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BAUXITE - ALUMINA - ALUMINIUM:
MAIN FACTORS FOR DECISION-MAKING ON INDUSTRIAL DEVELOPMENT*

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1. Introduction

Aluminium is the most widespread metal in the solid earth's crust representing its 7-8%. This figure is one and a half times larger than that of iron and it is the multiple of other metals technically applied. Aluminium is present in the earth's crust partly in the form of silicates, still bauxite containing alumina mostly in the form of hydrate is almost the only raw-material for aluminium production. Large high-grade bauxite reserves are known today and more are expected to be discovered in the future. The reserves already discovered could ensure the supply of aluminium production for the time period of at least 75 years, even if aluminium consumption will continue to increase by the rate experienced in the last three decades. As additional sources of aluminium, high-silica bauxites, various alumina-silicates, shales, fly ash and a number of other raw materials may be considered on the long run.

Aluminium possesses a lot of favourable characteristics such as its excellent electric conductivity, easy deformability, good corrosion resistance, etc. in addition to its small specific weight and mechanical properties. As a consequence, aluminium has already been used in ever increasing quantitites and the explosion in energy prices has created further possibilities for expansion because of weight economy in transportation. Consequently, aluminium consumption is expected to increase in the years to come both in developing and developed countries.

The production processes of aluminium go back to a past of some 100 years. Processing of bauxite into alumina by means of the Bayer process and the electrolysis of alumina into aluminium metal by the Hall-Heroult process are still the methods overwhelmingly applied, but a number of research testing and even industrial scale applications have been carried out or developed directed on the one hand to producing the metal from raw material by direct reduction aiming at decreasing specific investment costs, and on the other hand to alternatives aiming at reducing the high specific eneggy consumption.

From the new methods tested so far, neither the subhalogenizing nor the carbothermic processes proved to be competitive and the process of direct producing aluminium has as its result the yield of an alloy, the use of which is quite limited. Recently the Alcoa smelting process has been developed; this process continues to rely on Bayer alumina production, but alumina is not electrolyzed by dissolution in fused cryolite salt, but transformed into aluminium chloride by reducing chlorination, and then the chloride is broken down to primary aluminium and chlorine via electrolysis after having dissolved in the fusion of molten alkali metal and alkali-earth metal chlorides recycling subsequently the chlorine product for repeated chlorination.

This process is carried out at a temperature of 700 °C operating with bi-polar electrodes and with direct energy consumption of 9 kWh/kg, according to the information provided.One has however to reckon with energy consumption in the phase of production of aluminium chloride as well and it is possible that the total energy consumption will be no less than the end value of less than 13,000 kWh/to of the declining trend in further developing the classical Hall-Heroult process. The success of this new Alcoa process may still be helped perhaps by some additional minor specific investment cost advantages.

After 15 years of research work Alcoa started up a plant 2 years ago with a capacity of 13,500 tpy using this process with the purpose of doubling it in a short time. Although detailed particulars have not been disclosed about the plant, it is known, that at least 5 more years are required until the Alcoa Smelting Process may be suitable for industrial utilization. Therefore the conclusion is that for a new smelter to be started up in the coming decade it is by all means the classical Hall-Heroult process to be taken into consideration.

In the Soviet Union alumina is produced on industrial scale from new materials others than good quality bauxite, e.g. from nepheline and alunites. In addition to alumina other useful products are also generated in the course of these processes; but they are considerably less favourable from a power engineering point of view than the Bayer process, still the given economic region and climate determines if they can be applied in an economic way. E.g. cement is required in the given economic region in large quantities and its production is not viable otherwise or its transportation is too expensive - the combination of this type of advantages may compensate the technical disadvantages of the process. It is expected that if and where bauxite is not available or its cost or price is prohibitive, but the conditions of establishing aluminium smelting are otherwise favourable, endeavours will be made to make use of comparative benefits of processing local raw materials, other than bauxite. Such efforts are reported from both the United States and Europe. This will, however, and in our judgement, not change the basic long-term trend that primarily Bayer alumina plants will be established in the future fed by good quality bauxite to meet further requirements in smelter grade alumina.

Consequently the basic technological line of making decisions on investment in the aluminium industry in the foreseeable future is:
bauxite - Bayer alumina production - molten salt electrolysis of criolite and alumina fusion - processing of primary aluminium product.

2. Bauxite Mining

Main factors of investment decision for mining bauxite for simple sales purposes are the quantity and quality of the bauxite as it is in situ, its cost accumulated until it reaches the site of consumption and its market value at the site of consumption. In case of a more complex decision of mining and processing of bauxite within the framework of the same project, the factors of decision are naturally also more complex and intricate.

2.1. Bauxite - quantity and quality

2.1.1. Quantity of bauxite

Distinction is made between geological reserves of bauxite, which means the total volume of ore laying within the boundaries of a given deposit and minable reserves, which are always less than the geological ones. The difference depends on the character of the deposit, the mining method chosen and on other technical and mining factors and considerations also on determining the so-called cut-off rate /lowest quality still intended to be mined/.

Minimal quantity of minable reserves required depends in case of direct close-by processing of
- processing capacity to be fed;
- minimum expected operating life of same;
- specific consumption of bauxite;
- losses of bauxite at mining, transport and eventual treatment /e.g. drying, crushing, classification, washing/.

Example: for an alumina plant of 600.000 tpy capacity for a life of operation of 30 years and in case of specific consumption 2,5/1 to/to an overall quantity of 45 million tons of bauxite is required to be supplied to the gates of the processing plant.

The minimal quantity of minable reserves still inducive to starting mining operation in case export purposes only, will depend on the results of simple economic calculations of returns and profitability, based on the minimum expected marketable price of the bauxite of given quality to be exported.

2.1.2. Quality of bauxite

The chemical and mineralogical compositions of bauxite are the decisive factors. Most important chemical components from this view point are the aluminium-oxide and silica generally characterised by the so-called silica modulus, $M = Al_2O_3/SiO_2$, weight percent. Generally first class bauxite would have a silica modulus above 10, second class bauxite is in the range of 7-10, third class bauxite is in the range of 4-7. First and second class bauxites would be generally suitable for the simple Bayer process of alumina production, third category is suitable for the combination Bayer process and for the so-called lime-soda-sinter process only. It is to be added, however, that the more the technology of processing and methods of evaluation of bauxites have advanced, the less satisfactory has single chemical evaluation of bauxites become.

Additional components considered to be undesirable for the Bayer process are: carbonates of calcium, magnesium and iron and also elements like titanium, phosphorus, sulphur, carbon, etc.

Mineralogical composition refers mostly to the mineralogical form of alumina, silica and iron oxides present in the ore. Alumina appears basically in the mineralogical form of trihydrate /gibbsite/ and/or monohydrates /boehmite and diaspore/. As it will be explained in more details later on, following this sequence the digestion of bauxite is more and more difficult and costly. Diaspore also increases significantly the cost of crushing and grinding because of its hardness.

