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Issue Paper 2

THE MASTERING OF THE TECHNOLOGY AND DEVELOPMENT OF THE IRON AND STEEL INDUSTRY IN DEVELOPING COUNTRIES *

Prepared by the
UNIDO secretariat

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1. Introduction

The mastering of the technology and development of the iron and steel industry in developing countries depends, to a great extent, on the strategy of industrialization. For this purpose, and in view of establishing a national and subregional coherent productive system, it is most important to develop a strategy which promotes the integration of the iron and steel industry with the capital goods sector and other sectors of the economy, as well as co-operation at the regional and subregional levels. It is also necessary to identify other relevant aspects which need to be mastered. These aspects are:

a) the selection of appropriate technology according to the size of the country, products to be produced, and national resources available;

b) the identification of techniques to be mastered in the context of the selected technology, for the manufacture, maintenance, improvement and adaptation of imported equipment, as well as for the design and construction of specific types of machines. This will enable the attainment of greater domestic capacity in the production of iron and steel;

c) the development of methodologies for the formulation of training programmes oriented towards mastering at the national level, the key aspects of the subsystem constituted by the iron and steel industry and its main users and suppliers.

d) the identification of available national engineering and trained manpower, as well as of possible international co-operation at Government and enterprise levels.

2. Technological alternatives

Iron and steel is considered as the classical heavy industry, but one easily forgets the constant evolution of its technology, the changes of some of its main characteristics such as size, as well as the role that economies of scale have played in its productivity.

2.1 Types of plant

The technological changes that have taken place in the iron and steel industry have created different types of plant:

a) The classical plant

This is, in general, an integrated plant based on the conventional route of the blast furnace-oxygen converter, as well as other schemes (blast furnace - open hearth, etc). Generally it is a large size plant, of more than a million tons, which produces a wide range of flat and non-flat products.

b) The mini-plants

It is difficult to agree on a single definition of a mini-steel plant. In developing countries mini-steel plants may have a capacity as small as 5,000 tons per year or less, and often have between 10,000 and 100,000 tons per year. In developed countries the usual capacity of mini-steel plants was between 50,000 and 500,000 tons per year and is now between 100,000 and 500,000 tons per year and may be as high as 1 million tons per year.

Mini-plants can be integrated plants that include all operations, beginning from the transformation of iron ore into pig or sponge iron, through conversion into steel, casting operations and rolling into finished products; semi-integrated plants that start with steel scrap and/or directly reduced iron ore (DRI) as a raw material to produce steel in an electric arc furnace and include casting and rolling into finished products;
non integrated plants that melt scrap and directly reduced iron ore in an

electric arc furnace, but only produce crude steel cast into ingots or billets; or simple re-rolling mills, that use semi finished products to produce finished steel products. 1/

2.2 The evolution of the production of the different types of plant

It is well known that large integrated iron and steel plants are expanding at a very low rate in the world. This is more evident in industrialized countries, but even in developing countries their growth is rather limited.

There is a clear trend towards an increasing proportion of world steel production by mini-plants. For example, while in 1970 the mini-steel capacity was 7 percent of the western world capacity, in 1985 it increased to 19 percent.2/

Much of the recent investment in new steel plants in large steel producing countries has been in mini-plants. In the United States, practically all new crude steel capacities are based on mini-steel plants. In 1980, approximately 27 percent of crude steel in the United States was produced by mini-plants, in Italy 55 percent, in Japan 23 percent, and in EEC countries, 26 percent.

In developing countries the role of mini-plant production is also impressive. Developing countries contribute 28.3 percent of the western world capacity of mini-steel. In Asia, including China, the capacity is of approximately 20 million tons; in Latin America, approximately 7 million tons, and in Africa, approximately 2.4 million tons. In Eastern Europe mini-plants appeared quite late. The first plant of this type is the Byelorusskiy Metallurgicheskiy Zavod at Zhlobin in the Soviet Union with a capacity of 720,000 tons a year.

1/ There is a third type of plant - the micro plant - which is only at a research stage with a production capacity of only 1000 tons per year. For further details see "The Project Future Steelworks. Final Report." The National Board for Technical Development, Stockholm, January 1983.

2/ IISI, 19th Annual Meetings and Conference, London, U.K., 6-9 October 1985.

