

Qualimetry Analysis as a Tool Lean for the Workplaces Design

D G Maksimov¹, N V Kotlyachkova¹, O V Kotlyachkov²

¹Institute of Economics and Management, Udmurt State University, 1,
 Universitetskaya St, bld. 4, 426034, Izhevsk, Russia

²Izhevsk State Agricultural Academy, 11, Studencheskaya Street, bld. 1, 426069,
 Izhevsk, Russia

E-mail: maksim.dan.gen@gmail.com

Abstract. Research in the field of measuring quality criteria and indicators of the production systems of enterprises is engaged over a long period of time. This led to the emergence of the 'lean production' direction. The primary object of applying the principles and methods of lean manufacturing is the workplace, since any labor process performed in any organization is carried out in a particular workplace. Each work process is an interaction between an employee and an employer, and the total number of jobs is a continuous interaction of employees in converting information, substance (material) and energy. The science of qualimetry is a tool for analyzing and designing workplaces. Qualimetry is the method for determining integral quality indicators. The development of the indicator begins with the presentation of the object of qualimetry analysis, that is, the basic part is selected, which determines the quality of the object in quantitative terms. The selected base part is accepted by the expert standard for the quantitative analysis of other parts in the field of study. The results obtained allow us to describe the workplace from the quantitative and qualitative aspects.

1. Introduction

The Decree of the President of the Russian Federation 'On National Goals and Strategic Tasks of the Development of the Russian Federation for a Period of Up to 24 Years' creates a focus on addressing the strategic tasks facing Russia and its society at present.

One of the projects, which is strategically important and affects workers, is 'Productivity and employment support'. In which one of the first paragraphs included such an indicator as the creation of standards for higher education programs in the areas of 'Lean Manufacturing', 'Scientific Organization of Labor'; Stimulating enterprises that increase labor productivity.

In all areas under consideration, the concept of 'Workplace' is of primary importance. It is the definition of this term that is the key point for further research on this topic, the creation of a variety of standards in the field of labor science and lean manufacturing.

In the widely adopted methodology 'Lean Production' [1], [2] the primary objects are such concepts as 'Workplace' and 'Workspace' [3].

The concept of 'Workplace' has given many definitions, among which are:

- a place of employment [4];

- ‘a place involving a permanent or temporary stay when working during the course of carrying out one’s working activities’ [5];
- ‘all places in which workers need to be to carry out their duties or from which they need to be followed in connection with their work where they are directly or indirectly under the direction of their employer’ [6].
- part of the workspace, equipped with the necessary technical means, in which labor activity is performed [3].

In our opinion, the most accurate definition that would meet the needs of the present and the future, the concept of lean production, is: ‘the workplace being an elementary part of the production space in which the allocated means of work, equipment which is required for that work, and the object of the work itself are interrelated with the implementation of individual work processes in accordance with the function of obtaining the product of the work’ [7]. Such a definition of the workplace will allow us to characterize that ‘... the means of labor, the objects of labor, the subject of labor, the labor process, the product of labor are the scientific categories of economic theory, and, therefore, the concepts of lean production’ [8].

In lean manufacturing, knowledge is concentrated, the use of which can significantly increase the effectiveness of activities. The use of tools can lead to some result, but only an integrated approach allows us to provide a synergistic effect [8].

The set of standards for lean manufacturing does not have a single definite document that includes the above and other requirements of labor legislation. However, the recognition of the primary objects of lean production as ‘workplace’ and ‘workspace’ allows us to offer them a special document: ‘Ergonomic passport of the workplace’ [7]. The development of this document would be an important function in the structure of lean manufacturing. The content of the described document to some extent already exists in the production system. There are samples of passports, with their substantial and informational content.

One of the methods for measuring quantitative and qualitative characteristics is the qualimetry method [9] for measuring the labor intensity of products, and, therefore, one of the key characteristics of jobs.

To apply the method of qualimetry, it is necessary to create a system of norms and standards for a particular enterprise.

2. Materials and methods

As a methodology for determining the complexity of manufacturing, the qualimetry method [10] - [12] is used. The application of the principles of qualimetry allows you to calculate the parameters that form the basis of indicators of the quality of labor processes. The application of the method and principles of qualimetry in Lean manufacturing is necessary and important.

