Optimization algorithm for material processing according to metrological requirements of quality management system

Yelena Yu Lukyanova
V.I. Vernadsky Crimean Federal University, Prospekt Vernadskogo 4, Simferopol, Republic of Crimea, 295007, Russia

E-mail: lukianovahy@ukr.net

Abstract. Nowadays metrological requirements compliance is very important for modern economic units. It is in the basics of any quality system that provides competitiveness achievement to any business. The article discloses present-day optimization algorithm for material processing according to the quality management system metrological requirements. There are also disclosed developed algorithm steps for material processing economic units in stochastic conditions.

1. Introduction
Business entities activities are impossible without innovative technologies applying at the present stage of economic development. This applies material modeling and processing as well as economic and managerial operations. One of the management main tenets is that one can control resources, technologies and activities if they can be objectively measured. Such metrics and means of measurement are provided by metrology methodology. If earlier metrological approaches were considered in the narrow sense referring only to physical processes, now its effect is extended to all quality assurance processes, and also is reflected in international standards requirements, regulations and committees functioning (ISO/IEC GUIDE 99:2007, ISO 5725-2:2019, ISO 5725-5:1998/COR 1:2005, ISO 10012:2003, ISO 9001:2015, ISO/TS 9002:2016). Metrology is the science of measurements, methods and means of ensuring their unity and methods of achieving the required accuracy. The subject of metrology is the extraction of quantitative information about the properties of objects with a given accuracy and reliability [1]. Evidently nowadays metrological requirements compliance is very important for modern economic units. It is in the basics of any quality system that provides competitiveness and economic security achievement to any business. And if there are a sufficient number of metrology theory publications [2-13], then the question of metrological requirements of quality management system applying to material processing optimization requires additional research. This determined the research aim that is to determine possible algorithm of material processing optimization in accordance to metrological requirements of quality management system.

2. Materials and methods
General scientific and special research methods were used to solve mentioned aim. There are techno-economic, system and structural analyses, content analysis, economic modeling, graphical analysis, system and process, metrological approaches, statistic, quality management system standard
3. The study of optimization algorithm for material processing according to metrological requirements of quality management system

In the Southern Federal District (SFD) economic units that are budget-forming ones were objects for the current research. There were revealed certain patterns in these business entities functioning (figure 1).

![Graphical interpretation of innovations and metrological support applying by SFD budget-forming economic units (2010–2019) (%)](image)

**Figure 1.** The graphical interpretation of innovations and metrological support applying by SFD budget-forming economic units (2010–2019) (%) (based on the official statistics and author’s researches).

Dynamics of changes (figure 1) reflects the trends of general economic processes in the region. There was also evaluated economic units efficiency growth, their ability to increase competitive potential and strengthen economic security (table 1). There were analyzed few positions: economic unit efficiency growth (EUEG) for economic units that functioned without innovations applying, without metrological support (EUFWIWMS); economic unit ability to increase competitive potential (EUAICP) for EUFWIWMS; economic unit possibility to strengthen economic security (EUPSES) for EUFWIWMS; EUEG for economic units that applied innovations (EUAI); EUAICP for EUAI; EUPSES for EUAI; EUEG for economic units with metrological support applying (EUMSA); EUAICP for EUUMSA; EUPSES for EUUMSA; EUEG for economic units with innovations and metrological support applying (EUIMSA); EUAICP for EUIMSA; EUPSES for EUIMSA.

