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System Development of Estimated Figures of Volume Production Plan

Maksim A. Brazhnikov[a], Irina V. Khorina[a], Yulia I. Minina[a], Lyudmila V. Kolyasnikova[b] and Aleksey V. Streltsov[c]

[a]Samara State Technical University, Samara, RUSSIA; [b]Russian State Vocational Pedagogical University, Ekaterinburg, RUSSIA; [c]Samara State University of Economics, Samara, RUSSIA

ABSTRACT

The relevance of this problem is primarily determined by a necessity of improving production efficiency in conditions of innovative development of the economy and implementation of Import Substitution Program. The purpose of the article is development of set of criteria and procedures for the comparative assessment of alternative volume production plans and choice of optimum alternative. The leading method of the study of the problem is economic-mathematical modeling, providing the variability of volume plan development on the basis of different factors and variables, which reflect actual operating standards of a particular study subject. The results of the study: In the article, economic-mathematical model for development of aggregate production plan was presented, on the basis of which alternatives was produced, estimated figures, characterizing efficiency of derived alternatives, were justified, the key factors, which determine a specific set of variables and constraints, were considered. The article materials can be useful for experts, which are specialized in planning of production and distribution of the production program in choosing optimum alternative of aggregate production plan.

KEYWORDS
Aggregate planning, smooth production flow, estimated figures, economic and mathematical model

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Introduction

Volume planning within the hierarchy of production plans of enterprise is intermediate between main production strategy development and production scheduling. The main problems connected with aggregate plan development are

CORRESPONDENCE Maksim A. Brazhnikov ✉ max.brh@yandex.ru

dealing with production output optimization, providing compliance between production capacity and market demand level, effective using of working hours. In the most general meaning, volume plan provides the conversion of annual (or quarterly) current plans in more detailed production plans, specifying volume of production output, and based on the checking out compliance with the existing enterprise resources.

Theoretical basics of volume production planning in the national literature and practice were laid by K.G Tatevosov (1985). Aggregate planning issues have been further developed in the works of authors, among which the most promising, in our opinion, are the results of scientific researches of R.I Kurlyandchik (1989), V.V Tsarev (2002) and P. Aláč (2015). Noticing the authors' considerable contribution in solution of the problem, it should be noted that the issues of providing compliance between production capacity and market demand level require further development of theoretical basics, as well as application aspects. Thus, the methods and techniques for solution of volume planning problems, proposed in the monograph (Kurlyandchik, 1989), have not lost their relevance in market economy, but unfortunately, they are increasingly aimed at solution the problem of distribution of existing production program of schedule date. There is no doubt, that a presented variety of economic and mathematical models (Tsarev, 2002), which deserve attention, was reduced to development of production program based on various criterion of estimation.

Key purpose of any industrial enterprise is the most effectively meet the needs of target market, which means promptitude of product delivery in required volume with appropriate quality level based on rational use of resources. In its turn, it leads to the problem solution of clear proportions compliance between market demand level and using of production capacities. The process of achievement such an optimal combination has rather controversial character (Brazhnikov, 2007). At least due to the fact that the result of predictable market demand level can only be expressed in probabilistic assessments, and flexibility of enterprise production capacity is limited by configuration and structure of installed equipment.

The basis of allocation of development process of volume plans from the general planning system is based on a hierarchy of sequential managerial decision making for development of enterprise production capacity. The advantage of sequential hierarchical planning consists in decentralization of decision-making process. Each level of plan development uses smaller volume (in comparison with full database of production plan development system) of source data and has a simple structure.

Development of such a detailed schedule for providing problem solution of production capacity compliance rests on the impassable barrier - market demand structure. In conditions of multiply of stock items planning process causes serious contradictions.

Nowadays, the overwhelming majority of enterprises, which are concerned about decision of problem of production program distribution, make process of plan volume development , by giving the intuition behind, its own "past experience", by attempts and mistakes. W. Stevenson (1998), sharing the view of many practitioners, rightly points out that mathematical approaches have not received proper spread due to different reasons

The first is complexity of the mathematical rationale and calculation, as well as a high difficulty in preparation of source information. For example, in one method called "linear solution rule" - it is development of production cost function.

