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STUDY OF AN INTEGRATED DEVELOPMENT OF THE IRON AND STEEL AND CAPITAL GOODS INDUSTRIES*

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** The Group of Soviet Scientists.

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1. INTRODUCTION

In the wake of the growing crisis of capitalism and the collapse of the colonial system, numerous countries of Africa, Asia and Latin America have attained political independence.

Irrespective of the differences existing among the newly independent countries or the path they follow, their peoples are united in their desire to pursue an independent course of development and to resolve their problems without outside interference.

From their colonial past these countries have inherited a backward structure of production which, if preserved, would make them play the role of an agrarian and raw materials appendage for their former metropolies.

That is why the majority of the developing countries, particularly those following the path of non-capitalist development express a firm determination to industrialize which is regarded as a means of attaining the economic independence permitting to radically upgrade the technologies in all branches of the national economy.

Industrialization is an indispensable prerequisite of the economy development. The iron and steel industry constitutes a base for the development of other branches of industry including those involved in production of capital goods. Some developing countries have made a considerable headway in the development of their iron and steel industry. India, Brazil, Mexico, Algeria and many other countries have large ferrous metallurgy enterprises of their own thus meeting a substantial part of internal demand with their output. Iran, Libya and Indonesia have completed their ferrous metallurgy mills only in recent years. Many developing countries do not have even small-scale industries and are currently initiating their construction making use of financial and technological aid extended for this purpose by the industrially developed countries.

The USSR has provided and continues to provide economic assistance to the developing countries for the formation and development of ferrous metallurgy. Aided by the USSR, India, Iran, Algeria, Turkey and other developing countries are setting up and successfully developing their national ferrous metallurgy. The USSR economic and technical co-operation with the developing countries is particularly characterized by the Soviet Union's assistance in creating and strengthening the state-owned sector of their economy.

This is important for speeding up the rate of economic development and consolidating the economic potential of the countries.

The USSR economic co-operation with the developing countries in setting up their own metallurgy and mastering their natural resources is based on a long-term, stable, mutually beneficial position of equality and respect for national sovereignty, on the conditions securing the legitimate rights of the co-operating countries.

The metallurgy enterprises constructed with the USSR assistance are owned by the States of their territorial location.

Credits extended by the Soviet Union to the developing countries for the development of the metallurgical industry are long-term and favourable. It is common knowledge in the developing countries that the Soviet Union's crediting offers low annual percentage rate, long-term settlement; there are no special credit conditions attached to an agreement. The amount of the credit offered is guaranteed.

The USSR technical assistance to foreign countries in setting up ferrous metallurgy makes maximum use of local resources and locally produced equipment, metalworks and construction materials supplies. Such form of co-operation promotes the country's local resources being involved, secures a permanent employment of the population, gathers industrial experience of modern enterprises constructed in the countries, trains locally resident construction, assembly and operation personnel.

15 developing countries are currently running iron, steel and rolled metal production works, another 10 produce steel and rolled metal because they have small-scale enterprises processing scrap metal in small electric arc furnaces or small mills built in recent years. There is a group of countries producing rolled metal out of imported billets. About a third of all developing countries, especially the most backward ones in Africa, South-East Asia, Oceania and certain Latin American countries had no ferrous metallurgy enterprises by the early 1980s.

The implementation of the industrialization policy suggests a prior development of a program to follow the most effective road of industrialization depending on the country's specific features and the availability of foreign aid. A development of such a program suggests a great deal of calculations made in conditions of a total lack of industrial development historical experience.

A complexity of uncommon calculations destined to choose the road of industrialization requires an application of such methods that would permit to analize rather rapidly the consequences of certain modifications in the structure of the economy. In their former research made for the UNIDO (1)1/ the USSR experts employed for such methods the definition of technological complexity in producing the most representative types of metal production indispensable for producing the means of production in the developing countries and also the inter-sectoral models employed for the elaboration of medium-term and long-term programs of economic development in the developing countries. The production means technological complexity index employed permits, according to the UNIDO experts, to trace for the developing countries the most important strategic directions for the development of their industry, to assess the levels of complexity for producing the planned output and the time required for reaching these levels, to select the corresponding forms of the national industry integration, to trace a program for implementing the objectives and to adapt the education and vocational training systems for this goal. These experts have drawn a conclusion that the developing countries are capable of producing independently just about 40% of equipment owing to an insufficient industrial base.

1/ For references, see page 33.

The less developed countries have a possibility to produce agricultural machines and some types of semi-finished products. (2, 3, 4)

Thus, in order to determine the strategy of producing the means of production, it is necessary to know their material base which is connected with the employment of construction materials and above all steel constructions.

The "degree of complexity" index should be employed to determine a possibility of using this metal production from the view point of consumers ferrous metals utilization and real expenditures for their production.

The developing countries should know it all to solve the problem of a possible creation of their own metallurgy base, of a possible scale of its development (a construction of a metallurgical mill having a complete or incomplete metallurgy cycle of different output capacity accomplished by separate countries or jointly by groups of countries).

The ferrous metallurgy-produced metal output provides semi-finished products for the production of the means of production. They constitute one of the factors for determining the complexity of producing these means. At the same time, the metal production is the base for the development of other branches of engineering, construction and transport in the developing countries. That is why determining the strategy of the ferrous metallurgy development should procede from the economic needs of the developing countries whereas a character of its development should be determined by the metal production's technological complexity necessary for the economy.

2. THE ANALYSIS OF THE DEVELOPING COUNTRIES FERROUS METALLURGY INTER-SECTORAL RELATIONS WITH THE ECONOMIC SECTORS OF THESE COUNTRIES INCLUDING THE PERSPECTIVE ANALYSIS OF THE FUTURE DEVELOPMENT

The ferrous metallurgy occupies an important position in the industry. A study of inter-sectoral relations in the ferrous industry is very important for securing a balanced development of the national economy and determining the metallurgical production volumes.

The ferrous metallurgy output meets the basic needs of industrial consumption, the production of the means of production.

The inter-sectoral productions relations are sub-divided into those of the current consumption of the products of labour (current production) and the relations on the instruments of labour and the accumulation of the products of labour (for the extended production and the compensation of the retired production assets).

A comprehensive study of inter-sectoral production relations and their quantitative definition requires a great amount of calculations to be made. An inter-sectoral production and output distribution balance of a developing country constitute a most important tool for studying inter-sectoral relations and identifying the most effective relations. The inter-sectoral balances are elaborated in two stages. First a comprehensive version of inter-sectoral balance is worked out in which the process of social reproduction is reflected through major industrial sectors and the national economy as a whole. At this stage, the ferrous metallurgy is presented as a sector devoid of industrial products characteristic of the other branches, i.e. it is represented as a "pure" branch. While developing such a balance one takes into account the principle structural shifts occurring in the economic development as a whole and in each individual sector and decides on the major ways and directions for meeting the objectives. All of this finds a concrete expression in ferrous metallurgy's development rate and proportions.

The comprehensive balance indexes determine a detailed sectoral structure of each element of the end product to be used as a base for developing an inter-sectoral production and output distribution balance both in the sectoral and products expression.

The ferrous metallurgy entertains the production relations by way of consuming the output of the other branches, that is along the line of consuming material resources for producing its own output with nearly all the sectors of the industry. In this consumption, the share of a limited number of branches prevails (high degree of concentration of relations). The sectoral turn-over and the fuel industry, non-ferrous metallurgy, power industry and transport consumption volumes constitute the bulk of consumption involved. Apart from determining the inter-sectoral proportions in the ferrous industry it is necessary to identify the modifications in the coefficients of direct consumption, constituting over 90 per cent of all costs involved in the production of the ferrous metallurgy output These coefficients should be instrumental in establishing mutual dependence in the development of the ferrous industry and the major supplier branches.

