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CYBERNETICS AND PLANNING

By V. Belkin, et al

-USSR-

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[Following is the translation of an article by V. Belkin, A. Tret'yakova, I. Birman, entitled "Kibernetika i Planirovaniye" (English version above) in Ekonomicheskaya Gazeta (Economic Journal), No 143, Moscow, 16 Nov 1960, pp 2, 3.]

Electronic Machines will Compute Optimal Fuel-Energy Balance!

On June 12 of the current year an article entitled "Cybernetics and Life" appeared in the Economic Journal. It dealt mainly with the broad possibilities for economic research and planning opened by cybernetics. The editorial office received a series of letters from the readers requesting a more detailed explanation of the prospects in this field. Today's article is devoted exclusively to cybernetic methods and cybernetic machines for the solution of one of the most important problems of planning.

A Most Complicated Problem

The radical improvement of the fuel-energy balance of the USSR is one of the most important tasks of the Seven-Year Plan. Its significance can be judged even from the fact that in 1959 more than 25 percent of the basic industrial production funds of the country, and approximately 10 percent of the industrial workers were concentrated in the field of fuel-energy. The transportation of fuel exceeds one third of the entire commodity traffic.

Let us remind you that the main direction in the reorganization of the fuel-energy balance is the increase in the production of the most economic type of fuel. The role of petroleum and gas will rise through the Seven-Year Plan: in fuel output from 31 to 51 percent, in consumption (not including light petroleum products) from 16 to 36 percent. This will permit a saving of approximately 125 million rubles. The amount of petroleum and gas in the production and utilization of fuel will rise even more in the future.

However, after the main strategic direction is determined, and the main task undertaken, a series of economic, technical, and other questions pertaining to its practical realization arise.

At the beginning of last year the government entrusted the Gosplan (Gosudarstvennaya Planovaya Komisiya - State Planning Commission) of the USSR and the TsSU (Tsentralynoye Statisticheskoye Upravleniye - Central Statistical Administration) with the development of the planning and calculation of the fuel-energy balance in the Union as a whole and in economic cross sections. The balance is called upon to coordinate the production of different types of fuel and energy, on the one hand, and its utilization, on the other. The optimum balance must forsee such relationships between the manufacturers and consumers, that the total expenditure for providing fuel and energy to the national economy would be minimal.

Under capitalism, under conditions of private ownership and anarchy in production, a unified balance of fuel-energy cannot be established. In our country this problem has already, for a long time, attracted the attention of scientists and operators. The initial attempts to establish a common fuel-energy balance were already made with the development of the GOELRO (Gosudarstvennaya Komissiya po Elektrofikatsii Rossii - State Commission for Electrification) plan. However up to the present time they have not succeeded in putting it into effect.

The availability of hundreds of producers and of tens of thousands of consumers of fuel and energy, the wide range of interchangeable resources, the variety of routes and facilities of transportation -- all of this predetermines many different balance alternatives. The choice of the best one through the usual methods and facilities presents an unsurmountable task. Of course, on the basis of many years of experience, by means of highly labor-consuming and complex calculations, an alternative balance can be obtained, which will more or less approximate the optimal balance. This is inadequate when applied to the fuel-energy balance. An optimum in the strict sense of the word has to be found, for a deviation of even a small percentage will entail a loss measurable in billions of rubles.

Mathematics and Electronics Come to the Aid

In his speech at the July (1960) plenary session of the TsK KPSS (Tsentral'nyy Komitet Komunisticheskoy Partii Sovetskogo Soyuza - Central Committee of the Communist Party of the Soviet Union) the President of the Academy of Sciences USSR, academician A. N. Nesmeyanov, noted the computation of the optimal system of coal supply by electronic calculators at the Institute. As a result of the experimental calculation obtained with electronic calculating machine "M-2", 98 consumer-Sovnarkozes were conditionally attached to 30 coal-deposit areas in such a manner that the total expenditure for transportation of coal would be the smallest possible. Such is the first step for the investigations into the problem of creating the optimal fuel-energy balance on electronic calculators (EVM) using linear programming methods. The calculations were obtained in accordance with A. L. Brudno's algorythms, developed on the basis of A. L. Lur'e's methods of differential annuities. Algorythms mean the description of methods and strict sequence-consistency of computing operations for the solution of a specific problem. As the name of the method shows, the differences of locations of the suppliers with reference to the consumers are taken into account through differential annuities.

In order to go on to the calculations of the fuel-energy balance as a whole, it was necessary to surmount a substantial methodological difficulty. Its essence lies in the following:

Supplies of coal for energy constitute only a part, although not a small part, of the fuel-energy balance. However, can it be asserted that the optimal balance will be obtained by means of the simple addition of the optimal balance of coal, gas and electrical energy? The facts suggest a negative reply.

Assuming that the optimal coal balance will show that it is expedient to supply the power plants near Khar'kov with coal from the Donets, to ship coal from the Pechorsk and Moscow Basins to Leningrad, and so on. In calculating the entire balance we might obtain different results. For example, it will seem more rational to send the Shebelinsk gas to the Khar'kov power stations, to bring coal from the Donets to Leningrad, and the coal from the coal fields around Moscow -- to the brickyards in the Smolensk area and so on.

