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The ABC of Qualimetry

Toolkit for measuring the immeasurable

Ridero
2015
The publication provides basic information on the history, theory and practice of qualimetry. The Appendix contains an example implementation of the algorithm quality assessment using a simplified method. The book is intended for all those whose professional activity is connected with the quantitative evaluation of quality and the creation of qualitative techniques: students and University teachers, researchers, evaluators, quality assurance specialists, and HR-specialists.

ISBN 978-5-4474-2248-6
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Introduction

Anything that people produce with in a period of time, as well as, anything they encounter in the course of commodity exchange and consumption and, generally in their everyday life, can be expressed by a set of four elements: products, services, information, and energy. Each of these elements can be fully described by three fundamental variables:

— **Quantity** (in conventional units of measurement);

— **Cost** of production, distribution\(^2\) and consumption / utilisation / exploitation / application of a unit of quantity; and

— **Quality** of the unit of quantity.

The first of these, *quantity*, is basic to calculation in the engineering disciplines. The second, *cost*, is recognised and studied by the body of economic disciplines. As to the third characteristic, *quality*, until quite recently it was seldom if ever taken into account by either engineering or economic or management disciplines.

The reason was a lack of a theory and a toolbox for a valid quantification (assessment) of quality, such as the quality of products / services / information / energy. Without this kind of assessment it is very difficult, if not impossible, to maintain an effective economic or social structure, e.g., an important omnibus structure called the quality of life, otherwise known as the standard of living.

The foregoing applies, among other things, to management, political, legislative or analytical activities.

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1 Some times information and energy are subsumed under products or services.

2 Distribution may be subsumed under consumption.
For at least one time, almost every manager (as well as a policy-maker, law-maker or analyst\(^1\)) has faced the problem of quantitative evaluation of quality, e.g., the need for quality control; depending on the specifics of their work it may be the quality control of an industrial or a social process (including the control of life quality), a design, a product, personnel, etc.

In every such situation what the manager has to do is to convert the quality of a controlled object – a production or social process, a design, a product, personnel, etc. — within a given time from a given state, A, to a target state, B. Clearly, the manager cannot solve this problem unless he/she is capable of quantifying A and B, that is, assessing the object’s quality in quantitative terms.

Hereinafter in this ABC we will often discuss quality with special reference to the quality of life as the most important, succinct and general description of socio-economic processes. The quality of other objects, e.g., products, will be used to make our examples more graphic.

Secondly, quality must be quantified in those frequent situations where a manager must decide between two or more options. For example, with superior quality in mind a manager has to decide:

— Whether a consumer product is to be imported or to be manufactured at home;

— On an organisation/administrative structure best suited for controlling a social or manufacturing process; or

— An equipment package for building infrastructure facilities in an urban setting.

When the number of options is greater than two, given that the

\(^1\) For simplicity here in after they will all be referred to as managers.
quality of each option is determined by a combination of parameters (more about it later), the inescapable conclusion is that if one is to address this class of problem one must be able to quantify quality.

Lastly, we need to quantify quality when dealing with economic and social problems where, if we are to improve calculation accuracy, we have to take into account qualitative as well as quantitative factors (that is to say, if the former cannot be expressed in currency units), such as social, environmental, ergonomic or aesthetic ones.

With these considerations in mind the reader is introduced to an ABC of qualimetry, a relatively new scientific discipline concerned with the methodology and total quantitative assessment of the quality of different objects and of some of their qualitative characteristics that do not lend themselves to measurement in common monetary units. The fact is that despite there being a sizeable body of writing (more than 100 books with the term qualimetry in their title) any information found there is usually outdated and often plain wrong, which may lead to wrong decision making processes.

Because of the limited size of this text we can only describe the basics of qualimetry in its most common version rather than cover this discipline in full. For this reason Chapter 1 will focus on the so-called short-cut method of qualimetry. Unlike other methods, the approximate and the exact ones, it takes far less time to learn, understand and apply; however, it will help you solve, with reasonable accuracy, quite a few problems encountered in practice.\(^1\)

This ABC will be useful to specialists in the executive, regulatory and legislative branches, as well as, to all those interested in the methodology of decision-making pertaining to the quality of different kinds of objects.

\(^1\) For the same reason we will exclude from consideration other, less common types of qualimetric techniques.
The authors would appreciate any constructive comments on the subject matter of this book.
Chapter 1. Qualimetry in Outline

Over the years following the appearance of qualimetry, many new scientific related with this science resulted, but most of them are scattered over various small editions and remain virtually inaccessible to the broad reading public interested in quality assessment issues. The purpose of this section then is to give a systematic and fairly complete picture of the state of the art in the theory and practice of evaluation of the quality of various objects of a social or economic character.

1.1. General Information about Quality and Quality Control

1.1.1. The Essence of Quality and Quality Control

The Concept of Quality and What Makes It Different from Other Similar Concepts

As already noted in the Introduction, Quality Control is one of the main applications for qualimetry.

Unfortunately, modern economic theory and economic practice alike, has unambiguous and common interpretations of the terms quality and control, leading to frequent misunderstandings with resulting in completely different approaches to many important issues. For example, “What really happens to an object (e.g., life quality), which, as often claimed, is being controlled?” Is the process indeed a control one? Is it indeed quality and not something else that is subject to control?”
These are not idle questions. Unless we figure them out we cannot count on success in addressing the issue of quality. Therefore, let us clarify our definitions of the key terms, quality and control. At the outset we introduce some terms based on which it will be possible to define the desired term, quality control.

*Object*, a thing or a process; as applied to the theme of these introduction:

— An animate thing (e.g., a city dweller) or an inanimate one (e.g., a motor car);

— A product of labour (e.g., a dwelling house) or a product of nature (e.g., a natural landscape around an urban settlement);

— A physical object (e.g., an industrial enterprises) or an ideal one (e.g., an artwork made out in a book title);

— A natural object (e.g., a landscape) or a man-made one (e.g., a set of landscape design structures);

— A product (e.g., a piece of clothing) or a service (e.g., a medical service);

— Items (e.g., motorways) or processes (e.g., life activities, which collectively form the quality of life).

In what follows the term *object* will apply to an object (which can be called “singular”) such that its quantity, in common measurement units, equals one. Then, a city can be an object but not three cities taken together; likewise one airplane, one specialist, etc.

*Property*. A feature, characteristic or peculiarity of an object, that becomes apparent during its consumption/operation/use/application (henceforth, all these terms are used interchangeably) according to the purpose of its use (e.g., the mean lifetime of a communi-
ty).

The mention of the condition “according to its purpose” is caused by the following considerations: Imagine an emergency situation in which indoor sports facilities have to be used as temporary shelter for the inhabitants of a city whose homes were destroyed in a disaster (such as caused by Hurricane Katrina in New Orleans in 2005). The floor area of the interior, which can accommodate refugees, would seem to be a characteristic of a sports structure. The thing is that this kind of utilisation of athletic facilities is abnormal, out of keeping with their purpose. Therefore, a feature of a sport hall such as “the number of refugees it can accommodate” cannot be regarded as its “property” in a qualimetric sense.

We draw the reader’s attention to one more circumstance, which, although mentioned in the definition of the term property, is sometimes neglected in practice. Properties are not just any features/characteristics/peculiarities of an object, but only those that occur during its production or consumption/application/use/operation.

For illustration we give the following example (which for greater clarity relates to product quality). Any product made of a ferromagnetic material is known to possess the quality of magnetostriction, that is, the ability to change its shape and size in response to changes in the magnetic field.

Let us consider two different kinds of products made of a ferromagnetic material: a mechanical chronometer watch and the track shoes of a caterpillar tractor. Obviously, magnetostriction is incident to both.

In a chronometer magnetostriction shows in the way its accuracy is affected by exposure to a strong magnetic field. As for tracks, the phenomenon of magnetostriction in a physical sense does take place during their operation, but its impact (e.g., the magnitude of the absolute and relative changes in the linear and volumetric
dimensions of the tracks) does not affect the performance of the tracks as part of a caterpillar belt. We can assume, therefore, that magnetostriction is not manifested in the consumption of these products (that is not in a physical but an economic sense.)

It follows that for an object like a chronometer watch, the presence of magnetostriction is to be considered one of its properties, whereas for a caterpillar track it is not a property in the sense outlined above in the definition of property.

**Quality** is a property representing a set of those and only those properties that characterise the consumption results of an object, both desirable and undesirable, excluding the cost of their creation and consumption. That is to say, this set includes only properties associated with the results achieved in consuming an object, and does not include ones associated with the cost of providing these results.

Notice that:

(1) The properties that constitute quality do not include those that manifest themselves in the course of production/creation/development/manufacture of objects (hereinafter, unless otherwise indicated we shall generally use instead of four terms — *production, creation, development, manufacture* — a single umbrella term, *production*); and

(2) The entire life cycle of an object will be conventionally considered to consist of only two broad stages, those of production and consumption, with the consumption stage including what is known as distribution (which is only applicable to some objects, e.g., products of labour but not the quality of life).

Thus, when we analyse the quality of an object we can — even must — ignore its manufacturing technique and its production and consumption costs and focus instead on the results, both positive
and negative, achieved at its consumption stage.

**Cost Effectiveness.** The totality of properties characterising the capital input into the production and consumption of an object. (In some cases cumulative costs can be represented by so-called reduced costs or full costs.).

From the definitions and interpretations of the terms *quality* and *cost-effectiveness* it follows that the entire set of properties of an object can be divided into two disjoint subsets: the properties that form the quality of the object and those that form its cost effectiveness.

As consumers are not normally only care for either the quality of an object ignoring its cost effectiveness or, alternatively, its cost effectiveness without regard to its quality, the science of qualimetry, naturally, felt the need for a characteristic that would take into account the entire set of properties associated both with the consumption of an object (its quality) and the costs incurred (its cost effectiveness).

This characteristic is termed *integral quality* in qualimetry.

**Integral quality.** The property of an object describing the sum of its quality and cost effectiveness. Thus, integral quality is the most general characteristic of an object, which factors in all of its properties.

It should be noted that the engineering and economic literature uses concepts and terms similar in meaning to the ones introduced above, *quality* and *integral quality*. We will consider these concepts starting with those who are close to the concept of quality.

The term *engineering level* is usually applied to the quality of products (but not, e.g., to the quality of life). It is almost identical in scope to the term *quality*. However, it has several shortcomings
compared to the latter:

(a) In a purely linguistic sense, with some objects this term is perceived as much less suitable than quality. Imagine pronouncing phrases like “the engineering level of ladies” perfume”, “the engineering level of milk,” “the engineering level of a specialist,” “the engineering level of a managerial decision,” or “the engineering level of life.” Substituting quality for engineering level immediately improves the sound of these identical terms: “the quality of ladies” perfume,” “the quality of milk,” “the quality of a specialist,” “the quality of a managerial decision,” “the quality of life.”

(b) The term quality has a long history dating back to Aristotle’s days, while the term engineering level came into being (mainly in the Russian literature) in the last 30 — 35 years. This brings up the natural question: why use a new term if we have a long-established synonymous term?

(c) It is common knowledge that the quality of a finished product is defined by three factors: the quality of its design, the quality of its raw materials and semi-finished products, and the quality of its manufacture (that is, the extent to which its design parameters are met in manufacture). Sometimes the term engineering level refers to what is termed design quality in qualimetry.

Then the question arises: why introduce a new term, engineering level, if we can do with the good old term, quality (or more precisely, design quality)?

For these reasons, in the science of qualimetry (and in this ABC) the term engineering level is not used.

The term technical excellence is an absolute synonym of engineering level. Therefore, all that was said above regarding engineering level applies to technical excellence.
The term **utility** describes a property that characterises the aggregate of quantity and quality of an object (see, e.g., [1]).

For example, the utility of two houses is greater than that of one of exactly the same quality. However, utility and quality means the same thing when applied to one unit of quantity of an object. That is to say, we can assume that quality is the utility of one unit of quantity of an object. Since the quantitative estimation toolbox is better designed for quality than for utility in what follows we will use mainly the term *quality*, that is to say, consider mainly objects whose number is equal to one unit.

The term **value** is synonymous with *utility* but its use is normally restricted to the philosophical literature. All that we have said above about *utility* holds for *value*.

Concept of **use value**. If as shown above, quality is the utility of an object unit (that is, a property inherent in the object), use value is the object possessing this property, i.e. utility. As applied to an object whose quantity equals unity, use value is the object possessing this property whose quantity equals unity (see [1]). As the subject matter of this ABC is the quality of an object (e.g., the quality of life) and not its quantity, hereafter the concept of use value will not be generally used and our exposition will be in relation to the concept of quality.

The term **efficiency** has many different interpretations. With regard to the most commonly used one it is very close to *integral quality*. However, because of its ambiguity we will use it instead the term *integral quality*. On the other hand, since most of the statements relating to the concept of quality remain in force and applicable to the concept of integral quality, the latter will be used hereafter only in specified cases.

We introduce some more concepts related to the concept of quality.

Index value. Is a specific numeric value that an index can take. For example, the values for the property index “room temperature” can be 20° C or 22° C. Here the numerals 20 or 22 are the values of the property index. Similarly the term index value can be illustrated (this time in dimensionless units) with reference to quality. Let the quality index be expressed by the symbol $K^k$. Then in the expression $K^k = 0.68$ the numeral 0.68 is the value of $K^k$.

Where quality is analysed in general terms (i.e., not in a numeric but in an alphabetic form) the value of the index is expressed not by a numeral but by a lowercase letter (as opposed to the index itself, which is always denoted by a capital letter). For example, the expression $K^k = k_1^k$ reads as follows: the quality index $K^k$ has the value $k_1^k$. This applies to a quality index but also to a property index, an integral property index, etc.; to any index at all.

After we have clarified the meanings of the basic concepts related to the term quality we can analyse concepts related to the term control, which is in practice often linked with quality (e.g., in phrases like “product quality control”).

1.1.2. The Term Control and Its Difference from Other Similar Terms

Let us denote a given time point by $t_1$ and a time point in the future by $t_2$ (obviously, $t_2 > t_1$). Let us denote by $\Delta T$ the time elapsed from $t_1$ to $t_2$: $\Delta T = t_2 - t_1$.

Let us define our terms:

Pre-settime $\Delta T_{SET}$: a time period $\Delta T$, the value of which is pre-set by a human controller.
**Indefinite period of time** $\Delta T_i$: a time period $\Delta T_i$ the value of which is not pre-set/defined by human controller.

Let us introduce some terms:

**Object state**: the state of an object at an instant defined by its quality whose index has the value $k^K$.

**Given object state**: the state of an object at a given (initial) instant $t_1$ at which the value of its quality index is $k^K_1$.

**Future object state**: the state of an object at a future instant $t_2$ at which its quality index will be $k^K_2$.

**Quality variation**: a value given by the expression $\Delta K^K = k^K_2 - k^K_1$.

**Pre-set quality variation** $\Delta K^K_{\text{PRE}}$: a quality variation $\Delta K^K$ the value of which is given in advance by a human controller.

**Indefinite quality variation** $\Delta K^K?$: a quality variation $\Delta K^K$ the value of which is not given by a human controller.

**Object quality control**: the transfer of an object from a given state $k^K_1$ to a future state $k^K_2$ at $\Delta K^K_{\text{PRE}}$ with in $\Delta T_{\text{PRE}}$ (To rephrase it, to control the quality of an object is to ensure in the object a pre-set quality variation $\Delta K^K_{\text{PRE}}$ with in a pre-set time $\Delta T_{\text{PRE}}$).

It follows from this definition that if any of these conditions were not met (e.g., indefinite time $\Delta T_i$, instead of pre-set time $\Delta T_{\text{PRE}}$ or in definitive quality variation $\Delta K^K?$, instead of pre-set quality variation $\Delta K^K_{\text{PRE}}$ is used) it would be improper to refer to it as quality control. In actual fact a different process is in progress. Table 1 shows different processes and their relation to the quality control process.
Table 1. Kinds of processes related to variation in the quality of objects. NOTE: Lines 10 and 11 represent situations, in which quality control in the ordinary sense is indeed exercised.

Table 1 lists twelve situations differing in their combinations of $\Delta K^K$ (quality variation) and $\Delta T$ (time variation). Each has an associated process type related to quality variation, from total uncertainty to quality control, which may vary within pre-set limits within a pre-set time.

Regrettably, in practice the term quality control is frequently
applied to processes that can at best be described as quality improvement (see, e.g., line 4 above). In these processes (which in most cases concern industrial products) the value of an object’s property index could be improved by so many per cent within a preset time; e.g., the life of a component part could be increased by 30%. It is then concluded that the quality of the object improved by the selfsame 30% supposedly as a result of quality control.

There are two principal fallacies here. One is that the magnitude of increase in the value of the quality index was determined incorrectly, taking no account of the fact that an improvement in the value of a property of an object by $\alpha$% almost always leads to an improvement in its quality index by $\beta$% (with $\alpha<\beta$).

The second fallacy is neglect the following: a quality improvement in one property of an object will result in an improved quality index of the object to the extent that none of its other property indices has deteriorated. Yet, this is a fairly common occurrence. Let us suppose that in the above case a 30% increase in the life of a component part is often accompanied by an increase in its mass. This leads to a deterioration of its “product mass” property by so many percent. Unless we make a qualimetric calculation we cannot say a priori whether — and by how many per cent — the quality of the product deteriorated or improved. (Proofs of both these assertions are to be found in books on theoretical qualimetry; see, e.g., [2]).

Therefore, it often happens in practice that the term quality control is applied to processes which, in control theoretic terms, cannot be considered quality control and, not infrequently, cannot be even called quality improvement because in reality they only ensure some indefinite quality variation (see lines 2 and 5 in Table 1 above).

The grey background in Table 1 is used to highlight two lines, 10 and 11, which represent the criteria to be met if we are to have a real quality control process. Line 10 describes the conditions
under which, as common sense tells us, quality control is really achievable. That is to say, it is about a quality improvement is achievable to a pre-set extent within a pre-set time.

The case introduced by line 11 also belongs to control processes, though it is less apparent in the usual sense. Its only difference from case 10 is that the latter achieves a quality improvement (accordingly, $\Delta K^K > 0$), whereas in case 11 no improvement is envisioned, the only intention being to keep quality from deteriorating within a pre-set time period, i.e., to set it at a constant level, $\Delta K^K = 0$).

The process described in line 12 is also related to quality control is totally unobvious to common sense. In pure theory, however, one can imagine a situation where the goal is not to increase but to decrease the quality of a product within pre-set limits and within a pre-set time, e.g., in order to cut production costs so as to boost demand. Since this is more academic than a real-life situation the respective line (12) in Table 1 was not highlighted with grey.

The foregoing interpretation of quality and quality control suggests that if we are to control quality we must be able to calculate the values of $\Delta K^K$. To do it we must, in turn, be able to quantify or estimate quality using its index $K^K$. Consequently, we need a tool for the quantification of quality, which is provided by qualimetry.

There were also other factors, which made the appearance of qualimetry necessary, even inevitable. They will be discussed in the section that follows.
1.1.3. The Origin, Growth and Future of Qualimetry

1.1.3.1. The Reasons Behind the Rise of Qualimetry as a Science

Qualimetry is a consequence of knowledge quantification

The term qualimetry (from the Latin quale, “of what kind”, and the Greek μετρεω, “to measure”) was initially applied to a scientific discipline studying the methodology and problems of quantitative assessment of the quality of various objects, mainly of industrial products [3]. By 1970 enough experience had accumulated to permit a thorough investigation of qualimetry, its subject matter and its relations with various scientific fields. At the same time there was a growing awareness of the need to expand the scope of qualimetry from product quality (which was the focus of some researchers) to the quality of objects of whatever nature, including socio-economic objects such as the quality of life.

When the term (and the respective concept) was first used it seemed unexpected, almost fortuitous; some still regard it so.

However, it would be wrong to speak of the fortuity of qualimetry. On the contrary, its appearance should be seen as one of the many perfectly natural signs of the general broadening of the scope of quantification and the use of quantitative methods in scientific and, generally, cognitive activities at large.

The universal and imperative nature of this tendency to expand the use of quantification as a major tool of cognition was succinctly stated by Galileo, who said “Measure what is measurable, and make measurable what is not so.” The Russian Mathematician D. B. Yudin expressed nowadays essentially the same idea: “Quality is a yet unknown quantity”.
Many great minds were aware of the important influence that mathematics, as a general framework of quantification techniques, has exerted on the development of science.