The qualimetry approach is based on a statistical study of the dependences of the complexity of manufacturing a product on technical characteristics and requires calculating a large amount of design documentation. But at present, in the age of development of computer technology, this problem is not relevant. A program is being developed to automate the calculations. In this paper, we consider the methodology and its modification to determine the complexity, calculate the quantity and quality of jobs.

The methodology of qualimetry indicators for determining the labor intensity reflects such parameters of parts as structural and technological features, dimensions, weight. The identification of significant labor-intensive factors required the processing of a large number of technological maps.

As a result of the analysis of a large amount of information, it was revealed that the complexity of the production of parts of machine shops is most significantly affected [11], [12]:

- mass of the workpiece;
- complexity of the geometric shape of the part;
- material use factor;
- type and weight of the workpiece;

- parameters of the surface roughness of the part;
- material details;
- the number of parts in the batch;
- the complexity of assembling parts into assembly units;
- features of technological operations.

We decompose the assembly unit into separate parts and determine the qualimetry indicators for each part.

The general qualimetry indicator of parts manufactured using metal-cutting equipment is defined as

$$K_O = K_{GH} \cdot K_m \cdot K_M \cdot K_R \cdot K_{TF} \quad (1)$$

where K_{GH} – the qualimetry index of the complexity of the geometric shape (configuration complexity qualimetry) of the part; K_m – qualimetry indicator of the mass of the part (mass qualimetry); K_M – qualimetry index of the material of the part (material qualimetry); K_R – qualimetry index of the surface roughness of the part (qualimetry of the roughness); K_{TF} – a qualimetry indicator of technological features of the part (qualimetry of technological features).

The labor intensity of creating parts is determined using the formula [13]

$$T = (K_o \cdot T_q \cdot \sum_{i=1}^m p_i + \sum_{j=1}^l \Delta T) \cdot K_n \quad (2)$$

where K_o – a general qualimetry indicator, kvsht (kkg); T_q – normative labor intensity, standard hour; p_i – the normative ratio of the complexity of the types of technological operations performed; i – the number of technological operations performed; K_n – correction factor for the number of parts in the party; ΔT is the laboriousness of operations, which are additionally introduced in comparison with the foreseen technological operations in accordance with this methodology; j – the number of technological operations introduced additionally as compared with the stipulated technological operations.

3. Results and discussion

To represent the operation of the algorithm, we present a sequential calculation of the necessary parameters. We calculate the qualimetry indicators of the part and the complexity of manufacturing on a specific example.

As example, consider detailed drawing ‘Puller’ (Figure 1)

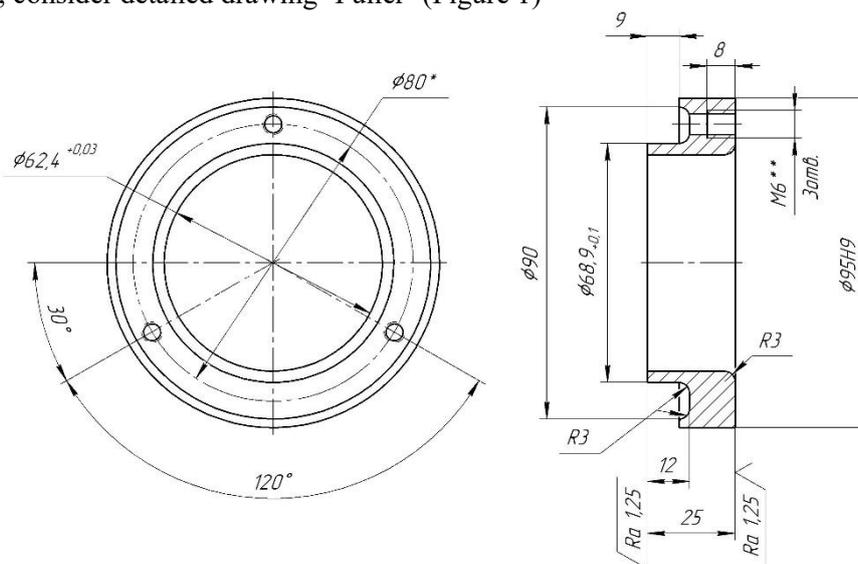


Figure 1. Puller.