The broad possibilities of replacing one form of fuel and energy by other forms have conditioned the necessity of solving a new problem. In order to construct a fuel-energy balance it has become necessary to find a method of determining the optimal system of transporting several mutually-interchangeable products simultaneously, and this method must correspond to the developed algorythms and programs of calculations on the EVM.

Such a method did not exist. Both here and abroad optimal systems of transportation of a single product were computed. It appeared that with the help of several sufficiently simple procedures the optimal system of transportation, with allowances for the interchangeability of different products, can be computed on the basis of the usual algorythm for the problem of transportation. The computation of the optimal fuel-energy balance for the current period was being obtained in this manner. The volume of the resources is known in this problem, and it is necessary to determine where, and for what needs, will it be most expedient to use them, as well as how to relate the consumers to the suppliers so as to bring the transporation costs down to a minimum.

But this is not sufficient for the compilation of a perspective balance. Another problem arises here: what types of fuel-energy resources should be used to supply enterprises which are being built or expanded, where and what types of mines, wells, or pipelines should be constructed. How can this be done in the most economical way?

It was discovered that this complex problem could also be solved with the aid of the transporation problem algorythm, by computing on a basis of the so called "open models".

Computing the Balance in the Annual Plan

In order to compute the fuel-energy balance on the EVM for the current year the initial data should be entered into the following table, presented here in a schematic form.

Left of the vertical line the producer-districts and the range of production of fuel-energy resources in terms of the designated fuel are shown. On top along the horizontal the consumer-districts (points) and the volume of demand for various forms of fuel and energy (also in designated terms) are indicated. Part of the demand is interchangeable and can be met by any or at least by several types of resources, part is "rigid" in character. In our example, the consumer A showing his "rigid" demand for electrical-energy, and a demand which can be satisfied either by petroleum, or gas, or coal. In regard to consumer V; he will be partly satisfied by petroleum, and the remainder -- by any of the indicated fuel-energy resources in the table.

At the point where the lines and the columns intersect, the cost of production and transportation of a ton of the designated fuel is underlined.

The calculation on the EVM is conducted by this table according to the algorythm of differentiated annuities. As a result an alternative, which guarantees a minimal total expenditure for the resource supply, is derived for the relation of the producers to the consumers. In other words, we derive the current optimal fuel-energy balance.

TABLE I

Producer districts	Forms of fuel-energy resources	Volume of production in designated units	Consumer districts, types and volume of demand in units of designated fuel			
			A		V	
			electrical energy	petroleum, gas, coal	Petroleum	petroleum, gas, coal, electrical energy
			100	470	150	465
	Petroleum	240		43	106	106
I	Gas	180		26		82
	Electrical energy	80	168			234
II	Coal	475		177		43
III	Electrical Energy	120	240			206
IV	Petroleum	90		40	75	75

Prices, Stimulating the Fullfillment of the Plan

In an actual economic situation even the best plans do not become fulfilled of their own accord. Therefore it is not enough to compute the optimal balance. It should be carried out in such a way, that not only the government as a whole, but every supplier and consumer individually would be interested in strict adherence to it.

Not infrequently the enterprises themselves disrupt the overall plan of production. One of the main reasons lies in the unsatisfactory correlation of prices and net costs. The plan is fulfilled in areas of "probitable" manufactured goods; in areas of small profits it is frequently not fulfilled.

How can this be avoided in the fuel-energy balance? Apparently prices should be set so that the adherence to deliveries specified in the plan would be profitable both for the suppliers and the consumers. Economic stimulation is undoubtedly more effective than administrative measures.

We discover, that when the computation of the fuel-energy balance is made by the method of differential annuities, simultaneously with the determination of the optimal system of deliveries, prices which stimulate adherence are computed.

The prices are uniform for the whole district, and it is irrelevant to the consumer from which supplier he obtains fuel or energy to meet his needs. At the same time only deliveries specified by the optimal are profitable for the supplier at given prices. Otherwise he suffers decrease in profits or even incurrs losses.

On the other hand, regardless of the consumer, the delivery prices of fuel and energy of the supplier are uniform. As a result disruption of the optimal balance is unprofitable for the consumer as well. Two systems of uniform prices -- that of the pre-paid suppliers and that of the pre-paid consumers -- are formed from the inclusion of the differential **annuities in prices.** Indeed, the difference between the prices of the pre-paid consumer of resources and the actual expenditures for their production and delivery constitutes a differential annuity in terms of the quality and location of sources.

Let us note another extremely substantial condition. It is well known to economists that in cases of limited availability of a particular product, its price must reflect additional cost. However, as yet it has not been possible to determine the amount of the increase, arising objectively from the existing economic conditions. It becomes obvious that in the computation of prices simultaneously with the optimal fuel-energy balance the objective proportion of increase for limited availability may be determined. If the consumer of some district presents a "rigid" demand for a certain type of fuel or energy, while the delivery of it is unprofitable, then as a result of computation a price is determined which includes an increase for the relative unavailability of the product in the district.