The inter-sectoral relations within the ferrous industry in the field of distributing its production, i.e. those with the consumers are wider whereas a level of concentration of relations is somewhat lower than those accompanying the consumption for the production. About one-third of all ferrous metallurgy output is consumed in the framework of the industry and half of it should go to the engineering and construction industries. The latter figure will rise along with the technical progress in the developing countries.

The coefficients of direct consumption for the ferrous metallurgy production in natural expression will differ from the coefficients of direct consumption in costs expression insomuch that they include the consumption of mineral resources related to the output produced both directly and by way of the output of other sectors within the framework of the ferrous industry. Thus, provided there is a coke shop at a metallurgical enterprise, the coal consumption for producing the coke will be included in the cost coefficient of the coal industry production direct consumption for the "Ferrous Metals" sub-sector output production. However, the costs coefficient holds only a part of coke-shop consumed coal costs corresponding to the share of this shop's output consumed at this metallurgical enterprise. Proceeding from this assumption, prior to calculating the costs coefficients on the basis of the natural ones it is necessary to add up to the latter the consumption of materials by other types of locally produced output. Or, in mathematical terms: $A_{kl} = A'_{kl} + A_{kv}A_{vl}(1 - W_v)$, where: A_{kl} = consumption coefficient of the k product for producing the l product employed for calculating the costs coefficient

A'_{kl} = coefficient of consumption of the k product for producing the l product;

A_{vl} = coefficient of direct consumption of the v product for producing the l product

A_{kv} = coefficient of direct consumption of the k product for producing the v product;

W_v = the share of the v product obtained for producing the l product from outside;

It is recommended to calculate the cost coefficients of direct consumption on the basis of the natural ones following the forumula:

$$A_{ij} = \frac{k_i}{k_j} \sum_{k=1}^{m} \sum_{l=1}^{n} A_{kl} \cdot \frac{P_k}{P_l} W_k d_l$$

where: A_{ij} = coefficient of direct consumption of the i-sector for a cost unit of the j-sector gross output in costs expression;

A_{kl} = coefficient of direct consumption of the k product for producing the l product in natural expression;

P_k = the k product unit cost;

P_l = the l product unit cost;

W_k = the k product share obtained from the outside in the total consumption of this product in the j-sector;

d_l = ratio of the l product gross output cost to the j-sector gross output cost;

m = the i sector k products total number;

n = the j sector l products total number;

K_i = coefficient of transforming the i- sector output wholesale prices to the end consumption prices;

K_l = coefficient of transforming the j-sector output wholesale prices to the end consumption prices.

A cost-expressed direct consumption coefficients level depends on the materially expressed direct expenditures coefficient values, materials and products, prices ratio, ferrous metallurgy gross output products structure and combining level.(5)

An inter-sectoral costs balance defines the national economy demand in the ferrous metallurgy output and its inter-sectoral relations. A demand in the major types of material production is determined by a materially expressed inter-sectoral balance.

An inter-sectoral material balance reflects the ferrous metallurgy inter-sectoral relations in producing and consuming the leading types of material production. This balance constitutes a system of interrelated individual material balances characterizing the resources and distribution of individual products. A system of inter-sectoral balance indexing allows to compare the resources and the consumption, consumption and accumulation, values of balance's other parts in its entire range.

An inter-sectoral material balance makes it possible to analyse inter-sectoral relations in producing the major types of output and to reveal progressive structural shifts in their production. Material balances trace the progress of a material social product as well as the main proportions and relations of the extended material reproduction (as opposed to the sectoral one for a costs balance). In particular both a costs and a material inter-sectoral balances permit to determine a ferrous metals consumption, for example for producing means of production. The factors conditioning these expenditures are as follows:

- shifts in the inter-sectoral structure of the engineering, a growing share of non-metal branches (radioelectronics, electronics, instrument engineering) and a decreasing share of metal consuming productions (power engineering, railway engineering etc.);

- upgrading the inter-sectoral co-operation based on a further specialization in producing units and parts. This promotes a growth in the engineering gross output without increasing a net volume of the sectoral end output due to a repeated calculation;

- replacing ferrous metals by non-ferrous materials (plastics, plastic wood etc.) as well as by non-ferrous metals and alloys;

- technological progress in engineering and ferrous metallurgy concretely resulting in a lower consumption of rolled products following a better designing of machines, equipment and instruments, wider range of goods produced, higher quality of metal used etc.

The relations existing among the productions of various types of output provide a base for elaborating a scheme and a mathematical model for a materially expressed inter-sectoral balance. A certain amount of steel is consumed to produce rolled stock and a certain amount of rolled stock, to produce electric locomotives. Steel, however, is indispensible for producing both rolled materials and the casting and rolled materials are necessary for making not only electric locomotives, but they are also consumed in construction, transport and other sectors.

A mathematical model for a material balance comprises a system of equations following the number of products in the balance. Here is what an equation for the first product looks like:

$$X_1 = X_{11} + X_{12} + X_{13} + \dots + X_{1n} + Y_1$$

where: X_1 = the need for producing the first product of the balance;
X_{11}= consumption of the first product for producing a product of the same type;
X_{12}= consumption of the first product for producing the second one;
X_{13}= consumption of the first product for producing the third product;
X_{1n}= consumption of the first product for producing n-product;
Y_1 = total demand of the first product for a non-productive consumption, exports, storage, reserves etc.

The demand of the i-product by the following equation:

$$X_i = X_{i1} + X_{i2} + X_{i3} + \dots + X_{in} + Y_i$$

For the whole balance a system of equations featuring the relationship among individual production types will run as follows:

$$\begin{cases} X_1 = X_{11} + X_{12} + X_{13} + \dots X_{1j} + \dots X_{1n} + Y_1 \\ X_2 = X_{21} + X_{22} + X_{23} + \dots X_{2j} + \dots X_{2n} + Y_2 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ X_i = X_{i1} + X_{i2} + X_{i3} + \dots X_{ij} + \dots + X_{in} + Y_i \\ X_n = X_{n1} + X_{n2} + X_{n3} + \dots X_{nj} + \dots + X_{nn} + Y_n \end{cases}$$

If the demand in each product is expressed through specific consumptions of one product for the production of the others (a_{ij}) the equation system might be conveyed by an elementary mathematical model of a materially expressed inter-sectoral balance:

$$X_i = \sum_{j=n}^{n} A_{ij} X_j + Y_i$$

Coefficients (ratios) of direct consumption of the material resources, volumes of the end product consumption and a volume of other consumption constitute the basic information employed for calculating material inter-sectoral balances.

In the developing countries the rolled goods may be employed in the engineering and metal treatment, capital construction and in the ferrous metallurgy proper as well as in other sectors of the national economy.

The major consumer of the rolled materials is the production of capital goods or the engineering and metal treatment. The engineering oriented rolled stock range is made up of 40% of structural type and sheet and of 20% of ordinary steel and plate steel. The quality rolled steels (over 52%) prevail in the tractor and agricultural engineering-consumed rolled stock, 66% of it being the structural steel. The automotive industry consumes both the grade and sheet structural rolled output. The ordinary sheet and plate rolled output constitutes over a half of the consumption range for the heavy, transport and power engineering.

Structural range steel constitutes half the machine-tool industry consumption and around 15% are ordinary rolled steels. The share of rolled sheet steel consumed by the electrical engineering amounts to over 85% with over 25% of dynamo steel, 13% of transformer steel, 18% of plate steel and 13% of cold-rolled sheet. In the rolled steel range for the engineering and light and food industry the cold-rolled sheet amounts to 30%, plate 15%, sheet 14%, bar structural steel 12%.

