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Measurability and feasibility of work in the management of an industrial enterprise in a flexible production environment

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Abstract: The issues of measurability and evaluation of work and various services, the feasibility of orders in production systems have been studied by many authors. Here we consider the development of these methods for organizing the management of manufacturing enterprises in the context of the transition to flexible production. The necessary and sufficient conditions for the feasibility of the work are formulated. Examples of providing car rental at specified time intervals and evaluating the feasibility of requests for equipment repair in a service center in the structure of a machine-building enterprise are considered.

Keywords: work, measurability and feasibility, industrial, enterprise, management, flexible production environment.

1. INTRODUCTION

The concept and definition of work produced by a certain force on a path and de-fined as the multiplication of this force by a path is well known and widely used in physics and mechanics.

In the process of production, economic and scientific activities, enterprises very often have to perform various works and provide services. There is a need for evaluation, measurement and mathematical modeling of labor and the work done with it. Here quite real physical and intellectual energy is expended. Unfortunately, there is no way to directly "measure" both the acting force and the path traveled by this force. The solution to this problem has recently become even more relevant due to the widespread introduction of artificial intelligence and automation methods in production processes. In production ecosystems, the development and improvement of methods for assessing the contribution of various physical works and intellectual services to the profit received through the sale of a certain product (herein-after: "measurements") become important scientific and systemic problems. For ex-ample, an automobile corporation accepts and fulfills orders for the manufacture of various cars. Orders are received continuously or in batches of various sizes, with deadlines that are also different. Given the uncertainty in the supply of components and the impact of factors such as a pandemic on the organization of the production process, the task of completing the production program on time and in full be-comes, in fact, key one.

It is well known that making a profit is the ultimate goal of any business activity. It would seem that the effectiveness of the activities and functioning of the enterprise, each of its sections, departments and people should be evaluated by their influence and share of the contribution to the profits of the enterprise. Unfortunately, this is not always feasible. It is difficult to predict not only the profit share of each participant, but even the profit of the enterprise as a whole (Bakhtadze et al., 2021a). The price of a commodity is finally determined when it is sold, and the profit is determined when summing up the results of economic activity, i.e. much later after production.

The issues of "measurement" and evaluation of work and various services, the feasibility of orders have been studied by many authors (Amirkhanov et al., 1995; Knollmanna et al., 2014). Here we consider the generalization and further development of these methods for organizing the management of manufacturing enterprises in the context of the transition to flexible production.

2. MEASUREMENT AND EVALUATION OF WORKS AND SERVICES IN ORGANIZATIONAL AND PRODUCTION SYSTEMS

2.1 Work measurement

First of all, it should be noted that for any measurement of various works and services, there must be their repeated repetition and the possibility of comparison. It is difficult to measure, for example, new ideas, fundamental scientific research. They are exclusively individual. Therefore, it is very difficult to compare them with each other or with anything. Such works and services are excluded from our consideration. Only more or less repeatable services and works are considered, for which it is possible to introduce units of measurement.

Any activity, work or service is measured, in particular, by the volume and duration of performance. To do this, it is necessary

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to ration human labor and work, as has often been done for quite a long time (Kiran, 2020). But this must be done dynamically consistently and completely. The volume of work will be denoted by r, and its duration by τ.

Note that when measuring, it is very important to describe the work in terms of the technology of its implementation, which allows you to divide the work into parts or elements that can be "measured". At the same time, the necessary specialists, equipment, areas (fixed assets), materials, energy (circulating assets), etc., necessary to achieve the goals set are listed (Sirazetdinov T.K., 1996). All of these quantities are measurable.

2.2 Measuring the amount of work

The amount of work performed in the production of any product is estimated (that is, “measured”), including the number of products produced, the type and number of technological operations, or fixed and working capital. The unit of measure for the number of products can be any physical unit: meter, kg, piece, etc., depending on how the product or operation is measured. Any operation and the entire production cycle take a certain required period of time.

Intellectual activity is described by its specific technology, uses some fixed assets, for example, computers, space, as well as working capital - energy, materials, financial costs, etc. Personnel and specialists act as fixed assets when they are assessed by quantity, level qualifications and as working capital when assessed by labor input. These quantities are also more or less quantifiable and measurable.

For example, the work of enterprises developing software can be evaluated, that is, "measured" by the number of programs: a unit of work performed can be taken to set up one standard software package of a certain cost and complexity in the enterprise. And the assessment of another software package can be made, for example, on the basis of a comparative analysis and the possibilities of using the developments available at the enterprise.