K. Marx was of the opinion that a subject could be called a science if it had a mathematical foundation. A century before him, I. Kant wrote in his *Metaphysical Foundations of Natural Science*, “I maintain, however, that in every special doctrine of nature only so much science proper can be found as there is mathematics in it”. Three centuries before Kant, Leonardo made a similar statement: “No human investigation can be called real science if it cannot be demonstrated mathematically”. Five centuries before Leonardo, in the 9th century, the famous Arab scientist Abu Yusuf Ya’qub ibn Ishaq al-Kindi, who saw in mathematics the basis and prerequisite of all science, including philosophy and natural history, pursued a similar line of thought. Another thirteen centuries earlier the Greek philosopher Xenocrates of Chalcedon expressed the ancients’ idea of mathematics in the following maxim: “Mathematics is the handle of philosophy”. Dozens of years before Xenocrates, or 2300 years before our time, his teacher Plato said, “Exclude from any science mathematics, measure and weight, and it is left with very little”.

Quantification is steadily broadening its scope of application, as evidenced by the growth of scientific disciplines or technical problem solving techniques that include the Greek μετρεω in their name. Here are a few examples:

Absorptiometry; autometry; autorefractometry; adaptometry; axiometry; actinometry; algometry; amperometry; angiostereometry; anthropometry; astrocalorimetry; astrometry; astrophotometry; audiometry; acidimetry; batimetry; biometry; bibliometry; veloergometry; visometry; viscosimetry; gigrometry; hygrometry; hydrometry; glucometry; gravimetry; gradiometry; densitometry; didactometry; dilatometry; dynamometry; dielectrometry; dosimetry; dopleometry; isometrimum impedancemetry; inclinometry;
interferometry; cliometrics; calipometry; calorimetry; chelatometry; conductometry; craniometry; coulometry; lipometry; luxmetry; mediometry; mercurimetry; morphometry; scientometrics; nitritometry; optometry; ordometry; oscillometry; optometry; perimetry; pirometry; pH-metry; planimetry; polarimetry; psychometrics; potentiometry; pulseoxymetry; radiometry; radiothermometry; redoxmetry; roentgenometry; refractometry; sensitometry; sociometry; spectrometry; spectroradiometry; spectropolarimetry; spectrophotometry; spirometry; spiroergometry; stabilometry; stereometry; sphincterometry; tachometry; tensometry; technometry; tonometry; turbidemetry; uroflowmetry; fluorimetry; photogrammetry; photocolorimetry; photometry; chronometry; equilibriometry; econometrics; exponometry; electrometry; echobiometry. Qualimetry is also a member of this steadily expanding family. (It would be wrong, however, to believe that every discipline using quantification has metry / metrics in its name.)

Qualimetry: A Tool for Enhancing the Efficiency of Any Kind of Work

What happened for the qualimetry to appear in the 1960s?

Modern management science has formulated five necessary and sufficient conditions for the success of any work, which can be represented by a “condition tree” (Figure 1).
Figure 1. Necessary and sufficient conditions for the success of any work

Four of these conditions, TO KNOW, TO BE ABLE, TO MANAGE, and TO MOTIVATE, are relatively easy to meet technically; regulatory documents for respective calculations are already in place. For example, every productive industry uses its own rate setter’s handbook (or a similar document), which is used to calculate the workforce and the time and tools needed to perform a piece of work (TO MANAGE condition). Other documents, like wage rate books, specify the requirements to be met in selecting the workforce to do some work successfully (TO BE ABLE condition). It is relatively easy to secure the TO KNOW condition: you only need to set the work executors a task. Finally, to meet the TO MOTIVATE condition all businesspersons or managers have a broad range of stimulatory actions they can use on their subordinates: material or moral; positive (“carrot”) or negative (“stick”); individualized or team-directed; one-off or time-phased, etc.

The TO EVALUATE condition is a very different case. What we evaluate is work. Any work (and its output) is characterized by three parameters: quantity, cost and quality. Arguably, the numerical evaluation of the quantity and cost parameters does not present any essential difficulties to most occupations in the real sector.

We have a different situation with the quality parameter. Here two aspects must be taken into account: the quality of individual labour and the quality of teamwork. As for individual labour, evaluating is
just a trivial task (particularly if it is to be done in a quantitative form and with due regard for the many characteristics that constitute its quality).

Evaluating even the simple labour of an industrial worker poses difficulties: it is by no means always that it can be evaluated using a simple reject rate index. These difficulties multiply when it is a matter of quantitative assessment of the quality of complex labour, e.g., brainwork.

Here is an example to illustrate the importance and complexity of this task. Back in the early 1970s a group of UNESCO experts surveyed 1200 research teams in Austria, Belgium, Finland, Hungary and Sweden. Their conclusion: the most vexed problem in raising working efficiency in science is the lack of a reliable methodology for assessing the quality of work of individual researchers and research teams. (Similar examples can be cited with respect of managers, health professionals, engineers, teachers, administrators, and some others.).

Let us now look at the issue of assessment of the quality of teamwork. It stands to reason that the quality of output is its most important characteristic. As already mentioned, the outcome of any teamwork is, a product, a service, some information or energy. Of these four the product is by far the most complex in terms of the quality assessment method and the most important in terms of the breadth of its existence domain, given that more than twenty million kinds of products are manufactured by developed economies over the world.

It all goes to show that:

1. In the present-day context, successful, i.e. effective, productive work is a key condition of the economic health of both an individual company and a country at large.
2. When we address the problem of increasing the success/efficiency of any labour the key element is the quantitative assessment—both of the process and the outcome of labour; primarily its product.

3. Of the three characteristics of labour (and its outcome) — quantity, quality and cost — quality is the most complex one in terms of quantitative assessment.

4. Until quite recently, the approach to the problem of quantitative assessment of quality (primarily of products) lacked sound methodological support. At best, isolated quality quantification techniques were created, which had not any sound and unified rationale to support them. As a result, different quantifications of the quality of the same object could be worlds apart if calculated by different methods.

5. A natural corollary to propositions 1—4: in the early post-WWII years every industrialised country felt the need for scientific rationalisation of methods of quantitative assessment of the quality of production work and its outcomes.

6. It was F. Engels who noted that when a technical need appears in society, it pushes science forward faster than a dozen universities. The origins of qualimetry can be seen as a natural response to a pressing need for generalisation and perfection of the techniques of quantitative assessment of quality.

1.1.3.2. History of Qualimetry: From Aristotle to Our Times

Theoretical Reason for the Relatively Late Origin of Qualimetry

One may ask: why did qualimetry appear as an independent scien-
tific discipline in the 1960s and not before?

There were two principal reasons.

The first, which we will tentatively call “theoretical”, is as follows. The term *quality* has existed in science for as much as 2500 years, since the days of Aristotle. His usage of the term referred to different concepts. (For convenience, hereafter the respective definitions for these concepts will be given a modern interpretation, in a concise form, which are more familiar and comprehensible than Aristotle’s definitions. — Auth.). Subsequently, it was depending on its interpretation that it was decided whether or not it was necessary and possible to quantify/estimate this concept.

**Interpretation I:** *Quality is an essential certainty of an object* (i.e., a thing, phenomenon or process), which *makes it what it is and not something else*. In other words, quality is the kind of certainty that distinguishes, say, a human from a horse or a table.

This interpretation was dominant for centuries and it was not until the 20th century that it gradually started to fall into disuse; today, it is of interest almost exclusively to professional philosophers. Clearly, in most cases it makes little sense to refer to this interpretation of quality quantification or estimation; possible exceptions may be biological taxonomy or computer-based pattern recognition.

**Interpretation II:** *Quality is an essential feature or property characterising a given object*. Or, as Aristotle said, “... for example, warmth and coldness, whiteness and blackness, weight and lightness, and likewise other similar definitions...”

Quality in this sense has long since been successfully quantified using tools of general sciences like metrology or commodity research of special sciences such as gravimetry, dosimetry, calorimetry, etc.
Because the contemporary literature of science and engineering is trying to get rid of polysemantic terms the second interpretation has all but grown out of use. The term property has come to replace quality, which fact was embodied in the U. S. S. R. State Standard (GOST) for product quality terminology back in the 1970s. Therefore, the above interpretation of the term quality has no direct relevance to our present discussion of quality quantification.

**Interpretation III:** Quality is the totality of properties of an object that become apparent during its intended use (operation, application or consumption). In other words, quality is a characteristic of an object such that if it is quantified it would allow, with the simultaneous recognition of all the properties of the object in quantitative terms, to measure the goodness of the object when used (operated, applied or consumed).

This interpretation echoes another interpretation of Aristotle’s, who believed that the term quality could be, applied “… in relation to a good and a bad course of action and, generally, both good and bad belong here.”

This, third, interpretation has become the prevailing, almost exclusive one. That is due primarily to the scientific and technological progress in industry, when an enormous variety of similar products appear around the world every year, as well as to the rapid growth of international trade in products, services and energy.

Naturally, after this interpretation became well established and then almost exclusive the need was felt for numerous quality measurement techniques, and as a consequence, for a special discipline to give a scientific justification to such techniques. Before the twentieth century the third interpretation had found very little use; accordingly, there had been little use for quality assessment; hence, no need for qualimetry.

Above we considered the “theoretical” reason for the relatively late
origin of qualimetry as a general method for quality quantification. (Late, that is, in comparison with the origins of the methods of measurement of the two other characteristics of any production output; quantity and cost.)

**Practical Reason for the Relatively Late Origin of Qualimetry**

There is a second reason, which we tentatively call “practical”. Its nature can be educed after we answer the question: Why qualimetry as an independent science was born as late as the mid-20th century if early quality quantification methods had appeared in and outside Russia already in the early twentieth century? We shall try to answer this question by drawing upon materials from the history of domestic science and engineering.

In Russia, the well-known mechanic and shipbuilder A. N. Krylov developed the first scientifically grounded quality measurement method back in the 1910s. He used it to solve the problem of choosing the best warship design from the many submitted to an international competition. (The best here refers to the totality of main properties, or quality, e.g. speed, protection, gun power, etc.). That selection was necessary for the restoration of the Russian navy after the heavy losses it sustained during the Russo-Japanese war.

Unfortunately, the Krylov method — which retains its importance among the many other qualimetric techniques to this day — upon development and successful application fell into oblivion, perhaps because it was designed for appraising the quality of rather unique objects, warships; a description of it could be found in a relatively obscure, almost rare publication (see [4]).

Some 20 years after Krylov’s method other methods for assessing the quality of different types of products appeared. They used a very different approach: where as warships were evaluated by the so-called “analytical” (i.e. non-expert) method, here a kind of expert approach was used. These methods began to evolve from
the late 1920s, when the Special Council on Product Quality under the Presidium of the Supreme Economic Council of the U. S. S. R. found it necessary to use quality indices as an important tool in promoting technological progress and improving product quality. The reference was not to indexes of particular properties but to general (complex) parameters characterising product quality in general.

An essentially similar approach was used to assess the quality of some processes, for example, the performance of a printing shop. At the same time, so-called “comparative quality factors”, which had a regulatory character, were developed for some consumer products.

In the 1930s, the scope of application of expert methods for quality estimation expanded and they were incorporated in some industries and national standards as well as in departmental guidelines. For example, the first half of the 1930s saw the development and application of methods for evaluating the quality of some food-stuffs such as butter, canned fish, bread, confectionery and dried vegetables.

Similar techniques were developed not only for food products but also for consumer goods, such as cotton yarn, fabrics and textile goods, and for evaluating the quality of industrial products, e.g. tractors and farm machinery.

Quality measurement methods multiplied after WWII, in the 1950s. However, qualimetry did not emerge as an independent scientific discipline yet. Apparently, a general pattern relating to the conditions leading to the appearance of a new research topic was at work. Indeed, history shows us that before a knowledge field receives the status of a science there is a latent period when some of its principles and methods are generated and put to test. It is followed by the accumulation of a large body of unsystematised empirical data. At the same time the need may be felt for conceptualisation
of the previous experience of generating those data and addressing emerging problems. The preconditions for a theoretical foundation of a new science are thus created. So emerged geometry in the ancient world. So emerged cybernetics, bionics, semiotics, operations research, econometrics, ergonomics, ecology, etc., in today’s world. So, again, it was in 1968 that qualimetry began to grow into a fully-fledged scientific discipline [3].

More recently qualimetry split into two separate branches or independent disciplines—applied qualimetry and theoretical qualimetry, which are briefly described below.

**Theoretical Qualimetry**

Qualimetry has evolved one more branch, *theoretical qualimetry*, which explores general methodological issues and problems of quantitative estimation of the quality of an abstract mathematical object rather than that of any particular objects (things, phenomena or processes). The rise of theoretical qualimetry served as a decisive argument in favour of making qualimetry into an independent scientific area. The fact is that an overwhelming majority of the quality evaluation methods that were proposed in and outside Russia before 1968 lacked of any comprehensive scientific justification and constituted, in effect, a mass of empirical data wanting analysis, justification and generalisation. (The only exceptions were the Krylov method and a 1928 paper by the Russian philosopher and theologian P. A. Florensky, dedicated to one of the problems of quantitative estimation of quality [5]).

An almost similar situation in the field of quantitative estimation of quality evolved elsewhere.

Then came a time when someone had to recognise the need for analysing, rationalising and generalizing the wealth of accumulated empirical material within a separate scientific discipline. Recognition could come somewhat earlier or somewhat later but it was
bound to happen at around that time, in the 1960s or “70s.

**Applied Qualimetry**

This discipline seeks to develop applied techniques for evaluating the quality of new, here therefore unevaluated types of objects (things, phenomena and processes). The essence of this type of qualimetric research is described by the term *applied qualimetry*, which is one of the two branches of qualimetry as an independent scientific discipline. In this respect there appeared different sub-disciplines, such as geographical qualimetry, automatic-machine qualimetry, construction engineering qualimetry, educational qualimetry, geodesic qualimetry, fabric qualimetry, etc.

**Qualimetry Institutionalised**

It happened that the first to arrive at this idea was a group of Soviet scientists (economists, civil engineers, car makers, architects), who were dealing with the problem of quantitative evaluation of quality. Gathering at an informal workshop in Moscow in November 1967, they came to the following conclusions:

1. The group members (Azgaldov, Glichev, Krapivensky, Kurachenko, Panov, Fedorov and Shpektorov) as well as some other researchers working on similar tasks were doing the same thing in terms of methodology, namely, trying to quantify quality, albeit in relation to quite different objects.

2. In their pursuits they faced almost identical scientific problem, and they used tools based on some common and similar concepts.

3. To achieve success in solving these problems and to improve the tools used it was advisable to bring together researchers engaged in quality evaluation in both the U. S. S. R. and abroad.

4. Such a pooling of efforts could best be achieved in the framework
of a joint research activity that met all the conditions qualifying it as an independent scientific discipline.

5. The most suitable name for that discipline was *qualimetry*. Indeed, the Greek root *metreo* has become commonly accepted in the international lexicon of science. As for the Latin root *qualis*, its derivative words in the majority of the languages accounting for the bulk of scientific and technical literature means “quality” (*cualidad* in Spanish, *qualità* in Italian, *kwaliteit* in Dutch, *Qualität* in German).

Therefore, the term *qualimetry* is quite handy: it is concise and it accurately renders the scope of the “quality measurement” concept; its main components are intelligible to people speaking different languages; its structure makes it easy to form any derivative words like *qualimetrologist* (a qualimetry scientist), *qualimetric approach* (quality measurement approach) etc.

Furthermore, this term is part of a logically consistent system of concepts and terms; e.g., the science of quality (qualilogy) and the related science of quality measurement (qualimetry); one can draw an analogy with some other sciences: economics — econometrics, biology — biometry, psychology — psychometrics.

A paper by the workshop participants, which substantiated the above five propositions, was published in the journal *Standarty i kachestvo* [3]. It provided content for an international discussion in the journal during 1968, in which an overwhelming majority of the contributors supported the idea of a new scientific discipline. Thus qualimetry was born.

**1.1.3.3. Qualimetry in Russia Today**

What we briefly considered above is the past history of qualimetry. What about its present?
Formally, if our analysis of the progress of qualimetry over a period of 43 years since its inception should rely on absolute numbers alone it may show a fairly optimistic picture. However, it would be more appropriate to evaluate qualimetry by the same qualitative approach, i.e., to consider not only absolute but also relative figures versus some benchmark or performance potential. We will apply this approach and try to show both the progress in and failures associated with the development of qualimetry. (Naturally, this analysis will take into account qualimetry-related facts and figures from the Soviet era as well as from the period of independent development of the Russian Federation).

As regards the scientific aspect, it may be noted that in the 1980s an Applied Qualimetry Laboratory operated at the National Research Institute for Standardisation and an educational qualimetry laboratory at the Academy of Pedagogical Sciences. These facts are gratifying by themselves. The word qualimetry was after a while removed from its title, and the laboratory changed its subject altogether. Something similar happened to the educational qualimetry laboratory.

Regarding another source of new scientific data in qualimetry, dissertation-oriented research, five doctoral and more than 45 master’s theses on qualimetric subjects have been defended to date. Not bad for a fledgling discipline. Unfortunately, the vast majority of this research deals with applied rather than theoretical qualimetry; in other words, qualimetry research is mostly growing, so to speak, in breadth not in depth.

In the Soviet era, two national scientific conferences dealt with qualimetry topics, one held in Tallinn (1972), the other in Saratov (1988); also, standing inter-republican scientific workshops were conducted in Moscow and Leningrad in the late 1980s. Due to a tight economic situation in which Russian science found itself in the 1990s these workshops ceased functioning. (nor is there any news call) Perhaps the only positive development in this regard
is an annual workshop (held since 1991) open to CIS participants, which deals with educational and health care applications of qualimetry.

It should be noted that qualimetry issues are discussed at special sections (or panels) of international conferences held by the European Organisation for Quality Control and the Asian Institute of Quality Management (Moscow — 1971., Oslo — 1974, Varna - 1977; Yerevan — 1982, Madrid — 1983, Moscow — 1988, Delhi — 1989).

In addition, reports on the application of qualimetry to scientific and practical problems in other areas have been presented at more than national-scale 90 conferences, symposia and seminars held in Voronezh, Zvenigorod, Yerevan, Kiev, Kishinev, Krasnodar, Lviv, Leningrad, Moscow, Novosibirsk, Odessa, Pushchino, Riga, Saratov, Suzdal, Tambov, Tartu, Tashkent, Tbilisi, Uzhgorod, Ivano-Frankovsk and Kharkiv.

Qualimetry as an independent scientific discipline is taught in dozens of technical universities in Russia (the name of the academic subject is “Quality Control”).

Yet, given the multisectorial and interdisciplinary nature of qualimetry, these kinds of academic convention should be much more frequent, for experience shows that out of every 10 researchers (from junior research fellowsto members of the Russian Academy of Sciences) hardly one has ever heard anything about qualimetry and its potential.

Administrative staff shows no greater familiarity with the essence and potential of qualimetry. Indicative in this respect is the practice of top government statistical agencies, both in the Soviet Union and afterwards in Russia. In their published annual, semi-annual and quarterly statistical reports almost every one of the 800—1200 figures contained therein refer to either quantitative or
purely economic (cost) performance indexes of the national economy. As for quality, at best they list sometimes (not always) the numbers of new Quality Seals. Quantitative assessments of quality level (by industry or product group — not to mention the quality of life) were not cited even once!

It is a good thing that qualimetry topics are dealt with by hundreds of scientific papers, including more than 80 monographs and that special subject headings are found in catalogues of some of the largest libraries in Russia: the National Library of Russia, the GPNTB, the Institute of Scientific Information in the Social Sciences and others, and that articles on qualimetry are included in the Greater Soviet, Russian and Economic encyclopaedias.

It is to be regretted, however, that the potential of qualimetry is often badly underestimated and that qualimetry proper is treated very narrowly. It is either invoked in connection with evaluating the quality of products only and not any objects, phenomena or processes, including the quality of life (the Greater Soviet Encyclopaedia approach) or it is considered merely as an element of quality control (according to the National Library subject catalogue).

