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Use of qualimetry method in production labour estimation

D. Maksimov[1,*], H. Kalkis[2], Y. Perevoschikov[1] and Z. Roja[3]

[1]Institute of Economics and Management, Udmurt State University, 1, Universitetskaya Str, bld. 4, RU426034 Izhevsk, Russia
[2]Faculty of European Studies, Riga Stradins University, Dzirciema street 16, LV 1007 Riga, Latvia
[3]University of Latvia, Raina blvd. 19, LV-1586 Riga, Latvia
[*]Correspondence: maksim.dan.gen@gmail.com

Abstract. Every work process of production organization involves employees and employer interaction with each other by "agreement". Such agreement is contracted based on the implementation of concrete types of work processes in particular workplaces. The general the total number of workplaces are continuous interaction areas of people to transform substance, energy and information. The solution of the assigned tasks requires the methodology for designing product quality, analyzing market consumer needs, forecasting potential prices and detecting effectiveness in order to present the strategic objectives in digital values. This study is part of a larger investigation which involves principles of economic metrology and qualimetry of work. The purpose of the research is to demonstrate use of qualimetry in the production organization, based on experience of several years in many industry organisations by focusing on engineering.

Key words: work, qualimetry, ergonomics, quantitative, manufacturing.

INTRODUCTION

The problem of estimating the complexity of the product manufacturing without a detailed design of the technological manufacture process is relevant. Many contemporary inventions have significantly transformed the meaning of manufacturing. Today there are new concepts in manufacturing, such as LEAN management, the theory of constraints, statistical process control, ergonomics and design etc. In order to reach high quality and efficiency in products and operations, many production solutions are implemented in creative ways. Therefore, methods of qualimetry analysis are also necessary to combine economic interests, in particular, labor costs, material costs, costs of electrical energy with engineering parameters, which are calculated based on the theory and methods of qualimetry (Hendrick, 2003).

There is a certain mathematical expression $y = f\,(x_1, x_2, \ldots x_3)$. Then the function y should be the price, and x is the parameters of the products that one wants to do. But if one puts just a detail, then under the word 'detail' all the parameters are merged that are included in the algorithm for performing calculations of economic parameters - the economic indicators of this detail. If one do not take these engineering parameters, then, therefore, it can only conditionally call the economic character in the form of an analogy, that is, those that have already been (Nazarov & Krushnyak, 2006). The detail is this, so the price will be the same, but it is not a scientific method, it is a method of expert evaluation (Freivalds & Niebel, 2009). Use of known methods for estimating labor intensity (Zandin, 2002; Genkin, 2005; Caragnano & Lavatelli, 2012) requires a huge amount of time. The research results presented in this article are gained and considered over a long period of time and involves the application of the qualimetry theory that can improve the technical and economic planning of production in engineering operations.

The theory of qualimetry got its start in the 60s of the 20th century regarding the works of Azgaldov (1968), Raikhman (1970), Glichev (1983), Syskov and others. Qualimetry originated as a science due to the great experience accumulated by mankind in assessing product quality. It relies on experimental and statistical research methods.

On the basis of the qualimetry method, the following studies were carried out: foundry production (Kalinkina, 1984; Kalinkina & Perevoshchikov, 2018), instrument-making (Nekrasov, 1985), determination of labor input (Kudryavtsev, 1993), packages (Lebedenko, 2003; Lebedenko Perevoshchikov & Perevoshchikov, 2018), industrial production (Mukhina, 1997; Khilchenko, 2013), small business operations (Maksimov, 2009), and clothing industry (Yeremeyeva, 2004; Pevoshchikov, Bobkov & Nemirovchenko, 2005), water qualimetry (Rozental & Averbukh, 2013). In the United States it is called benchmarking (Allmon et al., 2000). However, in author`s opinion, the used methodology reveals much more precisely the interrelation of the function of engineering parameters with economic rather than recommendations made in benchmarking.