Over 60% of sheet and plate steel make up the amount of rolled materials consumed by construction, road-building and communal engineering 2/3 of which are taken up by plates. Bar structural steel constitutes 18% and large sections 10%.

The general factors shaping up a developing country's future metal production demand are as follows:

- rates and scales of development for major metal consuming sectors of the economy;
- country's metal capacity;
- consumed construction materials structure (mass and volume), including iron-based metals production (rolled materials and steel and cast-iron castings), plastics, aluminium, titanium and other non-ferrous metals; other construction materials (asbestos cement, glass, foam plastic etc.);
- country's metal treatment stock, including the metal pressure treatment share;
- effectiveness of employing ferrous metals and their replacement by other structural materials;
- exports and imports volumes (6).

3. DETERMINING DEMANDS IN METAL PRODUCTION AND PRODUCTION VOLUMES DEPENDING ON ITS QUALITY

Among the objects of labour employed in the production a privileged position is occupied by construction materials constituting the material base of equipment, machines, instruments and devices, transport means, buildings and constructions. Such materials embrace ferrous and non-ferrous metals, construction metals, plastics and other materials as well as the metal, concrete, reinforced concrete and asbestos cement pipes, asbestos cement and slare tiles etc. produced on a mass scale.

The construction materials are the universal object of labour and they are produced and consumed on a mass-scale. The production of individual materials is united in sectors following the raw material employed or the common technological process used. At present the ferrous metals occupy the dominating position among the construction materials. The demand in the construction materials can be defined as an expected consumption of construction materials by the developing countries national economy sectors to meet their optimal needs introducing the latest achievements of science and technology into these sectors. The scientifically substantiated need of the production of the means of production in construction materials suggests that it should be calculated on the basis of progressive norms taking into account the requirements of the scientific and technological progress in the field under consideration. (7)

For forecasting the demand of the developing countries in the construction materials and metal products in particular it is expedient to apply:

(a) natural costs method (including the direct account or enlarged calculation methods);
(b) method based on taking account of the growth rate of output;
(c) expert assessment method;
(d) forms method;
(e) economic and mathematical modelling method;
(f) method of historical and geographical analogies.

When applying the direct account or enlarged calculation methods prospective output volumes in material or costs expression or the construction work volume, prospective individual or group metal consumption rate per unit (or group) of output, production output volumes or the volume per unit of construction works should have been determined in advance.

The need for construction materials including the specific types of metal production according to the direct calculation method is calculated following the formula:

$$II_i^t = \sum_{j=1}^{m} N_{tj}^t W_j^t$$

where: II_i^t = need for the i-type of construction material (metal output) for the t period in thousand tons,

W_j^t = production output volume for the t period, pieces, m^3 etc.

N^t= = prospective specific consumption of construction materials (ferrous metals) for the . period, t/pieces, t/m^3, t/t etc.

i = number of construction material consumed (rolled ferrous metals), (i = 1, 2, 3, ..., n)

j = production output type number (j = 1, 2, 3, ..., m)

t = prospective year number

W^t = production output volume in j-year.

A total need for all types of metal constructions is calculated following the formula:

$$Q^t = \sum_{i=1}^{n} II_i^t,$$

where: Q^t = total prospective need for all types of metal output for the t-period (or thousand tons).

When applying the method of enlarged calculations a need for rolled metal is determined in individual sectors, including engineering and metal treatment. The above method could be applied both for determining a general amount of rolled metal needed and the demand in a range of products.

When calculating the amount of metal needed using the method based on taking into account the production output growth rates a complicated formula should be applied:

$$II_i^t = \sum_{j=1}^{n} N_{ij}^t W_{ij}^o K_{pj}^t$$

where: W_j^o = volume of production output for a basic year, pes, m^3 etc.

K_p = chain rate of growth $(K_p^1 K_p^2 K_p^3 \ldots K^t)$

t = years (t = 1, 2, 3, ..., t) t=0 for a basic year.

When determining the demand using the forms method the data in possession of the leading metal constructions consumers is utilized. It is obtained by submitting and collecting special standard forms containing all the information needed.

While determining the demand using the method of expert assessments it is applied to new types of construction materials and metal production that are not produced at all at present or are not utilized on a mass scale (for instance metal-based laminate or finest tinplate).

Expert assessments are provided by highly qualified experts both individually and collectively.

The essence of the method of historical and geographical analogies lies in comparing a certain amount of actual and prospective technical and economic indexes in a given country with the same indexes in the industrially developed countries allowing to identify a trend in the development of the studied indexes.

In perspective the range of rolled products to be consumed will be determined by developing country's production of capital goods, by an expected growth of power consumed by individual machines and equipment and an ensuing growing consumption of large section and plate carbon, alloyed and low-alloyed rolled steel products and by a trend to produce a smaller-size output which envisages a stepped-up production of merchant-mill and sheet products including the products of cold rolling. These two contradictory tendencies are characteristic of the engineering as a whole and of the automotive industry, tractor and agricultural, road-building and communal engineering in particular. (6)

Quality indexes of metal output constitute the external factors in the development of ferrous metallurgy affecting both certain proportions of this sector's development and the development options for the engineering proper and for other sectors indispensable in the developing countries. Quality indexes of the metal output allow to identify a dependence between technological complexity of machines and a degree of technological complexity of ferrous metallurgy products and to extend necessary recommendations to the developing countries.

The problem of upgrading the quality of metal is the most important one for any country including the developing countries since the rate of utilizing rolled metal in different sectors of metal consumption varies within large margines and averages 0.8. Out of the remaining metal stock nearly 18% are intended to secure the safety factor indispensable owing to steel's non-uniformity. Taking into consideration a coefficient of steel consumption for producing rolled metal only half the total volume of produced steel is used as the end products.

The problem of upgrading the quality of metal consists in elaborating such ways of advancing its quality that would ensure a maximum headway in the productivity of social labour.

While identifying effective steps to be taken to upgrade the quality of metal, a relationship between modifications occuring in the characteristics of metal and its service properties should be established for each particular case (for instance between stepping up metal's purity and uniformity and enhancing its strength and reliability, between increasing metal's strength properties and bringing down the products mass or increasing their longevity, between modifying the rolled metals geometrical shape and decreasing the volume of metal treatment etc.).

An upgraded quality metal output equals a larger volume of an ordinary quality output consumer-wise. In this case the economy obtained depends on a modification introduced or a stage of production where the effect of upgrading comes to fruition. This is related to the fact that an amount of materialized labour in a unit of metal mass is increasing as it progresses from the initial stage of production towards the end stage of consumption.

If the effect of upgrading the metal is realized in the process of metal treatment and exploitation of metal products, an economy in capital and current expenditures for the whole of ferrous metallurgy is achieved by a relative reduction in metal production whereas in the field of metal treatment and engineering - by a lower amount of treated metal or by decreasing the number of machines and equipment produced.

In this connection along with a redistribution of capital investments within the ferrous metallurgy one should consider a possibility of additional capital investments through an economic advantage gained by the metal consuming sectors or through producing better quality metal items.

One can perceive the content of the production quality category in connection with the category of social consumption cost. K. Marx stated: "It is indeed the effect of the law of value not with reference to individual commodities or articles, but to each total product of the particular social spheres of production made independent by the division of labour ... The social need, that is the use-value on a social scale appears here as a determining factor for the amount of total social labour-time which is expended in various specific spheres of production".2/

This principle is a corner stone for realizing the economic meaning of consumer cost. A formation of socially justified expenditures is related to a consumer cost which in its turn is a prerequisite of the cost.