On the positive side, a number of colleges in Moscow, Kiev, Nizhny Novgorod and Kaliningrad have issued learning aids on qualimetry for their undergraduates. Still, these institutions constitute a negligible proportion (less than 1%) of all of academic institutions in which such texts would be useful. The same is true for short qualimetry courses occasionally offered in some technical universities. After all, the mastery of qualimetric techniques could be very useful in the future careers of many college graduates, especially in the engineering, design, economy and managerial professions.

In this regard it should be noted that the first step towards recognising qualimetry as an important element in management training was made in 1995. Two State Standards for the college training
of general managers were adopted, which decreed that students specialising in Quality Control must be taught the discipline of Qualimetry.

On the surface of it the biggest advances of qualimetry have not been in the fields of science, education or information, as mentioned above, but in product quality assessment (mainly in the framework of quality control and product quality certification systems). In this aspect, numerous industry-specific quality assessment methods have been developed, and on this basis, the quality category certification of products (including the Quality Seal certification). Thus, quality quantification (i.e. qualimetric) methods have become a routine tool in the product quality improvement efforts. All this would appear to be quite satisfactory...

In fact, not only is there no reason for satisfaction, but on the contrary, one notes with regret that the situation with product quality in general and with the use of quantitative evaluation methods in particular, instead of improving has shown a strong tendency for degradation. Let us explain this statement using just one case in point relating to a relatively recent campaign to increase the share of commodities bearing a Quality Seal.

A product assigned the Quality Seal was supposed to meet world-wide quality standards and thus be competitive in international markets. It was logical to assume that products bearing the Quality Seal were perfectly exportable. It would follow that the greater the quantity (in absolute and relative terms) of Quality Seal products being turned out the greater — other things being equal — should be their exports.

In reality the opposite was true. From the late “70s to the mid-80s the Soviet Union dramatically (by an order of magnitude) increased the number of articles that received the Quality Seal. Their number shot up to about 100,000. As for relative indices, according to the Soviet Central Statistical Administration, about 45% of all certifi-
able products turned out in 1986 bore the Quality Seal. Moreover, there were entire industries in the U. S. S. R. (such as construction and road machinery, and the electrical industry) in which the percentage of products awarded the Quality Seal was as high as 60%!

What about the exports that, apparently, had to grow too? The share of machinery and equipment in the Soviet exports to capitalist countries instead of growing was actually falling: to 5% (and later to 2%). Speaking of high-tech products, they amounted to only 0.23% in the Soviet trade with the West in 1985 (the situation is still worse today). Thus a paradoxical situation arose: as the share (and the absolute volume) of Quality Seal products increased, their export actually declined! There is only one rational explanation for this paradox: the method by which quality was measured (and the Quality Seal was awarded) was imperfect, to say the least. They allowed an upward bias in the true assessment of Russian-made products, leading to self-deception. (What exactly was wrong with those methods and why it was so, will be discussed in a chapter below).

To summarise our analysis of the current state of qualimetry in Russia, qualimetry is developing on both the theoretical and practical levels, but to a much lesser extent than it can and should.

1.1.3.4. Qualimetry Beyond Russia Today

As for the current international practice of quantitative evaluation of quality, when it comes to applied qualimetry, the consumer’s need for qualimetric evaluations of goods and services is met by specialised journals, which regularly provide quality ratings of similar consumer goods of different manufacturers available on local markets.

Some of these media are specialised in certain product types, e.g. the British Which? Car Magazine. Others, like the German Test, the
French *Que choisi* or the American *Journal of Consumer Message*, provide qualimetric information for a particular type of product but also across the whole spectrum of consumer goods.

These publications have a fairly high circulation. For example, German magazines containing quantitative estimates of the quality of consumer goods have a circulation of about one million. German economists say that the comprehensive character of this information, its ease of access and its availability in quantitative form help the average consumer to take bearings in today’s market. It is also a powerful incentive for manufacturers to continuously improve the quality and reduce the production costs of their products. In this respect, the presence of this kind of information (which is essentially qualimetric even if it is not called in that way) is seen as one of the factors in the steady scientific and technological progress in German industry.

Regrettably, nothing like this is found in the Russian market today, with the possible exception of quality ratings of Russian and foreign videos and movies, which are periodically, published in the journal *Video-ACC* or sporadic reprints from the German *Test*, published by the Russian-language journal *Spros* (“Demand”). This lack of qualimetric information about products available on the domestic market is not due merely to a lack of choice; it is caused mainly by the deep doubts given by the majority of Russian economists and managers regarding the possibility of obtaining and using such information.

As for international research in theoretical qualimetry its findings appear mainly in periodicals devoted to utility theory, operations research, decision theory, technometrics or benchmarking. It should be noted that the term *qualimetry* is not used there very often or used in a somewhat peculiar sense. For example, a group of French researchers printed in the journal *Epure* (1994) a paper describing an instrument for measuring various characteristics describing alternating current quality (voltage stability, frequency
stability, etc.). They called it, the Qualimeter.

1.1.3.5. The Future of Qualimetry: Developing in Breadth and in Depth

Now, what is the future of qualimetry? Let us decide in advance the kinds of future we have in mind. Talking about a short-term outlook, it is not very interesting because it is separated from our time by only three — five years. If we consider a long-term perspective, the uncertainty of our forecast will grow very much. Therefore, it seems to be most appropriate to give a medium-term forecast of the future of qualimetry.

We consider this problem, firstly, in relation to applied qualimetry, and secondly, in terms of three critical aspects: expanding its scope of application (by industry sector), the deepening of analysis (the extent of coverage of problems addressed by an industry) and improvements in quality evaluation techniques.

Extending the Scope of Application of Qualimetry

In contrast to the current situation there is a very strong reason to believe that the area of application of qualimetric analysis is going to get much broader. Having said that, qualimetric information will be used to address two broad classes of problem (for briefness, they are described in tabular form):

— To evaluate quality as a means of ascertaining the information used (Table 2); and

— To evaluate quality as a means of choosing the best solution to a multi-criterion problem (Table 3).

The information listed in the tables does not seem to require further explanation.
Let us consider the possible course of development of qualimetry as exemplified by the use of quality ratings as a market adaptation tool and a market mechanics element.

One of the important uses for qualimetric information is its adaptation to the needs of market participants:

— Manufacturers of goods and services;
— Vendors (procuring and trade agents);
— Purchasing firms; and
— Consumer societies (associations) as spokesmen and advocates of individual customers/consumers.

The literature of qualimetry has identified and classified 44 kinds of qualimetric information of benefit to one or more market entities. These kinds are arranged in tabular form under six headings: 1) analysis of simple properties of products; 2) analysis of complex properties of products; 3) analysis of product quality; 4) analysis of the price-quality relationship of products; 5) analysis of product competitiveness; and 6) analysis of the quality of manufacture of products. Since all of these kinds of qualimetric information have been described in periodicals (see, e.g., [6]), their consideration here is limited to the above notes.

Let us mention one more aspect of the future of qualimetry. Whatever form of distribution should evolve in the future (other than today’s normal shopping and services) — e.g., the selection and ordering of goods by e-mail, the provision of services at the customer’s convenience, the recognition of the customer’s every wish, etc. — it is always desirable that the consumer before purchasing any goods or services should have at their disposal not only quantitative data about their price (and operating costs if applicable), but also about their quality.
Moreover, this qualimetric information should not only be full and comprehensive (i.e. quality as a whole and its component properties such as reliability, functionality, user-friendliness, etc.), not only comparative (i.e. such that allows to compare the quality of different goods or services having the same purpose), but also ineligible to the ordinary consumer who is likely to be a non-expert. At the very least this kind of information should be included in the label/price tag/passport of a product.

<table>
<thead>
<tr>
<th>Quality ratings as means of clarification of information used</th>
<th>Intermediate quality information necessary for obtaining different information (about a product, service, energy etc.)</th>
<th>At price analysis</th>
<th>At utility analysis</th>
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<tr>
<td>Quality of processes or phenomena</td>
<td>Resources</td>
<td>Labour resources</td>
<td>Labour resources</td>
</tr>
<tr>
<td>Quality of situations or phenomena</td>
<td>End products</td>
<td>Information for domestic market</td>
<td>Information for domestic market</td>
</tr>
<tr>
<td>Quality of things</td>
<td>Quality of work</td>
<td>For manufacturers (determining marketing opportunities)</td>
<td>For consumers (choosing the best product variant)</td>
</tr>
<tr>
<td>Quality of a situation or phenomenon</td>
<td>Individual specialist (in science, medicine, industry, etc.)</td>
<td>Information for external market</td>
<td>Information for external market</td>
</tr>
<tr>
<td>Quality of processes or phenomena</td>
<td>Team (gang, department, workshop, etc.)</td>
<td>At exports (determining competitiveness)</td>
<td>At imports (choosing the worst product variant)</td>
</tr>
<tr>
<td>Quality of situations or phenomena</td>
<td>Industry/sub industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of a situation or phenomenon</td>
<td>State-of-the-art in industries/sub industries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of a situation or phenomenon</td>
<td>Standard of living and quality of life of population (including by region and social group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of situations or phenomena</td>
<td>Ecological situation (including by region and industry/sub industry)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Possible applications for quality ratings as means of clarification of information used
Table 3. Possible applications for quality ratings as a means of multi-criterion decision-making

1.1.4. Qualimetry: An Independent Scientific Discipline

Before showing the relation of qualimetry to other sciences we will analyse whether qualimetry is an independent scientific discipline; and if is, where is its place among the other scientific disciplines?

Unfortunately, in the professional literature there is no clarity with respect to the necessary and sufficient conditions (criteria) for delimiting a science from other human cognitive activities. Different sources treat these conditions differently.

To summarise current thinking on the criteria to be met by a scientific discipline, here are the most frequently cited ones: a subject of inquiry, an empirical (“prescientific”) history, a theory, a range of problems, a conceptual apparatus, and verifiability of findings.

Let us examine qualimetry in terms of meeting each criterion.

**An independent subject of inquiry.** Quantitative assessment of the quality of various objects (things or processes) is an independent and very important problem, which is the subject of inquiry
of qualimetry. There are several scientific disciplines concerned with the quantitative study of objects in a way related to quality, such as utility, value, performance (as discussed above). But “quality” is not synonymous with utility, value or performance and for that reason it is studied within the framework of an independent scientific discipline.

An empirical (“pre-scientific”) history. Before 1968 (when qualimetry began to come into its own), hundreds of techniques for estimating the quality of various objects had been developed and applied in the U. S. S. R. (Russia) and internationally. But since these methods are usually developed on an empirical level, without a common scientific basis the period up to 1968 can be considered the “prehistory” of qualimetry.

Presence of a theoretical framework. There is an intuitive understanding of the necessity for this criterion, which is sometimes formulated in an explicit form. We note in this connection that the basic tenets of the qualimetry theory have partly been published in several monographs.\(^1\)

Presence of specific problems. It is true of any evolving science that once some problems are solved they are followed by other problems, which may be more numerous and complicated. This situation is typical of qualimetry. The further it develops, the greater the number of problems related to its future research areas that come to life. To illustrate, one of the earliest papers on problems of qualimetry identified eight problems whereas in more recent studies their number arose to 17, and later research on one of these problems singled out 26 independent sub problems [7]. Thus, the existence of qualimetry as an independent scientific discipline is fully justified in terms of the quantity and complexity of the problems to be addressed.

\(^1\)Here in after, except as otherwise stated, we will discuss theoretical qualimetry; see, e. g, [2].
Availability of a specific conceptual apparatus. Science in general and a single scientific discipline in particular, area specific kind of human activity. Its specificity shows in the fact that virtually every independent scientific discipline has a terminology, a conceptual apparatus and a language that are more or less specific to it. Qualimetry fully meets this criterion: its terminology is quite specific and not normally used by other scientific disciplines (or used in a different, non-qualimetric sense). This is confirmed by several Russian state standards for qualimetry terms.

Verifiability of scientific results. It seems that verifiability (testability) is a necessary condition for making your results scientific, as well as a criterion for the existence of science as a special kind of human activity. Thus the question is not whether “to test or not to test?” but “how to test?“Some scientists believe that this kind of test can and should only be experience-based. But if it were the case we would have to “banish” from the domain of science the so-called deductive sciences, whose theory is based on pre-set axiomatics, including most branches of mathematics. As regards qualimetry, it is feasible to test for consistency, say, quality ratings of consumer products calculated by qualimetric methods with consumer preferences determined, say, through trade statistics.

On the other hand, some people are of the opinion that a test do not need to be empirical but can be theoretical as well. From this point of view qualimetry also meets the scientific criterion: you can always check the logic of the constructs underlying the theory of qualimetry (these constructs are given, e.g., in the shape of the deductive-axiomatic theory of qualimetry). Thus, qualimetry has this capacity for verification (either experimental or logical).

In addition to the above six characteristics that a science must meet, some other criteria are sometimes found in the literature. Yet, these criteria either itemise the above characteristics or are not essential. For example, as shown by V. V. Nalimov [8], the methodological novelty condition often used as a criterion is invalid: a new
scientific discipline does not necessarily feature a novel research method.

Thus, in terms of meeting conventional criteria qualimetry can be considered a scientific discipline in its own right, which has special relationships with other scientific disciplines. Let us analyse these relationships.

It seems that this analysis it best applied to sciences whose data are used by qualimetry (metrology, experimental psychology, applied mathematics, etc.) and to sciences that themselves use data obtained in qualimetry (efficiency theory, operations research, axiology and others).

1.1.5. Interrelations of Qualimetry

Sciences Used by Qualimetry

Qualimetry and metrology. One of the first operations performed in a qualimetric (i.e., complex quantitative) estimation of quality, is computing the values of relative property indices, $K_s$. For this operation we must know the absolute values of these property indices, $Q_s$. In most cases these indices are measured by a physical experiment using instruments.

However, physical tools cannot measure many properties, and estimates of $K$ are obtained by expert judgements without determining the values of $Q$. However, this is a stopgap method, as the mainstream trend is to substitute metrological techniques for expert techniques, which still have to be rather widely used in the measurement of $Q$.

\[^1\] Of course, we are not suggesting that experts are not to be used in qualimetric problems. As things stand today experts are apparently indispensable when we have to identify and classify properties that characterize quality.
Thus, considering the relationship of metrology and qualimetry, we can conclude that qualimetry makes use of data obtained in metrology as the foundation for its future constructs.

**Qualimetry and experimental psychology.** Expert methods play an important role in qualimetry. They are the main tool in developing product and customer classifications, building a hierarchy index (an index tree), defining the weight of $G$; they are often used to determine the nature of the relationships between the absolute indices $Q$ and the relative indices $K$, and finally, they can be a perfectly acceptable basis for solving some problems of qualimetry.

The development of expert methods is inconceivable apart from data obtained by experimental psychology such as the psycho physiological capabilities of humans/experts; the necessary psychological characteristics of experts; guidelines for the most appropriate expert survey procedure; corrections for systematic and random errors in expert estimates, etc. Thus, qualimetry’s use of expert judgements necessitates its close link with experimental psychology.

**Qualimetry and applied mathematics.** Theoretical qualimetry has analysed a number of problems of a mathematical nature. Some of them can be solved quite easily using existing tools of applied mathematics. Others are more complex, and it is possible that if they are to be solved we will have to develop new branches of applied mathematics. For example, it has been noted [9] that “the statement of the applied problem of assessing the quality of performance of measuring systems in the Mendeleev Metrology Research Institute led to the solution of a number of new problems in the theory of Markov and semi-Markov processes...” and in some other branches of mathematics. Thus, it can be assumed that, like most other sciences, qualimetry uses methods, techniques and principles of mathematics, i.e., that it is a “consumer” of “offshoots” of mathematics such as mathematical statistics or theory.
of measuring.

**Qualimetry and typology.** Typology is a scientific cognition method that relies on breaking down systems of objects and grouping them with the help of a generalised, idealised model or type. In the same manner as the related disciplines of systematics, classification and taxonomy it makes available to qualimetry some methodological techniques that allow you to create a hierarchical, multi-level model of the quality of an object — a so-called property tree. Strictly speaking, the above applies not only to qualimetry but also to almost any branch of knowledge; e.g., classification and systematisation are an essential element of any scientific work. Yet, typology and taxonomy are particularly important for qualimetry because creating a quality model in the shape of a property tree is the central task of the problem of quality quantification.

**Qualimetry and general systems theory.** What has been said in the preceding paragraph largely characterises the relationship of qualimetry and systems theory. Indeed, despite the fact that general systems theory is not a complete theory in a formal sense (as it has no axiomatic of its own), some of its results, in particular those set forth in the monograph *Theory of Hierarchical Multilevel Systems* [10] and belonging to the multilevel multi-purpose systems, are very useful for a theoretical justification of the tree derivation rules.

Let us turn to the second group of sciences, those supported by qualimetry. We will not, of course, consider all scientific disciplines, but we will restrict ourselves to those in which the methodology of qualimetry seems to be the most important.

**Sciences Using Qualimetry**

**Qualimetry and operations research.** Today it is not yet possible to assert that there is general consensus in respect of operations research as an independent scientific discipline. The name itself,
operations research, has been used along with the terms systems engineering, complex systems analysis, decision theory, management science, etc. As for its methodology, E. Fels and G. Tintner [11] are of the opinion that operations research is merely as a research area and it is not different from economics in terms of methodology. However, in recent years, there have been increasing numbers of supporters of the view that operations research is a scientific discipline in its own right, which has an independent theory and an accurately delineated area of research. Accordingly, operations research in most cases is interpreted as a branch of the science concerned with determining the best (i.e. optimal) strategy. However, the notion of “optimal strategy” assumes a criterion (“a goal function”) by which optimality is determined. Therefore, the entire class of operations research problems is characterised by the use of this kind of optimisation criteria.

But, how are we to define these criteria? There is no agreement on that score.

If we consider the class of problems associated with the use of operations research for quality control, then in cases where the sought-for strategy involves quality optimisation (i.e. the existence of a balance of all indices $Q$ such that the quality rating $K_k$ will have an optimal value) operations research uses a mathematical model of the quality rating which in most cases is very approximate and thus inaccurate. This is understandable, since previously we can create a more accurate model we will have to solve a number of problems specific to qualimetry and not typical of operations research.

Therefore, it is qualimetry, which develops optimisation criteria (i.e. quality ratings) that are used in operations research for solving a class of problems associated with the optimisation of quality parameters.

**Qualimetry and decision theory.** By no means all authors con-
sider decision theory an area different from operations research. In any case, it follows from the Greater Soviet Encyclopaedia article on “Operations Research” that the two names actually refer to the same discipline. However, since there is extensive literature on decision theory we provisionally assume that the latter is an independent discipline, though close to operations research. In this regard all that was said above about the relationship of qualimetry and operations research can largely be extended to the relationship of qualimetry and decision theory.

Indeed, it is easy to see that in decision theory, as in operations research, the question of criteria for evaluating alternatives is a central one, on account of which some authors even factor it out from decision theory on the assumption that in a decision-making model the goal (or criteria) of evaluation of possible alternatives is known in advance. If the goal of a decision is quality control or optimisation, for this large class of problems, qualimetry offers a method for constructing a mathematical model of quality assessment — the model used as a criterion for evaluating alternatives in decision-making. In this sense qualimetry can be considered a part of decision theory, namely its branch concerned with the justification of aggregated criteria in decision making related to the quality of objects.

**Qualimetry and systems analysis.** It has often been suggested that systems analysis is a part of operations research. However, a larger group of authors consider systematic analysis an autonomous scientific discipline. However that may be, one of the important problems addressed by systems analysis is expanding each so-called general goal into a hierarchy of goals and objectives. Qualimetry has largely developed this technique of expansion as

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1. It seems that there is a close link between evaluation goals and criteria; at least “every goal contains latent solution criteria” [12].
2. Clearly, the subtitle “Qualimetry and decision theory” is not really accurate as the two concepts cannot be compared, one being a genus, the other a species.
applied to the derivation of so-called property trees.

Thus, qualimetry can offer a support tool for solving one of the problems of systems analysis.

**Qualimetry and utility theory.** The notion of utility in a modern interpretation is roughly this: it is a characteristic of a phenomenon that the phenomenon actor or Decision Maker seeks to maximise. The modern theory of utility in some cases can get quite constructive results (for example, to justify the criteria for evaluating alternatives in some operations research problems solved under risk). However, it has some weaknesses, which might possibly be alleviated through the application of qualimetric tools\(^1\). These weaknesses relate to three main factors.

