

ON THE PROBLEM OF METROLOGY INSTITUTE DEVELOPMENT

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Abstract: Arrangement of the metrology field is a condition to satisfy a series of needs in science, health care, industry, assurance of quantity and quality of products and services, quality system, environment protection, etc. In the case that metrology field is not able to satisfy the needs that meets, it would represent the limit in work and development of other fields, in which it plays a significant role. Consequences of that state may be very serious, with financial losses higher than investments in assurance of suitable state in the field of metrology.

However, there are rare examples when for metrological activities it was possible to provide unlimited financial and other resources. Just for the series of limitation in the development of some metrology institute, as the particular problem, states definition of directions in development of the institute, in order that it may gives maximal effects for given investments or available resources.

Based on this, in the paper are pointed out some of the problems in defining the development of metrology institute.

Keywords: Metrological infrastructure, metrology institute, modeling

1 INTRODUCTION

Metrology institute, disregarding its organizational level (national, regional or enterprise level), may have a series of defined activities. Let limit us, this time, that the basic task of metrology institute is - measuring instrument examination. In that case it is expected that metrology institute fulfill the needs regarding the examination of certain number of different measuring instruments in the particular territory. In order to provide this it is necessary to satisfy series of requirements, but in that way to give maximal effects for available resources. To reach such an objective it requires, besides clear notice of requirement, definition of appropriate model for planning of work and development of that institution. Defining of such model is desirable, above all, to enable simulations for discovering suitable solutions.

2 DEFINITION OF REQUIREMENTS

Requirements stated in front of previously defined institution, refer to the examination of: (a) certain kind of measuring instruments; (b) certain number of measuring instruments for each kind in specified time interval; (c) certain distance of measuring instruments from the testing center. It is presumed that for each measuring instrument are defined: (1) measuring range (MO); (2) reference conditions (R); (3) accuracy (T) (figure 1).

Defined characteristics of measuring instruments require assurance of appropriate conditions that enables examination of these measuring instruments. In addition, two basic groups of requirements may be noticed: (1) priority requirements, that must be fulfilled due to certain higher interests and no limitation is stated for them, and (2) regular requirements, that are subject to certain limitations. Just this second group of requirements needs appropriate planning. In addition, for available resources, the objective function may be defined, in order to obtain: (1) maximal effects, i.e. maximum number of examinations of measuring instruments, or maximal profit from measuring instruments examinations, and (2) minimal expenses for measuring instrument owner.

Having in mind defined objective functions, metrology institute will, maybe, not decide to satisfy all the requirements, but certain of them only. Those, for which it decides not to satisfy, it will leave to some other institution, until they become included in defined objective functions.

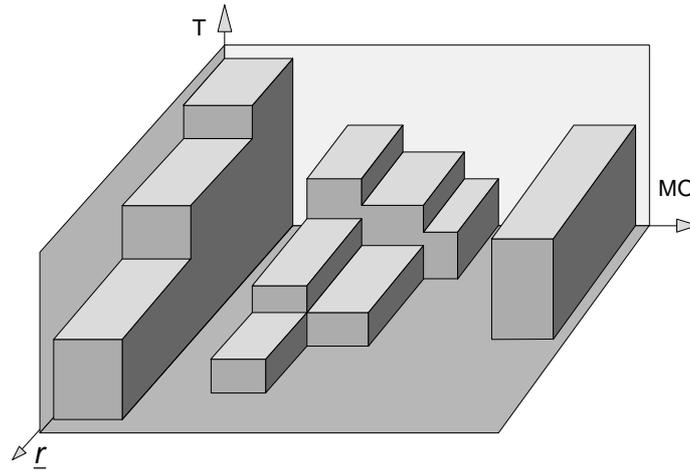


Figure 1. Defined characteristics of measuring instruments.

3 RELATED CONDITIONS AND LIMITATIONS

The fulfillment of defined basic task of metrology institute, i.e. measuring instrument examinations, means fulfillment of a series of conditions (figure 2). It relates, above all, to provide: (1) appropriate personnel and its permanent education; (2) development and improvement of metrological regulations; (3) measuring test equipment and its maintenance, including its regular examination; (4) laboratory premises for housing test equipment; (5) measurement standards for examination of test equipment; (6) related means (material, energy, etc.).