As regards the least developed countries, one can also note the development of the mini-plant capacity. For example, in some African countries mini-plants have been developed with a capacity of less than 50,000 tons a year. Among these countries are Angola (30,000 t/year), Cameroon (40,000 t/year), Ghana (30,000 t/year), Ivory Coast (20,000 t/year), Kenya (30,000 t/year) Mauritania (36,000 t/year), Togo (20,000 t/year) and Uganda (24,000 t/year).

Consequently, it is important to examine the main causes of increasing mini-plant production in world-wide steel production. The main aspects which can help to explain this trend are the following:

a) the present financial crisis and the restructuring taking place in the capital goods sectors at the world-wide level have decreased the demand for steel products, reducing the possiblities of estabiishing a large integrated plant;

b) large integrated iron and steel plants are very costly from the point of view of capital costs, and require large financial resources, which is a major constraint to developing this type of unit, especially in developing countries. In addition, these large integrated iron and steel plants require large and costly infrastructure from the point of view of supply (mines, energy, refractories) as well as of transport and housing (railway, port, cities). Significant financial resources are also needed for the training of a large number of people needed in this type of plant.

c) the capacity of mini-steel plants is more suited to the size and level of demand of many developing countries, thus creating conditions for a better integration with other sectors of the economy at the national and subregional levels;

d) the total capital investment per ton of installed capacity required for a mini-steel plant is lower than for a conventional integrated plant. In addition, the construction period can be shorter - in some cases as low as 2 years in comparison with 4 to 12 years needed for a conventional plant;

e) some operations such as sintering facilities or a coking coal plant, and expensive infrastructure (extensive transport equipment) needed by a conventional integrated plant, are not required for a mini-plant, which makes it a less expensive and a less complex technological route. In general, mini-plants require less-skilled manpower, thus, reducing, the costs of training, which is an advantage to countries where trained personnel is limited.

However, it is important to point out that at present mini-plants have the disadvantage of producing a relatively limited range of products. This is not so in the case of large integrated iron and steel plants, which therefore could result in some cases in making them irreplaceable.

3. Mini-plants

Due to the aspects mentioned in point 2.2 above, the mini-plant technological route is becoming an important technological alternative, particulary for "newcomers" to the iron and steel industry.

In industrialized countries the main structural characteristcs of mini-plants are different to those in developing countries.

In industrialized countries, mini-plants have the following main technological characteristics :

a) they use electric arc furnace based on scrap, as raw material;

b) they produce mainly light long products (bars, wire rod, small beams or merchant iron);

c) steel is continuously cast in billets, although it can also be cast in small ingots ("pencil ingot");

d) billets are rolled in one, sometimes two mills.

The possible future evolution in industrialized countries, of this "classical" mini-steel plant is towards a more diversified production. In future mini-plants will enter the field of "flat products". As is well known, a definite move is taking place in this direction with the production of plates from electric furnace steel-making; the design of new casters to produce thin slabs; and the adaptation of existing mills (steckel or semi-continuous) or design of new mills (planetary).

In developing countries, the development of mini-plants takes place in a different context. The capacity of these plants is in general, smaller than in developed countries due to the size and level of demand of many developing countries. The size of the plant is also affected by the need to build up the necessary infrastructure which, in the case of most industrialized countries, already exists. On the other hand, quantities of available scrap in a developing area vary to those in an industrial one. In developing countries, there is often a lack of scrap which can lead to the selection of either direct reduction or another metallurgical scheme. In addition, from the energy point of view, "newcomer" countries often lack a reliable electric supply which again, can lead to other metallurgical schemes.

3.1 Problems encountered in mini-steel plants

In a survey carried out by the UNIDO secretariat on 74 mini-plants of a wide range of size and type, located in 23 developing and in 13 developed countries, a variety of different problems was encountered in developing countries to those in developed countries, as well as in the different regions.[3/]

The problems encountered in mini-plants in developing countries were related mainly to raw materials, energy, technology and financial aspects. In Africa, the main problems were shortage of raw materials, specifically shortages of local scrap, as well as shortages and high prices of electric power. Financial problems were due to lack of hard currency for the payment of foreign debts, as well as lack of available financing.

Asian plants faced problems mainly related to raw materials, specifically in the irregularity of supply and the high prices, as well as the lack of

3/ For further details see: "Mini steel plants: an analysis of their main characteristics and level of integration and the possibilities for co-operation", ID/WG.458/4. Background paper for the Fourth Consultation on the Iron and Steel Industry. Vienna, Austria, 9-13 June 1986.

foreign exchange to cover payment for the import of raw materials. India was an exception to this pattern: energy was the area in which Indian mini-plants faced major problems due to shortages and irregularity of electric power supply.