**First.** Utility in the form of the so-called utility function is quantified under certainty and under risk. In either case, the utility function is normally defined only on the ordinal scale, and rarely on the interval scale. However, in handling many practical problems it is desirable to be able to use not only the ordinal scale and the interval scale but also the more general ratio scale and the methodology of qualimetry can help in attaining this goal.

**Second.** In most cases, a numerical value of the utility function is based on an analysis of consumer preferences on the assumption that preferences are primary and utility is secondary. With this approach to the determination of the utility function it is in principle impossible to determine, for example, the usefulness of a product before it is marketed: it has no customers, no preferences, and there is no way to determine the parameters of its utility function. Yet, in very many (if not most) situations we need to be able to determine the usefulness of a product not after but before it is launched on the market. Qualimetry explores these problems as

\(^1\)Some qualimetric experts (eg A. I. Subetto) interpret the term *qualimetry* broadly and consider utility theory as a branch of qualimetry.
well.

Third. In many cases the utility of an object is estimated by a single parameter, useful property, whereas very often it is desirable to consider several properties (e.g., with regard to life quality). In this respect it may be appropriate to use the methodology of qualimetry. Notably, one of these authors has developed a utility model in which utility is a function of the quantity and quality of an object.

**Qualimetry and axiology.** Axiology (value theory) offers general approaches to the estimation of all the categories that are valuable to man: spiritual values (ethical, aesthetic), material values (useful objects and phenomena, and their quality, the benefits they provide, etc.).

So far, value theory in its logical constructs has dealt exclusively with qualitative, not well-defined categories. Its concepts and methods are not even formalised, far less quantified.

Thus, the quality of an object, which is made of material — and in some cases also spiritual -value to an individual, on the one hand, is an object of study for axiology, and on the other hand, an object of quantitative analysis for qualimetry. In terms of quality evaluation, qualimetry can be regarded as a branch of axiology, one dealing with the application of quantitative methods of analysis. So, the following analogy would be in order: axiology relates to qualimetry in the same manner as economy does to econometrics; biology to biometrics; sociology to sociometry, etc.

**Qualimetry and efficiency theory.** Most efficiency theories (for example, the theory of economic efficiency) use multiple efficiency criteria, which have one thing in common: they are all built on weighing the benefits obtained by society through a particular economic activity against its cost. While cost is normally expressed in monetary units, (less frequently in man-hours of useful work),
benefits may be defined in monetary terms or in natural physical units such as pieces, tonnes, or metres of a product. As a result, the dimension of an efficiency criterion is usually of the form rub/rub, physical unit/rub (or vice versa).\(^1\)

This method for efficiency determination is only acceptable for situations in which costs and benefits are purely economic categories, which have not any other effects. However, recently, there has been a growing conviction that when we measure efficiency we need to consider not only economic but also other (e.g., social) effects, such as when we evaluate the quality of life. Qualimetry does have an apparatus by which we can quantify any noneconomic effects, which can thus be factored into efficiency calculations, making them much more accurate.

In addition, when qualimetry is applied to efficiency calculation, it is possible to ensure qualitative comparisons of alternatives, a condition which is invariably emphasised by various regulations on the definition of economic efficiency but which, unfortunately, is often ignored in practice.

**Qualimetry and statistics.** On this issue we quote E. M. Chetyrkin-na, editor of the book *Statistical Measurement of Quality Characteristics* [14]: “... it would be appropriate to make some remarks on the relation of qualimetry and statistics. Historically, statistics has not considered problems studied by measurement theory. The assumption is that facts recorded in a statistical observation are measured somehow. However, this is not always true. Therefore, the development of methods of qualimetry will probably help expand the area that can be covered by statistical analysis.” We can only associate ourselves with this observation by a well-known statistics expert.

\(^1\) Besides the above-mentioned efficiency theories, which are based on the so-called input–output concept, there are other approaches to efficiency theory building; they are analysed in [13].
**Qualimetry and forecasting.** At present, the forecasting of the development (in a qualitative aspect) of the output of a particular product is usually limited to the variation of numerical values of the absolute indices of its individual properties. With a qualimetric approach we will be able to predict the variation of not only these indices but also of product quality in general, including as complex an object as the quality of life.

**Qualimetry and management-by-objectives.** We first note that there are other terms to denote what is in fact the same scientific method: goal programming, program planning, PPB (Planning, Programming and Budgeting), etc. However, every variety of this method is characterised by one feature: the need to build a hierarchical multilevel system of objectives (an objectives tree). As already stated, the rules for deriving property trees (which are almost identical to those for objectives trees) have been developed and validated by qualimetry. Thus, qualimetry can be a useful tool and an important step in management-by-objectives, that of building an objectives tree.

**Qualimetry and the morphological analysis method.** The essence of this method “... is the systematic study of all conceivable options following from the structural pattern (or morphology) of an object being perfected. In the process, not only known properties are synthesised but also new, unusual options that could easily be missed by the trial and error approach” [15]. Once a large variety of options are generated they must be compared in order to choose the best one. But this is a typical problem of qualimetry, which thus helps to realise the potential of morphological analysis in the most effective way.

**Qualimetry and the educational evaluation.** Educational evaluation is a component of the Educational Management. It has two purposes. On one hand it is a professional activity that educators need to undertake if they intend to continuously review and enhance the learning they are endeavoring to facilitate is the eval-
uation process of characterizing and appraising some aspects of the educational process; as such it is normally includes in the *curricula*. On the other hand, educational institutions (universities, colleges, technical organizations) now days require evaluation data to demonstrate effectiveness to funders and other stakeholders, and to provide a measure of performance for academic and marketing purposes. Qualimetry has proven to be quite helpful for solving problems arising from both purposes. [16]

To summarise this section, qualimetry does not replace any of the existing scientific disciplines but is in a state of continuous interaction with them, getting “assistance” from some and lending it to others.

### 1.1.6. Qualimetry’s Birthplace and Time of Origin Revisited

In recent years there has been in evidence an unpleasant and odd phenomenon: many Russian and foreign authors attempting to challenge the need for and usefulness of qualimetry. In addition the antecedence of Soviet and Russian scholars in dealing with qualimetry is being called into question.

We outline below some background information to help restore the historical truth.

As already mentioned, the case for qualimetry was first made in a multi-authored article by Azgaldov, Glichev, Krapivensky, Kurachenko, Panov, Fedorov and Shpekotorov, published in 1968 in the journal *Standarty i kachestvo* №1 (1968). Later on, that journal carried an international debate, the vast majority of the participants supporting the idea of a new scientific field, qualimetry.

The initiative of the Soviet experts received some international
recognition. For example, starting with the 15th International Conference of the European Organisation for Quality Control (1971), questions of qualimetry were discussed at several other international scientific and engineering conferences: in Oslo (1974), Varna (1977), Yerevan (1982), Madrid (1983), etc. A Qualimetry Section worked during the Asian Quality Symposium held in New Delhi in 1989.

Naturally, the first reputable (monograph-level) publications on qualimetry appeared in the Soviet Union. Suffice it to mention the following books that appeared after the term was coined (not to mention the following years, when their number increased considerably): What is Quality? (1968), Use Value and Its Measurement (1971), Quantitative Assessment of Quality (Qualimetry): A Bibliography (1971), Measuring the Quality of Products, Questions of Qualimetry (1971), On Qualimetry (1973). Obviously, the number of journal articles on qualimetry published in this country was greater in order of magnitude.

However, the fact that qualimetry in its conceptual, ideological and theoretical aspects was first rationalised in Russia (or more accurately, in the Soviet Union) has had curious repercussions. These manifested themselves in two ways.

The first way, historically, the vast majority of new research areas, were actually recognised in the Soviet Union (and Russia) and became part of the daily activities of home researchers after they had found their way into non-Russian scientific publications. Without any claim to generality we will name just a few well-known examples of relatively recent research fields that have broadened the scope of contemporary science: axiology, analysis of hierarchies, bionics, industrial design, informatics, operations research, cybernetics, logistics, macroeconomics, marketing, microeconomics, brainstorming, neurolinguistic programming, semiotics, systems engineering, fuzzy-set theory, decision theory, project management, futurology, heuristics, ecology, econometrics and
ergonomics.

All of these new research areas (or new research techniques) were embraced by Russian scientists without any objection and without any special explanation of their necessity and validity. A peculiar guarantee of their scientific worth was the fact that they came to Russia from abroad.

It was different with qualimetry. From the very beginning and, alas, to this day, many scientific and technical experts when first introduced to the term “qualimetry “will ask a questions like, what about qualimetry outside Russia? The implication is that until and unless we are recognised “over there,” there is little point in talking about it “here.”

Apparently, what we see here is a kind of scientific inferiority complex: whatever is new in science can supposedly only come to us from abroad. At length things came to such a pitch that in a book on quality control written by a Russian college professor he said flatly, “The concept of product quality in terms of its meeting customer requirements evolved inside a free-market economy. The idea of this approach to product quality measurement belongs to the Dutch scientists J. van Ettinger and J. Sittig. They developed a specific branch of science — qualimetry. ” (Emphasis added — Authors).

In partial vindication of this professor we can say that this untruthful statement had probably been borrowed from B. A. Raizberg’s Modern Dictionary of Economics. 1st Ed. The most amazing thing is that Raizberg, who had been an opponent at the preliminary presentation of G. Azgaldov’s dissertation “Development of the Theoretical Foundation of Qualimetry”, knew that van Ettinger and Sittig did not and could not have anything to do with the origin of qualimetry!

Against this background of Russia’s lack of self-esteem one is not
much surprised at some foreigners’ shameless disregard of Russian research in quality evaluation. Here are just two of the many examples.

A forum of international scientific societies specialising in economics was held in Moscow in the early ’90s, for the first time in the history of the Soviet Union and Russia. One of the dozens of sections of the forum heard a report (which the attendees regarded as pioneering) on the principles and methods of product quality evaluation. The presenters, a group of researchers from Germany and Israel, described almost verbatim the work on qualimetry theory that had been done in this country 20 years before (and which, incidentally, had been greatly improved by domestic researchers by the time of the Moscow Forum). However, the speakers failed to mention any of the Russian researchers who had, two decades earlier, acquired and publicised these research results. Nor did they ever name the term qualimetry or the Soviet Union, the country where it originated!

Another example; back in October 1997, Dr Zigmund Bluvband, CEO of ALD (Advanced Logistic Development) in the United States, held seminars to train managers in the application of qualimetric methods. He used what was basically the Russian knowhow in the theory of qualimetry (from the conceptual structure to the basic quality evaluation algorithms). Not a single mention was made to the fact that qualimetry originally appeared in the Soviet Union through the efforts of Russian experts. The promotional seminar materials found on the Web, mentioned only two names — an American and a Japanese both, incidentally, having nothing to do with qualimetry.

Here is another way, which is indirectly related to the first one. Some professionals, when you introduce them to qualimetry will immediately ask the question: what makes qualimetry different from other disciplines using a similar research methodology, e.g., systems analysis, operations research, hierarchies analysis, axiolo-
gy, or utility theory? (By the way, Russian scientists seldom if ever ask such questions with respect to new research fields that appear worldwide)

For example, a Russian translation of the book: *Taking Decisions. Method of Hierarchies Analysis* by T. Saaty, the famous American expert in decision theory, was printed in 1993. It was not until the mid-70s that early generalising publications on this method appeared in the United States, which was six to eight years after the first Russian publication on qualimetry and a few years after the 15th International Conference of the European Organisation for Quality Control (1971), which devoted to qualimetry one of its five sessions.

A careful examination of the essence of the Analytic Hierarchy Process (AHP) shows that it can be regarded as one of the methods used in qualimetry. (And not the best method, because it does not, for example, employ the rules for constructing these hierarchies — property trees developed and justified in Russian papers on theoretical qualimetry — or apply an important element of qualimetric analysis, the Determination of the Assessment Situation). All the same time, the Russian advocates of this method (for example, the translators of Saaty’s books) not once questioned the legitimacy of the name of that method for solving multi-criterion problems. And, of course, they did not say a word about qualimetry, which by the time of the Russian translation of Saaty’s books had been a standard term in the U. S. S. R. for 12 years. Witness U. S. S. R. State Standard: GOST 15467—79. “Product Quality Control. Basic Concepts. Terms and Definitions. The Term “Qualimetry”.

We can understand T. Saaty: Americans occasionally display a “superiority complex” because they may not take the trouble of keeping track of the international scientific and technical literature in their field. It is far more difficult to understand the translators of Saaty’s books on AHP, who were certainly aware that the qualimetric method predated the AHP, one of them having been
an active participant in the 2nd National Conference on Qualimetry in Saratov, U. S. S. R., in 1976. Even today, one can still hear this question: in what way does the method of qualimetry differ from that of the AHP? (The implication is clear: why use qualimetry if there is a respectable — because it came from abroad — method for the analysis of hierarchies).

In conclusion: one more (but not the last!) significant fact of this kind. A multi-author fundamental monograph on innovation published by one of Russia’s most reputable economic training and research organisations, the Higher School of Economics, does not employ the term qualimetry at all. Instead, it says that when one analyses the quality of innovation, one needs to use methods of benchmarking — a discipline similar to qualimetry, which appeared in the West much later than qualimetry did and which has far less validity and capabilities. As they say, comment is needless.

That was our brief historic resume of the Soviet (Russian) priority in that field of science.
Chapter 2. Main Methods of Qualimetry

2.1. Basic Terminology of Qualimetry

K. S. Stanislavsky is often credited with the famous saying: “A theatre begins with the cloak-room.” (As a matter of fact, the saying belongs to Nemirovich – Danchenko, Stanislavsky’s associate in the organisation and running of the Moscow Art Theatre).

To rephrase, we can say that any scientific discipline, qualimetry included, starts with its terminology. Therefore, let us first define those basic terms of qualimetry that have not been clarified in the previous chapter, where we introduced the terms object, property, quality, and integral quality.

**Complex property** — a property that can be subdivided (split, decomposed) into two or more less complex properties. For example, the property of being a “recreational area” is complex because with regularly shaped objects (e.g., a public park) it can be divided into a set of two less complex properties — length and width.

It follows that a set of properties may represent (though not always) another, more complex property of an object. For example, both life quality and integral life quality are complex properties of an object, with integral quality being the most complex of its properties.

**Simple property** — a property that cannot be divided into a set of two or more less complex properties. For example, the property of “length”, “width” and “height” for a regularly shaped object are simple, since none of them can be divided into less complex properties.
**Qualimetric information** — quantitative information about the quality of an object, which allows us to deduce that its quality is higher or lower (and to what extent) than another object.

**Quantitative evaluation of quality or integral quality** — a process leading to comprehensive, quantified qualimetric information about the quality (or integral quality) of an object, with respect to all rather than individual properties.

In this text, we shall use two words in combination with the term quality — evaluation (assessment) to describe a process and rating to describe its result.

We also take into account the following circumstance. In general, the evaluation of the quality of an object is divided into two main steps: creating a quality evaluation method (QEM) and its use in an assessment process. Naturally, when a QEM is created for multiple rather than one-off use (for example, to assess the quality of a complete set of objects of the same purpose), then the QEM development step is only relevant to the very first object in hand. But, given the methodological thrust of this text, we will expound our material in relation to the general case, when a QEM must be designed before it can be used.

**Qualimetry** — a scientific discipline that studies the methods and problems of quantitative assessment of the quality (and its component properties) of objects of any nature (in this context, socioeconomic objects, e.g., the quality of life).

The terms we introduced above are basic. Other terms will be defined as they appear in the text.
2.2. Main Methods of Qualimetry: Features and Areas of Application

Dozens of Methods of qualimetry exists. It should be noted that in what follows we will refer both to those that were specifically created to deal with qualimetric problems and to methods intended for other purposes, which are essentially adaptable to quality quantification tasks. Since it is impossible — as well as unnecessary — to consider all of them here, it is worthwhile to identify and explain those that will be referred to in this text.

In terms of the accuracy with which the results of quantitative assessment of the quality of any socioeconomic object are obtained, all qualimetric methods (and the corresponding QEMs) can be assigned to one of the three major classification characteristics.

A **rigorous method** for quality assessment is the one that depends on all the techniques and approaches that have been validated by qualimetry theory to date, to reduce error and to obtain more reliable results.

In order to find the values of a property index it is necessary to use the technique of multiple-accumulation (or multiple integration) with respect to time and the environment parameters of the object in question.

For example, if we are to use this method to obtain the value of the “climatic characteristic of an urban settlement” index, we must integrate the function describing the behaviour of this index over time and many environmental parameters affecting the climate component of life quality (over seasonal air temperature, humidity and dust content, the aero physical composition, altitude above sea level, the degree and nature of forestation and water reserves, etc.).

Clearly, this method is characterised by the highest labour intensity.
A short-cut method of quality evaluation — a method characterised by the maximum allowed magnitude of error and the minimum allowed magnitude of the reliability of end results.

For example, the values of a property index in the framework of this method are accepted as “single-value” without any summation or integration. For the above example, “climatic characteristic of an urban settlement” will be expressed by a single number; say, the average annual temperature \( T = 5 \) degrees Centigrade.

Of course, in comparison with the rigorous method the short-cut method is characterised by much lower labour intensity, accuracy and reliability.

An approximate method for quality evaluation — a method that, in terms of accuracy and labour effort, is in between the rigorous and short cut methods.

For example, determining the value of a property index by this method requires a single addition (or integration) over time but not over the parameters of the object environment.

In the great majority of cases, the short-cut methods of qualimetry are used both in Russia and internationally. For this reason, they will be given emphasis in this ABC.

The second important criterion by which qualimetric methods can be best classified, is the source of information about the values of some important numerical characteristics to be identified in the evaluation process, that is, during the creation and application of the QEM (for example, the values of individual property indices and the values of their weights, etc.).

To determine the values of these characteristics three groups of methods are used: expert, non-expert and hybrid.
**Expert methods** for quality evaluation are methods whereby expert knowledge is used to determine the values of most of the above-mentioned numerical characteristics.

**Non-expert (also known as analytical methods)** — methods that dispense with experts in finding these values. This is not to say that experts are not needed at all; their services may often be needed to perform one of the quality evaluation operations, deriving a property tree. (This question will be dealt with at length in the section devoted to this procedure).

**Hybrid methods** — methods in which the values of some (but not a greater) part of the numerical characteristics of an object are determined by an expert method, and the rest, by non-expert methods.

In the Russian and international practice of quality evaluation, hybrid methods are used in more than 90% of all cases and occasionally, purely expert ones. Therefore, the focus of this ABC will be on them.

When deciding which method to use in a particular evaluation context, their pros and cons should be considered.

### 2.3. Expert and Non-expert Quality Evaluation Methods: Pros and Cons

#### 2.3.1. Expert Methods

**Advantages**: relative procedural, ease of use, small QEM development and application costs.

**Disadvantages**: high labour intensity due to the need for enlisting the services of many competent specialists as experts, a relatively
high error rate and low reliability of the end results.

2.3.2. Non-expert Methods

**Advantages**: low labour intensity due to the absence of the need to enlist the services of many competent specialists as experts; relatively small error rate and high reliability of end results.

**Disadvantages**: relative procedural complexity and more time-consuming QEM development.

2.3.3. Features of the Expert Quality Evaluation Process

The QEM Designer is the key figure in the quality evaluation process. The QEM Designer can all alone, without any help, develop a QEM provided, the object in question is simple and, moreover, the analytical method is used rather than the expert or hybrid one.

Then, if the expert of hybrid method is used and hence several persons are involved in QEM development (and sometimes also application), the question arises, how to best structure their job? Should they be generalists (capable of doing any work) or specialists?

Experience shows that specialisation is preferable to generality in this field. Therefore, below we consider the question — what is the best way of grouping the QEM development participants? In general, three groups are created for the development (and sometimes also use) of a QEM: steering, technical and expert groups.
2.3.3.1. Forming a Steering Group (SG)

A SG is formed to provide guidance to QEM design. The QEM Designer heads it.

If the evaluation object is complex (e.g., the standard of living in a large region), and the time quota for QEM development is small (e.g., for a short-cut method, no more than 1.5 months), the SG will comprise 1 — 2 experts on the object in question. Their main task is to assist the QEM Designer in guiding the QEM development effort. If the QEM Designer has no need for extra help from experts the QEM Designer himself will perform the SG functions.