Secondly, due to a number of economic assumptions, which make mathematical model not quite realistic. The main constraints of linear programming is the necessity in providing linear relationship between different variables, as well as presence of one criterion for solving the problem, but in practice, an enterprise pursues several goals at once

The third is that some methods lead to solutions, which are not feasible in practical conditions. It refers to simulation modeling methods, which consider manufacturing enterprise as a close, rather than an open system.

The main problem, which limits the spread of the presented methods, is "closeness" of algorithm for solving the problem due to mathematical complexity (Kozlowsky, Markina & Makarov, 1998). The manager usually seeks to understand how and why models work, and in what decision-making algorithm is concluded. It allows to justify their choice in favor of one or another alternative solution more accurate. At the same time, when process of decision-making is confidential, a manager does not feel himself belonging to the established alternative, moreover he cannot explain why we should take the proposed (by a model) version of a plan as a basis.

By the reason of such "distrust" to mathematical methods and models, many managers use an intuitive approach for development of aggregate production plan for choice of appropriate managerial decision.

It is the most convenient approach, which can be used by a manager, which is responsible for volume plan development. Due to the fact, that this method is based on experience and intuition, so it allows to take into account a lot of different (and often controversial) factors in development process. In quantitative methods (mathematical models) a part of factors is ignored in order to simplify a situation. At the same time, result validity of such an approach usually is in doubt. Certain company services mostly project their own interests. Understanding the difference in purposes, we can say with confidence that production plan, based on intuitive approach, would be largely subjective and not optimal.

A key problem of volume planning lies not only in development of "transparent" algorithm for production scheduling, but also in justifying choice of "unique correct one" alternative. Choice of estimated criteria should be based on achievement of purposes of operating strategy.

Methods

Research methods

The main method of the study is economic and mathematical modeling. Defining methods allow to select specific conditions for functioning of production system, which are reflected in the form of variables and constraints of volume plan development model.

Methods of statistical data manipulation and methods of vector optimization provide comparative analysis in order to choose optimum

alternative of distribution of production program with the help of segments of planning period, based on the system of variables and constraints.

Experimental study facilities

The objects of the study are particular producing departments of the leading machine-building enterprises in the Samara region - JSC "VOLGABURMASH", JSC "Aviaagregat", JSC "Gidroavtomatika". The study results of specificity of production program development and operation mode of producing departments may be represented as a game (simplified) model of aggregation plan development.

The source data for volume production plan development is characterized by a particular set of estimated figures. First of all, it comes to choice of plan period and time interval, within which it will be economically advantageous and functional to perform volumetric calculations of production capacity using.

The level of market demand and production capacity of enterprise determines the source data, indicating degree of required balance between assessment of market demand and nominal production capacity. This group consists of: sales aggregate forecast and forecast by individual stock items, volume of production-possibility per time unit, stocks of finished products and general scheme of stock reservation.

Analysis of resource endowment in each interval of plan period requires an assessment of original situation of production (labor time reserve, amount of working assets), and recommendations for empowerment of production system (organization of overtime work and placement of order on the side).

Stages of the study

The study was carried out in three stages:

- In the first stage, an economic-mathematical model of volume production plan, which takes into account specific characteristics of functioning of machine-building production.

- In the second stage, on the basis of change in the specific values of certain variables, as well as constraints (working time fund, level of production reserves, staff number) alternatives of volume production plans were received.

-In the third stage, there was comparative assessment of alternative production plans, in order to choose the best one, based on figures of production costs, compliance of production volumes with level of market demand and stability of working capital tie-up.

Results and Discussions

Model formalization

A formalized representation of aggregate planning problems can be expressed as the following economic-mathematical model.

Value of expected (predictable) market demand (Y) for each particular period of time (t) of complete planning horizon (T) determines level of volume of output (Q).

It is required to set a level of tangible assets (Z) and total working time fund (F) of industrial staff (P), as well as value of other factors in such a way to

provide minimum of working capital tie-up (S) in the form of work-in-process inventory throughout planning horizon t = 1, 2 … T.

Factors of aggregate planning

Organization can take into account a wide range of external and internal factors in process of aggregate planning (Chase, Evilayn & Jacobs, 2001).