A certain amount of uniform consumer costs should be produced to meet some social demand. Within the scope of a society these uniform products naturally vary in quality and in individual labour involved. A degree of this difference depends on the social reglementation of the quality of production, industrial level etc.

2/ Marx K., Engels F., Coll., v.25, p. II, p. 185-186.

As the productivity of social labour is on the upsurge the society has wider options to meet its demands. In other terms, as the productive forces are developing the degree of satisfying the existing demands changes and the new ones are emerging.

With the development of science and technology there emerges an option to produce the same kind of output with lower labour consumed. The economic necessity has emerged to discard the current quality level output to be replaced by an upgraded one. In this connection the degree of production's usefulness, the social level of consumer cost are changing and the average social level of productions' quality is consequently rising. Thus in the social production a better quality of production is objectively justified by the development of productive forces and by the growing productivity of social labour involved.

This contains the essence of the economic content for the quality of production category. A continuous amelioration of useful qualities of industrial products owing to the development of society's productive forces, scientific and technological progress and growing popular demand constitute the content of the continuously advancing social consumer cost. Growing production quality characterizing each instant of the developing social consumer cost is a factor of growing productivity of social labour.

Growing labour productivity as upgrading the quality of production is more difficult to attain than as a growing production level. In order to modify the quality of production, its positive properties must be perceived as well as the understanding of society's emerging needs, the development of its technological potential, a corresponding adaptation of production etc.

The quality of production as a form of a growing labour productivity is far from being passive towards its own content - the degree of social consumer cost. Thus if, while producing an upgraded quality output, the society is not altogether saturated with this or other output which creates a lower social consumer cost compared to the one that is determined by the working time indispensable for this production, this results in lowering the productivity of social labour. Vice-versa if when producing an upgraded quality output social demand in this production is greatly satisfied within the same productive time, a greater social consumer cost is created resulting in a growing labour productivity.

Thus, a disparity between socially required labour to be involved and a social consumption cost characterized by a corresponding quality of production brings about a change in social labour productivity.

The socialist production relations create a possibility to attain a greatest possible harmony for a balanced development of productive forces and social consumer cost, for continuously growing social demand and a social average level of the quality of output. However, these options may become a reality only on the basis of a scientifically planned production and a growing quality of output. In the USSR national economy state standards constitute the major instrument of planning the quality of production. They constitute a kind of state-planned balance of a level of productive forces and social consumer cost.

The state standards dealing with the ferrous metals reflect a guaranteed quality of metallurgical output and those major production trends that allow to secure its further growth.

The quality requirements for metal products include those dealing with their appearence, shape, dimentions, section precision, mechanical properties and other physical and chemical characteristics ensuring a sensible and purposeful use of metal in a sector of the national economy.

The state standards set obligatory norms and methods for testing the metal at metallurgical mills to secure checking up every lot of output, the so-called end control. However, this procedure involves a norm assessment and checking up only those metal properties that require no lengthy tests. They feature yield strength, ultimate strength, hardness, impact strength and some others. At the same time the ferrous metals have various properties that individually may come useful for one purpose or useless or even detrimental for the others. Thus, maximum strength with sufficient plasticity are needed for producing metal constructions, and plasticity is of major importance for deep forging.

In this connection the ferrous metals consumer cost is characterized in most cases by a number of properties possessing no common measure. In practice, it is measured by identifying the principle quality of the metal among all others, which is the most important one for a specific purpose. A comparative assessment of metal's qualities may be based on this principle property (on its strength, for instance) provided the other properties are within the range permitted for this purpose. This study attempts to break into groups qualitative indexes for various ferrous metals (Table 1).

At present in the USSR the characteristics indicated in the norms are generally employed when assessing the qualities of ferrous metals. The standards worked out for ferrous metals always indicate metal's chemical composition norms, its mechanical properties (yield strength, ultimate strength, elongation or compression, sometimes impact strength, bend test etc.). On top of this the norms of hardness, macrostructure, heat treatment etc. are established for an upgraded metal. Apart from this over 100 various stepped-up requirements are envisaged to the quality of a metal. It is quite important to identify the stage of production where the upgraded quality effect is realized. This is related to the fact that the amount of materialized labour in a unit of metal is increasing as it goes from the initial stage of production to the final stage of consumption. For instance, if the amount of wastes is decreasing in the wake of introducing an upgraded steel the effect is attained mostly via savings on the capital and current outlays in the steel casting and rolled metal productions.

The employment in the engineering and construction of a metal having high strength characteristics and of an optimal range of products lowers its consumption, raises productivity securing lower machines and construction costs. The use of machines made of better quality metal brings down the exploitation outlays allowing to cut down a stock of machines and equipment, power consumed etc. Therefore, if the stepped-up quality effect is realized in the process of metal treatment and metal products exploitation, an economy in the capital and current spendings is secured in the whole of ferrous metallurgy owing to a relative decrease in the production of metal and also in the metal treatment and engineering due to a lower amount of treated metal and a fewer number of machines and equipment produced.

Table 1. Ferrous metals principle and auxiliary quality chararacteristics for various employments

Metal	Quality indications	
	Principle	Auxiliary
Ordinary carbon low-alloyed steel for constructions	Yield strength or ultimate strength at static test (or endurance limit)	Plasticity-elongation or impact strength
Structural carbon and alloyed steel	Same	Same
Tool carbon and alloyed steel	Durability of a certain type tool in operation or steel hardness after hardening	Hardenability
High-speed steel	Red-hardness, that is preservation of hardness at higher temperatures	Hardness and hardenability
Heat-resistant steel	Long-term strength, creep limit at higher temperatures	Strength and plasticity
Corrosion-resistant steel	Corrosion resistance in a certain corrosion forming environment	Same
Heat-resistant high-alloyed steel and heat-resistant alloys	Long-term strength at high temperature	Strength and plasticity
High-ohmic resistance alloys	Survivability at high temperatures	Specific ohmic resistance
Electrical low-carbon steel	Minimum coercitivity	Plasticity
Electrical silicon steel (dynamo and transformer)	Minimum specific wattage losses	Magnetic induction
Magnetic steel	Maximum coercivity	Residual magnetic induction
Steel hot-rolled and cold-rolled sections for constructions	Ratio of resistance moment at lateral bending or minimum inertia radius at buckling to 1 m section mass	Strength and plasticity

An effective employment of upgraded metal brings about an increased production of the output employed in the ferrous metallurgy and a better use of ferrous metals due to their diminishing losses and wastes, products lower metal consumption, their safer and longer operation, other better exploitation characteristics of machines and products.

Depending of the nature and stage of effectiveness the calculation formulas have their specific particularities.

1. If the effect is attained in the process of metal treatment and the upgraded metal-produced articles exploitation properties do not change, this results in a lower consumption of metal and in a diminished volume of its treatment in the metal consuming sectors. For instance the use of shapes instead of die-rolled sections, bars of additional intermediate dimensions, sheets in coils instead of ordinary sheets etc. lessens metal and waste losses. In this connection the required metal and the volume of its treatment decrease which results in lower capital and current outlays per unit of the given product in the metal consuming sectors.

2. The use of upgraded metals (low-alloyed steel, heat-treated rolled metal, light-weight beams and channels, roll-formed sections etc.) allows to decrease the mass of 1 meter of reinforcements, products for metal construction, manifolds, machines and other products per unit of productivity. At the same time provided a lighter weight of constructions does not affect their exploitation characteristics (for instance when producing stationary metal constructions), the effect spells a decreased metal consumption and a lower volume of its treatment. (8).

