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DISPLAN (DIalog System of PLANning) – New Planning Technology

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In [1] a new approach to solving the problem of optimizing inter-industry balance sheets was proposed. Since this approach focused on the purely mathematical aspect, many other important points were only touched upon in passing or not at all. As a result, many readers have a one-sided (and sometimes incorrect) view of the proposed model. There is, in particular, an opinion that the DISPLAN is a purely static model intended mainly for short-term planning. Some readers did not even notice that the DISPLAN is a tool not only for balancing, but also for deep optimization of plans.

The role of DISPLAN as the core of a new technology for all planning (and not just inter-industry balance sheets) is not completely covered in [1]. This gap is partially filled in [2] and [3], but a number of aspects of the problem need to be made more clearly and in detail (especially given the limited publication of work [3]).

Displan technology is designed primarily for long - and short-term planning across a country (or group of countries), as well as on any designated territory. Optimization of plans is based on the socialist principle of maximum satisfaction of the material and spiritual needs of the population in this territory.

Replacing the optimization criterion with a criterion that does not use the value of non-production consumption (profit maximization, growth rates, etc.), allows to use the displan technology for planning purely production facilities (industries, associations, etc.).

The further presentation of the displan technology is based on the main territorial-industrial, rather than purely industrial interpretation.

The technological cycle of planning in the DISPLAN system begins with the selection of the main time interval of planning T (planning period) and its division into intermediate subintervals $t_1, t_2, ..., t_k$. Next, the aggregate product range for this planning period is set for the highest level of planning - the summary plan. The maximum volume of such range, further indicated by the number n , is determined primarily by the power of the computer equipment available in our location and the convenience of conducting a dialogue. The latter condition is satisfied if the time of operations such as multiplying a vector by a matrix (of dimension n) is performed within a few (usually no more than 5-10) minutes. For computers with a speed of about a million operations per second according to Gibson, the maximum volume of the range is about 10 000.

Note that the displan technology provides a real summary plan, and not pre-planned outlines used in drawing up the plan, as is the case in traditional macroeconomic optimization models.

A specific unit of measurement (rubles, tons, cubic meters, etc.) is fixed for each item of the range. Note that, as is the case in real planning, the displan technology assumes the possibility of using different types of products at all stages of planning (including inter-industry balance). To quickly transfer planned indicators from one unit to another, the information and mathematical support of the DISPLAN includes the corresponding tables in the software package.

As already noted, the DISPLAN is not a static model, but a dynamic one. However, unlike classical dynamic models that deploy the economy sequentially, period by period, the DISPLAN uses a fundamentally different approach - the projection of dynamics on statics.

In essence, any numerical implementation of any dynamic model deals with the projection of dynamics into statics. But in the classical case, this projection is made in small time steps Δt from $t=0$ to $t=T-\Delta t$, where T - is the selected planning period.

In contrast, in the DISPLAN, the projection (with the corresponding plan optimization) is made immediately for the entire planning period. And only after that, the resulting plan is divided and adjusted (also with optimization) for individual sub-periods (for example, for years of the five-year plan). This approach significantly reduces the number of steps in the optimization process and, most importantly, allows a systematic approach to optimizing real plans with all the necessary depth of detail (up to individual enterprises and workshops).

The main tool for projecting dynamics into statics is a multi-level system of aggregation of norms, starting at the level of enterprises and design institutes and ending at the level of the summary plan for a given territory (for any required planning period T).

There are three main types of primary norms in the DISPLAN: direct product costs, direct operating time of fixed assets (stock-hours), and direct labor costs (man-hours). It is convenient to combine the last two types of norms under the general name of resource-hours. In addition to the aggregate product range described above, the aggregate resource range, i.e. different types of fixed assets and labor resources, is also recorded for this planning period. The total number of aggregated resources m usually (though not necessarily) has the same order as the number of aggregated products n .

For aggregated types of fixed assets, units of measurement (rubles, units, etc.) are selected. As for products, it is possible to quickly recalculate from one unit to another. Labor resources are measured by one indicator - the number of employees of certain specialties.