External factors include:

– Nature of economic situation in industry - market volume, development dynamics, customer requirements, degree of government regulation;

– Strategy and tactics of its leading competitors (central ring) - cooperation degree, sales volumes distribution, market share, long-range goals

– Level and nature of market demand - degree of irregularity (distribution dynamic) by length of planning period, absolute value;

– Availability of production primary components – raw materials and supplies, completing items and intermediate goods

– External production capacity - possibility of part order placement on the side, including external production staff (labor market).

Internal factors - «5P» production system of enterprise: Staff (*people*), production departments (*plants*), subjects of labor (*parts*), processes (*process*), operational planning system and production management system (*planning and control systems*).

Some of these factors will be beyond the decision-makers competence, so these factors can be taken into account as constraints. For example, external factor - strategies and productive capabilities of competitors form constraint by level of demand within the frameworks of appropriate market share of enterprise. Or internal factor - production capacity constraints: configuration and degree of equipment utilization throughout planning horizon remains practically unchanged, despite the fluctuations of market demand. For this reason, value of enterprise production capacity can be considered as a stable internal factor.

Factors within the competence of aggregate plan developers can be divided into two groups:

1. Demand factors: differentiated pricing; strategy for market promotion of products; order reservation; extra demand making.

2. Supply factors: working-time fund change; staff number; inventory management; volume of cooperation-based supplies.

Development of volume production plan

Development of volume preliminary production plan with the help of segments of planning period, taking into account current need satisfaction in finished products and reserve stocks creation are presented in Table 1.

Table 1. Release program generation, ths. units.

Planned indicator	planning period						Totals
	1	2	3	4	5	6	
Predictable level of demand	1 820	1 540	1 120	880	1 048	1 592	8 000

Production stocks at the beginning of period	398	455	385	280	220	262	
Working days	22	19	21	21	22	20	125
Buffer stock	455	385	280	220	262	398	
Production output	1 877	1 470	1 015	820	1 090	1 728	8 000
Production stocks at the end of period	455	385	280	220	262	398	

Necessary (required) production output is determined from the following relationship of base values:

$$Q_t = D_t + Z_t^{\text{p}} - Z_t^{\text{н}}, \quad (1)$$

Q_t – production output in planning and accounting period (t), units;

D_t – value of market demand in planning and accounting period (t), units;

Z_t^{p} – buffer stock, units;

$Z_t^{\text{н}}$ – finished product stock at the beginning of the month, units.

Value of buffer stock is defined as:

$$Z_t^{\text{p}} = d_z D_t / 100, \quad (2)$$

d_z – share of finished product buffer stock,%;

Volume (stock) of finished products at the end of planning and accounting period:

$$Z_t^{\text{к}} = Z_t^{\text{н}} + Q_t - D_t = Z_t^{\text{p}}. \quad (3)$$

In order to simplify analysis processes, calculation and comparison only those costs, which will vary depending on a particular volume plan variant are performed. Using this assumption, it's possible to eliminated material costs from calculations. With the same purpose, it's possible not to perform calculation related to maintenance of the equipment stock, administrative costs, etc.

Necessary number of workers (staff) for the program is calculated by the formula:

$$P_t = Q_t t_j / n t_{\text{см}}, \quad (4)$$

Q_t – production output, unit;

t_j – labor input per unit of production (j), hour;

n – a number of working days (working shift) in planning and accounting period;

$t_{\text{см}}$ – duration of working shift, hour.

This product $(Q_t t_j)$ is labour input of release (T_t) in planning and accounting period (t): $T_t = Q_t t_j$.

Four alternative aggregate plans were developed, based on combination of variables - production workers staff, working-time fund, possibilities for co-operation and inventory management (Table 2.).

Each alternative is characterized by a specific set of indicators. Value of production output volume characterizes production quantitative proportions in part of each segment of planning period. Cost parameters, which include remuneration of staff labor, costs of carrying inventory, staff rotation costs, stock-out costs, costs of cooperation-based supplies, reflect level of production costs.