Coefficients of saving the metal are relative indexes for the quality of the produced metal. These coefficients indicate what amount of replaceable traditional metal output is saved when 1 ton of upgraded metal output is used instead of it. These coefficients help assess the influence of a planned upgrading in quality on the envisaged volumes of ferrous metals to be produced and consumed.

The overall savings in metal stock following an extending of the range of products produced and upgrading in the quality of metal output is determined as the product of a concrete economy (savings) coefficient into an advanced gain of the corresponding type of upgraded metal.

In the USSR the average value for coefficients in each position of the upgraded metal output is calculated proceeding from a value of economy (savings) coefficients and a share of growth in demand for this output expressed by each sector.

In every position the economy coefficient is determined as a weighted average value following the formula:

$$\bar{K}_e = \sum_{1}^{i} K_{e1} \cdot q_1 + K_{e2} \cdot q_2 + \ldots + K_{ei} \cdot q_i$$

where: $K_{e1}; K_{e2} \ldots K_{ei}$ = economy coefficients for various spheres of employing this type of upgraded metal

$q_1; q_2 \ldots q_i$ = growth share for each sphere in the overall share of growing demand for this type of upgraded metal.

Methods of calculating the coefficients differ depending on a mode of metal saving:

- lowering the weight of output
- lowering the metal intensivity by increasing the productivity of equipment when using an upgraded metal,
- lowering the amount of metal wastes when manufacturing the products,
- increasing the longevity of products following: a short-term use with the service time inferior to one year; long-term use with the service time over one year.

Determining the metal saved by decreasing the weight of products using stronger metal or more rational profiles and sections is based on the principle of equistrong substitution. In each particular case the principle of equistrong comparison is made use of in different ways: in some cases this is achieved by comparing an amount of metal consumed per product, in the others, per rolled stock length unit. The coefficient of saving the metal is calculated according to the formula employed for this particular case:

$$K_e = \frac{Q_1}{Q_2} - 1$$

Q_1 = weight of a metal product of the former quality (tons)
Q_2 = weight of a metal product of the upgraded quality (tons)

Coefficients of economy related to the employment of metals with upgraded strength properties operate within a considerable range owing to various degrees of using these properties depending on the operating and exploitation conditions.

Thus the real amount of saved metal is generally inferior to the one obtained via the correlation of indexes due to the fact that the sections and dimensions of bars, for instance, used for calculations do not correspond to those really produced.

In the instance where the use of upgraded metal allows to raise the productivity of the equipment the economy coefficient may be calculated according to the formula:

$$K_e = \frac{P_{m1} \cdot \alpha_e - P_{m2}}{P_{m2}}$$

where: P_{m1} = the former quality metal consumed to produce an item
P_{m2} = the upgraded metal consumed to produce an item

α_e = coefficient of equivalency indicating the number of the former quality "stock produced item" of the new quality.

The coefficient of equivalency is determined as follows:

$$\alpha_e = \frac{Q_n}{Q_c}$$

where: Q_n = annual productivity of "a stock produced item" produced with the use of an upgraded metal

Q_c = annual productivity of "a stock produced item" produced of an ordinary quality metal.

As a result of advancing a section and dimension range in metal treatment, the amount of wastes and chips is decreasing, the weight of the item remaining the same. In this case the economy in metal is determined by a difference in the consumption norms of ordinary and upgraded metal following the formula:

$$K_e^P = \frac{P_{m1} - P_{m2}}{P_{m2}} = \frac{P_{m1}}{P_{m2}} - 1$$

where: P_{m1} = ordinary quality metal consumption per item (tons)

P_{m2} = upgraded metal consumption per item (tons)

Determining the amount of metal saved by way of raising the longevity of items is generally quite specific. Raising the service life of products does not result in a modification of the norms for metal consumption per item or some other unit. Growing longevity mostly entails cutting down a consumption of metal meant for repairs and maintenance needs.

With the working life of a part or product being less than a year, the coefficient is calculated using the following formula:

$$K_e = \frac{T_2}{T_1} - 1$$

where: K_e = economy coefficient, ton/ton;

T_2 = working life of an article made of upgraded metal, ton/ton;

T_1 = working life of an article made of ordinary metal, months.

A particularity of calculating the economy of metal when increasing the longevity of extended working life parts operating over a year consists in the fact that attaining this economy does not coincide in time with the use of the upgraded metal.

Annual economy of metal may be calculated by way of the difference between:

(a) the volume of produced metal that would be necessary in a given year to replace all the items provided their working life would not change and,

(b) production volume for the metal that is indispensable to replace longer working life items discarded this year.

The annual metal economy is calculated by using this equation:

$$E = A_{T-t} - A_{T-t_1}$$

where: A = production volume of upgraded metal;
T = the year that the metal economy is calculated for;
t = working life of the ordinary metal items;
t_1 = working life of upgraded metal items;
$T-t$)
$T-t_1$)= indexes of the years for calculating the production volumes;

In order to determine the influence of raising the quality of metal products on the indexes of their technical complexity it is necessary to calculate coefficients of metal economy using several examples.

The low-alloyed steels employed in producing the rolled metal output ensure a considerable economy in metal consumption. The low-alloyed steels have increased strength characteristics. They are suitable for welding and generally have good bending and stamping properties as well as an increased corrosion resistance. They are to be employed in most heavily loaded elements of constructions.

In the USSR the most widely used low-alloyed steels with the yield strength within 30-40 kgs/mm^2 are: 09G2S, 14G2, 10G2S1, 15HSND, 10HSND etc.

These brands of steel employed mostly in carrier constructions and elements of buildings and structures instead of the ordinary St 3 steel. securing about 17% (0.21 ton/ton) metal savings.

The use of steels with the yield strength ranging 45 through 75 kg/mm^2 might amount up to 35-40% metal economy for the basic carrier constructions of buildings and structures if used instead of the St 3 steel. The low-alloyed rod steels employed in the built-up and cast-in-place reinforced concrete constructions provides a 0.275 ton/ton metal economy as compared to the ordinary steels.

The employment of the low-alloyed steels for producing car hot rolling sections amounts to 0.126 ton/ton and sheet metal; 0.18-0.22 ton/ton. In the USSR the use of these steels bring about the economy coefficients amounting to 0.14 ton/ton in car building, 0.16 ton/ton in diesel locomotive building, 0.224 ton/ton in metallurgical engineering, 0.231 ton/ton in hoist and transport engineering, 0.110 ton/ton in mining engineering industry, 0.16 ton/ton in coal engineering industry, 0.14 ton/ton in chemicals and oil engineering industry, 0.16 ton/ton in construction and road building engineering, 0.20 ton/ton in tractor and agricultural engineering, 0.16 ton/ton in ship-building industry and 0.1 ton/ton in other sectors.

Another method to save on the consumed metal consists in hot hardening of the rolling stock consisting in an intensive cooling of the metal heated up to the hardening temperatures. There are several methods of hot hardening such as a sheet and bar hardening with consecutive tempering, hardening of reinforcements while rolling etc.

The hot-hardened rolled products may be employed for producing metal structures for construction works, reinforced concrete reinforcement stock, and the ones made use of in mechanical engineering.

The employment of the 28-40 kgs/mm^2 yield strength low-alloyed, carbon and hot treatment steel secures a 0.126 ton/ton metal economy.

The employment of low-alloyed hot-hardened bar and sheet in welded bridge span constructions brings about a 0.28 ton/ton economy in replaceable parts.

The average metal savings obtained by using a hot-hardened rolled sheet stock in the construction sector for producing metal constructions amounts to 0.175 ton/ton against 0.28 ton/ton in the transport engineering, 0.25 ton/ton in automotive engineering, 0.18 ton/ton in heavy and transport engineering, 0.277 ton/ton in reinforcement steel, 0.207 ton/ton in the rolled bar output for the purposes of mechanical engineering.