Latin American plants, especially in Colombia and Venezuela, had problems related to importing scrap and to shortages of spare parts due to lack of foreign currency. Financial problems were mainly due to high interest rates. Fluctuation of the world market was another problem which had an important impact on the evolution of the exports of those countries and which affected the level of utilization of their production capacity.

In developed countries the main problem encountered was the high and fluctuating price of scrap. Other problems were the decrease of domestic demand, as well as financial problems due to the high cost of capital, insufficient past investment and high working capital requirements.

3.2 Integration of mini-plants with other economic sectors

The 74 mini-plants studied, reveal an important orientation of their production towards domestic consumption and also integration of those plants with the construction and capital goods sectors.

The mini-plants studied oriented their production mainly towards domestic consumption which accounted for approximately 72 percent of their output, with 28 percent being exported. The plants in developing countries concentrated more on production for domestic consumption: approximately 80 percent of their output, while in developed countries about 64 percent was for domestic consumption and 36 percent was exported.

These mini-plants reveal an important integration with key sectors of the national economy. The final users of the products of mini-plants studied can be grouped into the following main categories: construction; manufacture of equipment, machinery, motor vehicle parts, tools and other industrial products; pipes for gas and water; and steel cables used in the system of electrification.

There are some differences in the patterns of use of the output of plants studied in developing and in developed countries. In the developing countries the output of approximately one-third of the plants was used entirely for construction; the output of 28 percent of the plants was used for both construction and manufacture of capital goods; 20 percent was used mainly for manufacturing capital goods; 10 percent was used for pipes for water and gas; and the output of the remaining 8 percent was used for cables and other uses. In the developed countries the output of 42 percent of the plants studied was used entirely for construction; 33 percent was used for both construction and the manufacture of capital goods; and 25 percent used entirely for the manufacture of capital goods.

There are also differences in the use of the output of mini-plants studied in developing countries. In Africa, most of the output (80 percent) was used in the construction sector, while in the other regions the production of iron and steel was used more in the manufacture of capital goods, pipes and steel cables used in the system of electrification.

3.3 Motivating factors for the establishment of mini-plants and technical co-operation

The main motivating factor that determined the establishment and location of mini-steel plants in both developing and developed countries was the domestic demand. That aspect was true of 82 percent of all plants studied and of 93 percent of plants in developing countries. The second most important factor was the availability of raw materials, which was proved by the location of 45 percent of plants in both developing and developed countries. Some other factors were the availability of infrastructure, energy, skilled labour and financial resources.

Most of the plants studied (90 percent in the developing countries and over 60 percent in developed countries) expressed interest in participating in technical co-operation activities.

The areas in which mini-plants in developing countries expressed interest in receiving technical assistance include technical aspects (electric arc furnace technology, continuous casting); training; maintenance procedures; quality control; energy saving; as well as management for the reduction of costs. Several plants in developing countries, mainly in Mexico, in India and in Brazil, expressed interest in providing technical assistance.

4. Training to master the development and technologies of the iron and steel industry

4.1 Aspects to be considered

Training is a key aspect to attaining a greater domestic capacity for mastering the development and technologies of the iron and steel industry. For this purpose, methodologies and programmes of training should take into account numerous internal and external factors of a diversity of nature - technical, economic and social - which are mainly responsible for the efficient production and development of such a complex industry.

Training for this industry in developing countries, should be conceived in mastering, not only production operations and organizational aspects of a specific plant or plants, but also the infrastructure needed for its development, as well as its links with other sectors of the economy that are suppliers and users of the iron and steel industry. In cases where exports play an important role, methodologies and programmes of training should take into account the need to master the mechanisms of world market functioning.

The methodologies and programmes of training should aim at mastering technical and especially socio-economic complexities, because of the need of integrating the plant, in a harmonious way, within the national economy. In other words in the conception and the development of the plant, existing economic and social structures should be taken into consideration.

In this respect, it is important to identify the different types of training needed for the effective building up of the infrastructure required for the integration of the iron and steel plant with its environment. This means, in some cases, the need to master the supply of energy and water, communications, the construction and operation of a port, and the creation of a whole new city. The methodologies and programmes of training should also aim at achieving harmonious and efficient links between the iron and steel industry and the mining sector which provides the plant or plants with the iron ore, the industries that supply spare parts, as well as with the construction and capital goods sectors, petroleum industry and other sectors which use steel products.