Table 2. Alternative Plan

Planned indicator	Planning period						Totals
	1	2	3	4	5	6	
Plan №1							
Production output, units	1 877	1 470	1 015	820	1 090	1 728	8 000
costs of carrying inventory, ths.,rur..	1 280	1 260	998	750	723	990	6 000
staff rotation costs, ths.,rur.	2600	2000	7200	2400	1400	4600	20200
remuneration of staff labor ths.,rur..	37540	29400	20300	16400	21800	34560	160000
Plan №2			n				
Production output, unit	1 562	1 350	1 358	1 243	1 302	1 184	8 000
shortage cost, ths.,rur.	4 689	6 492	1 344	0	0	0	12 525
costs of carrying inventory, ths.,rur..	814	142	214	1 116	2 042	1 812	6 140
remuneration of staff labor, ths.,rur..	26 048	22 496	24 864	24 864	26 048	23 680	148 000
overtime pay, ths.,rur..	7 800	6 750	3 450	0	0	0	18 000
Plan №3							
Production output, unit	1 408	1 216	1 344	1 344	1 408	1 280	8 000
Shortage cost, ths.,rur..	7 035	10 845	5 910	0	0	0	23 790
costs of carrying inventory, ths.,rur.	597	0	0	525	1 590	1 662	4 374
remuneration of staff labor ths.,rur..	28 160	24 320	26 880	26 880	28 160	25 600	160 000
Plan №4							

Production output, unit	1 877	1 470	1 142	1 142	1 197	1 171	8 000
costs of carrying inventory, ths.,rur..	1 280	1 260	998	941	1 398	1 825	7 701
Cooperation costs, , ths.,rur...	24 487	15 710	0	0	0	3 002	43 200
remuneration of staff labor ths.,rur..	23 936	20 672	22 848	22 848	23 936	21 760	136 000

Comparative analysis

Comparative assessment of alternatives is made on the basis of analysis of indicators of production cost value, degree of compliance of production volumes and level of demand and stability of working capital.

Traditional indicator in assessment criteria development is value of total production costs (Table 3).

Table 3. Costs of production, ths,. rur.

cost items	alternative plan			
	№1	№2	№3	№4
staff rotation costs	20200			
overtime pay		18 000		
costs of carrying inventory	6 000	6 140	4 374	7 701
Shortage cost		12 525	23 790	
Costs of cooperative deliveries				43 200
remuneration of staff labor	160000	148 000	160 000	136 000
combined costs (class)	186200 (2)	184665 (1)	188164 (4)	186901 (3)

Assessing criterion of least costs, at first glance, it is possible to make an unequivocal conclusion, that in such conditions, alternative №2 is an obvious leader. However, differences are insignificant: deviation between the maximum and the minimum costs value is not more than 2%. Therefore, primary conclusion should be adjusted: additional criteria of assessment are necessary.

Analyzing the value of absolute deviations of production volume from market demand level (tab. 4), we can say that alternative №1 is on the first place. Its "advantage" over alternative №4, which is on the second position, more convincingly, than in previous case, when total cost indicator was estimated, - more than 50%.

However, using this criterion, you can notice some contradictions. If company tries to provide the greatest degree of customer satisfaction, so "fight" for choice of alternatives will be between two options: №1 and №4.

Table 4. Compliance of production volume to level of demand (by progressive total), ths. units

Planned indicator	Planning period	Average absolute

	1	2	3	4	5	6	deviation (class)
cumulative level of demand	1 820	3 360	4 480	5 360	6 408	8 000	
Plan №1: Production output	1 877	3 347	4 362	5 182	6 272	8 000	
absolute deviation	57	-13	-118	-178	-136	0	84 (1)
Plan№2: production volume	1 562	2 912	4 270	5 514	6 816	8 000	
absolute deviation	-258	-448	-210	154	408	0	246 (3)
Plan №3: Production output	1 408	2 624	3 968	5 312	6 720	8 000	
absolute deviation	-412	-736	-512	-48	312	0	337 (4)
Plan №4: Production output	1 877	3 347	4 489	5 632	6 829	8 000	
absolute deviation	57	-13	9	272	421	0	129 (2)

In favor of the first option, as already mentioned above - the lowest values of deviations from value of market demand. But Plan №4 provides a "fore-run" of demand, as if it anticipates tendency development, while Plan №1 is «late». The rest of alternatives admit availability of shortage of products, as well as high deviation of production outputs from market demand.

The third option, on the basis of its values the comparative analysis was made, - value of working capital (table 5.) Assessing stability of working capital tie-up, it's possible to give a preference to alternative №3.

