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Business Process Simulation with Algebra Event Regular Expression

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Abstract: The present study have shown that the model of a business-process can be presented in several equivalent ways: verbally at a substantial level, graphically as a oriented graph and analytically using regular expressions of events algebra. At business-processes management the common use of verbal, graphic and analytical forms of models is of interest. The new method, algorithm and computing procedure of business-processes management modeling is developed on the basis of production functions and regular expressions of events algebra which differ from known for more perfect graphic interface focused on the end user of the computer. The developed method, algorithm and computing procedure of operative business-processes management modeling are a part of mathematical supplying of the enterprise on monocrystals manufacture and have allowed to increase quality of made production essentially.

Key words: Business-processes modeling, business-processes management, conditions algebra, graph-schemas of algorithms, logic circuit of algorithm, expressions of events algebra

INTRODUCTION

Application of the traditional functional approach to production management does not allow to take into account intrasystem factors and displays of the environment, and received administrative decisions are late in time. The developed instrument of modeling is focused on re-structuring of business-processes which will considerably reduce expenses for manufacture, will raise the quality of manufactured production, will improve the use of a working capital and will increase the profit of the enterprise. The ultimate goal of business-processes management is the formation of sequence of managing influences, which organizes conducting processes according to the set of quality criteria.

The suggested process approach allows to get rid of inconsistency of functional processes and to increase the system's effectiveness of administrative decisions acceptance support.

PROBLEM FORMULATION

The urgency of the problem of business-processes modeling is to generate a sequence of managing influences, which will provide behavior of the system according to the set quality criteria. Starting creation of algorithm of production management, it is necessary to construct mathematical model of business-process in form of the basic and auxiliary components of process bringing the individual share in final cost of the manufactured product or service.

The analysis of the modern state of the researched problem testifies that two basic approaches now are applied at management: the traditional functional-hierarchical and perspective multistage process approach (Hammer and Champy, 1997). In the first approach business-processes are constructed with the principle of realization of concrete functions. In the second approach observed in the work, activity of the organization is considered as a chain of the interconnected actions penetrating manufacture from the input up to the output and directed on realization of the end product or service.

The purpose of research is development of a method, algorithm and computing procedure of business-process modeling which will raise the efficiency of various kinds of activities participating in business-process through coordination and matching of use of available business-resources.

SOLVE OF THE PROBLEM

The mathematical description of business-processes is oriented on carried out functions and hierarchy of industrial divisions. For the description of business-processes the device of mathematical linguistics, algebra

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of logic, the graph theory and theories of sets is used. Linguistic models approach to language verbal descriptions and are used at situational production management. Operational and regressive equations are applied to construction of balance models, production functions and forecasting of business-processes conditions.

The wide class of tasks of business-processes management is described by mathematical model in an operational form:

$$y = Ax,\ Y \in y \subset E_y,\ x \in x \subset E_x \quad (1)$$

where, A – the operator of system representing a set of mathematical actions, which are necessary to execute on the vector of n-dimensional entrance variable x to receive a vector of n-dimensional target variable y; X, Y - sets of elements $x_j, j = \overline{1,m}$ and $y_i, i = \overline{1,n}$ which belong to metric spaces E_x and E_y accordingly.

At business-processes forecasting models in form of production functions are frequently used

$$Y = \varnothing\,(\theta, x) \quad (2)$$

which display some allowable set of resource $x \subset E_x$ on the set of probable production outputs $y \subset E_y$.

There are various variants of approximation of expression (2), including with the help of the equation of multifactorial regression:

$$y = \theta_0 + \sum_{j=1}^{m}\theta_j x_j + \sum_{\substack{j=1\\ j<k}}^{m}\theta_{jk}x_j x_k + \sum_{j=1}^{m}\theta_{jj}x_j^2 + K \quad (3)$$

where y – the value of function of the response; x_j- factors forcing on the process; x_jx_k- effect of pair influence; θ_j - the factors (parameters) of regression reflecting influence of the factor x_j on the response function, calculated at exception of other factors;- θ_0 the free member describing average value of the response function at zero values of all factors; θ_{jk}- the factors of regression describing pair influence of factors x_j and x_k.