The accounting department is engaged in the preparation of reports on the activities of the enterprise, the issuance of wages, monitors the inflow and outflow of funds, etc. If the organization is large, then the accounting department of such an enterprise is divided into departments and subdivisions. In such cases, in order to assess the performance and workload of individual accounting employees, it is desirable to measure and evaluate the volume of all work and the work of each department. It may well turn out that some departments simply duplicate each other's work, and perhaps they need to be somehow combined or their responsibilities re-distributed. All this requires research and analysis. For example, in this case, re-porting on extra-budgetary funds can be taken as a unit of work, and other reporting can be measured in shares of this one. The unit of measurement will be the volume of work on extrabudgetary reporting.

3. AXIOMATIC DEFINITION OF WORK AND POWER.

The amount of work r is some non-negative scalar quantity that has two properties:

1. Additivity. Two volumes of the same type of work r_1 and r_2 are added: $r_1 + r_2$;

2. Uniformity. The amount of work r is multiplied by the number: αr (α - number) and when performing these two operations, we again get the amount of some work.

That is, the estimation of the amount of work is a linear operation.

Elementary work (EW) is described by the amount of work r, and the time interval $[t, t+\tau)$, where t is the beginning of the work and τ is the time interval during which this work must be performed. Denote EW by R, it is described by the triple $R = (r, t, \tau)$. Works of a general type are compiled from the EW.

To measure the volume of work carried out in systems, a unit volume of this type of work is introduced per unit of time, or for some time, so that by unifying it is possible to compare and measure the volume or quantity of similar work.

Let the intervals $[t_i, t_i + \tau_i)$, where $i = 1, 2, \dots, n$, be given arbitrarily on the time axis and the amount of work to be done in these intervals, respectively. Here the number n can take any integer finite value. In these intervals elementary works $R_i = (r_i, t_i, \tau_i)$ are given. Then the set $R = \{R_i, i = 1, 2, \dots, I\}$, where $R_i = (r_i, t_i, \tau_i)$, is called the common work.

A production or organizational system has a certain ability to perform certain types of work or services. The ability or capacity of a system to do some work is called its power. Power, as well as work, is characterized by magnitude and time interval. The maximum amount of work that an organizational system can do is called its capacity.

Any work is performed in a certain time interval. Therefore, the ability to perform this or that work or the power of the system depends on the time interval. (Sirazetdinov R.T., 1998). Therefore, the concept of power in the interval (interval power or t, τ - power) is introduced.

Let m be the power value, i.e. the maximum amount of work that the system can perform during a given interval. Then t, τ – power or power on the interval $[t, t+\tau)$ will be represented by a triple $M = (m, t, \tau)$. In particular, the interval τ can be unit.

Axiom of work feasibility: elementary work $R = (r, t, \tau)$ is feasible with power $M = (m, t, \tau)$ if the condition $r \leq m$ is satisfied.

Let intervals $[t_i, t_i + \tau_i)$, where $i = 1, 2, \dots, I$ and powers $M_i = (m_i, t_i, \tau_i)$ be given. Then the set $M = \{M_i, i = 1, 2, \dots, I\}$ is called the total or aggregated power of the system. Power is the ability of a system to do some work.

4. THE TASK AND CONDITION OF THE FEASIBILITY OF THE OVERALL WORK

Let work $R = \{R_i, i = 1, 2, \dots, I\}$ be given, where $R_i = (r_i, t_i, \tau_i)$. Here the intervals $[t_i, t_i + \tau_i)$ for different values of indices i can intersect. If they do not intersect, then there are no problems with the implementation of the work plan. They are independent elementary works. If two intervals partially overlap, then in the common part the volumes of work are added up and for its feasibility, the power value must be no less than the sum of the volumes of work in this area. So several sections can intersect, and in an arbitrary way. To obtain the general conditions of feasibility, we introduce the moments of time as follows.

Select the set of points $\{t_i, t_i + \tau_i, i = 1, 2, \dots, I\}$and arrange them in ascending order, which we denote by $T_1 = t_1, T_2, T_3, \dots, T_J$ .The value of $T_j$can be equal to t_i or $t_i + \tau_i$. Let $t = t_1$ be the smallest value among all t_i, where $i = 1, 2, \dots, I$. If there are coinciding points among them, then we will take them as one point and denote them by one index. We keep the index j behind the points $T_j$and the index i behind the points $t_i, t_i + \tau_i$. Moreover, $j = 1, 2, \dots, J$, and $i = 1, 2, \dots, I$.