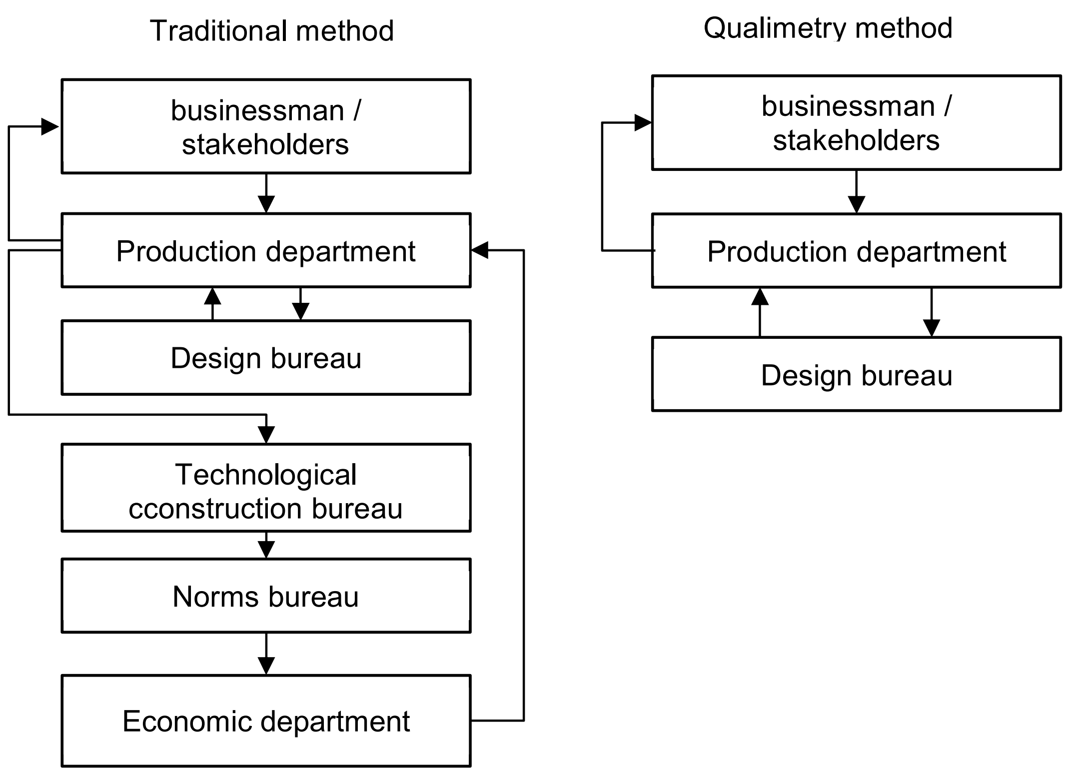

Figure 1. Diagram of order execution.

Qualimetry method of preparing documents for the product production can significantly reduce the duration of the creating the design and estimate necessary documentation. For the application of the qualimetry method, it is important to create a system of norms and standards that helps calculating production costs and the predicted price for the product manufacturing in real organizational and technical conditions.

Based on the developed technique, a new algorithm was presented, which can be seen in Fig. 1.

Fig. 1. (Yeremeeva, 2004) shows order flow of two patterns: traditional and qualimetry method. The comparison shows that qualimetry method allows to reduce the time of order passing between departments and is less complex as traditional method procedure. It involves only direct interaction between production department and design bureau and relation to stakeholders or business decision makers.

MATERIALS AND METHODS

As a research methodology, a qualimetry approach is applied. Qualimetry is a method for determining integrated and integral quality indicators. The development of qualimetry indicator starts with presentation of fulfilled certain conditions to the object of qualimetry analysis in accordance with the provision of the methodology.

In the qualimetry approach, the base part is selected, which determines the quality of the machinery in quantitative terms. The selected base part is adopted by the expert standard for the quantitative analysis of other parts in the field of research. Further the parameters are calculated, that are called the quality parameters of the parts. The qualimetry parameters of the part include: the complexity of the geometric shape, the mass of the part, the material of the part, the roughness parameter, the features of technological operations.

The qualimetry method is based on a statistical study of the labor intensity dependencies in manufacturing process. Technical characteristics of the product requires a large amount of design documentation to be created. In this paper, the main part of the price calculation will be considered – this is the definition of the labor intensity in manufacturing process. In contemporary age of computer technology development, this problem is not so relevant. There exists a development software for the calculation automation. In this paper, it will be briefly considered the modification of the method to determine the complexity. The methodology of qualimetry indicators for determining labor intensity reflects such parameters of parts as constructive-technological features, dimensions and mass. The identification of significant factors of labor-intensiveness required the processing of many technological charts, maps of the manufacturing process. Having analysed a large amount of information, it was found that the amount of complexity of the production parts is significantly affected by:

- 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.

Authors decomposes the assembly unit into separate parts and defined qualimetry indicators for each part. The overall qualimetry index of parts manufactured using metal-cutting equipment is defined as

$$K_O = K_{GH} \cdot К_m \cdot K_M \cdot K_R \cdot K_{TF} \tag{1}$$

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).

Hence it can be pointed out description factors and their parametric values that form a qualitative set of properties:

1. Length, width and thickness (expressed in mm)

2. The geometric shape of the part according to the Classifier of the unified system for design documentation (ESKD, 1986). Classification code was applied.