At research of production processes it is frequently required to take into account inertance of SMO, showing that the value of y_t of a parameter y at the moment of time t is to a certain extent predetermined by its values at the moments of time t - 1, t - 2..., t - k. Presence of inertance in change of technical and economic parameters results to the fact that the state of process in future becomes dependent from its state in the past and present and is described the equations of auto regression:

$$y_t = \sum_{j=1}^{k}\theta_j y_{t-j} + \varepsilon_t \quad (4)$$

where, θ_j - the factor of auto regression reflecting influence of value y_{t-j} on the variable y at the moment of time t; ϵ_t - value of measurements error.

Efficiency of modeling is determined on a set of quality parameters, such as stability, asymptotic speed of convergence, reliability on concrete means, accuracy of approximation. As criterion of approximation it is possible to use the minimum of middle-power norms of measurements error

$$f_p(\theta) = \sum_{i=1}^{n}\lambda_i \,\|\, y_i - \hat{y}_i \,\|^p = \sum_{i=1}^{n}\lambda_i \,|\, \varepsilon_i \,|^p \rightarrow \min \quad (5)$$

where, λ_j - adaptive weight factors; y_i - results of measurements; $\hat{y}_i$- the modeling values obtained using estimations $\theta_j, j = \overline{1,m}; \varepsilon_i = y_i - \hat{y}_i, i = \overline{1,n}$ - measurements errors, p -exponent on which value properties of estimations (unbiased ness, a solvency, efficiency, stability) depend.

The mathematical description of production functions of business - processes can be presented by various sorts of ratios - from the linear algebraic equations of the any order up to the recurrent ratios tying states of investigated object at various periods of time. Originally production functions are set in the multiplicate form, and then translated into the additive form. Each of forms of representation of production functions has advantages and disadvantages.

Production function (2) represents dependence of change of a productive parameter of made production volume y from cumulative change of several parameters-factors $x_1, x_2, \ldots, x_n$ and can be written down by a ratio:

$$y = f\,(x_1, x_2, \ldots, x_n) \quad (6)$$

where, y – productive parameter (volume of made production, the net profit); $x_1, x_2, \ldots, x_n$ - parameters-factors (capital investments, expenses of work and means of production, displays of the environment); y = f (•) ⁻ functional linear or nonlinear dependence concerning required parameters of model and results of observation.

Classical example of nonlinear production function is static production function of Cobb-Douglas in the form:

$$Q = A\,K^{\alpha}\,L^{\beta} \quad (7)$$

where, Q – result of manufacture; K – financial resources (capital); L - labor expenses (amount of working people); α and β – factors of elasticity of production function: α characterizes relative gain of production function on a unit of gain of financial resources at L = const, β characterizes relative gain of production on a unit of gain of labor expenses at K = const.

Dynamic dependence of manufactured production from the time is described by production function of Tin Bergen in the form:

$$Q = A K^{\alpha} L^{\beta} \exp(\lambda t) \quad (8)$$

where, exp (λt) – the dependence reflecting the time tendency, caused by scientific and technical progress; factors of elasticity α and β can be in some mutual relations and also can satisfy the condition of normalization $\alpha + \beta = 1$.

Having found the logarithm of the ratio (8), we receive expression:

$$\ln Q = \ln A + \alpha \ln K + \beta \ln L + \lambda t \quad (9)$$

from which after introduction of new variables we receive linear multifactorial model of production function:

$$y = \alpha_1 + \alpha_2 x_2 + \alpha_3 x_3 + \lambda t \quad (10)$$

where, $y = \ln Q$, $x_2 = \ln K$, $x_3 = \ln L$, $\alpha_1 = \ln A$, $\alpha_2 = \alpha$, $\alpha_3 = \beta$ – rates of increase of production manufacturing, financial resources both labour expenses and corresponding to them factors of elasticity.