Methodologies and programmes of training should be mainly oriented towards mastering the process for the selection of appropriate technological alternatives according to the resources, size and infrastructure of the country, as well as the different techniques involved in the production process - manufacture, maintenance, adaptation and construction of machinery and equipment. This requires a proper knowledge of metallurgy, electricity, mechanics, mechanics of fluids and thermodynamics.

Training should also be oriented towards acquainting people to work at relatively high physical magnitudes, temperature, pressure, power and speed that are common characteristics found in the iron and steel industry. In addition, training in team-work should be developed, due to the nature of the process of production of this industry which is a continuous one, and where productivity is based mainly on the harmonious flow of production and on the proper balance between labour, raw materials and energy.

In developing countries, it is of great importance to identify the constraints of the national education system and the possibilities of improvement to meet the requirement of general and specialized training in the iron and steel industry.

4.2 Towards a methodology on training: some relevant aspects

In order to master the technical and socio-economic complexities of all the iron and steel subsystem of production, the methodology or methodologies of training should identify the key aspects that will permit mastering the main lines of "fragility" created by the relations between the enterprise and its socio-economic environment, and within the enterprise itself between the different individual jobs needed for the harmonious functioning of the plant. The main lines of "fragility" are generally related to the process of obtaining the inputs and services required, the spare parts needed, and the links with the main users of iron and steel products.

The mastering of the technological complexity, resulting from internal and external technical factors and their interrelations, has to be achieved mainly through the acquisition of appropriate technical know-how by the different persons involved in the subsystem of production of the iron and steel industry. The socio-economic complexity can be mastered through the development of adequate behaviour that takes into account the cultural and socio-economic environment, and through adequate definitions of authority and responsibilities which have to be in harmony with the social and technical organization existing in the country and within the enterprise.

In other words, the adequate combination of know-how, behaviour and authority/responsibility must lead to an effective mastering of the technical and socio-economic complexities of the iron and steel subsystem of production. These main aspects can be complemented by others, in accordance with the realities of each country.4/

To master, for example, the supply of spare parts required by the continuous casting, which is only a part of the production process of an iron and steel plant, it is necessary to master its main relations inside the plant which involve production activities, maintenance, engineering, and management of stock activities, as well as the external relations resulting from the need to buy spare parts from the domestic industry or to import them. Table 1 shows the main activities and their relations for obtaining spare parts for continuous casting.

To identify the line of "fragility" created by the relations mentioned above, it is necessary to determine the posts, mainly key posts, needed to carry out the different activities of production, maintenance, and engineering, and to administer the supplies and stocks involved in the supply of spare parts for continuous casting. Key posts can be identified by evaluating the requirements needed by each of them in relation to know-how, behaviour, and authority/responsibility. The factors and weight given to each of these main elements will depend on the realities of each country. Table 2 shows, as a reference, the main factors which could be considered in defining a post.5/

4/ For further details see: "Normative guidelines for the mastering of technology in iron and steel through training", ID/WG.458/1. Background paper for the Fourth Consultation on the Iron and Steel Industry. Vienna, Austria, 9-13 June 1986

5/ See footnote 4/.

Requirements of know-how, behaviour, authority/responsibility of the posts, define to a great extent, the main content of programmes of training.

There is the need to create, from the different sectors involved in the development of the iron and steel industry (transport, energy, mining, industry, education, commerce), a national group of persons responsible for defining a strategy of training and for formulating and implementing methodologies and programmes of training.

Co-operation in the field of training, between developed and developing countries and between developing countries themselves, has to be aimed at creating a domestic capacity which will permit the mastery of the development and technology of the iron and steel industry.

4.3 The development of new projects in developing countries and the selection of training alternatives

There are several possible scenarios of training for the establishment of a new project in developing countries. Some rely mainly on external support, others basically on national resources and effort aimed at achieving a more self-reliant development of the industry.

The modality adopted to implement a project will lead to different types of training. Where a plant is basically installed by a foreign partner, training does not play a central role, the pace is mainly set by the foreign partner.

The establishment of an iron and steel plant, in this case, can be the following:

a) request for proposals, according to a minimum of parameters determined such as the level of production and types of product to be produced, from sellers of equipment. The proposals should be presented free of charge;

b) international bidding by different firms in order to select the best proposal for the establishment of the plant on a turnkey basis;

c) analysis and evaluation of the different proposals by a consulting firm;

d) signature of the turnkey contract with the winning firm;

e) implementation of the contract by the foreign firm.