The employment of the die rolling and the cross-rolling procedures constitutes an effective way of curbing wastes. The use of these sections secures metal savings averaging 0.13 ton/ton, including 0.122 ton/ton for the heavy, power and transport engineering, 0.109 ton/ton for the automotive industry, 0.206 ton/ton for the tractor and agricultural engineering, 0.236 ton/ton for the construction, road-building and communal engineering, 0.139 ton/ton for the electrical engineering.

The metal economy obtained due to the employment of cold-rolled sheet in substitution of hot-rolled sheet stock is made up of savings secured by more stringent tolerances (3-4%) and a possibility of using a finer sheet stock instead of the hot-rolled one. This leads to a 20% average economy whereas the coefficient of economy averages 0.25 ton/ton.

When calculating the savings of metal due to a growing production of cold-rolled sheet, electrical steels and coated metals should be excluded from the production volume owing to the fact that the cold-rolling of these types of metal does not result in decreasing the thickness of the consumed sheet stock.

The coefficient of economy resulting from a growing use of thin hot-rolled 1.2-1.8 and 2mm sheet stock amounts to 0.25 ton/ton as compared to a wider thickness range fine sheet stock.

The employment of rolled sheets in coils permits to save on the metal comsumption by a better nesting of blanks and a resulting reduction of wastes due to an advanced technological pattern.

The steel in rolls employed in the electrical engineering brings about a 5-8% economy and 5% in the automotive industry. The average coefficient of metal savings due to an extensive employment of metal in coils amounts to 0.05%. When making use of this kind of metal labour intensivity of location and spacing of blanks is reduced by 35-40% relieving a great amount of corresponding equipment. The use of sheet stock in coils contributes to introducing the automative stamping of parts.

The automative, agricultural industries and tractor and agricultural engineering are the major consumers of steel in coils.

4. FORECASTING THE SCIENTIFIC AND TECHNOLOGICAL PROGRESS AND ASSESSING THE INDUSTRIAL DEMAND IN PRODUCTION RESOURCES

The scientific and technological progress forecasting consists in identifying various options for the development of science and technology in a given period of time on the basis of analizing the development and social demand trends.

Forecasting the scientific and technological progress in the ferrous metallurgy is made up of the following forecasts:

- identifying the major directions for the development of the sector (new types of output, new types of raw materials and stuffs, new technologies, new equipment including the means of automation and mechanization etc.);

- technological and economical characteristics of the new equipment, technology, organization and management of production;

- extent of introducing the new equipment, technology and production management within the period being forecast;

- economic effect of the scientific and economic progress.

The elaboration of forecasts involves using an objective information on a level of scientific and technological progress attained in the ferrous metallurgy (including the overseas development data) based on the study of the latest achievements in fundamental sciences (scientific research and experimental industrial papers, author's certificates, patents, publications etc.).

The scientific and technological progress forecasting is elaborated on the basis of studying new equipment and technology that are on various stages of development in different countries:

(a) industrial employment and exploitation
(b) semi-industrial introduction
(c) designing
(d) scientific research.

For instance, the first group embraces a perfection of the existing metallurgical processes; the second one, new processes of direct reducing iron; the third one, the metallurgical application of electrolysis processes; the fourth one, utilizing the heat generated by steel-melting slags.

Major directions for perfecting the equipment and technology as well as scientific and economic indexes (productivity, efficiency, specific consumption of raw materials, power, stocks, specific capital investments, labour intensivity etc.), volumes of equipment introduced and the effect of introduction are identified for the first group.

Technical and economic indexes, volumes and deadlines of introduction, effect of introduction are determined for the second and the third groups.

Deadlines of scientific solution and technological realization are determined for the fourth group.

A graphic model for forecasting the scientific and technological progress is based on this group. It characterizes forecast's principle objectives and their relationship.

A choice of directions for the technical development is made by analyzing a "targets-means" matrix.

The development of a grafic model and identification of individual objects makes it possible to conduct their autonomous forecasting to be followed by their synthetizing and co-ordination.

The principle methods of scientific and technological forecasting that are recommended are as follows:

- methods of analogies, including a comparison with foreign countries;
- methods of expert assessment;
- methods of "tree of targets" and matrixes "targets-means";
- methods of statistic dependences and modelling;
- methods of processing technological and economic, design, reference and patent information;
- methods of extrapolation.

4.1. Methods of analogies

Among these methods there is a comparative method recommended for a wide use in scientific and technological forecasting to determine the deadlines for introducing the equipment, values of the technical and economic indexes, and volumes of the up-to-date equipment and technology introduced. This method envisages a comparative analysis of the technical level of foreign countries and also using the experience of those countries where the equipment (technology) under consideration is employed or a certain experience has been gathered on its development and forecasting. The method of historical analogies suggests making use of the prior experience on introducing the technologies comparable to a certain extent to the studied one.

It is necessary to pay particular attention to comparability of the compared indexes and to the local conditions considered.

4.2. Expert assessment methods

The expert assessment methods break into individual and collective expert assessments.

Individual expert assessments are subdivided into two groups of the "interview" and analytical expert assessment types. The collective expert assessment methods comprise the following groups: the "commissions methods" and the "relative assessment method (brainstorming), the "Delphi method" and the "Pattern system".

An "interview"-type appraisal suggests a forecaster's interview with an expert in the course of which in conformity with a specially developed program a forecaster poses some questions regarding the perspectives of development of the object being forecast.

Analytical expert evaluations (unlike the "interview"-type evaluations) suggest a long-term expert research aimed at analyzing the trends and assessing the future state and ways of development of the object being forecast. The methods of "memorandum" and "accidence analysis" are the most widely-used ones among the individual analytical expert assessments recurred to at the present time.

The elaboration of a "memorandum" suggests that the expert has an inclination towards a detailed treatment and a time-consuming consideration of the problems facing him.

The "accidence analysis" method is based on a scheme for considering the objects being forecast elaborated in advance for identifying possible solution options. At the same time various types of characteristics of the analyzed objects and their different properties with the indication of the elements of each type are also identified. Then different variants are formed for developing the objects undergoing the analysis that are based on considering all possible combinations of characteristics of each type.

The employment of the accidence analysis makes an expert face taking a choice between directions of development based on customary set elements combinations and such directions that suggest the use of most surprising combinations.

A body of competent experts called upon to take part in an assessment constitutes a radical way of advancing precise and profound forecasts based on the expert assessment method. This method is widely used as a "commissions method". To a great extent its success depends on choosing the right people as corresponding commission members and on an organizational level of its work. However, in any case, this method has two shortcomings of the following nature. The process of active and creative brainwork is not evenly shared by all the experts involved. Their appraisals and considerations are generally affected by certain factors devoid of scientific argumentation such as the authority and status of their colleagues, considerations previously pronounced, unwillingness to publicly repudiate one's own opinion etc.

An attempt to overcome these shortcomings is offered by a special method of "brainstorming". This method suggests a certain time that would divide delivering the ideas and their critical appraisal. The experience of applying this method indicates that its success depends on a number of intervening conditions. Among them: barring any criticism at the stage of generating the ideas, putting forward a greatest possible number of ideas and securing a possibly freer forum of ideas.

The "Delphi method" - a research based on filling up forms with the experts opinions on a prospective development of the object to identify the prevailing viewpoint. Unlike the traditional approach aimed at reaching a consensus by way of open discussions, the Delphi methods suggests a total departure from a collective discussion. It pursues the purpose of reducing such psychological factors as joining a standpoint of the most authoritative expert, unwillingness to repudiate a publicly expressed opinion, following in the footsteps of the majority. When using the Delphi method the opinions of experts are generalized and submitted back to them with an additional information after which the experts make their opinions more precise. This procedure is repeated several times to reach an acceptable similarity in the expressed opinions.