Silica may appear in so-called reactive and non-active forms /e.g. caoline and crystalline quartz/. The non-active forms are discarded from the process without loss of reagents, but up to that moment they also increase the volume of material flow and equipment. From various forms of iron oxide, goethite /FeOOH/ is the least welcome because of possible losses of aluminium oxide embedded in its lattice. It may also negatively inluence the technological behaviour of bauxite /sedimentation of red mud/.

It is imperative today already that laboratory evaluation of bauxite include also technological evaluation which comprises evaluation of the behaviour of various mineralogical forms of the main chemical components and its effect on technology and equipment, cost of processing and investment. E.g. results of technological evaluation may lead to a decision of selecting a less expensive processing technology, implying additional losses of alumina present in a specific mineralogical form, in case bauxite is available in large quantities and at relatively low mining costs.

2.2. Factors of cost of bauxite

Character of mining operations required is one of them. It depends on whether the ore is located on the surface /thickness of overburden/ or requires underground mining and whether does it occur in large massives or in scattered form embedded in gangue material.

Open-pit mining may be applied in dependence of thickness and physical properties of overburden and degree of mechanization available. As a general approach the open-pit method is always viable economically if the overburden is of favourable physical properties /e.g. dry, sandy/ and the ratio of overburden in cubic meter to be disposed of for mining one ton of ore is less than 5. In case of overall mechanization this ratio may increase to up to 10. Scattered types of deposits are economically viable to mine by open-pit method only. Open-pit mining - like earth moving - has a great flexibility concerning labour/capital substitution. It may provide job for large number of people. Under tropical conditions and with manual work applied manpower requirement is about 3-4 man-hours per ton of bauxite mined. In case of large scale fully mechanized operation this may decrease to 0.3 - 0.6 per ton of bauxite. Impact of meteorological conditions is also a cost factor and if it is significant the mining capacity has always to be larger than the rated supply of the ore required. Storage of bauxite mined, may also be necessary at location not affected by weather conditions.

Replacement of overburden for re-use of the surface after mining is over, may be required and this may also result in higher overall mining cost.

Underground mining. The specific investment costs in this case are several times more than that of open-pit operations. Other important features: nature of soil to be tackled, possible complications from the presence of water, gas and coal in the deposit, less dependence from weather conditions, less elasticity in labour/capital substitution, the value of surface area which may be affected by mining operations, etc.
If large scale mechaniaztion is applied, ore layers of the deposit less than 2 meters thick are generally disregarded for mining. Manpower requirements for manual operations amount to about 4 man-hours/ton, for mechanized operations - about 1,5 man-hours/ton.

Economic scale of operations depends on a number of factors and it may range from 5-10 thousand tons per year for surface deposits to at least 300 thousand tons per year in case of highly mechanized underground operations. The latter figure may be required to achieve also for open-pit operation at remote location when considerable infrastructural investment is required. The smaller figure may be justified in case of little of no overburden of high-grade bauxite and of possibility or necessity to use to a great extent manual work.

2.3. Investment and mining costs

2.3.1. Investment costs. The main factors are: character of mining operation /surface or underground/ ratio of cubic meter of overburden to be moved for mining 1 ton of bauxite /in case of surface operations/, treatment of bauxite at mine /drying, washing, classification, etc./, scale of operation, specifics of location, infrastructure required. Costs vary within wide limits.

Open-pit mining: 8-80 $ per annual ton of processible ore. Examples: Ghana 8-9 $/ton; Hungary 10-12 $/t; Jamaica 20 $/ton; Guinea-Boke 45 $/ton; Brasil, Amazonas region 76 $/ton.

Distribution of factors in investment costs: construction 12-18%, machinery and equipment 45-55%, other 32-39%.

Underground mining: 70-150 $ per annual ton, which does not include costs of water pumping and disposal and transportation costs more than to the next railway station or to the nearby alumina plant.

2.3.2. Mining costs: These may include fuel, electric power, explosives, labour, administrative and overhead costs, depreciation, debt servicing. These costs vary greatly depending on various factors mentioned above.

Excluding transportation to larger distances, production cost for open-pit mining amounts to 2-3,5 $/t in case the ratio cubic meter overburden to be moved per ton of bauxite mined is less than 1. Any additional specific cubic meter added would increase production cost by about 0,5 $/t of bauxite. For underground mining production cost in Hungarian bauxite mines vary between 16-25 $t of bauxite mined.

2.3.3. Transportation of bauxite

Since specific consumption of bauxite for alumina production is between 2-3 tons it is a general rule that transportation of alumina is preferable to transportation of bauxite. The lower the quality of bauxite, the more this general rule applies. Exclusion from this general rule may be justified e.g. by geographic and terrain conditions prohibitive to locating large industrial processing operations in the vicinity of large ore deposits /e.g. India, Brasil/ or by extremely favourable conditions of investment and construction of alumina plant at another location e.g. the new Anguinish alumina plant in Ireland. Continental transportation may be provided by rope-ways /especially difficult terrain, relatively small quantities to be transported - up to 300 tons/hour/, belt conveyors /no road infrastructure, limited distances, large volume of ore/, road vehicles /favourable terrain conditions, limited distances/ and railway transportation /large quantities, long distances/.

Water transportation is convenient and less expensive in itself where deposits are close to tide-water or river /e.g. Jamaica, Greece, Australia, Brasil, etc./. Cost of complementary operations such as loading, unloading and also relevant natural conditions /harbour, depth of sea and river, meteorological conditions/ may be critical /e.g. North-Brasilian deposits/. Solutions of loading of ore for ocean shipping may require and investment of up to 50 million US dollars.

Adverse accessibility of the deposits, underdeveloped transportation infrastructure, long distances, unfavourable natural conditions may doom the best quality bauxite deposits to be idle for a considerable period of time /e.g. deposits in Guinea, Kamerun, etc./.

2.4. Market

As it was mentioned already, information available show that the world possesses ample reserves of bauxite and expected to be discovered in the future.

Consequently - competitive cost or price at consumer's location is a key condition of successful marketing. The new guiding price of IBA - 24 $ US/to CIF US port destination - may provide some orientation, but we are aware of offers as low as 12 $ US/to FOB of excellent Bayer quality.

The policy of states and governments of countries possessing, mining, processing or exporting bauxite may also have significant influence on the success of marketing /incentives, subsidies, levies, political factors, etc./. This aspect, is specifically relevant to those developing countries, where the value of bauxite mined and processed or exported in the form of ore or alumina constitutes a significant part of the overall national product and export value of the economy. Effective technical and financial control and supervision of mining operations being carried out by private and foreign companies may also be of definite significance for the national economy.

3. Alumina Production

3.1. General

In 1976 27,5 million tons of alumina was produced in the world's alumina plants and the present production capacity may be estimated to be around 31,5 million tons. The majority of alumina produced, that is 93-94%, serves for aluminium smelting purposes and the remaining 6-7% is the basis for manufacturing white corundum, refractory materials, aluminium salts, fine ceramics, catalyst carriers, etc.