According to the ESKD classifier, the ‘Puller’ part belongs to class 71 [14]: details of a revolution body such as rings, disks, pulleys, blocks, rods, bushings, glasses, columns, shafts, axes, rods, spindles, etc. The code details: 711345.

The qualimetry indicator of the complexity of the geometric shape of the part is determined based on formula 1.

The number of common dimensions $I = 39$, including internal dimensions $I_{id} = 31$.

The symmetry of the geometric shape of the part can be determined in three ways:

- based on the methodology for calculating the symmetry of parts manually [15];
- based on the methodology for calculating the symmetry of parts using a computer program created for this purpose [10];
- based on the developed tables [16].

Symmetry: $\alpha = 0.81$.

The symmetry coefficient of the geometric shape of the part in question will be

$$K_{GH} = \ln I \cdot e^{\frac{I_{id}}{I} - \alpha} = \ln 39 \cdot e^{\frac{31}{39} - 0.81} = 3.609$$

Qualimetry mass index details:

$$K_m = 0.23 + 0.111 \cdot \ln(m \cdot 1000) = 0.23 + 0.111 \cdot \ln(0.44 \cdot 1000) = 0.906$$

Qualimetry index of the material of the part (K_M) is determined using the methodology [12]. The material of the part is ‘ЧЧ20’ (grey cast iron), according to the table qualimetry indicator of the material details is $K_M = 1.40$.

The smallest roughness parameter indicated on the detail drawing (see Figure 1) is $R_a 1.25$, therefore

$$K_R = R_a^{-0.347} = 1.25^{-0.347} = 0.925$$

Qualimetry indicator of technological features (K_{TF}) is taken equal to 1.03.

Having private qualimetry indicators, we calculate the total qualimetry indicator

$$K_O = K_{GH} \cdot K_m \cdot K_M \cdot K_R \cdot K_{TF} = 3.609 \cdot 0.906 \cdot 1.40 \cdot 0.925 \cdot 1.03 = 4.361$$

Calculate the qualimetry mass of the part

$$K_{mq} = 0.44^{0.08} \cdot \left(\frac{1}{0.21} - 1\right)^{0.28} \cdot e^{0.2 \cdot (0.44 - 1)} \cdot 0.943 = 5.291$$

The obtained data is stored for future use in the database, as well as in conjunction with the drawing in the form of a table (table 1).

Table 1. Qualimetry indicators details.

Code	α	I	I_{id}	K_m	K_{GH}	K_M	K_R	K_{TF}	K_O	K_{mq}
711345	0.81	39	31	0.906	3.609	1.40	0.925	1.03	4.361	5.291

According to the methodology, the complexity of manufacturing the part will be as follows (table 2).

Table 2. Project labor intensity.

Name of technological processing	Labor intensity	
	Part	Time, working hours
Cutting	0.08	0.456
Turning	0.45	2.563
Finishing	0.01	0.057
Drilling	0.1	0.569
Grinding	0.08	0.456
Locksmith	0.12	0.683
Project labor intensity		4.784

Determined the complexity of manufacturing each part from an assembly unit is presented in table 3.

Table 3. Summary sheet of indicators of labor intensity of manufacturing parts of the product “Stamp”.

Item designation	Part name	Code	Project labor intensity, working hours
18-1	Base	741512	12.55
18-2	Column	716711	4.341
18-3	Puller	711345	4.784
18-4	Matrix	713622	4.367
18-5	Spring	753513	1.032
18-6	Ring	711142	2.755
18-7	Punch	716412	5.437
18-8	Ring	741324	2.506
18-9	Holder	715324	7.938
18-10	Ring	711142	0.949
18-11	Stove	741324	13.341
			60.00

Based on the data obtained, it is possible to tie the resulting labor intensity to a specific workplace. The results can be used to model jobs depending on the volume of production.

4. Conclusions

The results obtained allow us to connect the capabilities of the workplace with a quantitative and qualitative side. The main indicators of the work performed can be classified as follows: a) techno-economic map for a particular enterprise; b) the cost of production of parts in a certain period, that corresponds to the technological capabilities of the enterprise at a particular workplace. Automation will significantly reduce the complexity of applying this technique.

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