Norms aggregation is a unified process that is performed sequentially at all levels of the planning hierarchy. For any type of direct cost norm a_{ij} the corresponding aggregate norm $a_{IJ}^{(T)}$ for the planning period is calculated using the formula

$$a_{IJ}^{(T)} \leqslant \frac{\sum_{i\in I}\sum_{j\in J} x_j^{(T)} a_{ij}}{\sum_{i\in J} x_j^{(T)}} \qquad (1)$$

Here j runs through all the technologies for the production of various types of specified products included in the aggregated position J , and i - all types of specified products included in the aggregated position I . $x_j^{(T)}$ indicates the total volume of specified products produced using the j -th technology, which is planned for the period T .

Formula (1) has a remarkable feature, namely: using it, you can perform step-by-step aggregation in accordance with the existing planning hierarchy, rather than performing it immediately for all specified positions and technologies. To do this, in addition to the partially aggregated norm $a_{I_1 J_1}^{(T)}$, it is sufficient to transfer to the next level of the hierarchy the planned volume (for the period T) of the corresponding aggregated output $x_{J_1}^{(T)} = \sum_{j\in J_1} x_i^{(T)}$.

At the next level of aggregation, the values of $a_{I_1 J_1}^{(T)}$ and $x_{J_1}^{(T)}$ are replacing in formula (1), respectively, the values of a_{ij} and $x_j^{(T)}$. At the level of the summary plan, as a result of the last stage of aggregation, we get the planned total outputs $x_{J_1}^{(T)}$ (for the period T) and the corresponding norms of the aggregated range.

Of course, when aggregating, the units of measurement for products and resources within each aggregated item must be the same. If this is not the case, then the corresponding recalculations of aggregated norms and output volumes must be performed first.

As a result of the described process, two matrices $A^{(T)}=|a_{IJ}^{(T)}|$ and $B^{(T)}=|b_{IJ}^{(T)}|$ of averaged direct product costs and resource-hours are obtained, as well as a vector $x^{(T)}=|x_j^{(T)}|$ of total output for a given planning period. In the process of averaging (aggregation) of norms, the actual planned (starting from the lower level of the hierarchy) dynamics of technical progress and capacity commissioning over the entire period of T, associated, of course, with the corresponding investments, were taken into account. However, although the result of the investment is reflected in the data obtained, the same cannot yet be said about the provision of these investments.

The corresponding data is obtained as a result of direct summation (with the corresponding aggregation of indicators) of direct costs of resource-hours spent on construction, installation and design work (including supporting Research), as well as direct product costs (in particular, provision of construction sites) that provide these works. All expenses, of course, relate to a given period of T. In the context of planned training of personnel, the process of such summation should also take into account the costs that support this process.

It is convenient to represent the hierarchical process of aggregation of material security of investments in the form of sequential aggregation of network graphs (in general, multi-purpose) of construction projects and the part of scientific and technological progress (including personnel training) that is brought to program-target management. At the same time, consolidated network graphs should remain at the level of the summary plan, with appropriate support for the largest construction projects and the most important target programs. As for the final total projection of costs for this planning period T, it is done inside the upper level of the displan model. This projection results in a vector $c_1^{(T)}=|c_{1J}^{(T)}|$ of direct product costs and a vector $r_1^{(T)}=|r_{1J}^{(T)}|$ of direct resource-hours spent on ensuring economic development during a given period.

Note that it is convenient to represent transport services as one of the types of products. In this case, it is necessary to provide the addresses of future consumers and suppliers of products from the lowest level of planning and calculate the corresponding cost norms for various modes of transport, followed by their aggregation according to the scheme already described above.

Similarly to the vectors $c_1^{(T)}$ and $r_1^{(T)}$, direct summation results in vectors $c_2^{(T)}$ and $r_2^{(T)}$ of direct costs of products and resource-hours in the non-production sphere (trade, public catering, health, culture, etc., as well as defense, public order, foreign policy, etc.)

Note that from a systemic point of view, it is desirable to allocate all investments in the non-production sector in separate positions, forming the appropriate vectors $c_2^{'(T)}$ and $r_2^{'(T)}$.