The prices which take into account the unavailability factor will show, on one hand, which resources it will be profitable to develop in the given district, and secondly, where the production of the corresponding types of fuel and energy should be increased.
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The Development of Economy and the Perspective Balance

As it was noted above, the perspective balance in contrast to the current balance, must not only forsee the optimal bonds between producers and consumers, but it must also provide a more expedient system for the development of production and the consumption of fuel-energy resources in the future. This projected system embraces the allocation of the projected supplying enterprises and of enterprises which consume fuel and energy, as well as the most efficient choice of units being expanded and renovated -- their transportation connections and the possibilities of utilizing the most economical of the interchangeable resources are taken into consideration.

The table of the initial data of the so-called "open model", according to which the persepctive balance is computed, contains on the left the production indices of fuel-energy resources, not only for existing, but also for projected enterprises of all the variants of the plan. As a result of this the total volume of production in the model will significantly exceed the demands (for this very reason, it is called the open model).

The difference between volume of production represented in the table and demands is equal to the demand of the so called "ficticious consumer", which is introduced into the table by a special graph. The indices are identical in all lines and their absolute value is irrelevant.

In the end result, the calculations of such a table on the EVM, according to the algorythm of differential annuities, will show the suppliers with the highest expenditures related to the "ficticious consumer". They are excluded from the balance. Those same suppliers who will be related to real consumers are the most economical and these are precisely those variants which should be accepted into the plan.

Let us note that among those attached to the "ficticious consumers" there may be not only projected ones, but also actually existing suppliers. This will testify to the fact that they should stop the production of the corresponding type of fuel-energy resources. There is nothing surprisiing in this. For example, the economic expediency of closing down a certain number of mines of the Moscow and Donets Basins is well known.

Should it be found undesireable for any reason to close down functioning enterprises, then the expenditures for manufacture and delivery for the products of these enterprises are artificially lowered in the initial table. In the final allocation they will be attached to the real consumers, and consequently only the expediency of different variants of constructions and renovations of fuel-energy enterprises will be subject to examination.

Three Problems Which Are Yet to be Solved

Already at the present time on the basis of information available at the planning and statistical organs, and on the funcioning EVM, it is possible to carry out expanded computations of the optimal fuel-energy balance. They will provide results adequate for practical application which is corroborated by experimental works.

The computations will become considerably more effective if they are to be based on precise data, and will take into account more fully the specifications of the consumers of fuel and energy, and will become more detailed. Hence, the following three problems must be solved.

First — the optimization criteria. They are represented by expenditure indices. It is necessary that such indices should reflect more precisely public expenditures for production and transportation. For this, economically founded prices are needed for metals, timber, machines and other material resources employed in the production of fuel and energy and in the construction of fuel-energy enterprises and transportation facilities, as well as economically founded transportation tariffs.

In our opinion such prices and tariffs should be formed on the basis of production costs, i.e., they should be computed from the net cost and profit — computed proportionally to the principal and revolving production funds.

The July (1960) plenary session of the TsK KPSS entrusted the Gosekonomsovet (Gosudarstvenyy Ekonomicheskiy Sovet - State Economic Council) with the determination of the methodological bases for the revision of wholesale prices, projected for 1961-1962. This revision will bring the prices closer to actual expenditures. At the same time it must be stressed that computations of fuel-energy balance even at current prices and tariffs will bring sufficiently favorable results.

The second problem pertains to the manner of accounting for the interchangeability in cases of the differentiated effectiveness of individual types of fuel and energy with different consumers. A recently developed method permits us to take into account the interchangeability when it was assumed that all forms of fuel and energy are equally effective for all consumers, in terms of the correspondence to the calorie equivalents. The materials contained in planning and statistics and the utilized methods are also based on this assumption. But in actual reality the coefficient of utilization of mutually interchangeable fuel-energy consuming complexes is not uniform and fluctuates over a wide range.

The computation of the optimal balance in cases of differentiated effectiveness coefficients can be realized according to the universal method of linear programming — the simplex method. However, in order to accomplish this, it will be necessary to increase considerably the dimensions of the initial tables, which will considerably complicate the resolution of practical tasks on the existing EVM. It would be preferable to perfect the well-known algorythms of solving the transportation problem in such a manner, that with their aid the corresponding computations could be conducted.

For detailed calculations of the fuel-energy balnce the basic parameters of the EVM will have to be substantially improved, i.e., the volume of their memory and speed of computations. Apropos, the pioneering works in the realm of the application of the EVM and of mathematical methods in planning show, that as a rule, more powerful EVM's are needed for the solution of economic problems than for the solution of technical problems. The creation of a powerful rapidly functioning EVMs designed especially for economic computations represents the third problem.

The unfolding of practical work in the compilation of a fuel-energy balance on the EVM, is of course, associated not only to the three problems which have been pointed out above. Considerable efforts are required on the gathering of the necessary information and for its prelimenary processing for the solution of a series of relatively specific methodological questions. But these difficulties will surely be surmounted by the joint efforts of the economists, power specialists, mathematicians, and electronic specialists.

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