A characteristic feature of the world's alumina production is that the regional distribution of producing capacities is of a pattern, different from that of reserves and mining of bauxite, as illustrated below:

1977:	The proportion of participation in the world's		
	bauxite reserves	bauxite prod.	alumina prod.
Western Europe	1,2%	2,9%	13,4%
Eastern Europe x	4,8%	19,0"	18,7"
Africa	28,0"	15,2"	2,0"
Japan	0,0"	0,0"	5,1"
Asia without Japan	5,0"	5,4"	3,3"
North-America	2,5"	2,5"	23,2"
Latin-America	30,5"	25,1"	11,7"
Oceania	28,0"	29,9"	22,6"
Total	100,0%	100,0%	100,0%

x= including Jugoslavia and Greece

It is clear from the given data that significant quantities of bauxite are required to be transported overseas annually in order to supply the alumina plants of North-America, Western Europe and Japan with raw material.

The average single production capacity of today's some 80 operating alumina plants is 390,000 tpy, however, there are some amongst them with a capacity of above 2,3 million tpy as well. Seven years from now, in 1985 the average plant size - as a result of the scheduled and in-process expansions- will reach the level of 470,000 tpy.

The average rate of increase of the production was 6,5% in the period of 1966-76,/which can be estimated to be 5,4 at the present time/and according to the estimates it is expected to be some 4,1-4,3% by the early 80's.

The world's alumina production is almost exclusively carried out by the so-called Bayer process. The quality of bauxite, determining fundamentally the economic efficiency of the production, can be characterized by an average of 53% Al_2O_3 and 4,0-4,5% SiO_2 content.

3.2. Siting of alumina plants

There has been a fundamental change in the siting of alumina plants during the past decade. While earlier new alumina plants were sited almost exclusively in industrially developed countries - consumers of relatively much aluminium,-alumina plants are established now - apart from a few exceptions - at locations where sufficient quantities of ore of satisfactory quality are closely available.

This phenomenon is a result of the changed significance of specific bauxite costs /price of bauxite + transportation costs/ per ton of alumina.

Up to the 70's the price of bauxite had been 8-9 $/t which even with the costs of ocean transportation added did not exceed the value of 15-17 $ at the large overseas alumina plants. With the change of prices of raw materials and fuel and last but not least with the foundation and activity of the International Bauxite Association the price of bauxite of ordinary quality has increased to about 25 $/t CIF North-American and European ports. In other words the specific bauxite costs of alumina production have been increased by a round 50 %.

It is evident then that siting of new alumina plants is determined basically by the size and the vicinity of available bauxite reserves.

Beside the outstandingly important aspects of raw material supply the most significant **objective siting factors** are as follows:

- Vicinity of sea ports, waterways, railways and roads;
- Satisfactory solution /independent of seasons/ of technological water supply;
- Possibility for inexpensive disposal of red mud and other waste material;
- Meteorological and soil conditions;
- Possibility of establishing the infrastructure required;
- Location of the market for the alumina produced.

3.3. Main factors determining the economic efficiency of alumina production

3.3.1. Quality of bauxite processed

The quality of bauxite processed has a significant impact on the economic efficiency of alumina production. From the technological point of view we have to jointly examine the mineralogical and chemical composition of bauxite as the determining factors of quality.

As it was mentioned already alumina is present in bauxite basically in three different mineralogical forms, such as

gibbsite /hydrargillite/
boehmite and
diaspore.

Gibbsite can be digested in the easiest way and the generally applied digestion temperature is 140 °C only. The importance of this becomes evident when it is taken into consideration that generally for the production of 1 t of alumina from bauxite of gibbsite type some half a ton less steam is required than in the case of the boehmite type. It is also important that as a consequence not only the specific investment costs are lower, but net production costs are also less in case of producing so-called sandy alumina end product. This type of alumina is characterized by definite physical properties and it is more and more preferred to the other so called floury type of alumina.

The digestion of bauxite of boehmite type is already more difficult and the generally applied temperature is 220-240 ^{o}C.

Of the oxidhydrates of aluminium, both from the point of view of grinding and digestion /temperature and chemical conditions/ it is the diasphore which poses the most stringent requirements. Generally it is digested at a temperature of above 250 ^{o}C in the presence of lime.

In addition to the aforesaid, further important features of the mineralogical composition of bauxite are the forms of silica and of iron minerals present. As it was mentioned already, silica may be present in non-active and active forms and from the iron minerals goethite shows generally a poor settling and thickening capability, whereas hematite presents more favourable technological features if prevails in a given type of bauxite.

If the reactive silica content increases, the quantity of bauxite and caustic soda required for production of alumina will grow as well. That is why the Al_2O_3 content of bauxite is not enough in itself for analyzing processing costs. Bauxite with higher Al_2O_3 content may be more expensive to process to one unit of alumina if its reactive SiO_2 content is high as opposed to bauxite of possible, smaller Al_2O_3, but also smaller reactive silica content. Presence of goethite instead of hematite may result in higher specific investment cost of processing and in additional losses of aluminium-oxide and caustic soda.

A useful indicator for decisions to be taken is the "available alumina" - that is - what may be expected to be produced practically. It is established by experimental digestion and it actually reflects the quantity of aluminium-oxide lost with the reactive silica content as compared to the full aluminium-oxide content.

Amongst other technologically undesirable impurities of bauxite attention has to be drawn in the first place on the carbonate /calcite, dolomite/ and organic materials content, but the titanium, sulphur and phosphorus content cannot be left out of consideration either.

3.3.2. Size of the alumina plant

In the last one and half decades efforts aimed at decreasing the specific investment costs led to installing units and plants of larger production capacity. In the 50's up-to-date alumina plants were established with production lines of 120-150,000 tpy, whereas the size of lines recently constructed in up-to-date plants is mostly between 300-500,000 tpy.

Although there are exclusions originating from specific conditions, still it can be stated as a rule of thumb that under similar circumstances the increasing of productivity of production lines and overall capacity by 50% would mean the decrease of the specific investment cost by some 15-20%.

Better investment efficiency is not the only advantage of large capacity lines and plants. Considerable advantage is constituted by more favourable heat and electric power balances secured by larger equipment units, not to mention the specific manpower requirement which can be an important factor occasionally in itself.

3.3.3. The technical level of production

The technical level of production is one of the main factors influencing the economic efficiency of alumina production. Companies of world-wide reputation in technology of alumina including those in socialist countries e.g. in Hungary engage in this area many outstanding experts and scientists in numerous teams in the field of technological research and development.

The regular and concentrated technical development activities have resulted in the implementation of continuous processes of important phases of production, the switching over to wet grinding, multi-stage flashing, the introduction of falling film evaporators, etc. The latest achievements are: high-temperature digestion with additives, synthetic floculants, the use of counter and mixed current evaporation, intensive removal of salt and impurities, fluidized bed calcination and cooling, automatic process control, high-perfection of material testing and in-process control.

3.3.4. Space requirements and infrastructure

Alumina production requires relatively large space. An up-to-date plant of 600,000 tpy capacity requires a land of 80-100 hectare, which includes the territory within the plant fence only. Land requirement for red mud ponds could be 2-4 times bigger in dependence of the given situation. Protective zones around the plant have to be considered as well.