Thus, by direct summation (and corresponding aggregation) of the planned import and export from a given territory (import and export), the vectors of import $c_3^{(T)}$ and export $c_1^{(T)}$ are formed in the positions of the aggregated range, as well as the vector $r_3^{(T)}$ of direct resource-hours spent on ensuring external trade. At the same time, to unify calculations, it is convenient to consider different types of currency as a kind of product - the result of the actions of foreign trade organizations.

Similarly, vectors related to the replenishment and use of state reserves are formed.

Summing up all the obtained vectors $c_i^{(T)}$ (while the vectors of import and deblocking of state reserves are taken with a minus sign), we get the vector $c^{(T)}$ of final products that are expected to be produced during the period T. The formula

$$c^{*(T)}=A^{*}c^{(T)}=(E-A)^{-1}c^{(T)} \qquad (2)$$

determines the total output that provides the final product $c^{(T)}$. To ensure this output, we must spend the resource-hours specified by the vector

$$S^{*(T)}=B^{(T)}c^{*(T)} \qquad (3)$$

Adding these costs with the resource costs of non-production sphere and on economic development, we get the final vector $S^{(T)}$ of the required resource-hours for the period T.

In addition to the specified regulatory calculation of the necessary costs, DISPLAN provides (throughout the planning hierarchy) a direct account of the total amount $s^{(T)}$ of resource-hours of various types that we will have during the period T. This account is based on the actual planned (in the lower levels of the planned hierarchy) dynamics of commissioning and development of production capacity and personnel training. In addition, it takes into account (based on the demographic forecast) the dynamics of changes in the labor force that go beyond the organized training system. When calculating expected availability of resource-hours the planned dynamics of shift coefficients of industrial equipment load and changes in working hours, duration of vacations, size of retirement age (of occupations), the expected loss of working time due to sickness and other reasons are also taken into account. The formula

$$d^{(T)}=S^{(T)}-s^{(T)} \qquad (4)$$

calculates the vector of scarcity of resource-hours during the period T according to the types of aggregated resources. Recall that they include both production capacity (fixed assets) and labor resources.

In addition to the vector $d^{(T)}$, the unbalance vector of production plans $\Delta^{(T)}$ for the period T is also determined, calculated using the formula

$$\Delta^{(T)}=c^{*(T)}-x^{(T)} \qquad (5)$$

If all components of the vector $d^{(T)}$ and $\Delta^{(T)}$ are negative or equal to zero, then there are no deficits or unbalances. By reducing the planned targets $x^{(T)}$ to the required values $c^{*(T)}$, we get a balanced plan $(\Delta^{(T)}=0)$ that in principle can be implemented and can be adopted.

However, with such a solution, there would be absolutely no optimization elements in the planning. In addition, in practice, such a situation does not actually occur. As a rule, our wishes regarding the size of the final product significantly exceed the possibilities of their actual implementation. In addition (and this is the most important thing), the DISPLAN approach to optimizing plans is in principle different from the classical one. Instead of searching for an optimum point in a given (unchangeable) acceptable area P, DISPLAN immediately sets the desired optimum point M_0, which usually lies outside the initial acceptable area P_0.

The essence of the optimization process is to adopt a sequence of agreed (across all levels of the planning hierarchy!) decisions on changes to the plan that result in not only moving the point M_i, but also purposefully changing the allowed area P_i. In the resulting sequence of pairs $(M_i, P_i,)$, there may be pairs in which the point M_i falls within a valid area P_i.

In this case, the control system of the upper (Directive) level evaluates each time (not in a fully formalized way in human-machine mode!) values of optimization criteria (usually several of them), as well as difficulties and time to prepare solutions for further optimization. This evaluation results in one of two decisions: either stop the optimization process or continue it. In the first case, the last point M_i is accepted as the final plan, in the second, the top-level system (in cooperation with other systems) assigns a new point M_{i+1} (usually outside the area P_i) with improved criteria values, and the optimization process continues.