The installation of an iron and steel plant, mainly based on national effort, can be presented as follows:

a) preparation by a national team of a study aimed at identifying the main economic and technical characteristics of the project;

b) creation of a multi-institutional committee involving the different actors participating directly or indirectly in the establishment of the plant (industry, education, energy, transport, commerce);

c) formulation of pre-feasibility and feasibility studies by the national team, which can be assisted by foreign experts in some aspects of the study;

d) co-ordination with the different institutions at the national and international levels in order to begin training the personnel needed to operate the new plant, as well as to introduce training courses on the iron and steel industry in the national education system;

e) implementation of the project by the national team with the support, if necessary, of foreign expertise (individual experts or firms).

As can be seen, this second scenario will require a greater effort in training as well as extra financial resources. In this case, the development of the project will take more time. However, the future development of the plant will be guaranteed to a greater extent and will also have a major impact on the creation of a national technological infrastructure.

4.4 Costs of training

Training in the iron and steel industry, as has been pointed out, does not only involve the personnel directly responsible for the plant, but also those indirectly involved in the development of the iron and steel industry (building up of the infrastructure and policy makers).

The type of plant and technological alternative selected, influence training costs. This is mainly due to the differences in the amount of personnel involved in the direct operation of the plant and in the building up of the infrastructure needed for the functioning of the plant. If the size and product mix of a plant are larger, so are the requirements for the personnel directly and indirectly involved.

A classical mini-plant, based on scrap and specialized in one product, with a production capacity of 200,000 t/year, will require approximately 230 persons of different qualifications to operate at optimum conditions. A larger mini-plant (400,000 t/year), with an enlarged product mix (bars, wire rod, merchant iron), will need approximately 650 people; the same mini-plant integrated with a direct reduction plant will need approximately 750 people, and a classical large-scale integrated plant of 3 mt/year, between 6600 to 8300 people.

Training costs in developing countries are greater than in developed countries because of the need to build up the necessary or to improve the existing infrastructure (energy supply, water system, housing) and because of the lack - total or partial - of trained personnel and training facilities (training centres). This means that, for similar plants, developing countries must spend more resources for training than developed countries.

A mini plant of 400,000 t/year in a developed country where there is no need to build up new infrastructure, will continue to require approximately 650 people, whereas, in many developing countries the building up of the necessary infrastructure will increase the people involved to approximately 1380, which will have great impact on training needs and costs.

In many developing countries the establishment of a mini-plant, with the characteristics mentioned above, requires training of most of the people involved (around 1380) before the start of operations, in order to master at the national level, the technology and the development of the plant to be established. Training should include specialized training for the iron and steel industry and general training of the whole personnel. Specialized training costs can vary from US$ 5 million to US$ 10 million, according to the specific conditions of developing countries. The cost of general training of the whole personnel can be as much as US$ 50 million or even more.6/ This means that in countries where the general level of education is low in relation to the requirements of the iron and steel industry, the impact of training costs on the general cost of the project can be relatively high compared to those in developed countries.

Financing of specialized training could be related to a specific iron and steel project; the resources needed for this purpose are important. but are essential for the operation and development of the plant. General training is a deeper problem involving major resources which, if possible, must not be related to a single project; this type of training contributes to a more general development and should get a special financing.

5. Final considerations

In order to contribute in a decisive way to the creation of a national coherent productive system, the iron and steel industry needs to achieve an integrated development and to master its technology and future evolution.

The adequate selection of technology, according to the size and resources of the country and to the iron and steel products needed, and which is generally identified at the level of the feasibility study, will generate a positive impact on the main macro-economic parameters (employment, use of

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6/ For further details see: "Importance and possibilities of financing of infrastructure and personnel training in the iron and steel projects", ID/WG.458/2. Background paper for the Fourth Consultation on the Iron and Steel Industry. Vienna, Austria, 9-13 June 1986.

national resources, earning of foreign currency) of the country and on the efficiency of the plant. Appropriate methodologies and programmes of training can also contribute to decreasing the vulnerability of the plant, and promote a more self-reliant development.