If to neglect the change of productivity of the equipment after a time λt due to its ageing and to take into account casual revolting influences u, reflecting measurements and noise errors than the production function (10) will become:

$$y = \alpha_1 + \alpha_2 x_2 + \alpha_3 x_3 + u \quad (11)$$

where, α_1, α_2, α_3 – parameters of production function model.

For the sample consisting from m observations of the variable y and n - 1 explaining variables $x_2, \ldots, x_n$, at presence of indignation u the linear model of production function (11) can be written down as:

$$y_j = \alpha_1 + \alpha_2 x_{2j} + \ldots + \alpha_i x_{ij} + \ldots + \alpha_n x_{ni} + u \quad i = \overline{1,n},\ j = \overline{1,m}, \quad (12)$$

where, $y_j, x_{2j}, \ldots, x_{nj}$ - results of j-th observation; $\alpha_1, \alpha_2, \ldots, \alpha_i, \ldots, \alpha_n$ – required parameters of production function, which estimation are necessary to obtain as the result of observation; u - indignation with unknown parameters of distribution.

Set-theoretical business-processes modeling is based on use of the basic concepts of abstract algebraic systems, such as set, relation, algebra, structure and model (Friedl, 2000; Hop-Kroft *et al*., 1998).

The set further is meant as some entity considered as a single unit, consisting of objects of the arbitrary nature which are possessing some properties and being in certain relations among themselves and with elements of other sets. The mathematical description of set can be presented by a cortege:

$$M = \langle K, P, C \rangle \quad (13)$$

reflecting a quantitative measure of elements of set, properties of elements and relations among them and elements of other sets, where K - the quantitative characteristics determining the number of capacity of final set or cardinal number of infinite set; P - qualitative characteristics which are given to elements of set as the various properties set in some way, and including partial orderliness; C - operations on sets (relations among elements of initial set and other sets), playing the paramount role for formation of a various sort of algebraic structures.

The set X is considered to have been set if is known the way with which help concerning any element $x_1, x_2, \ldots, x_n$ it is possible to find out whether it belongs to the set or not. A set can be defined with the signature (the description of characteristic properties which elements of set possess), the list (enumeration of its elements), analytically (representation of elements by a formula) or by a predicate (by giving of a common determining property p(x) which should possess elements of set $X = \{x | P(x)\}$ where P(x) takes value "true" for elements of set).

The set

$$AC = (E: \varphi_1, \varphi_2, K, \varphi_m: R_1, R_2, K, Rn) \quad (14)$$

of the basic set $\{e_1, e_2, \ldots e_k\} \subseteq E$ of mathematical objects or objects of other nature, family of algebraic operations $\{\varphi_1, \varphi_2, \ldots \varphi_m\} \subseteq \Phi$ and family of relations or predicates $\{R_1, R_2, \ldots R_n\}$ among elements of basic set Å represents algebraic system. The family here is meant as set of objects of the same type continuously depending on parameters.

If the set of relations of algebraic system (14) is empty, i. e., $R = \varnothing$ such structure

$$A = (E: \varphi_1, \varphi_2, K, \varphi_m) \quad (15)$$

is a universal algebra. In this expression $\Sigma = (E: \varphi_1, \varphi_2, K, \varphi_m)^{-}$ the signature of algebra A, representing set of operations Φ determined on basic carrying set E; the ratio $\varphi: E^n \rightarrow E$ represents n-operation on set E which is provided with the internal law of a composition $\varphi: E^n \rightarrow E$; n – dimension of the vector of the signature Σ

operations arties which determines the type of algebra A.If the set of operations of algebraic system (14) is empty, i.e., $\Phi = \varnothing$ such structure

$$M = (E, R_1, R_2, ..., R_n) \quad (16)$$

is an abstract model. In this ratio $E = \{E_1, E_2, K, E_K\}$ – carrying set of the mathematical objects displaying elements of the system (universe): $\Sigma = \{R_1, R_2, K\ R_n\}$ – the signature of model M, representing a set of relations or predicates determining ties between elements on basic set E.