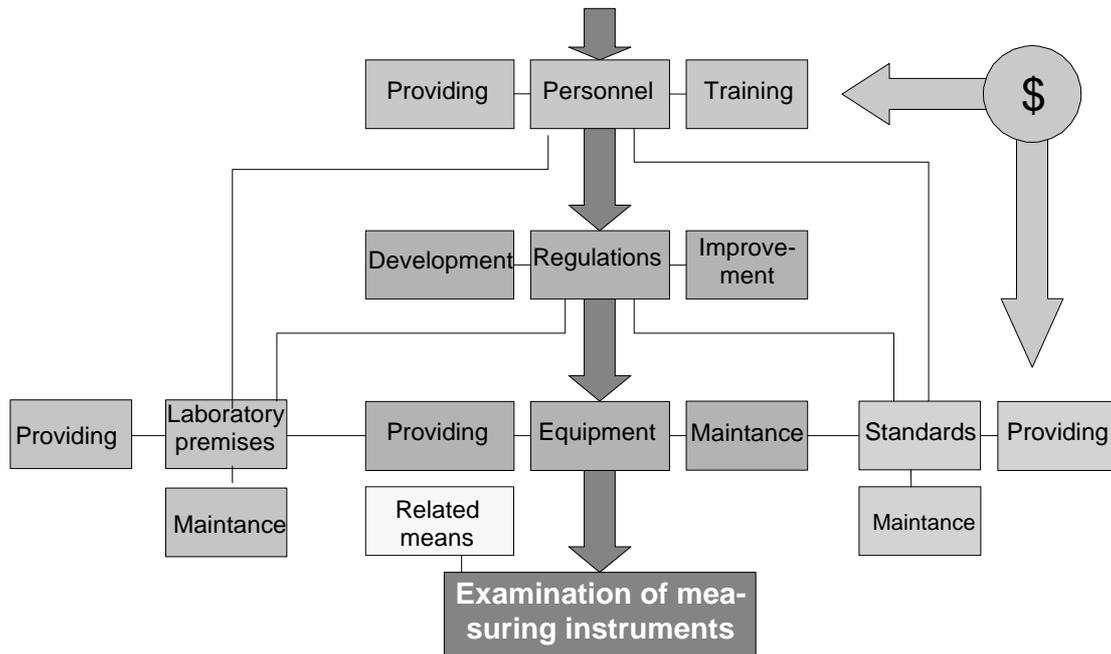


Figure 2. The fulfillment of defined basic task of metrology institute.

From the above conditions originate basic limitations in the fulfillment of stated task. They relates, primarily, to provide: (a) appropriate personnel and (b) financial resources for: (1) testing and standard measuring equipment; (2) adequate laboratory premises; (3) related means; (4) current expenses, including staff allowances. In a particular case, no matter of financial resources, it may arise limitation in acquisition of sophisticated measuring and other equipment.

Elimination of the mentioned limitations requires certain period of time, e.g. for: training of staff, building of laboratory premises, and acquisition and installation of measuring and other equipment, and this also must be kept in mind.

4 DIRECTIONS IN DEVELOPMENT

Starting from the requirements concerning the examination of measuring instruments with defined characteristics, and from defined objective functions and limitations, different directions are noticed in possible development of metrology institute, or fulfillment of given requirements and objective function.

The fulfillment of objective function concerning minimal expenses for measuring instrument owner, requires design of such location of testing laboratory (figure 3), that will provide the fulfillment of that function. This optimization problem represents typical case of location-allocation problem with limited supplier capacities, which can be solved by using Cooper algorithm. In addition, two variants are noticed, when they are possible, i.e.: (1) selection of portable test measuring equipment, that enables examination of measuring instruments in the vicinity of its use, or (2) selection of stationary test equipment, meaning that measuring instruments have to be transported to it from their place of use.

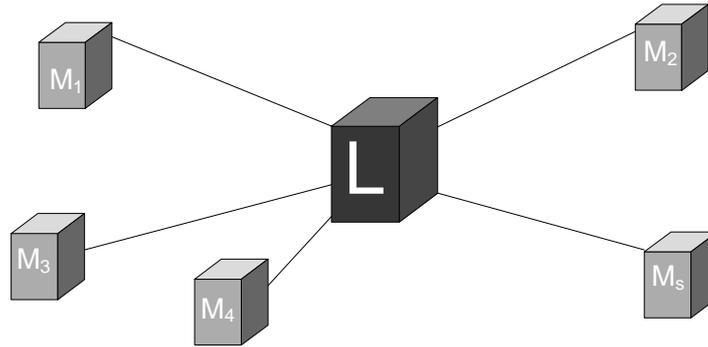


Figure 3. The location of testing laboratory.