Consider now the intervals $[T_j, T_{j+1})$. Any interval $[t_i, t_i + \tau_i)$ contains at least one interval $[T_j, T_{j+1})$. Taking this into account, we keep the coefficients a_{ij} according to the conditions:

$$a_{ij} = 1 \; if \; [T_j, T_{j+1}) \subset [t_i, t_i + \tau_i)$$

$$a_{ij} = 0 \; if \; [T_j, T_{j+1}) \not\subset [t_i, t_i + \tau_i)$$

Coefficients a_{ij} allow us to write the amount of work r_i in the interval $[t_i, t_i + \tau_i)$ in the form

$$r_i = \sum_{j=1}^{J} a_{ij} r_{ij} \qquad (1)$$

In the maintenance problem, in the intervals $[t_i, t_i + \tau_i)$, the amount of work r_i, to be performed is specified. Formula (1) determines the amount of work in the user's task through its expansion into intervals $[T_j, T_{j+1})$.

The total amount of work to be done in the interval $[T_j, T_{j+1})$ is made up of the work in the intervals formed by the intersection of the interval $[T_j, T_{j+1})$ and all intervals $[t_i, t_i + \tau_i)$ formed when i runs through the values from *1* to *I*. Taking this into account, we write the sum of the volumes of all work that needs to be done in the interval $[T_j, T_{j+1})$ as

$$w_j = \sum_{i=1}^{I} a_{ij} r_{ij} \qquad (2)$$

The service system has a certain power, and in different intervals, different power. Let the power in the interval $[T_j, T_{j+1})$ be given and equal to m_j. Then the power of the serving system in this interval is written as $M_j = (m_j, T_j, T_{j+1} - T_j)$. The given jobs are performed if the amount of work w_j does not exceed the power m_j. Here w_j represents the required capacity and m_j represents the available capacity of the system. In this case, r_{ij} represent some positive quantities (volumes of work) that satisfy equalities (1).

Theorem. In order for the work $R = \{R_i, i = 1, 2, \dots, I\}$, where $R_i = (r_i, t_i, \tau_i)$, to be feasible by the serving system with capacities equal to $M_j = (m_j, T_j, T_{j+1} - T_j)$ it is necessary and sufficient that there exist such non-negative numbers: r_{ij} $(i = 1, 2, \dots, I; \; j = 1, 2, \dots, J)$, for which the following system of inequalities holds:

$$\sum_{j=1}^{J} a_{ij} r_{ij} \; \geq r_i \; (i = 1, 2, \dots, I), \qquad (3)$$

$$\sum_{i=1}^{I} a_{ij} r_{ij} \; \leq m_j \; (j = 1, 2, \dots, J), \qquad (4)$$

$$r_{ij} \geq 0 \; (i = 1, 2, \dots, I; \; j = 1, 2, \dots, J). \qquad (5)$$

Proof

Need. Let each amount of work r_i be feasible, i.e. the powers of M_j are sufficient to do the amount of work r_i . It is necessary to make sure that the fulfillment of conditions (3) - (5) is necessary, i.e. there are constant values $r_{ij} \geq 0$ satisfying inequalities (3) - (5). The meaning of the constant values r_{ij} is the amount of some elementary work in the interval $[T_j, T_{j+1})$. Therefore, there are some $r_{ij} \geq 0$ representing part of the scope of work r_i. Otherwise, the meaning of the amount of work is lost.

The sum of the volumes of work performed in the interval $[t_i, t_i + \tau_i)$ must not be less than or at least equal to r_i, i.e. fulfillment of inequality (3) is necessary. Otherwise, the amount of work r_i will not be executed. Thus, the fulfillment of inequalities (3) and (5) is necessary.

Now consider the set V of all non-negative numbers r_{ij} satisfying inequalities (3) and (5). Let's call them admissible set V of values r_{ij} .

The set V includes all possible variants of realizing the scope of work that are admissible by inequalities (3) and (5), i.e. volumes not less than r_i. The amount of power required to perform all the work r_i in the interval $[T_j, T_{j+1})$ is equal to w_j (2). It should not exceed the value of the available power M_j in this interval. If there are no values r_{ij} satisfying the inequalities $w_j \leq m_j$among the admissible set V, then the given amount of work is not feasible. We come to a contradiction. This means that there is not enough power to do work in at least one interval, for one index j. Thus, if the amount of work is feasible, then inequalities (4) are satisfied. Necessity of fulfillment of inequalities (3) - (5) is proved.