Table 5. Stability of working capital tie-up, ths. rur.

Planned indicator	Planning period						Average absolute deviation (class)
	1	2	3	4	5	6	
Plan №1: common costs	41 420	32 660	28 498	19 550	23 923	40 150	
absolute deviation*	33	5	-8	-37	-23	29	23 (3)
Plan №2: common costs	39 351	35 880	29 872	25 980	28 090	25 492	
absolute deviation *	27	16	-4	-16	-9	-18	15 (2)
Plan №3: common costs	35 792	35 165	32 790	27 405	29 750	27 262	
absolute deviation *	15	13	6	-12	-4	-12	10 (1)
Plan №4: common costs	49 703	37 642	23 846	23 789	25 334	26 587	
absolute deviation *	60	21	-23	-23	-18	-14	27 (4)
* Value of absolute deviations is calculated from average value							

Such a simplified analysis of the alternatives is evidence of diversity of possible choice of solutions.

In order to choose preferred variant, it's possible to use ranking methods, as well as methods of vector optimization on the basis of normalized values of the studied parameters (tab. 6).

Table 6. Methods of vector optimization

Cost items	Alternative plan			
	№1	№2	№3	№4
F1	186200	184665	188164	186901
F2	84	246	337	129
F3	23	15	10	27
Method of grouping criteria – ranking				
F1	2	1	4	3
F2	1	3	4	2
F3	3	2	1	4
Place-sum criterion	6	6	9	9
Method of grouping criteria - averaging normalization				
F1	1	0,99	1,01	1
F2	0,42	1,24	1,69	0,65
F3	1,21	0,8	0,56	1,43
Principle of uniform optimality	2,63	3,03	3,26	3,08
The principle of equitable compromise	0,51	0,98	0,95	0,93

Note. Criterion F1 reflects value of total production costs connected with implementation of the plan. Criterion F2 is assessment of correlation of production output and level of market demand, based on average values of absolute deviations. Criterion F3 is stability of working capital tie-up in goods-in-process-inventory.

Within the framework of discussion, it should be highlighted some problems in dealing with problem of volume production planning.

First of all, problem of uncertainty of market demand. The greatest influence on nature of operating strategy has unevenness of market demand, which leads to development of serious negative tendencies: increase of dependence of annual sale volumes on external factors, risk of working capital freezing, violation of financial flow proportionality, growth of production cost, arrhythmia of capacity utilization and industrial staff. Primarily, their influence affects on development of volume plan - shortage (overabundance) of production capacities, increase of manufacturing lead time, diversion of priorities in production schedule fuzzification, loss of efficiency in stock management, violation of production technology and unsatisfactory operating factor (Turovets, 2002).

The second is a problem of forecasting activity. Sale forecast making, regarding to tendency of demand development, connected with problem of choice of appropriate forecasting method, which will allow to provide getting sufficiently accurate results (Gellovey, 2002). It's important to make forecast by each stock item separately (especially when products are essentially differ by manufacturing and marketing characteristics), with following aggregation of needs. Combination should be based on labor, in extreme cases, physical or value indicators. It will determine approximate boundaries in order to assess necessary (required) production capacity.

The third is problem of productive resource support (Brazhnikov, 2003). Choice of the main types of productive resources, which provide alternative in volume plan development , depend on operational strategy goal: effective working- time fund of the main production staff, production volume (output) per time unit, value of working capital , invested in goods-in-process-inventory, an effective equipment working-time fund, volume of cooperative deliveries, as well as storage areas, tools and supplies, finished goods inventory, throughput of certain types of equipment. It should be noted that only the first three positions of represented list of required resources should be used in development of volumetric plan on a rotating basis

The fourth is problem of industrial strategy development. From this position, problem of volume planning reduces itself to the following decisions (Gavrilov, 2002) – demand and supply management. From the standpoint of providing the smooth production flow, the most promising mechanism is demand management, because, first of all, it does not lead to sharp changes in production output and utilize resources, and secondly, to inventory overstock creation . At the same time, demand management strategy creates the most accurate "answer" in response to changing market needs. But in practical conditions of domestic enterprises management, control strategy system is weakly involved in demand. The imbalance between production outputs and value of market demand is met by creating necessary inventory stocks, as well as through co-operated deliveries and overtime working.