In the context mentioned above, it is important to place emphasis during our discussions on:

1. Identifying the main aspects (technical, economic, legal) to be considered in order to master technology and development of the iron and steel industry at the national level, as well as on determining the main national and foreign actors to be involved in this process;

2. Identifying the main factors for the selection of the technology;

3. Identifying the main aspects to be taken into account in establishing methodologies for, and programmes of training, as well as ways and means to finance training which would have a lower impact on the financial structure of a project;

4. Identifying possible ways of co-operation among developing countries and between developed and developing countries which would permit developing countries to master the technology and improve the programmes of training of their iron and steel industry.

Table 1

THE SUPPLY OF SPARE PARTS

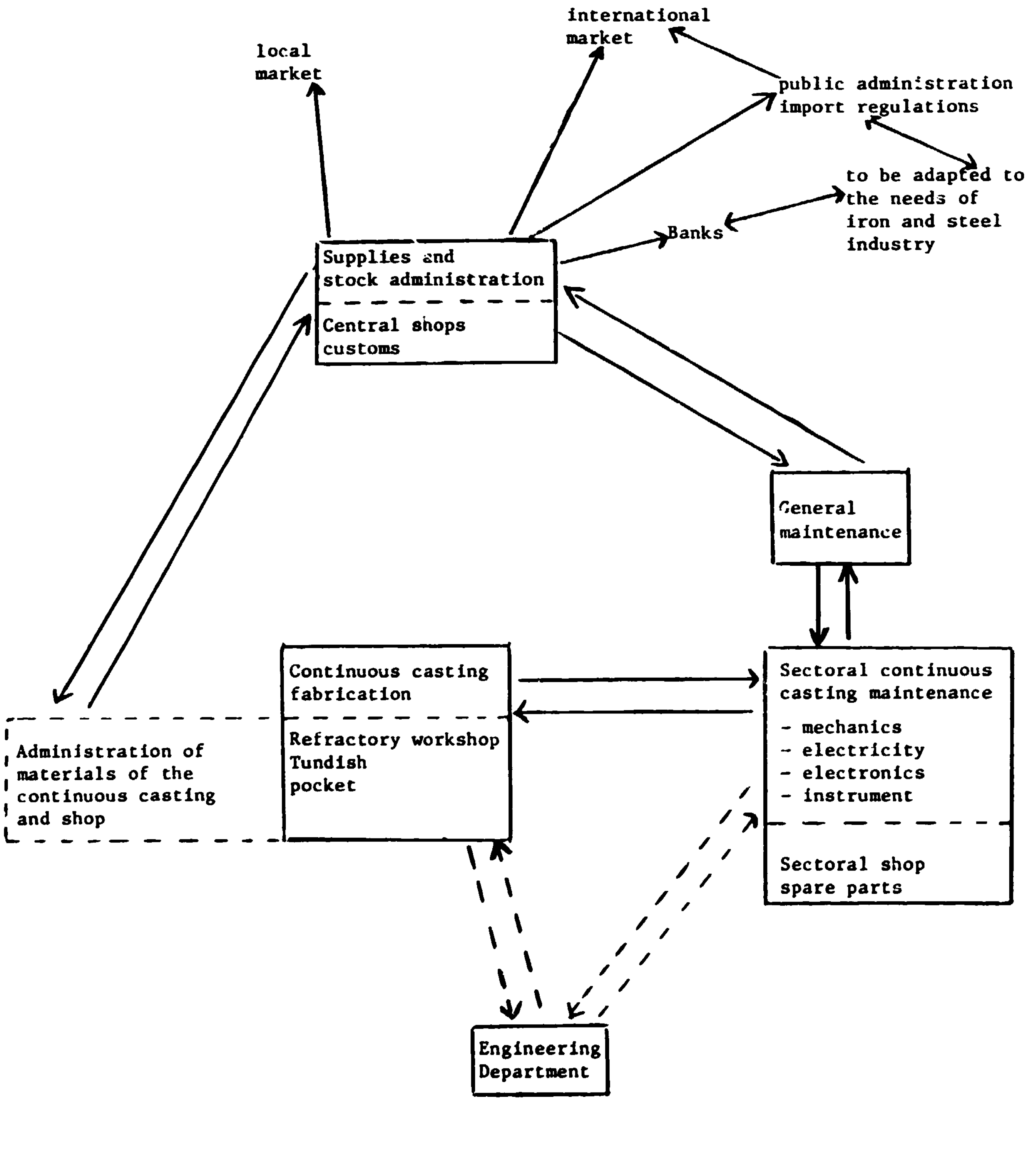

Table 2

SCHEMATIC ANALYSIS OF FUNCATIONAL COMPONENTS