3. The volume of the part in space (expressed in cm^3)

4. Determine the composition of the substance in the details, choosing the brand of material in the list of names placed in the classifiers of engineering materials (the conditional expression of the brand of material was used)

5. Calculate the mass of the part (expressed in kg)

6. Number of dimensions affixed to the drawing was substituted, which uniquely form the spatial image of the part (expressed in the number of dimensions reduced to linear dimensions).

7. Select from the total number of sizes, the dimensions affixed to the internal cavities, holes, grooves (expressed in the number of sizes, reduced to linear dimensions).

8. Determine the symmetry coefficient of the part`s geometric shape by calculating accordingly to the drawing and the volume part (ILM, 1988). Or in accordance with the six-digit code using an approximate method (HAN, 1988).

9. Determine the qualimetry measure of the detail's complexity.

$$K_{GH} = ln\, I \cdot e^{\frac{I_{id}}{I} - \alpha} \tag{2}$$

10. We determine the qualimetry mass index of the part K_m, depending on the mass of the part found in item 5.

11. We determine the qualimetry index of the material of the part, based on the information obtained in item 4.

12. Considers the requirements of accuracy and surface roughness of the part, subjected to processing (Ra) and determine the quality indicator of the part

$$K_R = {R_a}^{-0,347} \tag{3}$$

13. We calculate the qualimetry indicator of the technological features of the part.

$$K_{TF} = e^{\Sigma d_i} \tag{4}$$

14. We determine the general qualimetry parameter on the basis in formula 1. We enter the values into the special technical part`s economic map and determine the labor intensity of the part manufacturing using a special technique (currently being processed).

15. We save the received indicators.

Determine the labor intensity of creating parts (LIQ, 1988)

$$T = (K_o \cdot T_q \cdot \sum_{i=1}^{m} p_i + \sum_{j=1}^{l} \Delta T) \cdot K_n \qquad (5)$$

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.

RESULTS AND DISCUSSION

Based on the results obtained, a database is being created for qualimetry parameters and derived time rate. These indicators can be linked to the workplace that result as indicator of the ergonomic passport in the workplace (Maksimov & Kalkis, 2018).

They will be the basis for determining the various costs and results of labor in a given workplace and will not depend on a particular person.

The calculation of the technical and economic indicators of the product production at the design engineering stage is carried out both manually and automatically using the Kompas-3D CAD system.

In this paper we describe the sequential stage of the calculation of parameters. Kompas-3D was used as the CAD system for creating drawings and 3D models. There is a methodology developed by authors for qualimetry analysis and calculation of qualimetry indicators of engineering products, developed and tested in practice in the manual documentation of both the drawings themselves and their analysis (Perevoshchikov, 2015; Maksimov & Kalkis, 2018). Currently, there is an integrated automated system for performing graphic drawing, which included engineering calculations, isolation and generalization of information and economic-qualimetry analysis and justification of production efficiency indicators.

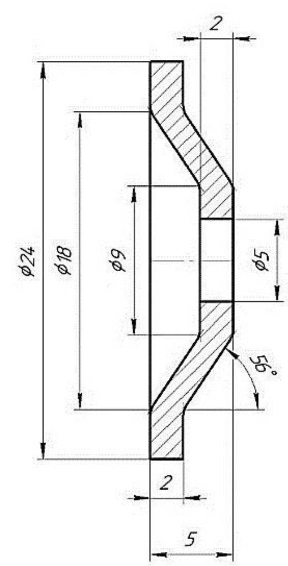

Figure 2. Drawing details of the washer.

A software (Ermilov, V.V. & Perevoshchikov, 2018a, 2018b) was used to automate the calculation of qualimetry parameters. When using this method, it is necessary to remember that it needs to be adapted to the specific organizational and technical conditions of the enterprise. To represent the work of the algorithm, authors present a sequential calculation of the necessary parameters. We calculate the qualitative parameters of the parts and the complexity of manufacturing on a specific example.

As one example, consider detailed drawing 'Washer' (Fig. 2).

According to the classifier ESKD determine the code details: 758491. To calculate the general qualimetry index of the part (formula 1), it is necessary to determine such parameters:

- -qualimetry indicator of geometric shape;
- -qualimetry mass index details;
- -qualimetry indicator of the material details;
- -qualimetry surface roughness indicator;
- -qualimetry indicator of technological features.