Adequacy. Let us assume that conditions (3) - (5) are satisfied, i.e. there are constants r_{ij} that satisfy these inequalities. It follows from (3) that work with volume r_i is decomposable into elementary tasks with volumes r_{ij} , and these volumes of work, on the one hand, are such that their sum over j for any fixed i is greater than or equal to the volume of work r_i, i.e. they cover the amount that needs to be done.

On the other hand, according to (4), these volumes r_{ij} are such that their sum over i for any fixed j, i.e. $\sum_{i=1}^{I} a_{ij} r_{ij} = w_j$ does not exceed the power m_j in the interval $[T_j, T_{j+1})$. This means that the power m_j of the system is such that it can perform the amount of work equal to r_i , and even exceeding this amount of work. At the same time, the fulfillment of inequalities (5) allows us to interpret the values of r_{ij} as the amount of work. Thus, the sufficiency of the fulfillment of inequalities (3) - (5) for the feasibility of a given work with the help of the available power has been proved.

Here we consider the problem of the feasibility of jobs of one type. There is also the problem of the feasibility of multitype jobs, when the volumes of jobs are not comparable with each other, which reduces to the problem of the feasibility of a set of jobs of the same type, if the capacities are independent (Sirazetdinov R.T., 2017). If the powers are connected by some limiting dependency, then the limiting dependency should be attached to the system (3-5) and the system should be considered together.

Example. Suppose a company needs to provide car rental at specified time intervals. Let us take one hour as a unit of time interval. The number of cars issued to customers indicates the amount of work that needs to be done. But the possibilities are limited by the amount of power, i.e. the maximum number of cars that can be issued per unit of time, which is equal to $m = 1/2$ (number of cars/hour). Suppose that, at the request of customers, for the time interval [0, 15) it is required to ensure the issuance of 5 cars, for [2, 28) - 4 cars, for [0, 40) - 5 cars, for [20, 20) - 3 cars.

The problem is reduced to solving the inequalities

$$\begin{array}{ll} i = 1 & r_{11} \geq 5, \\ i = 2 & r_{22} \geq 4, \\ i = 3 & r_{31} + r_{32} + r_{33} \geq 5, \\ i = 4 & r_{43} \geq 3, \\ j = 1 & r_{11} + r_{31} \leq 7{,}5, \\ j = 2 & r_{22} + r_{32} \leq 7{,}5, \\ j = 3 & r_{43} + r_{33} \leq 5. \end{array}$$

which need to be solved for r_{ij} to see if there are non-negative constants r_{ij} There are 7 inequalities and 6 unknowns r_{ij} . As is known, if a solution of inequalities exists, then it may not be unique. These conditions are satisfied by non-negative constants:

$$r_{11} = 5,\ r_{22} = 4, r_{31} = 2,\ r_{32} = 2, r_{33} = 1,\ r_{43} = 4$$

and

$$r_{11} = 5,\ r_{22} = 4, r_{31} = 2,\ r_{32} = 2, r_{33} = 2,\ r_{43} = 3$$

Thus, the solution of the inequalities exists and two variants of them are found. These constants represent options for performing work in the respective intervals.

5. ASSESSMENT OF THE FEASIBILITY OF REQUESTS FOR EQUIPMENT REPAIR IN A SERVICE CENTER IN THE STRUCTURE OF A MACHINE-BUILDING ENTERPRISE

The organization of repair and maintenance of equipment in a flexible production environment is a very urgent task (Jing Chen et. al., 2019; Kizim et. al., 2021; Estefany Soares et. al., 2021) . Previously, such problems were considered in publications (Averyanov, 1987; Karlova, 2004)

Consider the problem of assessing the feasibility of requests for repairs (scheduled and unscheduled) of the equipment of a manufacturing enterprise, taking into account the available repair capacities. Repair costs significantly depend on the repair complexity of the equipment design, which is usually estimated in conventional repair complexity units (CRC). The established repair complexity is a comparative assessment of the overhaul of a piece of equipment. As a unit of measurement for the CRC of the mechanical part of the equipment, for example, the repair complexity of a certain conditional piece of equipment can be considered. At the same time, we can assume that the labor intensity of the overhaul of the mechanical part, corresponding in volume and quality to the requirements of the technical conditions for repairs, is equal to a certain time in unchanged organizational and technical conditions of the repair shop of a machine-building enterprise.