When applying the Delphi method a working group of forecasters resolves the following questions related to the object of forecasting:

- scientific and technological directions are identified that are likely to be treated by experts;

- subgroups of experts are set depending on the classes of problems to be treated;

- the number of experts making up each subgroup and the composition of each subgroup are determined.

The work with the experts is conducted in three stages:

(a) experts are called upon to make more precise a model of the object of forecasting, groups of model's parameters, questions pertaining to the composition of a group of experts;

(b) submission to the experts of reference tables with an explanatory note describing the purpose of work to be done, structure of the tables, order and mode of filling them up;

(c) following the tables mathematical processing, all lacking information is obtained by consulting the experts.

4.3. <u>The "tree of targets" method and "targets-means" matrix</u>

This method permits to visualise a hierarchical division of the most common targets for the development of the system along with concrete directions and measures to be taken to help attain them.

This method in combination with expert assessments in the importance of the follow-up level directions for realizing the tasks of the preceeding level (using a "targets-means" matrix serves as a tool for evaluating total significance of measures that have been taken, a criterium for distributing the means etc.)

At the initial stage the system's common targets are set and coefficients of importance for every element of the first level are established.

At the following stage (II level development) the major targets are identified and coefficients for assisting or contributing towards meeting the targets are evaluated. These coefficients make up a "targets-means" matrix.

Specific weights of importance for each task are determined by multiplying assistance coefficients by importance coefficients for each I level element. All assessments are noted in the matrix.

The II level elements specific weights of importance thus obtained are made use of at the following stage while determining and assessing the principle directions of the III level etc. The computer application makes it possible to conduct a comprehensive calculation by multiplying the neighbouring levels series matrixes.

The "targets-means" matrixes are developed not only for assessing the neighbouring "tree of targets" levels relationship but also for assessing the mutual influence of various spheres of science and technology, for example "problems - fields of science", "tasks-types of equipment", "types of equipment-research directions" etc.

4.4. Methods of statistical dependences and modelling

This method is based upon a search for functions from and parameters (regressions) in which a forecast index serves as a dependent variable and the factors forming it as an independent variable. The use of statistical regressions in the forecasting suggests conducting a preliminary forecast for regressions's independent values.

The number of model's variables and parameters should not be great, 6 times fewer than the number of observations. Variables should be selected on the basis of professional experience and making use of the logical and structural system analysis. A correlation analysis which is a special statistical instrument for analysing the factors may also be employed. The choice of dependence forms for single-factor regressions is made by the graphical and analytical method. The regression's parameters are generally assessed by the least square method. The dynamization of parameters is made by calculating regressions by sub-periods.

A substantial stage of a forecast is appraising its reliability. A model-based forecasting is based on the assumption that the mutual forms and probability characteristics will be preserved in the future. The post-forecasting mode consisting in the current period forecasting using the past period model is also employed to evaluate reliability.

4.5. Methods of processing technical, economic and rolling-related information

The principle method of processing technical, economical and rolling-related information is the count-up procedure. Using the count-up method various technical and economic indexes are taken into consideration depending on specific features of individual productions. All the indexes and norms are calculated on the basis of a comprehensive study, analysis and generalization of the production and consumption technological and organizational conditions.

The elaboration of perspective norms goes through the following stages:

- determining the norm level within the basis period
- identifying the factors exerting substantial influence on the norm value
- determining modifications of the major factors within the prediction period as compared to the basic one
- assessing the influence of these factors on norm's value and determining its level within the period being forecasted.

For evaluating the influence of individual factors on norm's value the index method for correcting basic values should be made use of.

Solving the problem of introducing some specific technological cycle to produce ferrous metals in the developing countries depends on the amount of available production resources to materialize these cycles which will determine the level of production complexity to be taken into consideration as real (and not empirical) indexes of technological cycles.

In the ferrous metallurgy the technical progress is accompanied by creating the new and developing the existing technological and power equipment, advancing the technological combinations options, by a growing consumption of capital labour and power resources as a whole.

The ferrous metallurgy-related technological combining consists in an integrated employment of resources for the purposes of technology. Technological combining is aimed at stepping up the effectiveness of the metallurgical production (maximum level of production at minimal expenditures). The relations of balances of the ferrous metallurgy-consumed resources are quite diverse with all productions making up the structure of its individual subsectors.

When developing and analyzing capital, labour and power consumption balances, first of all it is imperative that the balance's expendable part should be determined correctly. Up to the present time this required developing various additional individual balances both relating to power consumption (fuel, electricity, heating) and the ones involving the materials (scrap metal, cast iron, stell etc.), and also the ones covering capital investments and labour resources. These balances were developed by multiplying individual resources comsumption norms by the volume of production output. However, the development of individual balances does not allow to obtain a quantitative appraisal of internal relations, to substantially assess the sectoral relations and intersectoral proportions in the development of the ferrous metallurgy. A shortcoming inherent in such a system is the fact that indirect material and power consumption remain unaccounted. They emerge in connection with their consumption through other types of output having an indirect relationship with the given end production output.

The matrix models and the corresponding mathematical apparatus for calculating the integrated consumption allow to embrace all capital, labour and capital consumption indexes, to appraise in quantitative and qualitative terms the relationship between individual subsections and the production.

The basic initial data is the one related to the ferrous metallurgy output in capital, labour consumption per every type of this output. On the basis of this data the direct consumption coefficients may be calculated by dividing on a row vector representing production volumes of the corresponding output. These consumptions constitute a base for calculating the ferrous metallurgy intersectoral proportions and characterize a direct relationship between individual types of consumption and the output. However, the direct consumptions proper do not represent the ferrous metallurgy total consumption and do not reflect structural modifications effect in individual productions. Thus a growing output of converter steel entails a larger consumption of steel compared to the open-hearth process which results in its turn in a power carriers increased consumption to produce cast-iron, coke, blast, oxygen etc.

Thus, along with the direct consumption reflecting the technological progress and basic correlation of technologically interconnected productions (for instance a coke and cast iron production) much more intricate sectoral and intersectoral proportions are required allowing to rightly express total capital, labour and energy intensity of the output and to develop and analyze the balances of sectoral resources on this base. This permits to obtain the coefficient of direct consumption taking into consideration not only a direct consumption per unit of the output in a given production but also indirect consumption in other productions and subsectors of the ferrous metallurgy and sectors of the national economy entertaining a relationship with a given production through the totality of intersectoral proportions and sectoral ties. That is the total consumption for a given type of production made not only within the last current stage of production but also all through the preceeding stages and cycles of production in all contiguous sectors.

In its economic nature the integrated consumption is similar to the total consumption but it is formed within the framework of more limited relations (within the framework of a proposed subsector-products complex). As applied to the sectoral consumption the economic sense of the integrated consumption consists in a continuous alternation of direct and indirect consumption for the production of specific types of output within the framework of the industry.

A departure point for obtaining direct and integrated consumption is a development of a square statistical table (matrix) constituting an overall scheme for distributing the materials, fuel, power, by-products of ferrous metallurgy and the total consumption of these resources for producing the ferrous metallurgy output both as by-products and end-products.

The development of such a table is the initial identification of individual elements determining the titles of its lines and columns. Every line of this table forms an independent balance of distributing a certain type of material, fuel, energy, by-products etc. Even a simple integration of many material balances within a single model (table) facilitates analyzing the qualitative intersectoral material relations in the process of producing various metallurgical products.