The preparation of coordinated decisions on changes to the plan in the process of its optimization occurs as a result of the interaction of various parts of the planning system (from Gosplan and below). Whenever, during the optimization process, there is a need to change the plan (i.e., move a point M_i) in such a way that the assigned optimality criteria change in any direction, the corresponding decision is made only with the approval of the upper (Directive) level system.

In the basic displan technology, it is assumed that the optimization criteria are the components of the aggregated final product $c^{(T)}$. However, the range of such aggregation is set by the top-level system and may change during optimization. To perform such aggregation, DISPLAN provides appropriate mathematical support.

The point M_i is the necessary production plan for the period T, i.e. the vector $c^{*(T)}$ at the corresponding optimization step. Finally, the area P_i is defined by the relations

$$d^{(T)} \leqslant 0 \quad , \quad \Delta^{(T)} = 0 \qquad (6)$$

also composed at the corresponding optimization step.

Note that the systematic approach typical of the displan technology does not allow making arbitrary changes to certain parameters when managing the allowed area P_i, for example, the components $x_j^{(T)}$ of the plans actually presented by the industries. Each such change must be accompanied by a system of decisions that are interconnected (in the appropriate parts of the planning hierarchy) and that actually ensure such a change.

In practice, this means the following: analyzing the vectors of resource deficits $d^{(T)}$, the summary department of Gosplan determines the order (priority) of tasks to eliminate deficits and unbalances in human-machine mode. One of the simplest strategies for determining this order is to give priority to the maximum relative deficits and unbalances. In other words, if the point M_i (the required plan) is outside the acceptable area P_i, then the change in the area P_i is managed by reducing the maximum of the relative deficits and unbalances that exist. Having received information about the maximum relative deficits and unbalances, the industries, together with the industry departments of Gosplan, concentrate their efforts on developing specific proposals aimed at reducing them. In Gosplan, these proposals are evaluated by the Central element of the DISPLAN (the inter-industry balance model). For this purpose, the values of vectors $d^{(T)}$ and $\Delta^{(T)}$ are quickly recalculated for each proposal. In [1] was proposed a method for such rapid recalculation that requires an order of kn^2 operations, where k - is a constant not exceeding 20, and n - is the dimension of the aggregated model of inter-industry balance (it is assumed that $m \approx n$).

The adoption of such proposals (one by one or in groups) is precisely the agreed decisions on changes to the plan that determine the optimization process.

The focus of this process on the maximum satisfaction of the material and spiritual needs of society is provided, first, by the method of choosing the starting point M_0 , and secondly, by the impossibility of changing the assigned optimization criteria without a top-level system. Thanks to this, production is pulled up (changing the area P_i !) to a given level of consumption and development, and only if it is impossible to fully meet this level, it is reduced.

We will not discuss the issues of ranking various components of final consumption, as well as optimizing the ratio between consumption and accumulation in this article. These issues are covered in [2] and [4]. Note only that the determination of the correct proportions between consumption and accumulation can be done within the framework of the already described part of the displan technology. This can be achieved by immersing the required planning period T in a significantly larger.

Some other important elements of planning, such as the balance of monetary expenditures and income of the population, also remain outside the scope of this article. However, this balance can be made within the framework of the already described technology. To do this, it is enough to consider cash as one of the types of products that are consumed (in the form of wages and other payments) in all industries (including the "industry" of pension provision), and produced in industries that charge money from the population (trade, public catering, etc.).

As for the breakdown of plans by sub-periods and territories, the technology already described applies one-to-one.

We also note that the capabilities of the DISPLAN in terms of optimizing plans are significantly increased if, instead of aggregation by legal industries, in the main version of the inter-industry balance, aggregation by technological (conditional) industries is used. At the same time, for example, instead of the concept of "tractor production capacity", the concept of foundry, machine tool, forging, electroplating, paint and assembly production capacities appears (within the tractor industry). Aggregating foundry capacity across all industries, we get the total resource-hours for foundry production across the country.