2.3.3.2. Formation of a Technical Group (TG)

A TG (sometimes referred to as a working group) is formed to provide technical support for QEM development, that is, to perform typewriting, drawing, and computation jobs.

A TG reports to the QEM Designer or, at his direction, to another TG member.

The numerical composition of a TG ranges from zero, when quality assessment is a relatively small job done by an appointed employee; to three persons, when a complex QEM must be developed within a short time, say, less than a month. Normally a TG is made up of one or two persons. Their work in the TG can be continuous (e.g., 25 days) or divided into segments (a total of 25 days spread over the three months of the SG work).
2.3.3.3. Determining the Required Strength of an Expert Group (EG)

For a short-cut method of quality evaluation the practical numerical strength of the EG is seven to ten persons depending on the complexity of the object.

In certain cases, when the QEM development time is limited (e.g., not more than a month), and the evaluation object is complex (e.g., the quality of life in a region or a country), it may be necessary to form two or even three EGs numbering seven to ten persons each. Then each group focuses on separate groups of properties and works in parallel, independently of the others (under the guidance of an SG member).

If a QEM is developed not by the short-cut but by the approximate or even rigorous method a more sophisticated (but also more accurate) way of determining the numerical strength of the EG is used. It is based on two main provisions.

First. The more experts the higher, ceteris paribus, is the soundness of the collective expert assessment $q^e$, i.e. the smaller the relative error $\Delta$ and the higher confidence level (reliability), at which the value of $q^e$ is calculated.

Moreover,
where: \( q^{tr} \) is the true value of the characteristic determined by the expert; and

\[ \varepsilon = \frac{\Delta q}{q^{tr}} \]

\( \Delta q \) is the absolute error that determines the confidence interval \( \Delta q = \Delta |q^{tr} - q^e| \).

Second. The more prior information about the EG and its estimates is known to the SG the fewer, ceteris paribus, experts there may be.

A monograph on theoretical qualimetry [2] includes formulas for many cases encountered in practice (their total number being about 100) by which we can calculate the required number of experts (with regard to the two provisions above).

### 2.3.3.4. Forming an Expert Group

A typical expert spends from one to seven days, working in an EG (depending on the complexity of the object). Moreover, it is not a continuous period but the sum of small (0.5 — 1 day long) segments.

With the short-cut method, the SG selects experts as follows:
From several specialists well familiar with the type of object to be evaluated a group of potential experts numbering two to five more than the expected strength of the EG is selected; as mentioned above, for the short-cut method their number is 7 — 10.

Next, the SG members in a personal talk with each potential expert try to get an idea of their quality as experts, i.e. determine the extent to which each specialist has what it takes to act as an expert in a qualimetric analysis (these properties are depicted by a tree in Figure 2).

Let us look into the essence of each property shown in Figure 2.

![Diagram of expert properties](image)

**Competence** – in-depth knowledge of the object and of the methods for assessing its quality.

**Confidence** — belief in the correctness of their assessment.

**Objectivity** — the ability of being unbiased, i.e. to resist departmental, superiors” or authoritative (“self-serving”) interests while participating in an examination.

**Efficiency** — the ability to quickly do the work in hand.

**Motivation** - the desire to do one’s work.

The SG then uses the expert method to select 7 to 10 experts who
exhibit these properties to the fullest extent.

If it is not a short cut but an approximate or rigorous method, then for each of an expert’s property one or more special methods for their quantification (measurement) are used. They are described in texts on expert methods [17 or 19]. “Competence” is the single most important property characterizing the quality of an expert. Therefore, with a short-cut method only this property is quantified.

Two of the methods commonly used to find the value of the competence index $K_{com}^c$ are:

— Self-appraisal, where experts, score themselves;

— Reciprocal appraisal, where each expert is appraised by all the other EG members and the reciprocal appraisal $K_{com}^r$ is defined as the mean of the appraisals.

The calculation formula (which has been repeatedly tested in practice) takes the form:

$$K_{com} = 0.4K_{com}^c + 0.6K_{com}^r.$$ 

### 2.3.4. Qualimetric Scales

Results obtained with qualimetric analysis (in quality evaluation) are most often expressed in one of three scales. (Here the term scale is understood not in the ordinary sense such as a numeric scale, dimensionless scale, point scale, etc., but in the meaning the term in what is known as the “mathematical theory of measurement” [18]).

Let us compare these scales by their main characteristics: the cost of their application (labour and time costs) and their results (the amount of information obtained).
2.3.4.1. Ordinal Scale (Synonym: Rank Scale)

Cost of use – minimal.

Results (amount of information obtained) — minimal.

Once objects are evaluated in this scale they can be arranged in the ascending or descending order of quality rating. But it is impossible to determine how much, or far less how many times, one object differs in quality from another.

For example, suppose the quality of two objects, A and B, was measured in a quantitative (e.g., point) scale receiving the following quality ratings: $K_A = 60$ points and $K_B = 40$ points. The information content of this scale is known not to exceed the capabilities of the ordinal scale. Then, it would be wrong to calculate the ratio

$$K_A - K_B = 20 \text{ points and } K_A / K_B = 1.5.$$  

The only correct inference we can make with regard to this case is: since $K_A > K_B$, the quality of A is higher than that of B.

A real-life example of measurement in the original scale (though not of quality but of temperature): a mother measuring her child’s temperatures by putting her hand to his forehead. Here, the temperature rise is measured in the ordinal scale: the mother can tell if the temperature is high but cannot tell by how many tenths of a degree (much less how many times). (We will explain how to choose the type of scale in one of the following sections of this ABC).

2.3.4.2. Interval Scale

Cost of use — higher than those with the rank scale (approximately by half an order of magnitude).


Results — the same as with the ordinal scale plus some extra information: how much one object differs in quality from another (i.e. with respect to the previous example, it is legitimate to calculate the difference: $K_A - K_B = 20$ points but not legitimate to try calculating the ratio $K_A / K_B = 1.5$).

Reverting to the temperature measurement example, we can say that the temperature is measured in the interval scale in degrees Centigrade (or Fahrenheit).

### 2.3.4.3. Ratio Scale

Cost of use — the highest (about 1.5 orders of magnitude higher than with the rank scale).

Results — the same as with the interval scale plus some additional information: how many times an object is different in quality from another (i.e., it is perfectly legitimate to calculate the ratio $K_A / K_B = 1.5$).

One example of using the ratio scale is the measurement of Kelvin temperature.

Of the three types of scale the ordinal and ratio scales are the most common. Hereinafter we will largely examine these two types.

### 2.4. Quality Assessment Algorithm

Outline flowchart of the short-cut quality evaluation algorithm. QEM development
For the qualimetric analysis of various objects theoretical qualimetry has evolved a sequence of work steps. The totality of these steps can be presented in the form of an outline flowchart of the quality estimation algorithm (Figure 3). Each rectangle in the flowchart carries information about the respective step: the figures on the left side indicate the step number and the abbreviations beneath the figure indicate the person responsible for the work at the step; the text in the left-hand part of the rectangle is the name of the step. (Recall that this flowchart shows only one set of steps, namely that, corresponding to the short-cut method of quality evaluation. For the approximate and, particularly, the rigorous method, this set is

<table>
<thead>
<tr>
<th>Step</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set the task of QEM design and application (DM’s responsibility) and appoint the QEM Designer</td>
</tr>
<tr>
<td>2</td>
<td>Define the evaluation context</td>
</tr>
<tr>
<td>3</td>
<td>Form groups contributing to QEM design and application: SG, EG and TG</td>
</tr>
<tr>
<td>4</td>
<td>Derive a property tree and an index tree for the object</td>
</tr>
<tr>
<td>5</td>
<td>Weight property indices</td>
</tr>
<tr>
<td>6</td>
<td>Define reference and reject values for property indices</td>
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<tr>
<td>7</td>
<td>Define the values of absolute property indices</td>
</tr>
<tr>
<td>8</td>
<td>Define the values of relative property indices</td>
</tr>
<tr>
<td>9</td>
<td>Define the values of object quality index</td>
</tr>
</tbody>
</table>

**Figure 3. Outline flow-chart of the quality assessment algorithm using the short-cut method**
much greater).

The following paragraphs will consider the individual steps of the algorithm one after another (except steps 1 and 3).

2.5. Defining the Evaluation Context

2.5.1. The Essence of this Stage

As shown in the flow-chart above (Figure 3), the entire qualimetric analysis procedure in the general case (i.e. when there is no ready-made quality evaluation method, QEM) consists of two parts: QEM development and QEM application. While you are working at the “Define the Evaluation Context” step, the entire future strategy of both QEM development and its use, is established.

The essence of this stage is that the QEM Designer upon receiving from the Decision Maker (DM) the task to develop a QEM; clarifies any ambiguities that may be associated with the task. He refers to the DM for any missing information. Such clarification is mainly necessary in order that: —

(a) The QEM Designer has sufficient information about the properties to be included in the property tree (which is to be built at one of the subsequent steps); and

(b) People using the QEM have a clear idea of the initial conditions that underlie the QEM and define its scope.

Unfortunately, after we reviewed most of the QEMs known from the literature it became clear to us that their designers never defined their evaluation context (or defined it incompletely). As a consequence, they did not select quite correctly the properties to be considered in evaluating the quality of their object and besides made
it difficult for the QEM user to correctly interpret the information received on its basis. The end result is that the quality ratings produced by such QEMs prove to be much less accurate than what could be achieved if they had completed the “Define the Evaluation Context” step.

For example, it is very often the case that a qualimetric analysis recognises only a subset rather than the whole set of properties describing an object; this is true, for example, of the majority of Russian and foreign methods for evaluating life quality. However, the theory of qualimetry has proved that if this is the case, all quality ratings obtained will not be expressed in a ratio scale (which is usually the preferred one because numbers presented in this scale lend themselves to any arithmetic operations). The scales in which they would be presented (the interval scale or especially the rank scale) are “cruder” than the ratio scale and thus allow for only a limited number of arithmetic operations.

The designers and users of such QEMs, being ignorant of the above circumstances, treat quality ratings obtained in this manner as if they were expressed in a “finer” scale, that is, the ratio scale. This is essentially wrong. (More about this and other common errors are presented in a subsequent section of this ABC).

Questions whose answers are subject to clarification during the “Define the Evaluation Context” operation, fall into three groups detailing:

— The application of the objects of the type being evaluated;

— The use of the computed quality ratings; and

— The QEM development technique.

Each group is discussed below in one of the three subsections 1, 2, and 3. Each question is dealt with in one paragraph of a subsec-
tion. The contents of each paragraph are expounded in a uniform sequence: a statement of the question followed by necessary explanations.

2.5.2. Questions Regarding Features of Application / Use / Operation / Consumption of Objects of the Kind Being Evaluated

2.5.2.1. Must All the Stages of an Object’s Life-Cycle Be Taken into Consideration?

The most complete and comprehensive evaluation of quality is achieved when all the properties of the object, that manifest themselves in all phases of its life-cycle, are taken into account: during its storage, preservation, de-preservation, transportation to the place of use, on-site deployment, take-down, maintenance and servicing, fuel and/or energy supply, direct application, disposal and/or recycling.

However, a Decision Maker determines which may be unknown or incomprehensible to the QEM Designer, he is in a position to neglect some of these life-cycle stages, e.g., the liquidation. The reason is that with regard to the vast majority of object types, the liquidation stage does not present any particular difficulties to object users. Still, for some very specific types of objects (for example, nuclear reactors, radioactive waste, manned space stations) this kind of consideration is badly needed because at this segment of a life cycle the need is felt for the input of extra effort and resources into the liquidation of such objects.

In cases where the stage of liquidation (or any other life-cycle stage) is not taken into account in quality measurement, it is necessary that the preamble to the QEM being developed should mention the fact of omission of one or more stages. This is to ensure that
in the future, when the QEM is applied, there would be full understanding of the assumptions on which it rests.

The mention of basic assumptions in the preamble to the QEM is necessary in relation not only to question 2.5.2.1 above but also in relation to the “Define the evaluation context” stage. Therefore, hereinafter to save space we will not specifically stipulate the mandatory mention of other assumptions in the QEM preamble.

The whole set of assumptions is best presented in a compact form, for example, in the form of a special QEM subsection — “Basic Assumptions for QEM Development”.

2.5.2.2. Must the Possibility of a Future Modernisation of the Object Be Taken into Account?

With many types of objects when we assess their quality we must take into account the possibility of their upgrading in the future due to a change of technical and economic requirements they are supposed to meet. We illustrate this by an example, which seems to be quite revealing.

The issue of modernisation is very topical in relation to residential and industrial buildings. It is a well-known fact that the Russian housing stock created in the 1950s–1960s (which is no less than 500 million square meters of living space) no longer meets current functional and aesthetic requirements for urban housing. Its modernisation is one of the most urgent and complex problems today.

It cannot be ruled out that the current situation is a natural consequence of the fact that in Russia, for example, at the time multiple-unit housing projects for low-cost housing were approved, when the quality of these projects (so-called “first-generation” projects) was analysed, they gave little or no consideration to the need and
opportunity for future upgrading of the housing. If this factor had been taken into account, the well-known series 464 might not have become so widespread, in which most of the apartments had one or two rooms, whereas in today’s environment mainly three-room apartments are required.

It would seem that combining adjacent one- and two-room apartments and cutting doorways in the walls can easily solve the problem of increasing the number of three-room apartments in this series of buildings. But the fact is that houses in this series do not lend themselves readily to upgrading because all the living-room walls are supporting ones (No doorways may be cut through these walls because bearing steel reinforcements would be broken, which is totally unacceptable). As a result, houses of this series in Moscow have to be pulled down now as in practical terms they defy modernisation.

In terms of upgradeability, other design schemes of residential buildings are more preferable: frame or frameless buildings (with spine walls). If in selecting the main series from among the first generation designs consideration had been given to adaptability to future modernisation (reconstruction), we are not at all sure that Series 464 would have been chosen. Thus, failure to take into account the possibility of future upgrading (reconstruction) in evaluating the quality of a project may create serious and intractable problems later on.

2.5.2.3. What Is the Life of an Object to be Centred On: Its Depreciation Period, Obsolescence Period or Both?

Often the QEM Designer cannot solve this problem single-handedly and must seek guidance from the DM, because without the latter’s decision the value of an object’s service life, $T_{sl}$, cannot be determined correctly. Yet, unless we know the value of this parameter,
we cannot determine the value of the efficiency retention factor, \( F_{\text{eff}} \), which is a member of the quality evaluation formula.

The correlation between physical depreciation, \( T_{\text{dep}} \) (or obsolescence, \( T_{\text{obs}} \)) and service life may vary depending on object type. For example, for housing settlements that happened to be in an earthquake zone and had to be moved to a less hazardous region (which was the case, e.g., after the destruction of some settlements in the Russian Far East by a catastrophic earthquake) it is obvious that their obsolescence period is less than their depreciation period. As for factory towns built around small deposits of a mineral, it can be assumed that their physical deterioration occurs earlier than their obsolescence after the field has been completely depleted. Finally, it should be noted that there may be object types whose periods of physical and moral deterioration are comparable or close enough — for example, urban outdoor heating systems operating in extremely cold climates.

2.5.2.4. What Groups of People Contacting with the Object Must Be Taken into Consideration in Quality Evaluation?

In the general case (for example, for the rolling stock of public transport — trams, trolley-bus, bus, metro) we can distinguish four groups of people:

(a) Those who use the object during its application (passengers);

(b) Those who operates the facility (drivers, guards);

(c) Those who service (maintain the operation of) the rolling stock;

(d) Those who are not directly related to the operation of the object but may come into accidental contact with it (e.g., pedestrians in the streets).
For other types of object a different number of groups can be identified, which is usually at least two. For example, in relation to a gurney for transportation of patients we will have three such groups:

— Those who operate the object (nurses)

— Those who use the object (patients),

— Those who repair the object (maintenance workers).

In relation to consumer goods such groups are often two:

— Those who use this type of product, e.g., leather goods or furniture, and

— Those who repair them.

The QEM Designer should be clear about which of these groups must be recognised in evaluating the quality of an object.

### 2.5.2.5. What Is the Place of the Evaluation Object in the Dimensional Classification?

With objects such as human settlements, when a life quality evaluation method is developed, we need at the start to specify the respective object in the context of the dimensional classification. In particular, we need to know whether the settlement is a workers” housing estate near a factory, a resort town or a university campus, and whether it is classed as a megalopolis, a city, a medium-sized or a small town?. This is due to the fact that the reference and rejection values of properties and the weight factors vary in objects of a similar purpose that belong to different types by the dimensional classification. It follows that for each type of object of a particular size there should normally be a separate QEM.
2.5.2.6. Which Climatic and Natural Conditions Affect the Quality of an Object and Thus Must be Taken into Account in Its Evaluation?

In general, we have in mind the following factors:

(a) Physical (temperature, humidity); electric and magnetic fields; various types of solar and other radiation;

(b) Chemical (possible contact with chemically aggressive gases, liquids or solids);

(c) Mechanical (dust, dirt; density, velocity of the environment — water or air; the bearing capacity of soil or other foundations);

(d) Biological (presence of rodents, insects, bacteria, plants that can cause damage to the object in question).

We should count among the factors listed above also catastrophic factors: natural disasters (earthquakes, hurricanes, floods, landslides, mudslides, etc.) or man-made disasters (fires, explosions, accidents, crashes, etc.).

It is very likely that AQEM Designer is not quite sure about this list of factors and, therefore, has to check them with the DM.

2.5.2.7. What Properties of an Object Reflecting Its Environmental Impact Must Be Considered in Evaluating Its Quality?

Many objects in the course of their use tend to have an unfavourable impact on their surrounding animate nature (flora and fauna) and inanimate nature (natural environment: air, water, landscape and artificial habitat: buildings, machinery, etc.). There-
fore, each case of neglect of any of the existing impacts of this kind should be explicitly stated in the introduction to the QEM.

Following we will find just one, but a well-known example relating to the erroneous neglect of these impacts.

Until relatively recently the principal approach over the world was to increasing the energy characteristics of petrol to improve its octane rating, chiefly through addition of lead to petrol. This choice was indisputably correct, if we only consider the main purpose of such additives, which is to upgrade the energy characteristics of petrol while ignoring its other properties — environmental friendliness and safety. If these properties are factored in, leaded petrol proves to be much inferior in quality to many other, more environmentally friendly forms of motor fuel; accordingly, in recent years its use has been almost universally prohibited.

2.5.3. Features of Application of the Quality Index

2.5.3.1. What Level of Social Hierarchy Must Be Taken into Account in Appraising the Quality of an Object?

Some evaluation objects have properties whose inclusion/non-inclusion in the property tree depends on the level of social hierarchy occupied by the hypothetical user of the object in behalf of whom quality is evaluated.

For example, if in evaluating the quality of life we take the lowest level of social hierarchy on which the role of the consumer is played by an impersonal individual, e.g., the citizen of a country, some properties do not have to be included in the property tree because they do not directly affect the satisfaction of any specific need.
of the consumer, e.g., “pollution of the water or air basin of the
globe, in violation of international agreements such as the Kyoto
Protocol.”

If, on the other hand, we take a higher level of hierarchy, on which
the role of the “total customer” is played not by a single individual
but by a city, region or country as a whole, these properties should
certainly be taken into account in quality appraisal and included
in the property tree.

It follows that one and the same object may get different values
of the quality index depending on the level adopted in estimating
its social hierarchy level.

2.5.3.2. Must the Quality of an Object Be
Evaluated on the Basis of the Quality Index or the
Integral Quality Index?

This question is closely related to the previous question, 2.5.3.1,
because as is usually the case, the higher the level of social hierar-
chy considered, the greater is the likelihood that it would be nec-
essary to use an integral quality index rather than a quality index.
However, one can conceive of a case where various options are com-
pared from the point of view of top-level subjects, while the selec-
tion criterion is still a quality index and not an integral quality
index.