Regarding the infrastructure of the alumina plant the following are highlighted:

- **Port**

  In case of location at the sea transportation is organized completely or mostly by sea. For the production of 1 ton of alumina 3,0-3,5 tons of raw and auxiliary materials are to be moved which means that in case of a 600,000 tpy alumina plant an average total material flow of 6,500-7,500 t/day has to be effected, not to mention the requirement of fixed assets' maintenance.

  The construction costs of the port may vary within wide limits due to differences in natural conditions and requirements. Today a cost item of between 10-20 million US $ may be accepted as being within the normal range.

- **Power station**

  In a 600,000 tpy alumina plant chosen as our example, an hourly consumption of 250 tons of steam and 20,000 kWh of electric power has to be considered. Because of peak consumptions and maintenance 3 boilers of 140 t/hour capacity each and 3 power units equipped with extraction/back-pressure turbines may be reckoned with. It is highly advantageous to link - if possible - the alumina plant to an operating high-capacity thermal power station, the latter also benefiting from the resulting more even and permanent load factor.

- **Water supply**

  The specific technological water consumption of alumina plants is generally 7-9 m^3/t with drink water requirements of the plant and the housing estate to be added. In the interest of securing undisturbed water supply high-capacity storage basins are to be built and operated.

- Housing estate

In order to ensure undisturbed operation housing estates located close to the plant are required even if there are larger settlements in the vicinity of the plant. Since most of the new alumina plants are established at locations remote from cities, a complete new settlement has to be often created at the plant, comprising beyond housing also shopping network, schools, educational and entertaining facilities, sanitary and other services, etc. Establishment of a suitable housing estate may be a primary condition since its absence may decisively affect the level of qualification and stability of manpower required.

3.4. Investment costs

Production of alumina is a typically capital intensive branch of industry. The specific investment costs depend on several factors /size of the plant, technology applied, sources of equipment and machinery, qualification and experience of the companies engaged in and contracted for construction and erection, etc./. That is why they have to be determined specifically in each concrete case. They are estimated to amount to within the range of 550-650 $/tpy capacity if starting design and construction in this year. During the last 10 years these investment costs have been increasing steadily and this tendency is expected to continue.
Characteristic distribution of investment costs: 35% construction, erection, mounting,- 45% machinery and equipment,-20% other.

Besides the investment costs proper, the working capital required and interest charges arising from the investment also represent a relatively high value and require naturally further considerable financial means.

A simplified break-down of capital required for the establishment of a new alumina plant is shown below:

investment costs	75-80 %
working capital	5-6 %
financing costs	15-20 %
Total	100 %

.5. Manpower requirements

It may be said with some exaggeration that the overall manpower requirement of an alumina plant is independent of its size within the usual range of capacity. The explanation lies in the fact that production lines of different capacity represent almost the same number of working places and higher productivity is reflected mostly on the specific requirements of maintenance. Other differences in most cases may be attributed to circumstances of material handling, to operating of own power station, to maintenance conditions in general and to the qualification of plant personnel.

A 600,000 tpy alumina plant employs 700-800 persons. Half of the staff may be semi-skilled, one third of the manual personnel are to be skilled with highly qualified mechanicians and special technicians on the top of them performing maintenance of electronic equipment. Beside the management personnel of technical-economic university qualification /some 2%/, there is a need for a number of engineers and economists of secondary qualification /some 15-20%/. Before starting up a new plant part of the operating staff should be given theoretical and practical training in an operating plant of similar design and technology.

As a result of the increasing automation of plants and processes and of increasing sophistication and complexity of technology applied the requirements towards the qualification of operating personnel grow steadily. Greater care given to improving levels of qualification would pay back abudantly in the phase of operation.

It is evident from the abovementioned that production of alumina does not have great flexibility in manpower/capital substitution, nor has its development significant effect on decreasing unemployment.

3.6. Factors of production cost

The quantity of materials and energy consumed in production of alumina depends primarily on the quality of bauxite mined, on the type of alumina produced and on the level of technology applied and equipment used. This is why it is difficult to provide guiding numbers of specific consumptions. As an orientation we mention the following:

bauxite consumption /dry weight/	2 0 - 2,5 t/t
caustic soda consumption	0,07-0,17 t/t
fuel oil consumption /for steam production and calcination/	0,28-0,38 t/t
electric power consumption	300-350 kWh/t

The structure of cost of production of alumina will also vary according to concrete conditions and circumstances. We are providing just as an example production cost structure of an imagined alumina plant based on assumptions and prices of 1977.

Let us suppose that the processed bauxite is of boehmite type with a composition of 53% Al_2O_3; 4,24% reactive SiO_2 and 14,5% Fe_2O_3 content. Iron oxide is present mostly in the form of hematite. The plant is located on the sea and it processes overseas bauxite. The so-called European Bayer process technology is applied with a digestion temperature of 250 °C. Steam and electric power is supplied from the plant's own power station. The production cost items per ton of alumina are the following:

			$	%
2,4	t	bauxite; 24 $/t	57,6	40,0
0.095	t	caustic soda; 150 $/t	14,2	9,9
0.350	t	fuel oil 65 $/t	22,7	15,8
		materials, repair and maintenance,	10,0	6,9
		wages and salaries,	14,5	10,1
		miscallenous	25,0	17,3
		Production cost:	147,0	100,0

Would the plant have its own open-pit bauxite mine with the net bauxite mining costs charged only, the above production cost could decrease to the value of close to 100 $/t.

In case the plant could rely also on own or close-by coal-supply for the production of technological steam, the net production cost could be reduced further to below 100 $/t.

3.7. Market relations

Since this subject is dealt with in more details and depths by other papers, we shall touch upon it here briefly only.

It is known that in the sixtieth over 90% of alumina produced in the world was consumed by smelters from within sources of the own group of companies. Since then this figure has decreased, but it is still on the level of 80-85%. Most of the balance has also been moving around under long-term contracts from producers to smelters.

It is also evident that there are a few developing countries only which could consume the full production of a new alumina plant with an annual capacity of hundreds of thousand of tons of alumina for local production of aluminium, such are e.g. India, Brasilia. An additional consideration is that the minimum economic capacity of an up-to-date alumina plant is at least two-three times larger than the alumina feed required for a modern minimum economic capacity aluminium smelter. The conclusion is that the decision on investment concerning a new alumina plant is all the more dependent on securing the long-term selling of the alumina product. No positive investment decision is taken nowadays without placing on the market in advance at least 2/3rd of the alumina to be produced.

As far as the long-term trend of world market of alumina is concerned it is clear that taking into consideration the consumption basically for aluminium smelting purposes, the market is dependent on the tendency of growth of aluminium production. In case aluminium production and consumption will grow on long term by say 4% annually this will be equivalent to about 1,200.000 tons of annual increase in requirement at the current level of world's aluminium production. It is difficult to foresee how steadily this growth rate will keep on in the function of time and to what extent the utilisation of this growing market will be accessable for new alumina plant ventures to be undertaken in and by developing contries.

4. Aluminium Smelting

4.1. General

As was already mentioned in the introduction the classical Hall-Heroult process is still the only solution to be considered.