As a unit of measurement for the CRC of the mechanical part of the equipment, for example, the repair complexity of a certain conditional piece of equipment can be considered. The assignment of the number of conditional CRCs to a specific type of equipment is fundamental here. In regulatory sources, there is not always a conditional repair complexity for a specific model of equipment, which causes difficulties in practical work. Therefore, it is customary to assign the number of CRCs to equipment according to options, depending on the availability of data: for example, according to standards, or according to the similarity of designs and tech-nical characteristics (Morozov et. al., 2015).

Equipment repair work is usually divided into two production operations of different types. The first operation is the production process of the repair service, which ensures the restoration or maintenance of equipment operability, the second is control over the compliance of the repaired object with the technical conditions. The second operation is a testing operation, carried out after repair at any convenient time and is not included in the feasibility calculation. If, according to the results of testing, the equipment remains faulty, then the application for re-repair of the equipment is carried out in the first place. Restrictions on working capital are also not taken into account here. Most of the parts are delivered on special orders, or are made independently. Lubricants, nuts, etc., working capital is also not taken into account, since restrictions on them are mini-mal and the likelihood of their shortage is unlikely.

Repair of mechanical, electrical and electronic parts can be performed in series and in parallel (Smirnova et al., 2017). In this example, we will consider the repair of the mechanical component as a priority type of repair. Calculations for the repair of electrical and electronic components are carried out similarly.

To calculate the feasibility of requests for equipment repair, consider the first operation. Work in the first operation is measured in units of repair complexity. Time is measured in hours. Let $R_i^1 = (r_i^1, t_i^1, \tau_i^1), i \in \boldsymbol{I}$ – work during the first operation of equipment repair in the $i-th$ order. Here r_i^1 is the amount of equipment to be repaired, (i.e. CRC), t_i is the start of the work, t_i^1 is the start of the first operation of equipment repair in the $i-th$ order, τ_i^1 is the duration of the first operation.

The initial data are presented in Table 1. Here τ_i^{min} is the minimum possible duration of the $i-th$ order, $t_i + \tau_i^{min}$ is the final moment of the minimum time to complete the work (rounded).

Table 1. Initial data

R_i	r_i	CRC			t_i	τ_i^{min}	$t_i + \tau_i^{min}$
		mechanical	electrical	electronic			
R_1	5	5	0	3	0	1,73	1,8
R_2	9	0	9	0	1,8	1,93	3,8
R_3	11	11	0	7	3,8	3,13	7
R_4	8	0	1	8	7	1,23	8,3
R_5	10	0	0	10	8,3	1,53	9,9
R_6	12	0	12	0	9,9	2,68	12,6
R_7	6	0	6	0	12,6	1,63	14,3
R_8	13	13	0	4	14,3	3,73	18,1
R_9	4	4	5	0	18,1	2,13	20,3
R_{10}	5	0	5	4	20,3	1,5	21,8

The terms of order fulfillment and the amount of work for the repair of equipment in terms of the mechanical component are presented in Table 2. The start time for the execution of requests in numerical calculations is conditionally taken at 0 hours.

Table 2. The terms of order fulfillment and the amount of work

R_i	r_i	t_i	τ_i	$t_i + \tau_i$
R_1	5	0	1,73	1,8
R_2	11	3,8	3,13	7
R_3	13	14,3	3,73	18,1
R_4	4	18,1	2,13	20,3

The order execution time for the mechanical component, starting from t_1^1, is arranged in ascending order and denoted by $T_1 = t_1^1, T_2, \ldots, T_p, p \in \boldsymbol{P}$.

According to the obtained formulas, we calculate the moments of time, and according to them, the intervals for the repair of the mechanical component in the $i-th$ order.

$[T_1, T_2) = [0,\ 1{,}8)$; $[T_3, T_4) = [3{,}8,\ 7)$;

$[T_5, T_6) = [14{,}3,\ 18{,}1)$; $[T_2, T_3) = [1{,}8,\ 3{,}8)$;

$[T_4, T_5) = [7,\ 14{,}3)$; $[T_6, T_7) = [18{,}1,\ 20{,}3)$.

$[T_1^1, T_1^1 + \tau_1^1) = [0, 1{,}8)$; $[T_2^1, T_2^1 + \tau_2^1) = [3{,}8,\ 7)$;

$[T_3^1, T_3^1 + \tau_3^1) = [14{,}3, 18{,}1)$;

$[T_4^1, T_4^1 + \tau_4^1) = [18{,}1,\ 20{,}3)$.