The carrying set of elements E and set of functions Φ carried out by them usually form several algebraic structures: set-theoretical structure in which mutual relations are set by operations; algebraic structure in which mutual relations can be set by regular expressions of logic events algebra; structure of the order, in which interrelation are set by relations of the order. Models of algebraic structures depend on the quantity of a priori set information in being structured sets.

Full model of algebraic structure

$$S = \{ E: \leq : \cup, \cap \} \quad (17)$$

represents set E with one binary relation of the partial order set on it such as « $\leq$ » no more and two binary operations such as « C » associations and « $\cap$ » crossings.

The truncated model of structure R for elements of a partly ordered set S determines a cortege

$$R = \{ S: \cup, \cap \} \quad (18)$$

containing elements of set S and usual set-theoretical operations of "association" of elements x and y, designated through $x \cup y$ and "crossings" of elements x and y, designated through $x \cap y$.

RESEARCH OF REGULAR EXPRESSIONS OF EVENTS ALGEBRA

which is maximal and endly-generated algebra containing all final events, i.e. the events consisting of final number of words. As additional operations in algebra of regular events operations of crossing and addition concerning which the class of regular events appears to be closed are used (Friedl, 2003; Hop-Kroft *et al*., 1998)

The mathematical device of algebra of events

$$A_{vnw} = < A_{op}, A_{co} > \quad (19)$$

is based on use of algebra of operators A_{op} and algebra of conditions A_{co} . Elements of algebra A_{op} are partial transformations (operators) Y_j of some abstract set B, determining activity of business-process and designating concrete acts of activity on transformation of entrance resources to a target product. Except for the basic operators Y_j , in algebra A_{op} two auxiliary operators exist: the identical operator Å and the empty operator Ø.

Elements of algebra A_{co} are partial predicates (all logic conditions) X_l which are determined on set B, accept values only $X_l = 1$ or $X_l = 0$ and are used for the description of discrete transformations. In this case the set B refers to as information set. Except for the basic conditions X_l , in algebra of conditions two auxiliary conditions exist: 1 – identical-true value and 0 – identical-false value.

The basic operation of algebra A_{op} is usual operation of multiplication (superposition) of operators. Except for this operation, for each condition β from B in algebra A_{op} two more operations are defined: β-disjunction and β -iteration of operators. Result of a β -disjunction $(P \vee Q)$ of operators P and Q is operator R such, that for any state $b \in B$ is fair the ratio at which bR = bP if the condition β is true on a condition b, bR = bQ if the condition β is false on a condition b, and at last, operator R is considered uncertain on a condition b if β (b) is not determined. Result of β-iterations {p} of the operator p is operator Q such, that for any condition $b \in B$ takes place $bQ = bp^n$ where n – the least from among m = 0, 1k such, that $\beta\ (bp^n)$ is true ($bp^n = b$ for any operator p).

On set B of algebra A_{co} conditions are determined usual Boolean operations of logic addition (disjunction), multiplication (conjunction) and denial which are distributed and to a case when values of conditions on some elements b of the set B are not determined. For example, the disjunction $\alpha \vee \beta$ of two conditions α and β is a new condition. This condition takes value 1, on those values of set B on which one of conditons α or β takes value 1. It takes value 0 on those values on which α and β are equal to 0, and it is not determined, if one of conditions α or β is not determined, and another is equal to 0, Except for these operations, operation $p\alpha$ of multiplicationof the operator on a condition is defined. The result of execution of this operation is the condition β which value is equal to value of a condition after execution of operator p.

If to fix in events algebra (19) the system of forming elements (elementary operators and elementary conditions) than it is possible to set the elements of the operators algebra and of the conditions algebra as the expressions made from these generative and operations of system of algebras. As is a convention such expressions are considered to be regular operational expressions and regular conditional expressions, and operators and the conditions working on set B which can be set in such a way, are considered to be regular operators and regular conditions.