**Table 1.** Evaluation of EUEG, EUAICP and EUPSES (%) (author’s researches, experts’ estimation).

| Year | EUEG EUFWIWMS | EUAI EUFWIWMS | EUEG EUAI | EUAICP EUFWIWMS | EUPSES EUFWIWMS | EUEG EUAI | EUAICP EUAI | EUPSES EUAI | EUEG EUUMSA | EUAICP EUUMSA | EUPSES EUUMSA | EUEG EUIMSA | EUAICP EUIMSA | EUPSES EUIMSA |
|------|----------------|----------------|-----------|-----------------|------------------|-----------|-------------|-------------|-------------|----------------|----------------|-------------|----------------|----------------|
| 2010 | 1.8            | 2.07           | 3.87      | 3.24            | 3.73             | 6.97      | 3.51        | 4.04        | 7.55        | 5.76           | 6.62           | 12.38       |
| 2011 | 2.16           | 2.48           | 4.64      | 3.89            | 4.47             | 8.36      | 4.21        | 4.84        | 9.06        | 6.91           | 7.95           | 14.86       |
| 2012 | 3.34           | 3.84           | 7.18      | 6.01            | 6.91             | 12.93     | 6.51        | 7.49        | 14.00       | 10.69          | 12.29          | 22.98       |
| 2013 | 4.13           | 4.75           | 8.88      | 7.43            | 8.55             | 15.98     | 8.05        | 9.26        | 17.32       | 13.22          | 15.20          | 28.41       |
| 2014 | 3.11           | 3.58           | 6.69      | 5.60            | 6.44             | 12.04     | 6.06        | 6.97        | 13.04       | 9.95           | 11.44          | 21.40       |
| 2015 | 2.1            | 2.42           | 4.52      | 3.78            | 4.35             | 8.13      | 4.10        | 4.71        | 8.80        | 6.72           | 7.73           | 14.45       |
| 2016 | 4.86           | 5.59           | 10.45     | 8.75            | 10.06            | 18.81     | 9.48        | 10.90       | 20.38       | 15.55          | 17.88          | 33.44       |
| 2017 | 3.18           | 3.66           | 6.84      | 5.72            | 6.58             | 12.31     | 6.20        | 7.13        | 13.33       | 10.18          | 11.70          | 21.88       |
| 2018 | 5.1            | 5.87           | 10.97     | 9.18            | 10.56            | 19.74     | 9.95        | 11.44       | 21.38       | 16.32          | 18.77          | 35.09       |
| 2019 | 6.14           | 7.06           | 13.20     | 11.05           | 12.71            | 23.76     | 11.97       | 13.77       | 25.74       | 19.65          | 22.60          | 42.24       |
There was made graphical interpretation (figure 2) based on the data from the table 1.

In the simplified form economic security indicator is a cumulative metric of economic efficiency growth ability and competitive potential increasing minus external environment negative stochastic influence and internal environment dynamic changes resistance.

![Figure 2](image)

**Figure 2.** Evaluation of economic units’ efficiency growth, their ability to increase competitive potential and strengthen economic security (2010–2019 years) (%) (on data from table 1).

Based on the obtained results (table 1, figure 2), business entities are in the least advantageous economic position at EUEG EUFWIWMS, and in the most advantageous economic position at EUPSES EUIMSA, when they implement innovations and apply metrological support, at the same time ones can’t completely exclude existing economic processes direct influence negative impact but it can be reduced due to quality management system commissioning. It was done relevant research as the result of which it was developed and successfully tested specific five-step algorithm for set conditions (figure 3) (mathematical formulation was presented earlier [13]). Step 1 is initiation that is characterized by material processing economic unit process management forming formal authorization: initial data are refined; resources content description and calculation, innovations and metrological tools are proceeded. At this stage it is necessary to choose process management implementation manager (if one wasn’t assigned yet), and document initial assumptions, limitations.