The problem of selection of test measuring equipment concerning: (1) physical quantity, or kind of measuring instrument, for the purpose of it; (2) measuring range; (3) reference conditions; and (4) accuracy, is considerably more complex. The series of different variants is also possible. To enable the noticing of problem more clearly, let us specify the basic variants (figure 4).

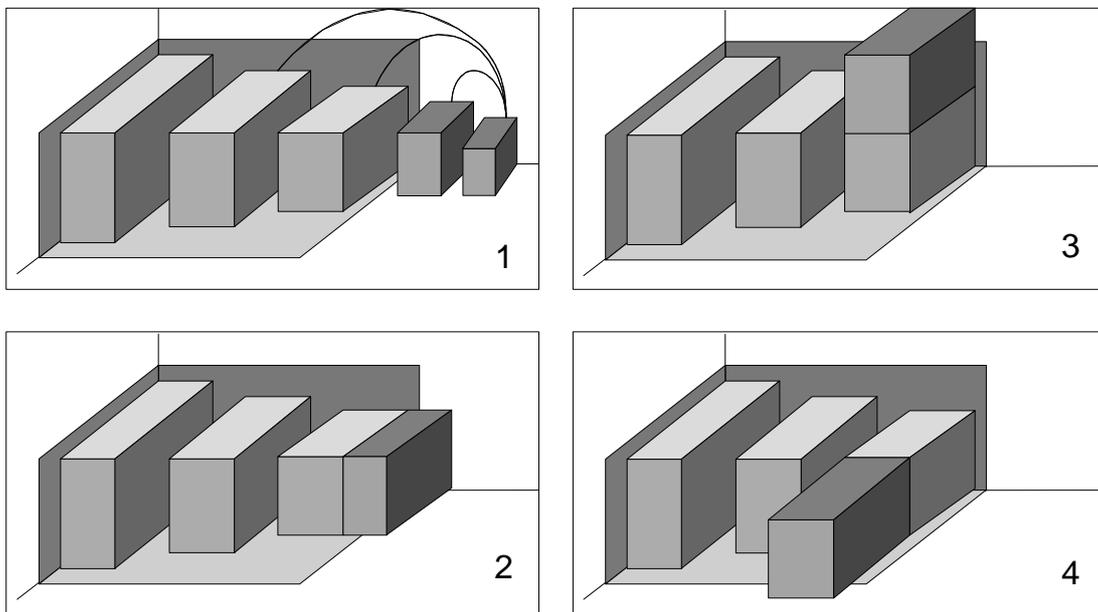


Figure 4. The problem of selection of test measuring equipment.

Each of them means providing of the conditions that enables:

- 1) organization of examination of the new kind of measuring instrument*;
- 2) examination of certain kind of measuring instrument in wider measuring range;
- 3) examination of certain kind of measuring instrument of higher accuracy;
- 4) examination of certain kind of measuring instrument in severe reference conditions.

Undoubtedly, the different combinations of cited basic variants are also possible, and each of them requires appropriate personnel and financial resources. In addition, as a task it is imposed selection of the most advantageous variant, or its combination, for which objective function, at given limitations, attain maximum value.

Observing, first, the variables of accuracy and measuring range for a certain physical quantity FV_i , at certain reference conditions (figure 5a), the variation of accuracy over the measuring range may be shown as the function $f_i = f_i(FV_i)$. In addition, the objective function is imposed, in the form of:

$$J_{FQ_i} = g_i \left(\int_{MO_d}^{MO_g} f_i(FV_i) \cdot dFV_i \right) \quad (1)$$

which analytical optimization is exceptionally complex due to variable integration boundaries.

