wheel loader 980H
		31.228.943	

option 6

173.666	1	173.666	Drill rig
1.124.000	19	21.429.161	Mining truck 777F
1.501.480	2	3.002.959	Excavator RH 120-E
314.303	1	314.303	Dozer D8T
289.765	1	289.765	Motor grader 16H
340.649	30	10.376.973	Dumper 725 without belt conveyor
656.209	1	656.209	Excavator 365C L
517.361	2	1.034.722	Wheel loader 980H
		37.277.759	

22 Appendix E