The fifth is cost estimation problem. A choice between combinations of plans is determined by relation of costs, connected with the change in the level of inventory stocks and costs, aimed at changing production capacity of enterprise, as well as structure of resources involved in production process.

Cost components, connected with changing in level of inventory stocks, should be divided into two groups. The first group includes cost of carrying inventory: amount of working capital, invested in inventory stocks, and interest payments on loans, insurance expenses of inventory stocks and taxation of capital fund, losses because of non-physical ageing and plundering, warehouse staff salaries and organization of protection, depreciation of capital assets. Cost items of this group are calculable and checkable, but determination of level of costs in the second group is a serious problem. The second group includes marginal costs of production shortage, which represent possible losses because of nonperformance of orders in conditions of market demand increasing : costs of production and order service, loss of goodwill, loss of opportunity (reduction of profit on sales because of nonperformance of an order). Marginal costs or losses that accompany appearance of product shortage, it is usually difficult to capture.

Although, it should be noted, that also stock-holding costs can be expressed by linear relation over a wide range, but still with a certain degree of conventions.

Costs, aimed at changing of level of production capacity, can also be divided into two groups. Main production costs, which include fixed and variable costs, required for manufacture of certain types of products during the period in question - it is direct and indirect labor costs for basic and overtime working The costs caused by a change in production rate – staff rotation (hiring and discharge) costs, change in the value of fixed assets, cost of works and services for cooperation. Costs of the first group can be accurately determined on the basis of balance sheet account or items of output cost determination; the second group of costs, reflecting efforts for changing the production rate, cause difficulties.

The sixth is problem of constraint system development. A particular constraint set will be substantially related to the choice of appropriate aggregate planning tactics. It should be noted, that reduction in a number of indicators is a simplification of a model, but abstracts it from actual prevailing conditions of functioning of production system. At the same time, the expansion of constraint set improves accuracy level and reliability of the result, but complicates procedure of method for solving aggregate planning problem. In this connection, there is a question about the desirability for using some indicators on the stage of volume of production planning. Constraint on composition of goods-in-process-inventory can be determined only with a certain approximation share, because of the process of solving the problem of volume time planning is distant from the beginning of production program delivery. Constraint of uniform load of the production equipment or production staff, in some cases(in conditions of wide variety of subjects of labor, particularly complicated design characteristics of production and significant production lead time) is significantly complicates solution of problem that does not increase the validity of the result.

Conclusion

Thus, aggregate planning allows granularity process of strategic plans into clear production categories - required staff structure, amount of inventory, level of production capacity.

It is necessary to answer these two questions during aggregate planning. First of all, how provide required level of production plan flexibility. Production planning system should have a very efficient mechanism for providing protection against uncertainty of market environment, which is primarily caused by fluctuation of market demand. Increase of flexibility can be achieved through development of alternative procurement source and improving situational production planning. Solution of the problem of increasing of flexibility can be directly related to the problem of minimizing of production costs

The second problem - is development of rules and decision-making procedures: development of priorities and system of estimated figures which will be used in schedule planning stage. Aggregated planning defines some framework concerning managerial decisions, forming a system of constraints for duration of target figure execution, delivery schedule of products, factory order volume, degree of plan tension and other factors. During current calendar planning, figures should be used as clear criteria for determining priorities of start-release target working tasks.

Choice of "only true" volume plan - is a question of the theory of decision-making in the framework of the implementation of lean production concept. The use of different estimates on the basis of vector (multicriteria) optimization, sensitivity analysis for changing in those or other planning factors will help shape the final choice of the choice positions.

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No potential conflict of interest was reported by the authors.

Notes on contributors

Maksim A. Brazhnikov is Associate professor of Samara State Technical University, Samara, Russia.

Irina V. Khorina is Associate professor of Samara State Technical University, Samara, Russia.

Yulia I. Minina is Associate professor of Samara State Technical University, Samara, Russia.

Lyudmila V. Kolyasnikova is Associate professor of Russian State Vocational Pedagogical University, Ekaterinburg, Russia.

Aleksey V. Streltsov Associate professor of Samara State University of Economics, Samara, Russia.

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