Whilst in establishing an alumina plant the main objective factors of decision concerning conditions of nature are the vicinity of bauxite and/or good transportation facilities /deep sea port/, the vicinity of energy sources is the indispensable condition for establishing an aluminium smelter. Transportation of electric power required for an aluminium smelter from a long distance requires large investment, it carries big losses and it is not acceptable either from the point of view of reliable plant operation.

The main material and power requirements of aluminium smelting for producing 100,000 tpy of aluminium are:

alumina -	193-196,000 tpy
petroleum coke -	44-47,000 tpy
tar pitch -	11-12,000 tpy
fluorides -	2,5-3,000 tpy
electric power -	1,5-1,6 **million MW-hours**

The latter is equivalent to an operating electric power generating capacity of 175-190 MW.

4.2. Siting. Role of sources of energy

The ideal condition is when sources of cheap energy and good bauxite reserves are close one to the other and the aluminium, produced has local market possibilities or it can be transported by sea at low cost to buyer's market.

In the past smelters were constructed in industrially developed countries and on cheap electric power sources, close to the aluminium market. /North-Western part of the USA, Quebec region of Canada, Norway, the Alps and the European parts of the Soviet Union/. With no bauxite available at most of these locations, bauxite and alumina were brought there from considerable distances. The increasing demand for aluminium required the establishment of larger and larger power generating capacities for new smelters and less and less resources of electric power at relatively cheap cost were available in industrially developed countries. Utilization of resources of electric power had been hampered also by growing considerations of environmental protection. On the other hand more and more electric power is required for industrial and communal purposes in developed countries. The price of energy generated by both old and new hydro-electric power stations has been adjusted more and more to its national average economic value also for aluminium smelters, disregarding the actual generating cost of the electric power. /North-Western part of U.S.A. or New-Zeeland/.

Similar considerations are expected to prevail in oil-producing countries for electric power generated from gas, which may be utilized also for other purposes and revalued upwards thereby.

There are huge hydro-power potentials still underutilized especially in Africa and Asia. Hydro-power is the cheapest of sources of energy, it is - however - investment intensive and requires long-term financing on favourable conditions. Recently /e.g. in Norway/ landscape protection aspects have been emerging against new decisions on establishing hydro-power stations.

Existing potentials of hydro-power will be utilized in the foreseeable future primarily at places where risks of investment are smallest and the return of capital invested seems to be guaranteed for decades. Starting from this consideration multinational firms often choose the second best solution if it involves smaller risks for the capital invested, e.g. locating smelter projects in industrially developed countries. Under such circumstances the absence of cheap electric power is compensated by other factors, e.g. benefits from further processing for local market, less investment costs, the linking up with the existing infrastructure, availability of qualified manpower. These factors taken together may stimulate the large aluminium producing firms to further develop the aluminium industry existing already in developed countries; e.g. in Canada, Norway or in the U.S.A. even in case of higher energy price. Other developed countries may join this trend on energy produced by nuclear or new coal-fired power stations at a reasonable price. Recent examples are the Reynolds smelter in Hamburg, the Pechiney smelter in Vlissingen, Holland, and the new smelter project in Hungary.

In any case possibilities of development of this character are limited and they will not satisfy the increase in long-term demand for aluminium expected to accelerate in the next years. This may further encourage construction of national smelters supported by state and government and based on decisions independent of the multinational firms /see Egypt, Algeria, Venezuela, Dubai).

In the past it was quite common that aluminium smelters paid unit prices for hydro-power which may be viewed today as insignificant. There are unit prices even today of 2-3 mill/kWh and their increase by at least 3-6 times is on the agenda of the new negotiations expected on the expiration of the valid contracts. Even in the most favourable cases of thermal power stations installed in 1976-77 new unit prices of at least 15 mills/kWh have to be calculated.

If investment and fuel costs keep increasing it may happen that this unit price may double within one decade and it may reach or even exceed 30 mills/kWh. Consequently the cost item of 220-240 $ of energy based on a unit price of 15 mills for the production of 1 t of aluminium is expected to at least double in the next ten years' period.

Whereas in case of oil-fired power stations the price of fuel represents 2/3rd of the price of energy, in the case of coal-fired power stations based on relatively cheap coal and lignite the same 2/3rd part of the price of energy is represented by capital cost factors.In case of nuclear power stations fuel costs are the least item and they do not reach even 20% of the price of the energy produced.

From data at disposal it may be calculated that hydro-power remains competitive if the specific investment cost per unit of capacity is maximum 15-20% more only than that of high-capacity nuclear power stations being established in developed countries.

4.3. Other main factors determining the rate of efficiency of aluminium smelting

4.3.1. Raw materials

The production of 1 ton of aluminium requires about 2 tons of alumina, hence from the point of view of both quantity and value alumina is the most important raw material and its cost generally amounts to 25-30% of that of aluminium. Although it is transported by tankers already, still the transportation costs may be considerable if long distances are to be covered and if reloading and railway transportation is required.

Generally it is advisable to secure stable supply of the smelter by concluding long-term contracts for at least 75-80% of the requirement; spot purchases may occasionally be very attractive but they may surprise us by their unreliability and by causing unexpected additional expenses. It comes into practice to fix the price of alumina as a certain percentage of the quoted price of aluminium.

Raw materials for anodes are also relatively expensive. Prebaked anode blocks used in up-to-date smelters should be produced at the smelter, otherwise they cost more, their transportation is difficult and the proper utilization of the butts representing still 20-30% of weight cannot be solved. Tight technical control of anode manufacturing is indispensable also because of the influence of quality of anodes on the operation of the electrolysis cells.

The raw materials of anodes - the petroleum coke /calcinated/ and tar pitch - are generally purchased and securing supply of stable quality by long-term purchase contracts is desirable. There are relatively few sources of raw materials for anodes available freely and in most cases with no much deviation in prices. Since the deviation of conditions is not significant either, the raw materials for anodes do not play significant role in taking investment decisions.

Starting from their quantity and value the same applies to fluorine salts and coal materials required for cathode lining as well.

4.3.2. Size of the smelter. Amperage

Half a century ago smelters established in developed countries were of very small size with capacities of 3-10,000 tpy e.g. those based on hydro-power stations in the Alps. The amperage applied was 20-30 KA. After the Second World War in order to satisfy increasing requirement in aluminium the amperage and pot sizes applied and unit capacity of smelters established have been increasing steadily. Today a smelter with a capacity of less than 100,000 annual tons can hardly be profitable due to the disproportionately high specific investment costs.

The pots having been recently developed operate on an amperage of 160-230 KA producing 300-550 tons per year of aluminium each. The number of pots in series may vary between 120-240, one line produces thereby 50-130,000 tons of aluminium in a year. Shorter series require somewhat larger investment for electric equipment for the same capacity, but on the other side operating problems arising will cause less losses if production and working conditions are more safe with lower overall voltage of a potline.
The conclusion is that today in general at least two pot lines of 50-75,000 tpy capacity each are to be built in order to achieve economic plant size. On the other end environmental pollution may cause problems above a contentration of 250-300,000 tpy of aluminium production even despite good gas collection and cleaning.