For example, if we are talking about a recreational and health com-
plex project, which is of national scope yet relatively modest
in cost, it is likely that in some cases the neglect of its cost efficien-
cy index may be justified, meaning that it is more reasonable to use
a quality index rather than an integral quality index. However, the
final decision usually falls within the authority of the DM, to whom
the QEM Designer must refer for clarification.
(Note that in the following for the sake of simplicity we will use in most cases the term *quality*, although nearly all the things relating to this term, unless otherwise specified, remain in force for the term *integral quality*.)

### 2.5.3.3. Must an Object Be Evaluated by the Rigorous, Approximate or Short-Cut Method?

Naturally, a QEM Designer usually cannot decide all alone which of the three methods (rigorous, approximate or short-cut) should be used in evaluating the quality of an object. Normally, it calls for additional information, for which the QEM Designer should refer to the Decision Maker.

(It will be remembered in this text because of its size limitations it will mainly describe the short-cut method for quality appraisal).

### 2.5.3.4. Is the Comparability of Quality Index Values Desirable? If It Is, What Type?

For reasons known to the Decision Maker (and possibly unknown to the QEM Designer) it may be necessary to ensure the comparability of the values of quality indices of the appraisal object of one type with those of other types of object.

This kind of comparability can in fact be of only two kinds:

One is *functional comparability*, whereby it is possible to compare the values of quality indices of dissimilar objects belonging to different kinds and even different classes; for example, the quality of life of young people and that of seniors. To ensure functional comparability, the QEMs by which the quality of dissimilar objects is appraised must be as nearly identical as practicable; that is to say, these methods must have identical measurement scales and criteria
for determining the values of indices.

The other is *temporal comparability*, which allows determining how the quality index of an object will vary with time. For example, temporal comparability can help to solve the following problem: if your current quality index for a given object is equal to $k^x$, what will it equal, say, in ten years” time if the values of absolute indices of all its properties during this period remain unchanged?

With the help of temporal comparability we can accomplish some other important tasks, including that of finding the minimum period in which the appraisal object becomes obsolete and, therefore, must be replaced.

We must distinguish between functional or temporal comparability and *formal comparability*, which only helps to express the quality of comparison objects in scales of the same scope but, nevertheless, does not allow us to judge which of the objects is better or worse than the others.

Formal comparability occurs when the criteria for determining the values of quality indices are not identical in different QEMs. For example, two QEMs built on different principles measured the quality of the object $A$ to be equal to 0.71, and that of the object $B$, to be equal to 0.65. In this case, we cannot say that the quality of $A$ is better than that of $B$. (Technically, however, this conclusion seems to be justified).

Thus, for purposes of comparison of the quality of different types of objects we can only use functional and / or temporal comparability, but not formal comparability. What types of comparability to be built into a QEM is something to be decided by the QEM Designer together with the Decision Maker.
2.5.3.5. In Which Scale Must a Quality Index Be Expressed: Rank or Ratio?

In this case, we only consider two types of scale because the other types, e.g., the interval scale, are relatively rare in the practice of quality evaluation.

As already noted, the values of quality indices expressed in the ratio scale allow us to determine to what extent the quality of one object is higher or lower than that of another. The rank scale, on the other hand, makes it possible to determine which one of the comparison objects is higher in quality, but not the extent of it.

For example, quality indices were obtained for two samples, $A$ and $B$:

$$K_A = 0.80 \text{ and } K_B = 0.88.$$  

If their quality is evaluated in the rank scale, we can only deduce that the quality of $B$ is better than that of $A$. If, however, we use a different scale, we can obtain some additional information, namely, that the quality of $B$ is 10% (or 1.1 times) higher than that of $A$.

Thus, a Decision Maker must establish the nature of the tasks to be addressed using quality indices. A QEM Designer, based on the nature of these tasks, will determine which scale (the rank or the ratio one) must be built into the prospective QEM.

2.5.3.6. What Is the Time Limit for Evaluating One Object?

The QEM Designer selects the method for quality appraisal depending on the time constraints: a rigorous one is the most time-consuming one; an approximate or short cut one requires the least time.
However, the following controversy may occur. A Decision Maker in response to a question raised by a QEM Designer (2.5.3.6) sets the task, when evaluating the quality of life in cities, of using at least an approximate method of qualimetry; and if possible, a rigorous one. Moreover, the Decision Maker determines that the time for evaluation of the quality of life in the city using the QEM in question must not exceed two days.

Because a city is a fairly complex object, and it does not seem possible to evaluate the quality of life in it in such a short time, the QEM Designer has to ask the Decision Maker’s permission to change the QEM criteria: either to apply a short-cut (rather than approximate) method of qualimetry, or raise the time limit for the approximate method to 18 days (Recall that this text describes mainly the short-cut procedure).

2.5.3.7. How Often Is a QEM to Be Used: Once Only or Repeatedly?

There can be, though rarely, a situation where the appraisal object is unique and the QEM is to be used only once. For example, in the outline design of a new urban settlement it may be necessary to compare alternative arrangements of its main elements affecting the life quality of its residents. In this situation a respective QEM will be used once only, to choose the best option.

However, a method designed for appraising the quality of existing urban settlements (of course, belonging to the same dimensional range) should lend itself to multiple use — as many times as the number of settlements of this type for which life quality must be evaluated now or in some period in the future.

When the method is designed for only one use, it makes no sense to create design charts, far less computer programs, to facilitate the calculation of a quality index; calculation formulas will suffice. If,
on the other hand, a QEM is designed for multiple uses, the method should preferably include design charts (and sometimes, computer programs as well).

Therefore, the QEM Designer together with the Decision Maker should decide the question of the frequency of QEM use.

2.5.3.8. Is a Quality Index Calculated Manually or on Computer?

Depending on specific conditions (to be defined and explained by the Decision Maker), a QEM may be designed for manual calculation or computer calculation. If it is manual it means that the values of the quality index are measured using calculation formulas (for a one-off QEM) or design charts (for a multiple-use QEM).

Computer programming may only be appropriate if, first, a QEM is to be used repeatedly, and second, the number $n$ of property indices considered is large enough (typically $n > 50$).

Since the QEM Designer’s work in both, these cases will have some features related to the writing/non-writing of a computer program for quality index calculation, he should ascertain the technology which he should target.

2.5.3.9. Do Quality Indices Need to Be Differentiated By Element, Application Environment etc.?

The QEM Designer must ascertain with the Decision Maker whether the QEM is to make it possible to evaluate not only, say, the quality of life in the whole country but also in some of its regions?

Differentiated assessments may relate not only to parts of an object
but also to its functions. For example, it may be necessary to assess the quality of life in a settlement depending on the capacity (recreational or industrial) in which it is to be used.

2.5.4. Questions Concerning QEM Development Features

2.5.4.1. Has Any Other Organisation a QEM for the Evaluation Object? If It Does, Can the QEM Designer Make Use of It?

On very rare, yet conceivable occasions a Decision Maker commissions a QEM Designer to develop a QEM for a particular type of object, being unaware that such a method has been developed at another institution. Therefore, to avoid unnecessary labour costs, the QEM Designer should first of all make sure that this kind of QEM has not be developed elsewhere. This analysis can be performed not only during the “Define the Evaluation Context” step, but also at an earlier stage, when the QEM Designer receives this commission.

2.5.4.2. Has the QEM Designer the Opportunity to Get Hold of Any Supplementary Material Needed for QEM Development?

A more common situation than the one described in the preceding paragraph occurs is having no ready-made QEM but having some supporting material necessary for its development. For example, there is a complete property tree that must be considered when evaluating the quality of an object; or the values of the weight factors of the individual properties; or there is information relating to the reference or rejection values of at least some property
Thus, even before starting work a QEM Designer should ascertain whether there are not any ready-made supporting materials, which could be used as part of the method to be developed.

2.5.4.3. What Are the Allowable Labour Costs of QEM Development in a Particular Context?

This information (which can only be obtained from the Decision Maker) is necessary because the choice between the rigorous, approximate and short cut evaluation methods largely depends on the labour limit that the Decision Maker allows to the QEM Designer.

For guidance we can consult the average standards for maximum labour input in the QEM development (for one type of object), $L_{max}$, quoted below. These standards relate to the conditions determining the following evaluation context:

— The object is the most complex one among those encountered in the practice of quality evaluation (the number of properties recognised is not less than 800); 

— The QEM is designed for repeated application without the use of computers;

— The quality index is expressed in the ratio scale;

— The evaluation method is short cut.

For these conditions, the labour input standards (rounded, in mandays) are as follows:

— Identify property indices: $P_I = 50$, with approximately one-half
of the labour input falling on the steering group (two persons), and the other, on the expert group (seven persons):

— Perform all the other procedures provided by the QEM development algorithm: $P_2 = 5P_1 = 250$;

— Total maximum labour input into the QEM development:

$$L_{max} = LP_1 + P_2 = 300 \text{ man-days.}$$

In the event of using other than the short-cut methods, the labour input would be much higher:

— For an approximate method: $L_{max} \leq 500 \text{ man-days}$;

— For the rigorous method: $L_{max} \leq 1100 \text{ man-days.}$

### 2.5.4.4. What is the Allowable Time Cost of QEM Development in a Particular Context?

This information (like the information obtained in response to the question from the previous paragraph) is required in order to correctly choose one of the three quality evaluation methods (short-cut, approximate or rigorous). In addition, the time limit is taken into account in order to select the correct strength of the steering, technical and expert groups involved in QEM development.

The reason is that, within limits, the time required for QEM development depends on the number of people whom the Decision Maker can put at the disposal of the QEM Designer. However, experience shows that, in any case, an increase in the number of people engaged in the QEM development should not be more three times greater than the normal number (which is given above in relation to the short-cut method).
Therefore, in view of this three-fold increase in the number of people involved in QEM development, the minimum time required for the most complex type of object can be:

— 1 month with the short-cut method;
— 3 months with the approximate method;
— 8 months with the rigorous method.

These are questions whose answers are essential for the “Define the Evaluation Context” step.

2.6. Building a Property Tree and Identifying the Indices to be Appraised

2.6.1. General Observations

The derivation of a property tree and the identification of evaluation parameters is the substance of step 4 of the QEM algorithm (see Fig. 3).

This step is very important for two reasons. One is that if its constituent operations are improperly performed, the quality index produced with the help of an incorrectly derived tree (and the respective QEM) may turn out to be quite wrong. Moreover, the resultant error can occur in any scale in which the values of the quality index are expressed.

For example, let there be two objects, A and B, whose quality indices, \( K_A \) and \( K_B \), are expressed in the ratio scale. Let us assume that the values of these parameters calculated with a well-formed tree equal \( K_A = 0.84 \) and \( K_B = 0.76 \). Then \( K_A/K_B = 1.1 \). If the tree is constructed incorrectly this ratio of quality indices is likely to vary
(upward or downward) from 1.1. It appears in the above situation that quality is not measured by a “metal” (hard) ruler but a “rubber” (soft) one, which, of course, is unacceptable for any measurement.

If, on the other hand, the parameters were measured in the ordinal (rank) scale and with a well-formed tree, the ratio $K_A > K_B$ were true, it cannot be ruled out that, given an ill-formed tree, the quality ratio of the same objects would be expressed by the opposite ranking: $K_A < K_B$! (Needless to say that here, no accuracy of any qualimetric calculations can be achieved).

A second factor contributing to the importance of this step of the QEM development algorithm is as follows: All the other steps of the algorithm (at the present level of theoretical qualimetry) are relatively simple methodologically, are “formalisable” and to a large extent can be automatically implemented. As for this (fourth) step, its implementation today (and in the foreseeable future) is still a largely no-formalised process, which requires a creative approach from the person developing the quality assessment method (QEM Designer).

It becomes clear, however, that when a tree is derived this creative approach is open to a very undesirable subjectivity. The desire to reduce subjectivity accounts for the development of tree derivation rules that impose certain constraints on the QEM designer’s actions. Due to this, the tree derivation process becomes less stochastic and more deterministic. This, in the final count, leads to a decrease in the error rate of the results obtained with the help of such tree.

The presentation of the set of respective rules is the subject of this section. Given the general theoretical significance of the tree structures it would be useful to preface the review of the sought-for rules by a brief historical overview of the origin and scientific use of such structures.
2.6.2. The Tree as a Knowledge Tool: A Brief Historical Note

Tree-type hierarchies are typically used to analyse the possibility of solving a complex problem.

This analysis can be carried out in different ways, e. g.:

— To identify sub problems, which taken together reflect the essence of the original complex problem (in this case, the tree is a problem tree),

— To identify a set of tools that can help to solve the original problem (the tree becomes a means tree or an activity tree),

— To designate and build a hierarchy of the goals for which a project or a program is implemented (a goal tree),

— To choose an optimal set of tools providing solution of the initial complex problem (a decision tree);

— To allocate resources (e.g., financial) for solving individual sub problems of a complex problem (a weight tree);

— To predict the possibility of solving individual sub problems of a complex problem (a forecast tree).

Other kinds of trees are used, too: a property tree, an index tree, a classification tree, a defect tree, a utility tree, a function tree, a relation tree, a resource tree.

Almost all of the above types can be viewed as special cases of the problem tree, which is most often used in practice. For these reasons, the material set out in this section will mainly be illustrated with a problem tree (which is close in meaning to the property tree and the index tree).
The first scholar to put forward the idea of a problem tree (though without a graphical interpretation) was apparently the famous French mathematician and philosopher Rene Descartes. In his *Discourse on the Method* (1637), he effectively introduced the tree concept when he stated two of his famous rules of logical thinking: “The second, to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution. The third, to conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend by little and little, and, as it were, step by step, to the knowledge of the more complex...”

Soon after, Descartes’ idea of a tree (as applied to the goal tree) was formulated by the famous English philosopher Thomas Hobbes, who in his philosophical treatise *Leviathan* (1651) wrote: “From a desire arises a thought of some means by which we see completed something similar to what we aspire to, and from that thought, a thought of the means to achieve these means, and so on, until we reach some beginning which is in our own power”.

Over the next two centuries trees were mostly used as classification trees (for example, Ernst Haeckel in 1866 used the term *phylogenetic tree*). And the English mathematician A. Cayley, who considered this type of mathematical objects in his Theory of Analytical Forms Called Trees, introduced the term tree itself into scientific circulation in 1857.

However, ten years before Cayley, in 1847, Gustav R. Kirchhoff used tree structures in his study of electrical circuits. In an even earlier period, the term tree was used in the hierarchical ordering of officer ranks as well as in genealogical research (*family tree*). After Cayley, tree structure (called geometric trees) was investigated by the British mathematician W. W. Rouse Ball, who in his book *Mathematical Recreations and Essays* (1892) devoted an entire chapter to them.
At present tree structures are most commonly used in systems analysis, forecasting, qualimetry and decision theory.

2.6.3. Terminology

Despite the rather widespread use of the term tree, the associated conceptual system still cannot be considered sufficiently mature and, most importantly, commonly used. The tree-related conceptual framework has been elaborated in most detail (to the level of formal definitions) with respect to property and index trees as used in qualimetry. Note that the set of basic concepts used there is quite suitable for most other types of tree. We explain it briefly with reference to the property tree, of which the index tree (which is the goal of the qualimetric analysis algorithm at this stage) is to a large extent an analogue.

A tree branch represents the basic concept, property. (In a problem tree a problem is an analogue of a property, in a goal tree it is a goal, in a resource tree, a resource, etc.).

All properties fall into three types according to degree of complexity:

First, there are complex properties, which are divisible into less complex ones. See, e.g., the section “The Essence of Quality and Its Management”): the complex property “integral quality” can be divided into the less complex properties of “quality” and “efficiency”.

Secondly, there are simple (elementary, indivisible) properties, e.g., the length or width of a rectangular building.

Thirdly, besides complex and simple properties a property tree may include so-called quasi-simple properties. These are properties that by virtue of being complex can, but need not, be divided into
less complex properties because there is a known correlation or dependence between a property and a group of less complex properties. For example, the property of “efficiency (costs)” can be divided into a group of properties: production costs and operating costs. Division is unnecessary because according to one of the formulas known in economic efficiency theory, e.g., the formula for reduced costs, the property “costs”, $Q_{gen}$, can be expressed through price, $Q_{pr}$, and annual operating costs $Q_{opr}$.

$$Q_{gen} = Q_{opr} + E \times Q_{pr},$$

Where $E$ is the normative coefficient of efficiency (until relatively recently it was used in economic calculations in a planned economy).

In such circumstances, this complex property does not need to be divided (decomposed) in the property tree. Therefore, it is conventionally represented in the property tree not as a complex (i.e. branching) property but as a simple (not branching) one, hence the name, quasi-simple.

Quality as the most complex property in the property tree (not counting integral quality) is treated as the trunk, usually considered to be located on tier 0 of the tree; see Fig. 4. (Graph theory, instead of the term trunk uses the term root of the tree, which, in our opinion, is less graphic). This complex property is divided (decomposed) on the next tier into less complex properties, each of which, in turn, is divided into progressively less complex properties, etc. Moreover, the properties of the lower, $(k-1)^{th}$ tier are generalising in relation to the corresponding properties of the next, $k^{th}$ tier ($k = 1, 2, ..., m$, where $m$ is the number of the highest (last) tier of the property tree).

For relatively simple objects (e.g., the quality of life in a sanatorium) $m = 4, ..., 7$. For complex objects (e.g., the quality of life in a small town) $m = 8, ..., 12$. For the most complex ones (i.e. the
quality of life in a country) \( m \leq 25 \).

In addition to the above, the property trees used in qualimetry include some other terms. For example:

**Group of properties** – an assemblage of less complex properties into which a complex property directly decomposes.

**Tree height** – the total number of tiers in a tree.

**Full tree** – a tree where the highest tier contains only simple or quasi-simple properties.

**Incomplete tree** – a tree whose top tier

\[
k (k = 1, m - 1)
\]

may contain also complex properties.

**Sub tree** – any branch of the tree extending to not less than two tiers.

**Truncated tree** – a complete or incomplete tree, in which in accordance with the features of a particular problem that can be solved using the tree we can eliminate one or more properties or sub trees.

The next two concepts and terms refer to objects (let us call them
“special ones”) in relation to which we can speak about the quality of life, but which are very uncommon in practice. These objects include, *inter alia*:

— Temporary camps to house rescuers in natural disaster areas;

— Temporary camps of polar explorers on drifting ice floes;

— Manned space stations and similar objects.

As for objects in respect of which it is legitimate to refer to “life quality” but which do not belong to the “special” category and, accordingly, are infinitely more likely to be found in practice, the purpose properties are properties that affect the life processes and in the aggregate form, the concept of “life quality.” Therefore, the term *purpose properties* need not be applied to such objects.

**Purpose properties** — a sub tree containing all the properties that characterise an object’s purpose, its primary function, i.e., what the object was made for. To illustrate, for a commercial motor vehicle the purpose properties are those of “fitness for the carriage of goods and (occasionally) people”; for a mobile service station, “fitness for maintenance operations”; for a tent, “fitness for support of life processes”.

**General property tree** — an incomplete tree whose properties represents the totality of properties of special objects of this class (for example, a temporary camp of re-locatable structures) but does not include those properties that taken together constitutes their purpose properties (see Fig. 8 — 13).
2.6.4. Tree Derivation Methods

Tree derivation (synthesis) in systems analysis, operations research, decision theory, etc. most often focuses on turned-over trees (see Fig. 5a) and less frequently on upward trees (Fig. 5b) or rightward trees (Fig. 5c). The least frequent are leftward trees (Fig. 5d). As far as qualimetry is concerned, in these authors’ experience, the rightward tree is the most convenient to derive and apply. Hereinafter this kind of tree will be used for illustration.

Three main forms of tree depiction are used in practice: tabular form, which allows representing the interrelations of tree elements in a compact, though not quite graphic, way (see. Figure 6a); and two so-called graph forms, less compact but more illustrative than the tabular. Graph forms are of two varieties, the strict graph form (see, e.g., Figure 6b) and the non-strict graph form (Figures 5a to 5d).

The strict graph form is used mostly in forecasting and in operations research. As for qualimetry, this kind of tree depiction is seldom used because, among other factors, it is not easy to type in the names of properties along inclined lines. The tabular form is used instead, (Figure 6a) when it is desirable, above all, to produce a compact image, or the rightward tree in a no strict graph form (Figure 5c), i.e. when the greatest possible visualisation of the relations of the tree elements is sought.
Figure 4. General scheme for decomposing complex properties (by tree tier) into less complex ones.