1. Qualimetry indicator of geometric shape:

The number of common dimensions I = 12, including internal dimensions $I_{id} = 7$. Symmetry $\alpha = 0.83$.

$$K_{GS} = ln\, I \cdot \mathrm{e}^{\frac{I_{id}}{I} - \alpha} = ln\, 15 \cdot e^{\frac{7}{12} - 0{,}83} = 1.832$$

2. Qualimetry mass index details

Weight of details: m=0.007 kg

$$K_m = 0.23 + 0{,}111 \cdot ln(m \cdot 1000) = 0.23 + 0.111 \cdot ln(0.007 \cdot 1000) = 0.446$$

3. Qualimetry indicator of the material details K_M=0,85.

4. Qualimetry surface roughness indicator

$$K_R = {R_a}^{-0{,}347} = 10^{-0{,}347} = 0.45$$

5. Qualimetry indicator of technological features K_{TF}=1.03.

6. Determine the total qualimetry indicator (formula 1)

$$K_O = 1.832 \cdot 0.446 \cdot 0{,}85 \cdot 0.45 \cdot 1.03 = 0.322$$

7. Calculate the utilization of the material indicator

$$K_{mq} = 0.007^{0.08} \cdot \left(\frac{1}{0.39} - 1\right)^{0.28} \cdot e^{0.2 \cdot (0.007 - 1)} \cdot 0.322 = 0.201$$

The obtained data is saved in the drawing and in the database. The qualimetry indicator details are represented in Table 1.

Table 1. Qualimetry indicators details

Code	α	I	I_{id}	K_m	K_{GS}	K_M	K_R	K_{TF}	K_O	K_{mq}
758491	0.89	12	7	0.446	1.832	0.85	0.45	1.03	0.322	0.201

Gained data on project labor intensity id summarized in Table 2.

For a more detailed disclosure of the methodology, authors define and compare the complexity of the manufacture of two products (Tables 3 & 4). Products have the same design but are released in different time periods.

Table 2. Project labor intensity

Name of technological processing	Labor intensity	
	Part	Time, working hours
Cutting	0.08	0.1262
Turning	0.51	0.8047
Finishing	0.001	0.0016
Drilling	0.15	0.2367
Project labor intensity	0.741	1.1692

Table 3. Summary sheet of indicators of labor intensity of manufacturing parts of the product 'Manual meat grinder GOST 4025-95'

No	Item designation	Part name	Code	Project labor intensity, working hours
1	G95.715511.001	Bolt 1	715511	0.610
2	G95.715521.002	Bolt 2	715521	2.674
3	G95.714633.003	Worm	714633	1.338
4	G95.753111.006	Nut 1	753111	0.555
5	G95.753151.007	Nut 2	753151	0.373
6	G95.713467.009	Body	713467	0.991
7	G95.712363.010	Cover	712363	1.406
8	G95.753436.011	Receiving knife	753436	6.299
9	G95.711144.014	Receiving grate	711144	7.201
10	G95.743111.015	Handle	743111	0.397
11	G95.711321.016	Pivot	711321	1.114
12	G95.758491.017	Washer	758491	1.169
13				24.127

Table 4. Summary sheet of indicators of labor intensity of manufacturing parts of the product 'Manual meat grinder GOST 4025-73'

No	Item designation	Part name	Code	Project labor intensity, working hours
1	G73.715521.101	Bolt	715521	3.835
2	G73.731467.105	Body	731467	1.180
3	G73.743111.110	Handle	743111	1.317
4	G73.712363.106	Cover	712363	2.477
5	G73.711144.109	Receiving grate	711144	12.454
6	G73.741684.108	Gasket	741684	0.000
7	G73.753436.107	Receiving knife	753436	8.406
8	G73.711321.113	Pivot 1	711321	1.518
9	G73.751742.111	Pivot 2	751742	3.888
10	G73.741314.115	Washer	741314	0.632
11	G73.714633.102	Worm	714633	1.874
12	G73.713111.112	Key (spline)	713111	0.179
13				37.76

Based on the findings, it can be concluded that the labor intensity of manufacturing identical products is different. This is influenced by the modified form of the product, the material of the product, as well as design features. The obtained results may be used in the future to determine the value of the product. It is also possible to use as a base of newly created similar products and individual elements of products - parts.

CONCLUSIONS

The qualimetry in production organization was demonstrated with the following solutions: the structure and content of automated planning systems based on the example of individual products was developed that involved the qualimetry method. Projects were made with specific products on automated systems based on the ideas of the standardized notion of qualimetry. The obtained results allow to bind the possibilities of the workplace from the quantitative and qualitative sides. The main indicators of the performed work can be categorized as follows: a) a techno-economic map for the specific enterprise; b) the cost of parts production in a specific period that is in accordance with the technological capabilities of the enterprise. Hence the automation will allow a significant reduction in the qualimety analysis of machinery parts as well as it will provide simple analysis that will allow to determine the influence of individual technical characteristics of the product during the manufacturing process.

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