The average annual production capacity of 170 odd aluminium smelters operating in the world today is about 90,000 tons. It has to be added that specific local conditions, financial considerations, requirements of the market or priorities set by government and state may in some cases justify the establishment of production capacities smaller or larger than what seems to be the normal range, based on direct technical, economic or environmental considerations.

4.3.3. Technology and environmental protection

The Hall-Heroult process itself has remained unchanged for nearly 100 years, the construction of the industrial furnaces have however become more and more sophisticated. For a new investment it is a requirement that the technology and technique applied keep to be acceptably up-to-date as long as possible. Aluminium smelters may have a life-time of 30-40 years before requiring basic reconstruction or final closing down. In the electrolysis halls pots can be continuously kept in good condition by carrying out carefully the pot maintenance required in every 4-5 years.

The latest and most up-to-date construction and technology being operated already by the designers on large industrial scale - this is what has to be selected for a new investment. The electrolysis furnace or cell or pot - which is the main and basic equipment of an aluminium smelter - consists of two main parts - cathode and anode. The construction of the cathode part of the furnaces or cells is known to be rather uniform. Concerning

the anode structure cells of two basic types have been evolved: the Söderberg anode type and the prebaked anode type. Söderberg anodes are further divided into 2 types: horizontal stud anodes and vertical stud anodes.
The horizontal type Söderberg anode cells have a closed main operating area with efficient local cell exhaustion but it is difficult to apply them for high amperages /above 100 KA/ and they have organic limitations to the increase of manpower productivity as well. Such pots are not constructed any more in newly built smelters and in the reconstruction of old ones either.
This type of pot provides still - however - 1/6 of the world's aluminium production.

The operating area of vertical stud Söderberg anode type pots may only partly be closed and the efficiency of local, cell gas exhaustion is 60-80% only. Some 1/3 of world's production is still produced in such pots. Great development has been achieved during the last decade by this type of pots, reaching an amperage of up to 160 KA, and significantly high productivity with good mechanization. Their advantage is that no separate anode baking shops are required, hence the specific investment costs are less for smaller capacities. By now - however - new requirements and regulations on environmental protection and working place conditions have been emerging. These requirements, when posed, may be met when using this type of cell by intensive ventilation only of the furnace hall with washing of the total quantity of gases exhausted therefrom. This results in additional investment costs, rendering the choice incompetitive against up-to-date prebaked anode smelters. About half of the world's aluminium production is carried out today in prebaked anode type pots. One version is the prebake sidebreak type, originally with a fully open operating area. New development of this type are pots with cover lids which are to be lifted when charging of alumina. However, this is unfortunately just the very period of most intensive hall pollution by cell gases, therefore additional roof gas washing is indispensable here too as a consequence of the latest regulations of environmental protection.

Today the center break type prebaked anode pots are considered to be most up-to-date. These pots may operate with a relatively well-closed operating area, which is to be opened partially only and rarely /for a period of 2-5 minutes/day/. The charging of alumina takes place automatically in closed position. As a consequence, the local cell gas exhaustion is effective and no roof gas washing is required.

Concerning environmental pollution problems of aluminium smelters, it is known that fluorine compounds and in in case of Söderberg type anodes applied, tar distillate components are the main polluting components of the cell gas and also of the roof exhaustion. The quantity of fluorine emission is 15-18 kgs for each ton of aluminium produced. Up-to-date large smelters with a capacity of 100-150,000 try would pollute the environment with 1500-2500 tons/y of fluorine if no gas washing is applied. Significant part of this fluorine would spread to the environment through the open potroom area if not the most up-to-date pot types are applied.

The upper limit of fluorine emission into the environment permitted today in developed countries is 0,5-2 kg per 1 ton of aluminium and it is expected that similar regulations may come into force within some time world wide, hence it is practical to consider this standard when establishing a new smelter. The heavy damage which may occur in the health of the operating staff and in the natural environment of a smelter when the control of emissions is neglected consists of possibility of developing incurable diseases for both human beings and animals and of destruction of surrounding vegetation.

Summarizing the aforesaid: in the interest of effective environmental protection

a/ such cell construction and operating technology have to be applied which ensure proper gas collection;

b/ the gas collected and exhausted has to be washed efficiently.

As per item a/ - the center break prebaked anode type cell is the satisfactory answer. As per item b/ - it is known that wet gas scrubbers applied earlier were satisfactory but they were too costly and the reclaim of fluorine was rather expensive. Lately dry gas cleaning has started to prevail. This method utilizes the capability of alumina having large active surface area to adsorb fluorine and its compounds. Alumina is lead trough the dry scrubber prior to be fed into the cells. On having been contacted with the gas there, it adsorbs the fluorine compounds and after having properly filtered out from the gas it is forwarded to the pots and fed through chargers into the process, recirculating thereby the fluorine adsorbed.

4.3.4. Infrastructure

For the operation of a smelter the infrastructure required is quite similar to that of an alumina plant.

First the conditions of transportation are to be taken into consideration. Quantity of materials to be transported in and out for a smelter of an annual capacity of 100,000 t is 400 000 tpy, that is more than one thousand tons per day. It is natural consequently that a plant located further from the seaside cannot do without junctions for railway and heavy road transportation in view of the big quantities of goods to be moved.

If the source of alumina is not close or not along the same railway line a deep-sea port is required. This would reduce transportation costs of both alumina and carbonaceous materials arriving and also aluminium products to be dispatched. The port has to be equipped with special unloading facilities for alumina and carbonaceous materials.

The existing infrastructure of industrially more developed countries may usually be utilized and the connection has to be ensured only. This means a distinct benefit regarding siting costs /ensuring and allowance of up to 10-25% of the investment/.

Sufficient siting area has to be available for the establishment of a smelter. A smelter with a capacity of 100,000 tpy requires a territory of 30-40 hectares and it is advisable always to consider possibilities of future expansions. The nearest settlement should not be closer than 500 m even in case of suitable environmental protection secured. For the operation of a smelter also considerable quantity of industrial water is required reaching 3-4 thousand m^3/100,000 t Al/year even in case of recirculation. Drinking and sanitary water is also to be ensured additionally.

Securing of operating staff may also have infrastructural preconditions. Vicinity of town and appropriate organization of transport of personnel /e.g. by buses/ may be an easy solution, otherwise a housing estate is to be constructed providing also shops, schools, clinic, etc. Stability of manpower and technical staff is indispensable for smooth operation.

It is a great advantage if the state or government undertakes to support the infrastructural investments considering them as part of developing the national economy. An important role may be played in this respect by international and regional foreign financing bodies, a number of which - as it is well-known - are prepared to finance infrastructural investments under favourable credit conditions in developing countries.

Vicinity of market, availability of alumina within easy reach and favourable investment conditions or infrastructure existing - all these together may make an aluminium smelter project economically viable even under less favourable energy cost conditions.

4.4. Investment costs

20 years ago an investment cost figure of 500-600 $/annual ton for establishment of a smelter was considered as relatively high. During the ten years period between 1964-1974 the average joint investment cost from bauxite through alumina to metal in the U.S.A. was 1100 $/annual ton of metal. This same figure increased to 2250 $ by 1974. In 1976 figures of 850-900 $ for the required 2 annual tons of alumina 1500-1600 $ for one annual ton of primary aluminium were contemplated. Latest data including the infrastructure

required indicate 2000-3000 $/t of investment costs for the smelter alone.