Figure 5a. Turned-over tree
Figure 5b. Upward tree

Figure 5c. Rightward tree

Figure 5d. Leftward tree
2.6.5. Tree Derivation Rules

As already noted, the most detailed tree derivation rules were developed in qualimetry, namely, with regard to the property tree. In particular, qualimetry has institutionalised a set of about 30 rules, which if followed, allow different developers with respect to the same concrete object to arrive at the same tree (which is a prerequisite for the reliability of results obtained with this tree). The more important of these rules are summarised below.
2.6.5.1. General Derivation Rules for Tangible Product Property Trees

Given below are the main rules to be always followed in deriving trees for objects that are tangible products.

— Maximum Height of a Tree

— Branch a tree until only simple or quasi-simple properties remain at its top tier.

— Preference Indifference of Properties in a Group

Each property in a property group in relation to any other property in that group must satisfy the “preference indifference principle” validated in decision theory. The essence of this principle is explained below.

Let us assume that two properties, $A$ and $B$, belong to the same group of properties. Let us also assume that the nature of these properties is such that, taken by itself (that is, in the case $A$ without considering the properties of $B$, and in the case of $B$ without considering the properties of $A$), greater values of each property are preferable to lower values. Then, $A$ is said to be in an indifference relation to $B$ if greater values of $A$ are preferable to its smaller values regardless of what values $B$ may take. (Preference indifference is defined similarly in cases where lower rather than higher values of property indices are desired, and also when $B$ is preference indifferent to $A$). For example, let there be the properties “living space per inhabitant” and “natural illumination in living quarters”. They are preference indifferent. Indeed, whatever the value of the first property, the best value of the second property is always preferable to the worst value and vice versa.

At the same time, two properties such as “ceiling height” and “floor space” are not in the preference indifferent relation for an obvious
reason: it is uncomfortable to live in a very high-ceilinged and also very small room, a kind of standing pipe. In relation to the above, we define two more terms.

**Independent property**, a property in a property group such that it is in the preference indifference relation towards any property in that group.

**Dependent property**, a property group such that it is not in the preference indifference relationship towards at least one property in that group.

Therefore, the property tree derivation rule discussed here is that when a property group is built, it must be checked for compliance with the Inadmissibility of Dependent Properties rule. That is to say, according to this rule, no property group must include any dependency property.

**Exhaustive Consideration of the Application Features of an Object**

According to this rule, a tree must include all properties that reflect the object application characteristics that were identified in the implementation of procedures 2.5.2.6 to 2.5.2.7 of the Define Evaluation Context step. It is clear that in this case the reference is only to those features that affect the variation in the values of $Q$, e.g., features associated with seasons (autumn and spring, summer and winter); with climatic conditions of the locality, etc.

An exception should be made only for features whenever:

1. The Decision Maker does not consider necessary to include them in the property tree,

2. The QEM Designer (SG) has no data that would allow establishing the values of $Q_i$ for the properties that recognise these features.
Figure 1.7. shows an example of recognition of one of these features.

**Exclusion of Reliability Properties**

Properties that determine reliability (for example, for the majority of tangible products of labour they are storability, fail-safe operation, maintainability and longevity) should not be included in a property tree. They will be considered when calculating the value of an integrated quality index for an object in the form of the usage factor $K_{use}$.

**Structural Rigidity of the Primary Tiers of a Tree**

For the majority of tangible objects primary tiers of a tree can be derived as special cases of the primary tiers of the General Property Tree; see Figures 8—14. Of course, one must consider whether these objects are ordinary or special. In the case of special objects (vehicles, machinery, installations) qualimetry has developed for the first 10—12 tree tiers a so-called “common property tree”, which is generally applicable to any type of object. The specificity of any individual object of analysis (including an ordinary one) is taken into account as follows: properties that do not match the specificity of the object in question are simply excluded from the common property tree and a purpose property sub tree is added, if necessary.

In other words, all the properties are excluded from a common property tree that by their nature and by the evaluation context need not be considered in evaluating the object.

The primary tiers of the common property tree for special objects are shown in Figure 8, and the remaining tiers, in Figures 9 to 14. A version of an incomplete tree that describes the quality of life is shown in Figure 15.
2.6.5.2. General Rules for Deriving Purpose Property Sub trees

Division by an Equal Characteristic

Any group of properties must have a single characteristic of division. This rule is violated, e.g., in Figure 16. Indeed, for the “Driver’s Comfort” property the characteristic of division is “Type of People (Rescuers, Driver) inside the Bus.” For the “Bus Microclimate” property, the characteristic of division will be “Bus Section (Driver Cab, Passenger Compartment) where microclimate is determined”. For the “Entry Door” property the characteristic of division will be “Entry Door Size (Width, Height)”. Thus, we came up with three different characteristics of division within one group, which is totally unacceptable! If we are to abide by this rule our division should be as shown in Figure 1.17.

Functional Orientation of Property Statements

In a group of properties it is desirable to apply characteristics of division that reflect an object’s functionality rather than its structural features. For example, when assessing the quality of life in a village the focus should be not on specific facilities such as residential, medical, recreational, etc., but on individual functional processes, e.g., household, health, recreation, etc. (unless, of course, the Define the Evaluation Context step foresees the need to assess the village precisely in terms of its constituent structures).
Figure 7. Recognising some features (climatic, seasonal etc.) in the exercise of the protective properties of a re-locatable structure

Figure 8. Primary tiers of the “Common property tree”
Figure 9. Sub tree A: Functionality (for special objects)

Figure 10. Sub tree B: Auxiliary function (AF) at the different stages of the life cycle of an (special) object
Figure 11. Sub tree C: Life support capacity (for special objects)

Figure 12. Sub tree D: Technical eco-friendliness (for special objects)
Figure 13. Sub tree E: Biological eco-friendliness (for special objects)

Figure 14. Sub tree F: Preservation capacity of an (special) object under the impact of the environment
Figure 15. Incomplete tree for Quality of Life in a city (a regular object)
Figure 16. The “division by an equal characteristic” rule is violated

Figure 17. The “division by an equal characteristic” rule is fulfilled

**Necessary and Sufficient Number of Properties in a Group**

The number of properties in a group must satisfy the necessary and sufficient condition. For example, the group in Figure 18 meets the “sufficient” condition but does not meet the “necessary” condition, because if we know the width and length of a room we can find its floor space.

In Figure 19, the “necessary” criterion is satisfied but the “sufficient” criterion is not: we cannot appraise the size of a room without knowing its ceiling height.
Figure 18. Meeting the “sufficiency” criterion but failing to meet the “necessary number of properties in a group” criterion.

Figure 19. Meeting the “necessity” criterion but failing to meet the “sufficient number of properties in a group” criterion.

Figure 20 shows a correct example.

Figure 20. Meeting the “necessary” and “sufficient” criteria.

Reference Number of Purpose Properties Within a Group

Suppose a QEM is used to evaluate two variants of a city stadium, all the properties of which are the same except that vari-
ant1 features a cinder track and variant 2 features playing field heating. Then, the purpose properties group should include both all the common properties and those differing in the two variants: a cinder track and playing field heating.

2.6.5.3. Specific Rules for the Application of the Expert Method to Weight Factor Determination

Random Order of Properties in a Group

As experience shows, when weight factors are determined by experts, expert judgement error may tend to grow, which is due to the fact that properties placed at the top of a group will be sub-consciously regarded as more important by some experts. To offset this deficiency it would be helpful to rearrange properties within the group so as to randomise their order. Moreover, the fact of the randomisation of the order of properties in a group must be brought to the attention of the experts who will determine the values of weight coefficients.

Minimum Number of Properties in a Group

It has been proved theoretically and experimentally that the fewer properties within a group the greater, other factors being equal, the reliability of the experts” appointed values of weight factors. In any case, the number of properties must not exceed nine.

This is due to the fact that there is a fundamental limit on the number of units of operational information an individual can handle simultaneously. In experimental psychology it is called “the magic number 7±2.” It manifests itself everywhere, in particular, in governance structures, whether civil or military, past or present. One example: any well-functioning superintendent will not have more than nine direct subordinates.
2.6.5.4. Specific Rules to Be Used if the Amount of Information Obtained in a Quality Assessment Can be Reduced Through the Use of the Rank Scale

If the assessment situation suggests that it is permissible to use a QEM to produce quality assessments expressed not in the ratio scale but in the rank scale, the following rules apply.

Exclusion of Equally Expressed Properties When the Rank Scale is Admissible

If an assessment expressed in the rank scale rather than the ratio scale is admissible, a tree may not include properties that are equally expressed in the variants compared. For example, if two comparable sanatorium complexes have the same beach area, that property can be omitted from the property tree.

Truncated Tree When the Rank Scale is Admissible

If the use of the rank scale is admissible in quantifying a quality comparison of objects, it is usually admissible to use a truncated tree, which reduces the complexity of the task compared with the use of complete or incomplete trees.

2.6.5.5. Specific Rules to Be Used if the Amount of Information Obtained in Quality Assessment May / May Not Be Reduced by More Precise Methods

Incomplete Tree When a Short-cut Assessment of Quality is Admissible

If the evaluation situation limits the QEM development time, an
incomplete tree is used (whereby, as already mentioned, less accurate quality evaluation data are obtained). One is to be guided by the following normal standards:

1. Derivation of an incomplete tree with five tiers \((m = 5)\) | 0.5 hours.

2. Branching out at each subsequent \((m + 1)\) tier \(\approx 0.25\%\) of the time needed for a tree with \(m\) tiers.

3. Expert check of the tree and corrections and additions made to it \(\approx 30\%\) of the time it took the SG to complete the tree.

**Complete Tree When Exact Quality Assessment Alone Is Admissible**

If the problem of comparing the quality of two objects is to be solved with a minimum error, (i.e. by applying the “rigorous” method of qualimetry), a complete tree must be used rather than, an incomplete or truncated one.

**2.6.6. Completion of the Property Tree Derivation**

After building a tree in accordance with the rules outlined above, it is necessary to complete this work in terms of individual sub trees, and especially an object purpose property sub tree.

**2.6.6.1. Completion of the Purpose Property Sub tree Derivation**

As already noted, the complex property “Suitability for Direct Utilisation” contained in sub tree A (Figure 9) is the trunk of the purpose properties sub tree. As a result of procedures implementing the above rules, this complex property was divided at the following level into a group of properties.
Each complex property in this group must in turn be divided into another group of properties, etc., until these multiple divisions result in the derivation of a completed purpose properties sub tree. Clearly, the building of a sub tree can be considered completed if and only if, in applying the rigorous method of qualimetry, any rightmost branch of the sub tree is a simple or quasi-simple property (but not a complex one).

The sub tree derivation process consists of several cycles, each resulting in the breakdown of a complex property into a group of properties. Furthermore, each cycle uses the same set of operations.

The only difference between the cycles lies in the order of priority in the breakup of complex properties. In other words, what is the sequence of derivation of a purpose properties sub tree?

Experience shows that the most rational order of derivation of a purpose properties sub tree is to start the division with the topmost complex property in the group; to follow with the topmost property in the resultant group, etc., until the division process leads to a group composed of only simple or quasi-simple properties.

Similarly, the next property at one of the previous levels is divided, etc.

Figure 21 illustrates the sequence of division of complex properties into groups of properties (i.e. the sequence of derivation of a purpose properties sub tree), with the numbers indicating the order in which complex properties are subjected to division.
2.6.6.2. Completing the Derivation of Sub trees Other than Purpose Properties Ones

As it was already noted, a purpose properties tree consists of separate sub trees, each represented in an incomplete graph (or tabular) form as a sub tree occupying a single sheet of paper.

For convenience of further work with the tree it is desirable that all simple and quasi-simple properties within each sub tree be brought to the topmost tier within the sub tree.

Figs 22 and 23 illustrate this operation.

In addition to bringing the properties to the last tier of the tree, upon completion of the tree derivation it is sometimes necessary to exclude from the tree some properties; for example, when during the definition of the evaluation context it is ascertained that quality assessment can be made in the rank scale). The respective algorithm is explained below.

The operation of exclusion from a sub tree of properties that are visible to the same extent in the compared samples can be done by two methods.

**Method 1.** Build a property sub tree in accordance with the above rules. Next, exclude from this sub tree all the properties equally expressed in the samples compared, and build anew a sub tree from the remaining properties. (Of course, it is no longer necessary — or possible — to observe the Necessary and Sufficient Properties rule).

This method is relatively labour consuming as a sub tree is, in fact, built two times, but on the other hand, it makes for the proper derivation of a sub tree. It can be recommended in all cases where SG members have not enough experienced with tree and sub tree derivation.
Method 2. This method is less laborious than the previous one, but it requires certain skills, which come with experience. In this regard it can be recommended only to SG members who have on several occasions designed trees for evaluating the quality of various objects.

The essence of this method lies in the fact that a purpose properties sub tree is constructed in a single step, rather than two, as with the previous method. On the other hand, all of the above tree derivation rules are immediately taken into account, including the Exclude Equally Expressed Properties When the Rank Scale Is Admissible rule.

One needs to consider one feature of the above property tree and sub tree derivation rules. In substance, these rules must serve the QEM Designer and the SG as a practical tool. Therefore, in stating these rules here we deliberately allowed some lack of rigour, which means that some of the rules are partly overlapping; e.g., the Necessary and Sufficient Properties rule and the Division by Equal Characteristic rule. This duplication of some rules, as experience shows, makes the QEM Designer and SG’s task of deriving trees and property sub trees easier and error-free.

If an SG has a fairly strong conviction that the property tree is correct and does not require any additional check by the EG, the creative part of the work on the property tree is considered to be completed (only the technical part of the graphic design of the tree remains to be done).

Otherwise — that is, when the SG (or QEM Designer) is not very convinced of the correctness of the property tree derived — this tree will be presented to the Expert Group members who together with the SG will make all necessary adjustments to it, augmenting it with new, unaccounted-for properties or eliminating unnecessary ones.

Checking and adjusting of a property tree by the Expert Group may
require up to 20% of the time ($T$) it takes the SG (or QEM Designer) to derive the tree. In turn, an approximate value of $T$ can be found based on the following averaged standards.

1. Two members of the SG (or QEM Designer) composing an incomplete four-tier ($k = 4$) property tree: 0.5 hours.

2. An incomplete property tree branched into one extra $(k+1)^{\text{th}}$ tier: 30% of the time it took to build a $k$-tier tree.

Table 4 shows approximate tree derivation times for a property tree with less than 16 tiers.

<table>
<thead>
<tr>
<th>Number of tiers in the tree</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time it takes two SG members (QEM Designer) to derive a property tree (rounded hours)</td>
<td>0.5</td>
<td>0.75</td>
<td>1.1</td>
<td>1.7</td>
<td>2.7</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>13.3</td>
<td>20</td>
<td>30</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 4. Property tree derivation time

---

complex property

---

simple or quasi-simple property

---

Figure 21. A sub tree whose simple and quasi-simple properties are not reduced to the top tier level
Figure 22. The sequence of derivation of a “purpose property” sub tree

Figure 23. A sub tree (similar to the one in Figure 22) whose simple and quasi-simple properties are reduced to the top tier.
The proper derivation of a property tree is an important condition, critical to the validity of any information acquired in evaluating the quality of an object. However, we need to consider these rules not only in order to reduce the error rate in qualimetric assessments but also in order to analyse the quality of the object so as to identify areas for improvement. Such improvement is necessary, for example, when dealing with tasks such as quality control, competitiveness, management-by-objectives, etc.

2.6.6.3. Choosing Property Indices

As it was already mentioned, the calculations used in the quantitative estimation of quality deal, not with properties, but with their indices, Qs. The procedure for identifying these indices is closely related to the property tree derivation procedure, which immediately precedes it.

In most cases, the Property Index Identification procedure does not present any difficulties. This is true, for example, of properties which are geometric parameters of an object (length, width, height, etc.) or which characterise its mass (in most cases it applies to purpose properties). In all these cases for each property there is actually a single definitive index and finding it does not cause any problem at all.

It is a different matter with a property that can be measured by two (or more) different indices. For example, the “moisture protection” property of a tent fabric can be described by two different indices: permeability (defined by the time in minutes to soaking of individual sections), and water resistance (defined by the amount of water in millilitres that penetrates through the fabric after it has been immersed in the water for 30 min. and for two hours).

In such cases, in picking an index the QEM Designer will take into account factors such as the labour intensity of obtaining the infor-
mation needed for determining the value of a property index and the extent to which the index suits the relevant property. (Clearly, the problem of choice of a property index only applies to properties at the top tier of the tree. For all other properties the name of the index is the same as the name of the property) /

One need also to take account of the following: most property indices have two forms of expression, of positive and negative value: e.g., efficiency and inefficiency, permeability and permeability, strength and weakness, etc. Property indices having a positive value are to be preferred.

There is another difficulty that can occur when one assigns property indices; most often one encounters it at early stages of design of an object. There may be situations when you need to evaluate multiple design options of an object, which have been worked out to the level of an outline design. In this situation it may be difficult, if not impossible, to obtain accurate values of $Q$ for some properties in each of the options being compared. Let us assume that the designer doing a preliminary design in the first approximation has developed several structural schemes for an object and wishes to evaluate the integral quality of these options to define the best one, to be taken for further, more detailed elaboration. However, at this preliminary stage of design it is practically impossible to obtain sufficiently reliable and accurate value for some indices of $Q$.

For example, if you are working out a QEM for living in a residential building for the earliest (outline) stage of design it is impossible at this stage to accurately determine the contract price of the building. Therefore, for the “construction economy” property you can use instead of the “contractor’s estimate” index the “approximate contractor’s estimate” index. Its value can be calculated by multiplying the number of occupants by the average cost of habitation per occupant in this class of house.

Thus, taking into account the above recommendations, the QEM
Designer together with the SG can find proper indices for all the properties found at the top tier of the property tree. What it means, in fact, is that the property tree has turned into an index tree. However, since in most cases the formulation of a property and that of its measuring index are the same we will continue to apply the term “property tree.“Where the formulations are not identical, the index formulation will be given in the tree in parentheses, following the respective property.

For some properties lacking generally accepted indices expressed in physical units we shall take conventional indices expressed in unit fractions (or percentages), which have the same as properties. Conversion tables are used for quantitative expression of these indices; their compilation is explained in qualimetry manuals.

2.6.6.4. Preparing a Property Tree for Use

Once the SG derives a property tree, it is presented for review to the experts who, if necessary, will make appropriate corrections and additions to the tree. This procedure can take anywhere from a few minutes to hours depending on the number of tree tiers. An adjusted tree finalised by the experts will be passed to the technical staff (TG) for preparation of the documentation necessary for weighting all the properties included in the tree, as well as for other procedures included in the algorithm. Technical workers will draw the tree on a large sheet of paper. Make the tree image large enough so that on a vertically hung sheet the names of properties should be discernible from a distance of about two metres. As they draw the tree the technical staff will number all the simple, quasi-simple and complex properties in the manner indicated in Figure 24.

It may happen that an evaluation object is rather complex in consequence of which its characteristic property tree is too large to fit into four standard sheets of drawing paper glued together.
If this is the case, the technical group will draw the tree on several separate sheets of writing paper, one for each property sub tree. The tree depicted on these sheets will be duplicated by the TG in as many copies as the EG strength plus one, an extra copy intended for the SG member who will guide the conduct of the expert survey.

Recall that, in terms of visual expression, the best tree is in the incomplete graph form, and in terms of sheet area economy the best tree is in tabular form.

Figure 24. The sequence of property numbering in a property tree
2.7. Determining Weight Factor Values

2.7.1. Basic Concepts

**Property weight factor (WF).** Is the quantitative description of the importance (value) of a particular property among the other properties. (Although it would be more correct to say “the property index WF” for simplicity’s sake we will use the term “the property WF.” Moreover, given the large number of subscripts and superscripts used with WF indices, we will in some cases give them in a larger font).

**Unnormalised group WFG"_i :** a WF such that:

— it describes the importance of a property only with respect to \( i^{th} \) properties belonging to the same \( (i'=\mu(1,n')) \), where \( n' \) is the number of properties in the group). For example, as shown in Figure 25,

![Figure 25. Unnormalised group weight factors](image-url)
\[ \sum_{i'=1}^{n'} G'_{i'} = 1. \]

Then \( 0 \leq G'_{i'} < 1 \) (for some \( i^{th} \) properties the value of \( G'_{i'} \) can be so small that can be considered negligible; in such cases we can take: \( G'_{i'} = 0 \)).