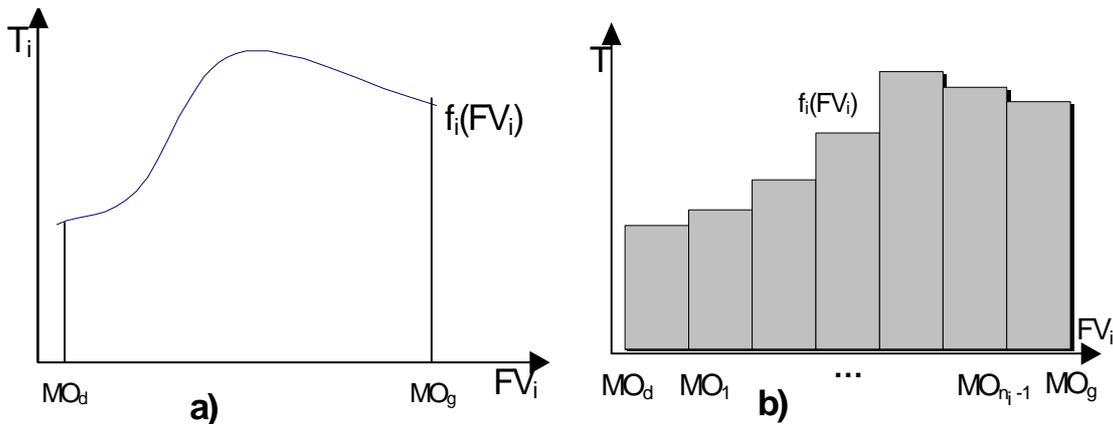


Figure 5. The variation of accuracy over the measuring range at certain reference conditions.

Having this fact in mind, and also nature of variations of $f_i(FV_i)$ for the most of physical quantities, it is completely acquitted to introduce the following assumption:

- Functions $f_i(FV_i)$ are constant in parts over corresponding intervals $(MO_d, MO_g)_{FV_i}$. (figure 5b)

Let have n_i intervals, with indications $MO_d = MO_0$ and $MO_g = MO_{n_i}$. Function $f_i(FV_i)$ may be than expressed in the form of:

$$f_i(FV_i) = \begin{cases} T_{i1}, FV_i \in [MO_0, MO_1] \\ T_{i2}, FV_i \in]MO_1, MO_2] \\ \vdots \\ T_{in_i}, FV_i \in]MO_{n_i-1}, MO_{n_i}] \end{cases} \quad (2)$$

Now, analyzing the variation of the accuracy of measurement of arbitrary physical quantity at variation of reference measurement conditions, for a point chosen in the measuring range, we can state the dependence of accuracy on m influence quantities when measuring the observed physical quantity. This dependence, even by nature represents more complex function, in practice is expressed as a function with constant parts, i.e. certain number of intervals are defined over which stated accuracy is guaranteed (figure 6a). Let indicate with R_{i0} the middle of the interval of highest accuracy at the variation of influence quantity R_i .

*Having in mind mutual connection of measuring equipment, care should be taken, as the providing of some measuring equipment, and their harmonization with the existed equipment, may achieve grater possibilities than having this single equipment.

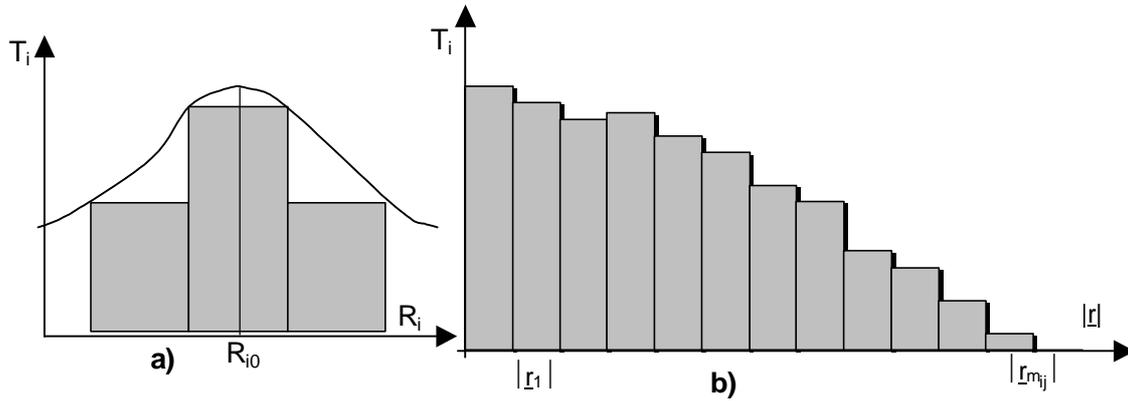


Figure 6. The dependence of accuracy of measurement of arbitrary physical quantity with variation of reference conditions, for a point chosen in the measuring range.

Introducing the vector of influence quantities

$$\underline{R} = (R_1 \ R_2 \ \dots \ R_m)^T, \tag{3}$$

and corresponding vector

$$\underline{R}_0 = (R_{10} \ R_{20} \ \dots \ R_{m0})^T, \tag{4}$$

it may be defined the vector of reference conditions deviation

$$\underline{r} = \underline{R}_0 - \underline{R}. \tag{5}$$

When the variation of accuracy is presented with intensity variation of vector of reference conditions deviation it also comes out constant function in parts that change the value for m_{ij} value $|r|$, i.e. when one or more influence quantity move from one accuracy interval to another (figure 6b).