The advantage of this method of aggregation is that it will give Gosplan a powerful lever to manage specialization and cooperation. After all, it often turns out that the volume of production of an enterprise, association, or ministry under a given plan structure is limited by one type of resource, while other resources are available in excess. These resources can be used to produce additional products only by changing the structure of the plan, i.e. purposefully managing specialization and cooperation. When aggregating capacities (resources) according to technological characteristics, the signal of the availability of reserves for increasing production due to changes in specialization and cooperation is the presence of an unbalance of the submitted and necessary plans in the absence of a shortage of the corresponding resource-hours (or at least a smaller amount of this deficit in relative terms).

Of course, after receiving the final plan $c^{*(T)}=x^{(T)}$ with a breakdown by conditional (technological) industries, its breakdown by actual (legal) industries should also be obtained. In other words, the DISPLAN must have two different aggregation systems running in parallel. Note also that when splitting the plan $c^{*(T)}$ by sub-periods, it may be needed to adjust it further. Thus, the plan $c^{*(T)}$ optimization process can be repeated several times.

A huge advantage of the DISPLAN approach to plan optimization is that at each stage of the optimization, decisions at the top levels are supported by corresponding decisions at all levels of the planning hierarchy. Therefore, the displan optimization technology is a real planning technology, when the optimized plans are brought to the final performers, and the optimization itself uses the informal knowledge available to these performers. This is the most important fundamental difference and advantage of DISPLAN over the classical macroeconomic optimization models, which at best do not provide a plan, but only pre-planned orientations, and also do not use a huge number of optimization opportunities that are in the hands (and brains!) of the lower levels of the planning hierarchy. However, this advantage is paid for by making it much more difficult to prepare solutions for each optimization step. Therefore, the problem of reducing the number of optimization steps as much as possible is very acute in the DISPLAN.

It is for this purpose that the classic "step-by-step" method of deploying dynamic macroeconomic models is replaced by the opposite, to some extent, method of projecting the dynamics of the plan over large planning periods. The same goal is served by an unusual approach to optimization itself, which rejects the principle of pre-collecting all the information that may be required for optimization, and replaces it with the principle of purposeful management of changes in the allowed area. The advantage of this principle is, first of all, a huge reduction in the primary information that is "shoveled" in the optimization process.

No less important is the fact that each link in the planning hierarchy throughout the optimization process retains not only the usual presentation of planning information, but also a clear understanding of its next tasks (which it ultimately aims at) by the summary department of Gosplan using the described displan technology. Due to this, each optimization step (performed in a human-machine, not fully formalized mode) becomes reasonable (the degree of which depends, of course, on the quality of the planning staff), which ultimately leads to a sharp decrease in the number of optimization steps.

Another important reserve for both reducing the number of optimization steps and increasing the available time reserve for it, is the transition (within the framework of displan technology) to continuous planning. This means, for example, that the five-year plan must move forward one year during each successive year. As a result, instead of about a year to develop and optimize a five-year plan with the usual (discrete) approach, we will have a year to extend and optimize an already largely optimized plan.

Finally, an informal use by planning staff of the results of preliminary calculations obtained using classical macroeconomic models (of course, for a much more aggregated range than in the DISPLAN) can help to increase the reasonableness of the optimization steps.

The reader who is used to classical statements of optimization problems may be shocked by DISPLAN’s (not fully formalized) concept of the optimization process and especially its final result. However, in practice, when optimizing complex multi-criteria systems, an approach similar to the displan approach is in most cases the only possible one. However, even with pure displan approach it is possible in some cases to reach fully formalized concepts and procedures. This will happen if, firstly, it is possible to reduce the multi-criteria formulation of the optimization problem to a single-criteria one, and, secondly, to reduce the control of the allowed area P_i and point M_i to fully formalized mathematical models.

In conclusion, we note that the regulatory planning method adopted in the DISPLAN implies increased requirements for the reliability of regulatory information. This means, in particular, shifting the center of gravity of the incentive system from encouraging the adoption of stressful plans to encouraging the integrity of the presentation of regulatory information. Related issues of building incentive and control mechanisms are covered in [3, 5]. Note that a properly organized system for collecting and aggregating regulatory information simultaneously solves the issue of creating the necessary reserves of resources at various levels of management. Without such reserves, no plan, even the most ideal one, can be successfully implemented.

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