The expression constructed from letters of the alphabet X (symbols of elementary events) and from symbols of operations of disjunction, multiplication and iteration with use in appropriate way parentheses, is considered to be regular expression of the alphabet X. Every regular expression R determines in some way event S (S is found out as a result of execution of all operations which are included in expression R). The events determined in such a way are considered to be regular events on the alphabet X.

In other words, regular events turn out from elementary events by application of final number of times of operations of disjunction, multiplication and iteration. If the alphabet $X= (x_1, x_2, x_3)$ consists of three letters x_1, x_2 and x_3 than regular expression $X = \{x_1 \vee x_2 \vee x3\}(x_1 \vee x_2)$ sets the regular event consisting of all words which begin with the letter and end with the letter x_1 or x_2. Only regular events take part in mathematical models of business-processes.

Representation of any operator from algebra A_{op} through the alphabet of this algebra containing all operators and conditions on set B of the capacity n, is regular expression of events algebra and is designated

$$R = (y_j, X_i, E, \varnothing, 1, 0) \tag{20}$$

and to conditional and linear operators of regular expressions correspond variables, sequences of operators – to operation of their production (concatenation), to in parallel connected branches – operation of disjunction of variables, to cycles – operation of iteration of variables; conditional operators are specified in brackets to distinguish them from linear operators.

WAYS OF REALIZATION OF REGULAR EXPRESSIONS OF EVENTS ALGEBRA.

The graph-schema of algorithm of management (GSA). The algorithm of management can be represented in the several invariant (equivalent) ways: verbally at a substantial level, graphically in form of an oriented graph and analytically by a regular expression of events algebra (Friedl, 2003 and Hope Kroft *et al*., 1998). At modeling of business-processes of manufacture management the common use of verbal, graphic and analytical forms of algorithm is of interest.

Graphic representation of algorithm is, that each of its stages is presented by a geometrical figure and all of them are tied with arrows which will show the sequence of carried out operations. Set of geometrical figures and tying arrows can be named the graph-schema of algorithm. To each top of GSA the operator is put in conformity. For a designation of the beginning and the end of GSA the initial operator and the final operator are introduced.

The initial operator Y_0 does not contain any entering arch, and one arch leaves it only. Into the final operator Y_k one or several arches can come, and leave it cannot any arch. Between initial Y_0 and final Y_k operators managing operators Y_j which form target managing signals, and logic operators X_i which realize logic conditions settle down. Tops of managing operators Y_k are represented by rectangles, and conditional operators X_i – by rhombuses.

The top of the managing operator can contain one or several inputs and only one output. The last speaks that after execution of this or that operation the management is transfers only one operation. Nevertheless, the logic top can have one or several inputs and only two outputs which are designated, as a rule, as 1 (yes or true) and 0 (no or false). The last is explained that after check of a logic condition X_i two outputs $X_j = 1$ or $X_j = 0$ are possible only.

The graph-schema of algorithm is made on the basis of the substantial description of operating conditions of the managing device. First on the graph-schema the initial top with the name "Begin" is represented. After it the first operational top with the name «Input of the numerical data» settles down. Then other tops of the graph-schema with managing and logic operators, and also all ties between them are represented. Last represents final top. If to write down in tops of a command at a substantial level we will get substantial GSA. If to proceed from substantial names of tops to symbolical designations we will get more compact symbolical GSA.

Representation of logic of business-processes management as a Graph-schemas of Algorithms (GSA) is convenient and evident only at the first stages of drawing up of the algorithm. By detailed consideration GSA occupies a lot of place and demands a significant amount of intermediate transformations before input into the computer. Therefore alongside with application of GSA, in practice other notations for the description of management logic are used also from which the logic circuit of algorithm and regular expressions of events algebra are most known.

The logic Circuit of Algorithm (LCA) representsL set of the managing and logic operators tied among themselves by a set of the interface arches, directed and numbered so that to realize a certain law of management. If the order of execution of managing operators in LCA is strictly fixed such algorithm is linear. If the order of execution of managing operaters depends on conelitins such alogrithun is ramified.