A combination of horizontal distribution lines makes up vertical columns reflecting the materials, fuel, energy etc. consumed for producing the output to be distributed. In this way it appears that there exist two tables in one: the lines make up a distribution table for materials, fuel, energy and by-products, and the columns constitute a table of consuming the same types of resources for their production (provided they are produced within the framework of ferrous metallurgy). The amount of columns equals the number of lines, i.e. an initial statistical table which in fact is a matrix has a n x n dimension (a square matrix). The above-mentioned particularities constitute an important advantage of the described initial table over a system of unintegrated individual balances.

In general the initial statistical tables may be expressed by a combination of equations represented in mathematical terms as follows:

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i \quad (i = 1,2,\ldots, n)$$

where: X_i = total consumption of i-type ferrous metallurgy resources
X_{ij}= consumption of i-type resources for producing the j type output
Y_i = commodity output or outside delivery of the i-type resource

The $\sum_{j=1}^{n} X_{ij}$ element which is a sum total of the industrial consumption may be transformed because:

$$X_{ij} = A_{ij} \cdot X_j$$

where: A_{ij}= direct consumption of i-type material for producing the j-type output.

In this case the formula will look like:

$$X_i = \sum_{j=1}^{n} A_{ij} X_j + Y_j \quad (i = 1,2,\ldots,n)$$

Proceeding from this formula the direct consumption may be calculated by dividing a consumption of the i-type resources necessitated for producing the j-type output, by the volume of j-type output:

$$A_{ij} = X_{ij} : X_j$$

This comparatively elementary formula provided a base for calculating the direct consumption on the basis of the initial statistical table. For this purpose the initial statistical table (a square matrix) was divided by the X_j row vector constituting the volumes of metallurgical output (j-type production) to obtain an A matrix for coefficients of direct consumption.

On the basis of direct consumption coefficients thus obtained the complex consumption coefficients were calculated because they are mathematically connected to the direct consumption coefficients:

$$C = (E - A)^{-1} - E$$

i.e. for determining the integrated consumption it suffices to identify a matrix inverse to E-A and substract a unit matrix from it.

The initial statistical tables to determine complex fuel and energy consumption when assessing the influence of technical options and of the advancement of existing technologies exerted throughout the framework of the metallurgical cycle starting from the ore and ending by the rolled output are rather big in size (80 x 80). They help develop over 6000 direct consumption coefficients and nearly 5400 coefficients of complex consumption. A mathematical model for the initial statistical table is represented in table 2.

Table 2. **Mathematical model of initial statistical table for calculating direct and complex consumption in ferrous metallurgy**

Resource or output type	Consumption					
	1	2	3	...	n	Total
1	X_{11}	X_{12}	X_{13}	...	X_{1n}	$\sum_{j=1}^{n} X$
2	X_{21}	X_{22}	X_{23}	...	X_{2n}	$\sum_{j=1}^{n} X_{2j}$
3	X_{31}	X_3	X_{33}	...	X_{3n}	$\sum_{j=1}^{n} X_{3j}$
4	X_{41}	X_{42}	X_{43}	...	X_{4n}	$\sum_{j=1}^{n} X_{4j}$
...	...	...	...	...	...	...
n	X_{n1}	X_{n2}	X_{n3}	...	X_{nn}	$\sum_{j=1}^{n} X_{nj}$
Row vector	X_1	X_2	X_3	...	X_n	

The authors suggest that the degree of complexity or complex capital labour and energy expenditures be calculated for 3 typical bar-range products (large sections, shapes and merchant-mill products), for 3 typical sheets products (plates, sheets and cold-rolled sheets) as well as for structural and alloyed steels.

In order to calculate this consumption progressive consumption indexes should be employed for the raw stocks, materials, by-products, fuel and energy in major metallurgical productions making up a total metallurgical cycle both a classical one (including the blast furnace iron-making + oxygen converter production), and a cycle involving electric arc furnace steel-making based on the use of scrap metal or iron containing products.

In order to calculate complex capital and labour expenditures the entire circle of composing integrated consumption of raw stocks, materials, intermediate products employed to obtain the assessed end-product is multiplied by specific labour and capital consumption. The integrated power consumption is computed by inverting a direct consumption matrix.

5. PERSPECTIVE DEVELOPMENT OF TOTAL METALLURGICAL CYCLE PROCESSES IN THE DEVELOPING COUNTRIES

The following technological routes are employed in the ferrous metallurgy:

(a) a classical route featuring a blast-furnace iron production out of processed iron ore stock using coke and a converter steel production;

(b) processing a metallized feed by way of non-coke metallurgy (or using an imported metallized feed) to be followed by the electrical furnace steel production;

(c) electric furnace scrap metal smelting to produce a required steel.

In these schemes a continuous casting may be used for all the steel produced.

A possible implementation of one or another metallurgical cycle in a developing country is determined by the availability of required material resources (iron ore or required composition, coking coal, natural gas) and the availability of scrap metal resources.

Equally important are the feasible capital investments that might differ substantially from various schemes of import-oriented currency outlays as well as locally available labour resources of a required qualification taking into account different levels of labour consumed in each scheme of metallurgical cycles for producing steel.

Therefore the complexity of steel production for the manufacturing of metal products is determined along with its chemical composition by the metallurgical cycle schemes including different stages and differing in equipment and technology.

It is also necessary to emphasize that in the developing countries attaining a required steel chemical composition may be dealt with depending on the available natural resources and stages of their economic development both by way of developing their own ferroalloys production and by importing ferroalloys and alloying elements. Each improvement in steel's chemical composition will naturally entail corresponding outlays for developing the ferroalloys production or hard currency spendings to import ferroalloys.

While determining the complexity of metallurgical cycle schemes one should keep in mind that the number of stages involved in a cycle might vary depending in country's available natural resources and import options. For instance the classical scheme "blast-furnace-converter" may see the number of stages reduced by involving imported oxidized pellets, and the scheme for producing steel in electric furnaces using a metallized raw stock - by rejecting the use of home-made metallized stock and importing it from other countries. The imported raw materials may be related to another scheme featuring the electric furnace scrap melting provided a country has insignificant scrap metal resources and is unable to secure a required amount of scrap, that is it has to be imported.

Consequently, from the viewpoint of technological complexity each scheme is characterized not only by the number of production stages of varying consumption resources for their realization, but additionally by the hard currency spendings to import the raw stock and materials unevenly required to carry through a metallurgical cycle. Otherwise "short-term" schemes based on importing the raw stocks might get an unjustified advantage in terms of technological complexity though in reality they are aimed at developing country's economy in the direction of establishing currency reserves to make the metallurgical cycles scheme function. However, for the developing countries using their natural resources to accumulate and make use of currency reserves, the development of the ferrous metallurgy following the raw stocks and materials schemes will allow to set up a home steel production within a shorter period and with lower resources consumed in the country.

The formation of metal output technological complexity along the second direction is determined by the set complexity of the sections and dimensions range the demand in which is identified on the basis of economic development of the country. Steel produced according to different metallurgical cycles schemes may be employed for producing the same types of metal products which have differing technological complexity as a result of it.

A possible production of metal output with varying complexity of sections and dimensions is determined by the available equipment for continuous casting of billets and also by the available rolling equipment. It is characterized by different levels of labour intensity to carry through the technological process and by its power consumption and capital expenditures for setting up shops. The employment of continuous casting machines for producing billets in combination with electric furnaces of various capacities and powerful transformers makes it possible to create the required metal production capacities practically with no limits in production's minimum volumes and in the values of economic indexes for the metal output. This expands the options for producing metal products of varying sections and dimensions complexity range in the developing countries.

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