We define non-zero intersection intervals in accordance with the formula:

$$\{T_{ip}^j\} = [T_p, T_{p+1}) \cap [t_i^j, t_i^j + \tau_i^j)$$

$\{T_{11}^1\} = [0, 1{,}8)$;

$\{T_{23}^1\} = [3{,}8, 7)$;

$\{T_{35}^1\} = [14{,}3, 18{,}1)$;

$\{T_{46}^1\} = [18{,}1, 20{,}3)$.

Let us determine the available capacities of the enterprise $m_p^{\text{м}}$ for the intervals corresponding to the equipment repair operation in the $i-th$ order from the time intervals $m^{1\text{м}} = 5$ CRC/h:

$\{T_{11}^1\} = [0, 1{,}8)$ $m_1^{\text{м}} = 8$;

$\{T_{23}^1\} = [3{,}8, 7)$ $m_2^{\text{м}} = 15$;

$\{T_{35}^1\} = [14{,}3, 18{,}1)$ $m_3^{\text{м}} = 18$;

$\{T_{46}^1\} = [18{,}1, 20{,}3)$ $m_4^{\text{м}} = 10$.

The first operation corresponds to the following non-zero values of the coefficients α_{ip}^j:

$$\alpha_{11}^1 = 1;\ \alpha_{23}^1 = 1;\ \alpha_{35}^1 = 1;\ \alpha_{46}^1 = 1.$$

Consider the feasibility of repairing equipment in terms of the mechanical component. The condition for the fulfillment of applications is the presence of at least one solution with respect to r_{ip}^j of the following inequalities:

$$\sum_{p=1}^{P} \alpha_{ip}^j r_{ip}^j \geq r_i^j \ (i \in \boldsymbol{I}, j \in \boldsymbol{J}),$$

$$\sum_{i=1}^{I} \alpha_{ip}^j r_{ip}^j \leq m_p^j \ (p \in \boldsymbol{P}, j \in \boldsymbol{J}),$$

$$r_{ip}^j \geq 0 \ (i \in \boldsymbol{I}, j \in \boldsymbol{J}, p \in \boldsymbol{P}).$$

Using these coefficients, we write the inequalities:

$$\sum_{p=1}^{8} \alpha_{ip}^1 r_{ip}^1 \geq r_i^1 \ (i \in \boldsymbol{I}),$$

$$r_{11}^1 \geq 5;\ r_{23}^1 \geq 11;\ r_{35}^1 \geq 13;\ r_{46}^1 \geq 4.$$

Next, we write the inequalities

$$\sum_{i=1}^{4} \alpha_{ip}^1 r_{ip}^1 \leq m_p^1 \ (p \in \boldsymbol{P}),$$

limiting the scope of work with the capacity of fixed production assets:

$$r_{11}^1 \leq 8;\ r_{23}^1 \leq 15;\ r_{35}^1 \leq 18;\ r_{46}^1 \leq 10.$$

If this system of equalities and inequalities has a solution, then the first operation of equipment repair in terms of the mechanical component is feasible, i.e. $\tau^{\text{мин}} = \tau^{\text{расп}}$, and then it follows, to check the feasibility of the second operation - testing. If the second operation is also performed, therefore, the workshop will cope with orders for the repair of equipment. If a solution does not exist, then the orders are not fulfilled, as there is an overload, and some measures must be taken: refuse some orders, or shift the deadlines for some orders, or introduce an additional shift of work.

The specified conditions are satisfied by the values representing the options for performing work in the corresponding intervals:

$$r_{11}^1 = 7;\ r_{23}^1 = 12;\ r_{35}^1 = 16;\ r_{46}^1 = 8.$$

Thus, one of the solutions of the inequalities has been found. The choice of a single solution is, in principle, arbitrary, and is carried out by the contractor.

6. CONCLUSIONS

The results obtained in the work on the generalization and development of methods of measurability and feasibility of work for organizing the management of manufacturing enterprises organically fit into the modern concept of the transition of enterprises to flexible production and are in good agreement with all known production planning systems. Of particular importance is the possibility of effective use of the results obtained for robotic production processes, as well as within the digital platforms of production ecosystems (Bakhtadze et al., 2021b).. As a result of applying the above approach, savings are achieved in all areas of production and working conditions are improved, which also provides an additional environmental effect.

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