After Step 1 there is “Is target achieved?” solution in this algorithm. It permits Step 2 realization when previous procedures were made with correct execution or the first stage is continuing with required additional actions. Step 2 includes procedures of planning and preparing for process management implementation to economic unit. It consists of permitting the decisions for business structure transforming. Then objectives are defined and sequenced taking into account efforts to achieve results that are regulated by target and innovations which must be applied for it. There is need to determine trigger for beginning of change and reformation actions that are aimed to economic unit objects. Business entity experts identify whether it is urgency and expediency for conversion of economic activity at the present time, check for financial and time resources availability. Experts use results of preliminary researches on business state, socio and economic prerequisites for different shifts in external environment that induces internal environment changing (for instance ISO 9001:2015 implementation run-up), etcetera. After there is made metrological and controlling plan for development and its content is formulated. Employees design procedures for hierarchic structure
forming, specify content for operations and interrelationships resources, estimate work-flows durations that results organization schedule, specifics of metrology, evaluation and costing. They formulate criteria for quality, human resources, communications, risk management, and develop foundation for their identification, qualitative and quantitative analysis, data response, contracts determination.

On the next stage in activity block of Step 2 there is building of a team. This team actually starts planning and forming of process management for economic unit that specialize on material processing. The team should consist of business entity specialists and independent consultants.

![Process Management Algorithm](image)

**Figure 3.** Material processing optimization algorithm according to the quality management system requirements (author’s research).

The conjunction of these experts allows improving realization of subsequent stages, excluding duplication of procedures and avoiding use of inappropriate time. During team forming there should be made team authorization, when are distinctly distributed duties and responsibilities, involvement for certain period of time between all members. The leave project when their part of work is finished.
The existing team determines boundaries for material processing economic unit process management forming, planned reforms and operations scope, timing, required funds, also selects, modifies, develops tools, researches internal environment designed project realization various limitations and their overcoming ways (for stochastic conditions).

“Is target achieved?” solution with algorithm indicated previous procedures correct execution permits the third stage realization or if procedures were not completed or any errors occurred, it analyses which operations caused failures that requires expertise and adjust actions. Step 3 is economic unit process management forming and implementation during which there is human and other resources combination for process management plan implementing, and quality administrating, confirmed procedures execution, and also requests contractors information and their choice actualization. The stage starts from identification of goods that satisfies specific market segment clients due to consumer properties which are significant to them ($G_{ai}$ according to [13]): market researching; market segmenting on consumers “requirements card” basis; identifying of goods that satisfies specific market segment clients due to consumer properties which are significant to them. Then business entity chooses methods for $G_{ai}$ positioning to the chosen market segment. After that experts define Balance Scorecard (BSC) targets (for instance, it can be profit maximization, process improvement, social effects increasing, etcetera). The targets should be real and measurable, also correspondent to business process improvement.

Then criteria (key performance indicators and metrological ones) are selected and their values are determined for desired future state ($E_{Ought To-Be}$) that aspired by material processing economic unit, withal these criteria suits for business entity current state estimation ($E_{As-Be}$), after it is analyzed improvement or modernization proper way. Thus, material processing economic units’ business processes will be restructured taking into account its limited resources, metrological methodology, Balanced Scorecard (BSC) requirements that needs particular algorithm, tools and methods to be developed (it will be disclosed in further publications). It is also taking into account that economic unit’s external environment is volatile, and entity needs business processes changes (correction) management mechanism for functioning under stochastic conditions. The mechanism is selected from existing methodologies or formed with different techniques elements combining for business process implementing particular stages. During process management forming and implementing domestic economy material processing economic unit receives tasks which weren’t solved heretofore. For these tasks solutions it needs peculiar operations realization that were not in economic unit’s procedures before that stipulates business entity’s organizational structure reforming during process-oriented innovations forming and implementing period. In the transitive period it actualizes with relevant department adding to management structure that will execute process management forming procedures taking into account BSC requirements, limited resources and external environment stochasticity.

“Is target achieved?” solution with algorithm indicated previous procedures correct execution permits economic unit’s process transformations realization beginning or return to previous procedures for their adjusting. Material processing economic unit changes realization includes realistic procedures on consulting and training services in process management implementing, changes evaluation, adjusting operations for chosen business entity. It consists of: work group and specific department forming for economic entity process management implementing, adjustment, and supporting (maintenance); economic entity process management implementing procedures planning and organization (work group forming for business processes improving, process approach trainings, operations planning); innovations application required resources use for economic unit conditions; forming system methodic commissioning and trial running (personnel selection, training and certification, implementation, organization's regulations monitoring and control formed on process approach basis and functioning analysis (requirements compliance), etc.