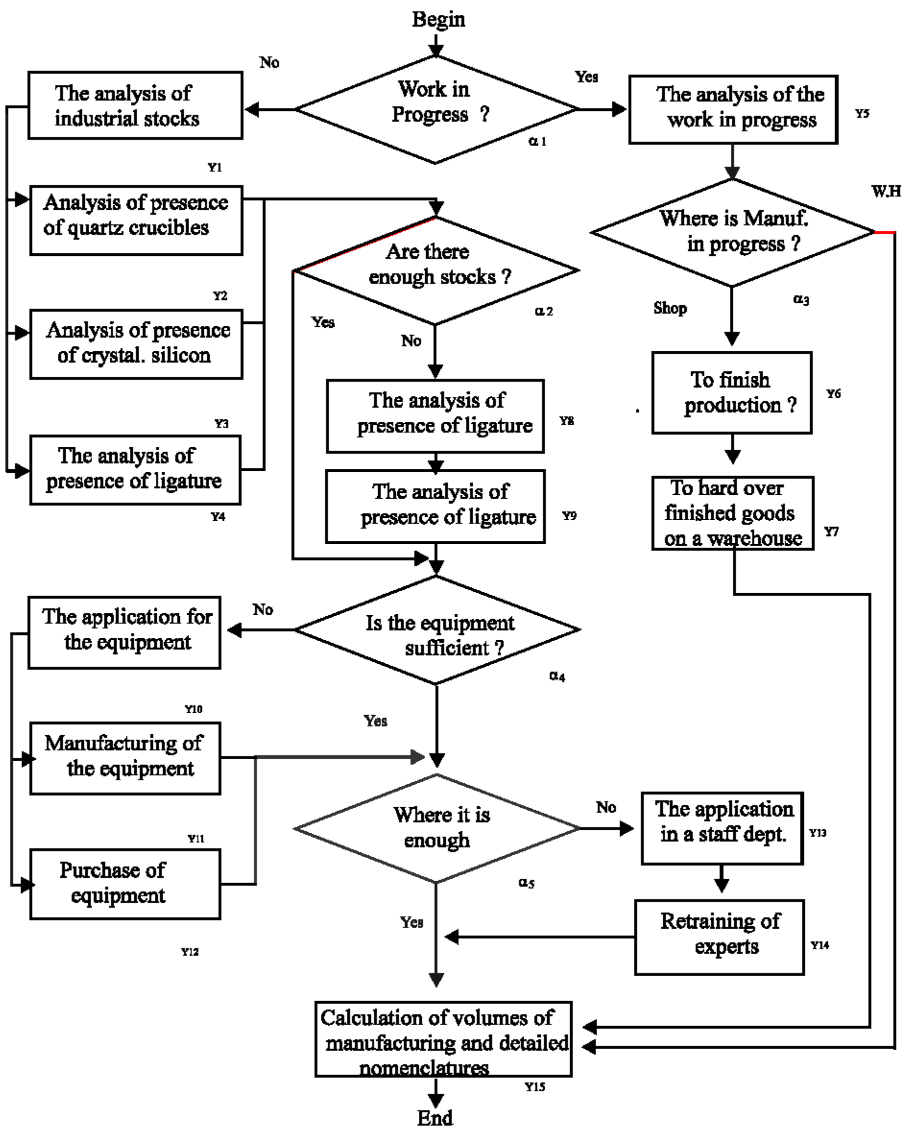

Fig. 1: The graph-scheme of algorithm of managing the formation of the monthly plan of silicon monocrystals manufacture business-process

If the order of Managing operators are designated by capital letters of the Latin alphabet (A, B, C, K) or the same capital letter with various indexes (Y_1, Y_2, Y_3, K, or Y1, i = 1, 2, 3, k). Logic operators are designated by small letters of the Latin (X_1, X_2, K, X_n or Greek (α_1, α_2, K, α_n) alphabet and can get only one of two values 1 or 0. Every i-th the logic condition α_i begins and comes to an end with a numbered arrow directed accordingly $^i\uparrow$ upwards and $\downarrow^i$ downwards, or numbered roun opening α_i(and a closed bracket) .