Spector assumed in early 1976 investment costs in dollar value for the same year as follows:

in USA	1550 $/annual ton
in Venezuela	1840 "
in Middle East	2250 "

The cost of investment may vary considerably in dependence of the location and existing infrastructure. It is also influenced by the capability of manufacturing locally the equipment required as against its importing at usually higher cost. Unavailability of qualified local construction and mounting personnel could also become a significant cost increasing factor. In any case investment financing ranks amongst the most important factors of making decisions on the establishment of a smelter. Capital costs may amount to 25-30% of the metal's total production cost and they may become higher than the cost items of alumina or electric power. They represent today a total investment cost of 250-450 M $ for a smelter of a minimum economic capacity of 100-150,000 tpy. This does not include, however, the investment cost of the hydro or thermal power station required to supply the energy for the electrolysis.

4.5. Manpower

As compared to the value of capital invested and of metal produced the manpower requirements of an aluminium smelter are relatively low. The number of staff required may change at a ratio of 1:4 depending on the technology, the degree of mechanization and automation chosen and on the availability or absence of external network of services capable to do the maintenance work. An up-to-date smelter with a capacity of 100,000 tpy and with a basically internal self-supporting maintenance organization requires a total staff of 600-1000 persons. It is evident from these figures that the establishment of even a large size, economic capacity aluminium smelter will not have a significant impact on employment. Still for smooth running and economic operation of a smelter the human factor has a prominent role. Highly trained operating and maintenance personnel is required to exactly observe the technological instructions, performing a fully disciplined work. Consequently stability of the majority of the personnel is a must. Deterioration of equipment of high value, consumption figures 10-20% higher than planned and expected, decrease of production could be the consequences of a frequently changing and therefore in the average insufficiently trained and experienced personnel.

The smelter demands wide range of knowledge of skilled work /e.g. training of electricians, technicians, mechanics, welders has to be organized/.

In developing countries smelters could educate and train skilled workers for other future plants planned thus they may become the basis of industrial development of an entire region.

Considering the aforesaid it is a point that both technical management and at least skilled workers be raised as early as possible from local resident population. Careful programming and well founded, consistent execution of replacement of foreign experts after an initial period of starting up and establishing smooth operation with simultaneous transfer of operating knowledge and skill - this is the ideal and reassuring solution developing countries have to strive at.

4.6. The factors of production cost

The three main factors of production cost - and at the same time factors of investment decision - with their weight indicated in percentage of the cost are:

- electric power /availability and price/	20-25%
- alumina /stability of supply and price/	25-30%
- capital charges /conditions of investment and financing/	25-30%

These 3 factors together cover 70-80% of the total cost with a close to equal distribution, still with the tendency that the share of alumina has a decreasing trend while that of energy and capital charges are increasing. Significant part of the remaining 20-30% /at least 10 absolute percent/ is made up by carbon materials and fluorine salts. The rest are labour, maintenance, other services, overhead and administrative costs.

4.7. Market relations

Finally - with special regard to the fact that other papers will deal with this subject in depth - a few words only about the market aspects of aluminium smelting.

It is advisable to secure long-term market outlets for products of an aluminium smelter to be established in a developing country. In most cases consumption of aluminium in these countries is a fraction only of the capacity of an up-to-date smelter hence stable export markets are to be found. We would not deal here in details with the prospects of aluminium consumption in different parts of the world but it may definitely be expected that many of the smelters to be established in developing countries in the foreseeable future will still have to find markets in industrially developed countries. It is also true that an aluminium smelter established in a developing country may well undertake the regional supply with metal of a group of developing countries, facilitating thereby greater economic independence and integration.

In any case, although the aluminium market - compared to that of other metals - has been relatively stable for a long time, still it is not free from periodical fluctuations. Therefore it is advisable to carefully analyse the market prospects and - if possible - to sell in advance considerable part of the production prior to making final decision on investment.

5. Aluminium Processing

Whilst for reasons of economic viability alumina plants gravitate towards bauxite deposits and aluminium smelters gravitate towards sources of energy; aluminium processing operations are to be located in the vicinity of buyer's market. There are huge metal processing operations in the developed countries offering wide range of products. In most of the developing countries the small local market does not encourage the establishment of metal processing operations of up-to-date scale and range of products. Introduction of regional cooperation and schemes of development may be one way of progress. Paying special attention to this circumstance we shall touch upon four major forms of semi-fabrication of aluminium as follows:

5.1. Rolling operation of the traditional type /slab casting - hot rolling - cold rolling - heat treatment - finishing/ ensuring a properly wide assortment of size, composition, and finishing can only be established with a production capacity of not less than 80-100,000 tons per year. Such large requirements in developing countries are quite rare. However, smaller economic capacities can still be established with a limited assortment based on continuous casting processes different from the traditional one. A casting and rolling shop consisting of two continuous casting units with cold rolling mills which represent an annual capacity of 25-30,000 tons may be economically viable already. It may be established at or not far from the smelter producing molten metal.

5.2. Extruding operation of a capacity of 2-5,000 tpy of extruded products can be established with one extrusion press and imported dies and it may operate economically. The establishment of an anodizing unit close to the extrusion may also be practical with possibility to be extended by stages of 2-3,000 tpy. As another viable extension, a shop for assembling aluminium window frames, doors and other building construction elements, may be considered if market is available.

5.3. Rod, wire and - as end product - power transmission cables can be manufactured at the smelter economically using continuous casting processes on a capacity of 15-25,000 tpy of semi-fabricates. Production of aluminium transmission cables may be viable economically on a capacity of 5-10,000 tpy already. Manufacturing of insulated cable products is more capital intensive and it requires in large quantities materials other than aluminium. Conditions necessary for an investment decision in this direction are more complex and difficult to fulfil

5.4. Castings are required primarily by the car-manufacturing, machine building and appliances manufacturing industries.
Securing supply of casting dies is a key issue, it requires the procurement and operation of expensive machinery and also highly specialized knowledge and experience especially in case of machine castings. Similarly to extrusion it is often advisable and economic to use purchased tools. Scale of operation has less impact and

manufacturing products of good quality and ready marketability at competitive cost may be successfully organized on a scale of 1000-2000 tpy already in case specialized knowledge, properly trained staff and well-organized operation, following closely the changes in the market are present. Role of marketing operations is even more important here than in the former cases of processing.

6. Investment climate, incentives for industrial development

In the previous chapters the natural, objective conditions and preconditions of industrial development were broadly reviewed and the main factors of decision of this kind were pointed out. It has still to be recognized that even if all the inducive natural conditions are present, developing countries may face the danger of failing to secure capital on suitable terms and still without jeopardizing national interests. In this respect the investment policy and support of state and government may also be a decisive factor of promoting industrial investment and development. One of the interesting new examples is the decision to start the investment of the 800,000 tpy Aughinish alumina plant in Ireland, which will have according to publications a specific investment cost of about 660 $ per annual ton of production and operate on bauxite imported from overseas, also exporting its production to smelters in Europe and North America. The climate and incentives created by the Irish Government by balancing the objective, natural drawbacks of this project proved to play a decisive role in attracting foreign capital and long-term customers of the product.