“Is target achieved?” solution with algorithm previous procedures correct execution permits the fourth stage beginning or return to previous procedures in accordance to the scheme. Step 4 is material processing economic units process management implementation monitoring, control and adjusting that includes its progress regularly evaluation possibility, plan divergences identifying, and in cases when it is necessary, corrective operations applying to targets achieving. Particularly there is procedure including operations on: economic unit process management monitoring and control; total changes
control; content confirmation; schedule, cost, quality process, transformation team, execution accountability, and participants control; risk surveillance and management; contract administration.

“Is target achieved?” solution with step 4 correct execution permits the fifth stage beginning or return to previous procedures in accordance to the algorithm. Step 5 is material processing economic unit process management implementation completion and summarizing. Results inspection is formalized and innovations implementation is summarized to correct fulfillment. Transformations are completed. Economic unit changes realization, process management implementing evaluation, control, adjusting and finishing are not disclosed in this article because entities process management implementation procedure control is sufficiently developed by domestic and foreign authors. This text is presented taking into account the fact that process management implementation proceeds in accordance to nowadays standards.

4. Conclusion
There can be made conclusions on information given above. Suggested material processing optimization algorithm according to the quality management system requirements for stochastic conditions allows realize it optimally and adapt entity to functioning in accordance to international standards and metrology requirements and modern business realities. Also, material processing economic units will receive with this algorithm not only operational processes optimization but also management and supporting ones as a whole. It gives competitive potential grows base and stability in modern economy.

Acknowledgments
This work is self-initiated and self-financed. Authors thanks committee of conference for participation possibility.

References
[1] Raghavendra N V and Krishnamurthy L 2013 Engineering Metrology and Measurements (Oxford: Oxford University Press)
[2] Mohr P J, Newell D B, Taylor B N and Tiesinga E 2018 Data and analysis for the CODATA 2017 special fundamental constants adjustment Metrologia 55 125
[3] Tian Z, Wang J, Fan H and Jing J 2015 Relativistic Quantum Metrology in Open System Dynamics Scientific Reports 5 1–6
[4] Oh Ch, Lee Ch and Lee S-Y 2019 Optimal Gaussian measurements for phase estimation in single-mode Gaussian metrology npj Quantum Information 5 1–9
[5] Kim J-H, Moon S, Kim J-W, Lee D, Park D-H, Jeong Y, Hand S, Wolf P D, Kim Y S and Shin C 2019 Advanced measurement and diagnosis of the effect on the underlayer roughness for industrial standard metrology Scientific Reports 9 1–8
[6] Oakley T R J 1954 Engineering Dimensional Metrology: Symposium at the National Physical Laboratory Nature 173 293–5
[7] Anscombe N 2008 Measuring up to industry Nature Photonics 2 672–4
[8] Sené M, Gilmore I and Janssen I G 2017 Metrology is key to reproducing results Nature News 547 397–399
[9] Harding K 2008 Engineering precision Nature Photonics 2 667–9
[10] Klitzing K v 2017 Metrology in 2019 Nature Physics 13 198–9
[11] Stange A, Imboden M, Javor J, Barrett L K and Bishop D J 2019 Building a Casimir metrology platform with a commercial MEMS sensor Microsystems & Nanoengineering 5 1–9
[12] Luiten A N 2001 Frequency Measurement and Control: Advanced Techniques and Future Trends (Topics in Applied Physics) (New York: Springer)
[13] Lukyanova Ye Yu 2018 Economic unit process management system forming theoretical and applied aspects for the national economy conditions (Simferopol: IT Arial)