Arrow - upwards $^i\uparrow$ or the opening round bracket α_i(lays down directly to the right near a logic condition which is designated as α_1,x_1 or p_1. number of a condition staying directly near arrow-upwards or a round opening bracket shows the operator where management of algorithm should be transferred in case a logic condition. X_i= o. number of a condition staying near arrow-downwards or a round closing bracket, shows the operator where management should be transferred. This operator stands directly after arrow-downwards or round closing bracket. If x_i= 1, after logic conditions the managing or logic operator staying directly to the right is carried out.

Work of algorithm begins with execution of the most left operator LCA and then the operator following on the right is determined. If this operator is managing than its execution is carried out. In case this operator is logic two variants are possible: 1) when the logic condition is equal to one, the following operator staying to the right is carried out; 2) when the logic condition is equal to zero, is carried out the operator on which shows arrow-upwards, located after that condition.

Among logic operators there can be a unconditional operator ω which does not demand check of a logic condition. Such operator transfers the execution of operation to other operator which number i is specified at arrow-upwards $^{i}\uparrow$ or at an opening bracket $\alpha_i($.

The order of execution of operators in LCA is defined by sequence of their accommodation in expression (20), and also by the distribution of the numbered arrows and brackets included in them. Work of LCA comes to an end, when last from carried out operators contains the indication of a stop of algorithm or when at some stage of work the operator who should be carried out is not found out.

Below are resulted mathematical models of business-process of formation of a monthly plan of silicon monocrystals manufacture in a class of regular expressions of events algebra which are submitted as the graph-schema of algorithm resulted in Fig. 1 and logic circuit of algorithm of the computing process, having the following form:

$$R = {}_{\alpha 1}(Y_1 \cdot [Y_2 \wedge Y_3 \wedge Y_4] \cdot {}_{\alpha 2}(Y_8 \cdot Y_9 \vee e)^{\alpha 2} \cdot {}_{\alpha 4}(Y_{10} \cdot [Y_{11} \wedge Y_{12}] \vee$$

$$\vee_{\alpha 5} \{Y_{13} \cdot Y_{14} \vee e\}^{\alpha 5})^{\alpha 4} \vee Y_5 \cdot_{\alpha 3} (Y_6 \cdot Y_7 \vee e)^{\alpha 3})^{\alpha 1} \cdot Y_{15},$$

where, Y1– the operator of the analysis of industrial stocks; Y2 – the operator of the account of presence quartz crucibles; Y3 – the operator of the account of polycrystalline silicon presence; Y4 – the operator of the account of ligature presence; Y5 the operator of the account of presence of not finished manufacturing rests; Y6– the operator of end of manufacture; Y7 – the operator of delivery of finished goods on a warehouse; Y8 – the operator of drawing up of the application in a department of MTM; Y9 – the operator of purchase of materials; Y10 – the operator of drawing up of the application for the equipment; Y11 – the operator of manufacturing of the equipment; Y12 – the operator of purchase of the equipment; Y13 – the operator of the application in a staff department; Y14 – the operator of a professional training; Y15 – the operator of volumes of manufacture and the nomenclature calculation;α1 – the operator of check of the work in progress level;α2 – the operator of materials enough check; α3 – the operator of the work in progress check; α4 – the operator of enough equipment check; α5 – the operator of enough manpower check.

RESULTS

The executed researches have shown, that the model of a business-process can be presented in several equivalent ways: verbally at a substantial level, graphically as a oriented graph and analytically using regular expressions of events algebra. At business-processes management the common use of verbal, graphic and analytical forms of models is of interest.

Scientific novelty: The new method, algorithm and computing procedure of business-processes management modeling is developed on the basis of production functions and regular expressions of events algebra which differ from known for more perfect graphic interface focused on the end user of the computer.

The practical importance: The developed method, algorithm and computing procedure of operative business-processes management modeling are a part of mathematical supplying of the enterprise on monocrystals manufacture and have allowed to increase quality of made production essentially.

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