Incentive measures of government and state may take the form of:

- assistance at the stage of effective preparation of investment decision
- assistance in financing /volume and terms/
- tax incentives and import duty concessions
- measures to facilitate and protect foreign investment
- fiscal and other benefits for export orientation
- assistance in attracting foreign expertise required and developing local skills.

Let us see a concrete example of a package of incentives which may be granted by state to a mixed -state and private - ownership industrial project with a majority national interest in the field of the aluminium industry.

a/ On taxation:

- sums equaling cumulatively to up to 100% of investment realized may be deducted from net profit before taxation for a definite period of time;
- depreciation allowances may be tripled before deducting from gross profit;
- expenses to create working capital may be deducted from profit before taxation for a definite period of time after the starting of investment;
- losses may be carried forward to get deducted from profit before taxation in a profitable period;
- a percentage of the FOB product price is deductable as non-taxable expense;
- interest on loans from foreign banks are exempted from taxation;

b/On other fiscal measures:

- government granting part of equity capital without exercising shareholder's rights and functions;
- government subsidy of a definite percentage unit off the rate of interest granted by local banks;
- government export incentive granted as a percentage of the FOB product price;

- exemption from custom duties on equipment and spare parts, from stamp duties and notary and mortgage fees;
- foreign exchange is made available for importation of raw materials and fuels;
- exemption from taxes and duties for imported raw materials and fuels, exemption from special loading and unloading charges;
- a definite amount of imported capital is made exportable for payments of know-how, consulting, engineering, etc.

c/ On attracting foreign capital:

- constitutional protection of imported foreign capital;
- assets of the project are exempt from expropriation;
- profits up to a definite percentage of imported equity capital may be annually exported;
- foreign capital may be exported at a definite annual percentage rate after production begins;
- interest up to a definite annual rate on outstanding debts are fully exportable;
- freedom of transferring foreign partner's share to the country of origin of the equity capital;
- foreign personnel employed has the right to export significant part of earnings.

From the possible items of assistance provided by state and government to promote industrialisation we wish to underline once more the importance of support at the very starting pre-investment stage. Presentation of techno-economic viability, bankable study and analysis reports on its financial attractivity, display of measures and incentives intended to be granted by state and government are indispensable instruments to attract money, market and intentions required for a new industrial project to materialise within a short period of time.

7. Conclusion

A broad review of factors of making decision on investment in the field of bauxite, alumina and aluminium was given. Natural resources and conditions, technology, capital, market, manpower and skill, governmental incentives and regional cooperation were mentioned and scrutinised. Our conclusion is that no uniform recipe exists for making decisions on industrial development. In each individual case detailed study and analysis of natural, human, economic and political factors has to be undertaken to ascertain the techno-economic viability of the project, to draw conclusions, to prepare well-founded decisions. We would like still to underline the role of the human factor. So many more favourable conditions, attractive possibilities, objective wealth of nature, existing in developing countries could be exploited and utilised for the benefit of their population and economy and still waiting for concentration of will and decisive action. Our paper is intended to be a modest contribution to this end.

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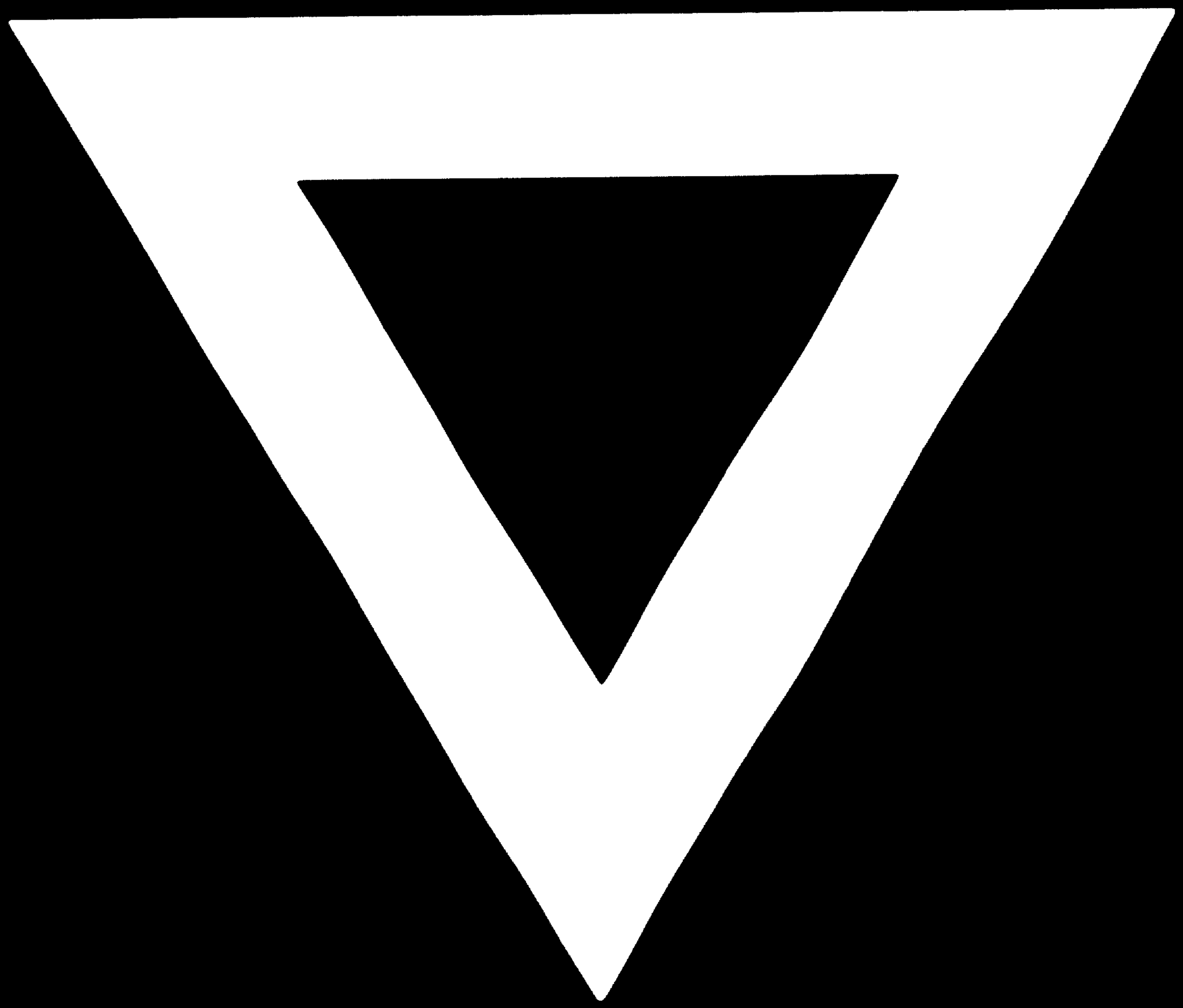

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