Now, it may be presented the dependence of accuracy of measurement of observed physical quantity with the variation of value of measuring quantity over the measuring range and intensity variation of vector of reference conditions deviation (figure 7).

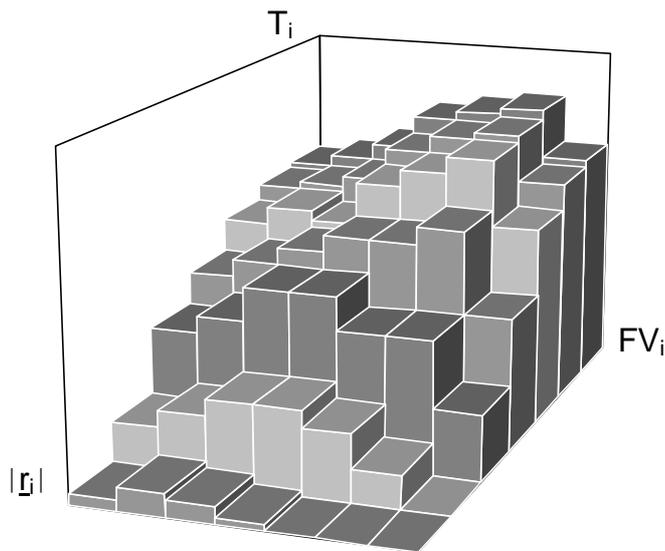


Figure 7. The dependence of accuracy of measurement of observed physical quantity with variation of value of measuring quantity over the measuring range and intensity variation of vector of reference conditions deviation.

Having in mind mentioned connections between variables, it is normal to adopt objective function as the sum of weighted normalized basic volumes, so that it assumes the following form:

$$J_{FV_i}^0 = \sum_{j=1}^{n_i} k_{ij} \cdot \frac{(MO_j - MO_{j-1})_{FV_i}}{(MO_{n_i} - MO_0)_{FV_i}} \cdot \sum_{k=1}^{m_{ij}} l_{ijk} \cdot T_{ijk} \cdot \frac{(|r_k| - |r_{k-1}|)_{[MO_{j-1}, MO_j]_{FV_i}}}{|r_{m_{ij}}|_{[MO_{j-1}, MO_j]_{FV_i}}}, \quad (6)$$

where k_{ij} and l_{ijk} , $i=1, n$; $j=1, n_i$; $k=1, m_{ij}$ are weighted coefficients for corresponding part of the measuring range, or for corresponding value of the vector of reference conditions. Coefficients k_{ij} are function of the number of measuring instruments which measuring ranges lies within the observed range of the measuring equipment, profit earned by the examination of these measuring instruments, and other parameters, while the coefficients l_{ijk} are primarily function of frequency by which vector of reference conditions deviation r takes the value r_k . This frequency is determined experimentally, e.g. yearly.

By using method of weighted coefficients, global objective function may be expressed in the form:

$$J = \sum_{i=1}^n C_i \cdot J_{FV_i}^0 \quad (7)$$

$$J = \sum_{i=1}^n C_i \cdot \sum_{j=1}^{n_i} k_{ij} \cdot \frac{(MO_j - MO_{j-1})_{FV_i}}{(MO_{n_i} - MO_0)_{FV_i}} \cdot \sum_{k=1}^{m_{ij}} l_{ijk} \cdot T_{ijk} \cdot \frac{(|r_k| - |r_{k-1}|)_{[MO_{j-1}, MO_j]_{FV_i}}}{|r_{m_{ij}}|_{[MO_{j-1}, MO_j]_{FV_i}}} \quad (8)$$

where weighted coefficients C_i are function of number of measuring instruments for particular physical quantity FV_i , profit earned by the examination of measuring instruments FV_i , connections with other FV , and other factors.

5 CONCLUSIONS

From the above analysis, it can be noticed that planning of work and development of metrology institute is connected not only with solving of metrological problems, but also with problems of planning. Exactly this requires defining of appropriate model, which is based on general modeling rules, but also takes into account particularities of metrological task.

Having in mind complexity of mentioned problems, in Federal Bureau of Measures and Precious Metals, in Belgrade, the appropriate model is developing, in order to serve for defining work and development in that Bureau, based on the results of simulation on that model. Due to limited length of the paper, the developed model and the results of simulation will be presented in some other paper.

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