A normalised WF, \( G'_{i'} \), is obtained from an unnormalised WF, \( G''_{i'} \), by means of the normalisation operation

\[ \sum_{i'=1}^{n'} G'_{i'} = 1. \]
Tier WF, $G_i$ (hereinafter, for the sake of simplicity, simply called WF): a WF such that characterises the importance of a property with respect to any other property that belongs not just to the same group but also to the same tier; even with respect to any other property located on any other tier of the tree.

WFs are always normalised, i.e. $0 \leq G < 1$.

In addition, within each tier of a tree is always assured.

Properties in a tree are numbered as shown in Figure 25.

In determining WF values the following general principle is observed: a WF is preferably determined by the analytical method. If the evaluation context prohibits or overly complicates it (not enough time or necessary data lacking) the expert method is used. Let us take a brief look at these methods.
2.7.2. Analytical Method for Determining WF Values

There are several varieties of this method. Some are based on the use of regression analysis (Academician Krylov’s method) or correlation analysis. In another variety of the analytical method a $G_i$ is taken to be proportional to the cost of manifestation (existence) of an $i^{th}$ property. Other varieties of the analytical method are based on different principles. In practice, however, analytical methods are used at most in 5% of all cases, the expert method accounting for 95% of the WF determination cases.

Given the limited size of this text in what follows we skip analytical methods and concentrate on the expert method, and that with regard only to the short-cut method of quality evaluation. Those interested in analytical methods for determining weight factors are referred to more substantial manuals on qualimetry, e.g., to the monograph [2].

2.7.3. Expert Method for Determining WF Values

To begin with, we note that the hierarchy analysis method is not described here because of its relative complexity, which is greater than in the case of the simplified method adopted here.

As set out in the chapter “Main Methods of Qualimetry” (the section “Determining the Required Strength of an Expert Group”), the expert group size $r = 7 — 10$ people, depending on the complexity of the object. The TG prepares for each expert a separate form for determining WF values. For the appearance of this form as applied to the tree in Figure 25, see Table 5.
2.7.3.1. Procedure of Interviewing by an SG Facilitator (as Applied to the Figure 25 Tree and the Sample Individual Form in Table 5)

1. Experts are seated at tables in single row or two rows according to their assigned numbers.

2. The TG hangs a sheet of drawing paper in front of them at a distance ≤1.5—2m showing a property tree; alternatively, each expert is handed a copy of the tree.

3. The facilitator then asks the experts to select, independently of one another, for the group placed at the beginning of the form (properties 1 and 2) the most important property in terms of the impact it has on an associated property at the preceding tier of the tree (Property 7). Apply to it and post in the “Round 1” column the values of $G_{1}^\prime = 100\%$. Let this be Property 2 (i.e. $G_{2}^\prime = 100\%$).

Then, for the remaining Property 1 in the group determine how many times (or how many per cent) it is less important than Property 2, which has $G_{2}^\prime = 100\%$. Let us assume that an expert defined $G_{1}^\prime = 80\%$. The same procedure applies when a group includes more than two properties. Properties in a group may have the same weight, yet, at least one must have $G_{i}^\prime = 100\%$.

4. The facilitator asks the experts in numerical order about their assigned values of $G_{i}^\prime$.

5. If the spread of experts’ estimates is small (≤25%) the facilitator will ask the experts to proceed to assign $G_{1}^\prime$ values for the next group in the form.

6. If the spread is > 25% the facilitator will hold a brief discussion during which the experts motivate their estimates and thus share additional information.
7. Next, repeat the procedure of point 3. The experts will enter its results (anonymously) into the “Round 2” column of the form.

8. In the same way define the values off or all the other groups in the form (see the sample form).

<table>
<thead>
<tr>
<th>Property number in Figure 25 tree</th>
<th>$G_{i}^{c}$ (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Round 1</td>
</tr>
<tr>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5. Sample individual form for expert determination of the values of unnormalised group $G_{i}^{c}$ and its completion as applied to the tree in Figure 25

2.7.3.2. Processing Expert Survey Results

The TG enters data from individual forms into a summary form, in which the mean value of $\mu(G_{i}^{c})$ across all the experts is determined:
where $k$ is the expert number and $r$ is the number of experts.

Then, in the same summary form, the unnormalised values of $\mu(G'^i_i)$ by the normalisation operation (within each group) are translated into normalised group values (see the formula at the beginning of this topic).

### 2.7.3.3. WF Normalisation Tier-Wise

Suppose the normalisation by group results in the $G'_i$ shown in Figure 26. The TG will write down these values in the tree in the numerator of the fraction placed inside a rectangle of each property. All the $G'_i$'s are formed from the $G'^i_i$ by using a common number assignment scheme for the tree (see Figure 26). That is, the index $i'$ (which codes the property number in each group) is replaced by the index $i$, which codes the property number for the whole tree.

We illustrate the tier-wise normalisation routine with special reference to Property 1.

$$G_1 = G'_1 G'_2 G'_9$$

It is evident that $G_9 = G'_9$ and $G_6 = G'_6$. 

$$G'^i'' = \frac{\sum_{k=1}^{r} G'^i'k}{r},$$
Our calculations will be validated if the following condition is fulfilled for each tier: \( \sum G_i = 1 \).

Figure 26. Tree conditioned for tier-wise calculation of WF values

2.8. Determining Reference and Rejection Values of Properties

2.8.1. Basic Concepts

*Absolute property index* \( Q \), a numeric characteristic of a property that defines the degree of its intensity or manifestation in a measurement specific to each property; e.g., the number of books in a city public library per inhabitant.
The value of the absolute property index, \( q \), a specific numeric value that can be taken by the index of a given property of the evaluation object; e.g., the number of books in a city public library per inhabitant, \( Q = 100 \) copies.

When letters are used instead of numerals the values of an index are expressed by the lowercase \( q \) (in contrast to the index, denoted by the uppercase \( Q \)).

Reference (base) value of the absolute property index \( q_{\text{ref}} \), the best value of the absolute property index achieved worldwide (in the quality evaluation period) as applied to similar objects produced anywhere in the world; e.g., the PC speed: \( q_{\text{ref}} = 200 \) million ops.

Acceptable value of the absolute property index \( q^{\text{acc}} \), the worst but still acceptable value of the absolute property index performance characteristics (for the quality evaluation period) as applied to similar objects produced anywhere in the world.

For example, in the 1930s-60s either design codes or architectural practices anywhere in the world allowed for a ceiling height in living rooms less than 2.25 m. Therefore, for that period we can accept \( q^{\text{acc}} = 2.25 \) m.

Rejection value of the absolute property index \( q^{\text{rej}} \), the worst value of a property index, which is yet the nearest to \( q^{\text{acc}} \). With respect to a living room ceiling height \( q^{\text{rej}} = 2.20 \) m.

2.8.2. Determining the Values of \( q_{\text{ref}} \) and \( q^{\text{rej}} \) for Property Indices Having no Physical Units of Measurement

In a complete tree the above properties include, for example, aesthetic and some ergonomic properties. In an incomplete tree, also any other complex properties.
For such properties the SG will assign:

\[ q^{\text{rej}} = 0\% \text{ and } q^{\text{ref}} = 100\%. \] (In what follows \( q^{\text{ref}} \) and \( q^{\text{rej}} \) are only determined for properties at the top tier of the tree).

### 2.8.3. Documentary Method for \( q^{\text{ref}} \) and \( q^{\text{rej}} \) Determination

Of the properties remaining at the last tier of the tree, the SG will determine those for which there are documentary data to help determine \( q^{\text{ref}} \) and \( q^{\text{rej}} \).

This data can be found in books, research reports, reviews, design and engineering documents, trade catalogues, exhibition brochures, specifications, etc. It is clear that the more such documents are available the more accurately we can determine the values of \( q^{\text{ref}} \) and \( q^{\text{rej}} \).

Let us suppose that the SG found \( m \) documents that contain data helping to determine \( q^{\text{ref}} \) or \( q^{\text{rej}} \). Then the approach to their determination is given by the formula

\[ q_{i}^{\text{ref}} = \sup \{q_{ij}, j = \mu(1,m)\}, \]

where \( i \) is the property number in the tree;

\( j \) is the number of the document from which the value of \( q_{ij} \) was derived.

\( \sup \) (supremum) is the operator of isolation of the best value from the set of values.

For example, for the floor areas of four-room apartments in a city the documentary method produced the highest values of \( q_{ij} \):
sup \{250; 280; 190; 270;200\} = 280 \text{ sq. m.}

Similarly

\[ q^{\text{acc}} = \inf\{q_{ij}\}, \]

where \( \inf \) (infimum) is the operator of isolation of the worst value from the set of values.

With \( q_i^{\text{acc}} \) known the SG can easily determine \( q_i^{\text{rej}} \).

### 2.8.4. Expert Method for \( q^{\text{ref}} \) and \( q^{\text{rej}} \) Determination

This method should only be applied to properties for which the documentary method proved impossible or impractical (because of high labour or time inputs into the search for documentary data on \( q^{\text{ref}} \) and \( q^{\text{acc}} \)).

The technique of expert determination of \( q^{\text{ref}} \) and \( q^{\text{acc}} \) is similar to that of expert determination of the values of \( g_i \) (i.e., a survey is conducted in one round or in two rounds if the differences in the experts’ estimates after round 1 is more than 25%). Next, we determine average reference and rejection values of the index for all the properties at the top tier of the tree over all the experts. These average values are accepted as the target values.

What makes it different from the technique of determination of WF values is that here the properties are not grouped but listed separately in the form. Besides, when experts determine reference and rejection values of indices they only write down the properties placed at the top tier of the property tree.
2.8.5. Determining the Reference Value of the Reliability Index

Russian regulatory documents (GOSTs) decree that for industrial products the properties that determine reliability include: storability, faultless operation, maintainability and durability.

These properties are fundamentally different from the rest of the properties of an object, designated above with the help of the absolute indices $Q_i$. Reliability properties are not of the essence in themselves but are important to the extent that when an object is used/operated/applied/consumed they allow the manifestation of those properties for which the object was produced to become apparent, i.e., those of functionality and aesthetics. Indeed, if there is no reliability there is no functionality and aesthetics, hence any quality. Given this specificity, reliability properties are not included in a property tree but are recognised through the so-called use factor $K_{use}$ (determined as described below).

Let us introduce definitions that apply mainly to objects we have described above as “special objects”.

**Lifetime $T_{lt}$**: the smaller of the two periods: the time to obsolescence $T_{obs}$ and the service life $T_{ser}$, i.e.,

$$T_{lt} = \min\{T_{obs}, T_{sl}\}$$

**Reference time to obsolescence $T_{obs}^{ref}$**: $T_{obs}^{ref} = \max\{T_{obs,j}\}$

where $j$ is the number of relevant objects (of the same type as the evaluation object), for which the values of $T_{obs,j}$ can be determined.
Similarly we have:

\[ T_{\text{sl}}^{\text{ref}} : T_{\text{sl}}^{\text{ref}} = \max \{ T_{\text{sl},j} \} \]

Similarly we have:

\[ T_{\text{ref}}^{\text{ref}} : T_{\text{ref}}^{\text{ref}} = \min \{ T_{\text{obs}}, T_{\text{sl}}^{\text{ref}} \} \]

**Downtime period** \( T_{dt} \): that part of \( T_{lt} \) when the object is in a state of failure or disaster recovery (i.e. repair) or maintenance. The concept of “downtime” applies to ordinary objects as well as to special ones.

\[ F_{\text{use}} : F_{\text{use}} = \frac{T_{lt} - T_{dt}}{T_{\text{ref}}} \]

The values of \( T_{lt} \) and \( T_{dt} \) are determined experimentally (e.g., by accelerated bench tests), by the documentary or expert methods in the same way as the values of \( q^{\text{ref}} \) and \( q^{\text{ref}} \) were determined.

While determining the values of \( F_{\text{use}} \) we assume:
a) For objects for which it is meaningless (e.g., in evaluating the quality of life of ordinary objects) \( F_{\text{use}} = 1 \);

b) For engineering or instrumentation products, \( F_{\text{use}} = F_{\text{eff}} \), where \( F_{\text{eff}} \) is the efficiency retention factor to be determined according to the guidelines set forth in the Russian GOST 27.003—83 “Choice of Normalisation of Reliability Indices”;

c) For objects not covered by pp. (a) and (b), \( F_{\text{use}} \) is determined in the manner described above.

2.9. Determining the Values of Property Indices and Quality in General

2.9.1. Determining the Values of Absolute Indices

2.9.1.1. Non-expert Methods

These methods are only used to determine the values of \( q_i \) for quasi-simple properties and some simple properties. This task will be assigned by the QEM Designer either to the TG or the SG, depending on the level of expertise required. Four varieties of the non-expert method are used: documentary, analytical (computational), physical measurement (experimental), and simple count.

**Documentary Method**

Details of \( q_i \) are usually taken from technical documents on the object; e.g., the number of operating modes of a home air conditioner.

**Analytical Method**
It is applied to *quasi-simple* properties; e.g., for a temporary mobile structure, cost-effectiveness can be determined by the formula of total costs of purchase and operation over its whole service life, $T_{sl}$.

**Physical Measurement (Experimental) Method**

This method is suitable for properties for which $q_i$ data can be obtained by measurements on working drawings or directly on the finished object. For example, in a bus for conveyance of road workers: the width of the door aperture.

**Simple Count Method**

This method can be applied, e.g., to a vehicle control board property index such as the number of control levers or gauge dials on the board.

**2.9.1.2. Expert Method**

This method should be applied to those properties for which the use of non-expert methods is either impossible or unpractical (because of high time, labour or time costs). The expert survey routine here is similar to that used to define $q^{ref}$ and $q^{rej}$. Note that $q_i$ is determined in the same units of measurement as the $q^{ref}$ and $q^{rej}$ for an $i^{th}$ property.

The above non-expert and expert methods concern not only $q_i$ values but also the values of the reliability indices $t_{il}$ and $t_{dl}$. 
2.9.2. Determining Relative Index Values

To ensure the comparability of the values of the absolute indices \( Q_i \) (by reducing them to the same scale and expressing them in the same units) we convert absolute indices \( Q \) into relative indices \( K \) by the normalisation operation

\[
K_{ij} = \frac{Q_{ij} - q_{ij}^{ref}}{q_{i}^{ref} - q_{i}^{ref}},
\]

where \( i \) is the property number; and \( j \) is the number of the evaluation object.

Obviously, \( 0 \leq K_{ij} \leq 1 \)

2.9.3. Convolution of Indices (Final Problem Solution)

By using the quality evaluation methodology already described in this ABC we can express the quality index \( K^k \) by means of the weighted average arithmetic mean formula:
\[ K_j^k = F_{use} \sum_{i=1}^{n} K_{ij} \cdot G_i \]

Notice one feature of calculating the value of \( K^k \). The QEM Designer together with the SG will single out from among the \( i^{th} \) properties so-called “critical properties”, i.e. properties such that for at least one of them the inequality \( q_{ij} < q^{rej} \) (where \(< \) stands for “not worse or equal”) is unacceptable. To illustrate, a critical property for any vehicle is “the presence in the exhaust of noxious fumes in concentrations exceeding the relevant maximum admissible concentration.”

If such an equality does exist for at least any critical property we shall assume \( K^k = 0 \).

As we conclude the first two chapters, describing the most common (now almost “classical”) version of qualimetry, we think it necessary to reiterate some of our points:

— the method described above is only one, though the most common, of the many methods of qualimetry;

— we have considered only a short-cut version of

this method, not an approximate and certainly not a rigorous one; and

— this presentation has necessarily been very brief, being only an
ABC of qualimetry.

The Appendix below contains some material describing the application of the above techniques to practical problems of a socioeconomic or other nature.
Appendix

Taking Stock of a National/International Competition: How to Improve Its Objectivity?

A Case Study of a Qualimetric Methodology

Qualimetric techniques can be used to quantify the quality of objects of any kind, including managerial decisions. Managerial decisions may relate, for example:

— Selecting the best business project;

— Choosing winners in a national competition focused on the support of young talent in business;

— Selecting best practices in support of entrepreneurship;

— Monitoring the activities of professional associations and selecting the best skill certification system;

— Monitoring the quality of products and services;

— Assessing the quality and competitiveness of products;

— Developing a method for estimating the use indices of professional qualification standards;

— Developing a method for estimating the reliability indices of engineering products;

— Selecting best practices of social institution development.
General Description of the Task

Many countries of the world hold trade, national or international competitions. Before the winner is announced a complex multicriteria problem of choosing the best one (in quality) from among the entrants must be solved. Since such problems involve the quantification of entrants’ quality/performance they are best tackled using the methodology of qualimetry.

What follows is a case study of the application of qualimetric analysis to one such problem using as an illustration eight entrants in the Golden Brand national competition.

Selecting the Best Franchiser

The Organising Committee of the Golden Brand Russian national franchise competition formulated the problem: to develop a quality evaluation method (QEM) with special reference to the Golden Franchise category.

The Organising Committee acted as Decision Maker. The winner in the Golden Franchise category is awarded a prize as the most successful franchiser

Key Concepts

Franchising is a kind of contractual relation between market entities whereby one party (a franchiser) assigns for a fee to the other party (a franchisee) the right to use the business model it developed. The franchiser transfers to the franchisee the right of use to its brand (trade mark), technologies and know-how, provides training and gives every assistance to the development of the franchisee’s business.

A franchise (franchising package) is a complete business system transferred by a franchiser to a franchisee under an agreement.
The success of a franchise company is a performance index characterising its output (the quantity and quality of its services and/or products) and its input (the costs incurred). Both the input and output are considered for a preset period; in our case, 24 months.

Constitution of the QEM Development and Application Groups (SG, EG and TG)

QEM Design and Application Teams (SG, EG and TG)

The Organising Committee of the competition assigned G. G. Azgaldov (as QEM Designer and also as the Steering Group), the Technical Group (represented by A. V. Kostin) and an Expert Group, whose members are listed below.

Table 6. Group of experts who defined weight criteria and factors

Expert 1 – Nickolay STRAKHOV, CEO Marketing Invest Group (Nick Erlan)
Expert 2 – Alexander KOSTIN, Ph. D., Academic Secretary, Research Council on Economic Problems of Intellectual Property, Economics Division of the Russian Academy of Sciences
Expert 3 – Natalia KOSTINA, managing partner, QUALIMETRY.RU
Expert 4 – Vitaly SMIRNOV, Ph. D., the artificial intelligence specialist, the QUALIMETRY.RU library expert
Expert 5 – Natalia VINOGRAODOVA, managing partner of the Agency of social programs “Point of Support”
Expert 6 – Andrey TATARNIKOV, researcher at the Central Economics and Mathematics Institute, Russian Academy of Sciences
Expert 7 – Prof. Garry AZGALDOV, Dr. Econ., Chief Researcher, Central Economics and Mathematics Institute, Russian Academy of Sciences
Given below is a method to address the problem of selecting Golden Brand winners. It uses the most common quality evaluation approach adopted in qualimetry, namely the short-cut method.

1. Description of the Evaluation Context

Questions Regarding Features of Application of the Evaluation Object

Possibility of upgrading the technique in the future

The QEM can be upgraded in the future if it is found necessary to improve the accuracy, reliability and the scope of its results or to change its application area, e.g., to determine the best innovative brand, the best franchiser, the best franchisee, etc. Of course, all of it can be achieved given the required labour and time resources.

Questions Regarding Computed Quality Ratings

The Social Hierarchy Level in Terms of Which Entrant Brands are Evaluated

This method is used to evaluate company brands with due regard for the interests of Russia as a whole. If necessary, the method can be upgraded to incorporate another hierarchy level such as regional or company level.

The Degree of Generalisation of an Object Evaluated by This Method

Qualimetry evaluates objects in terms of either outcomes (when their quality is said to be evaluated, e.g. the quality of a company brand) or outcomes and inputs (when their integral quality is said to be evaluated, which is synonymous with efficiency and profitability of the brand).
This evaluation technique takes into consideration both outputs and inputs.

*The Level of Accuracy Inherent in the QEM*

In terms of accuracy all the methods of qualimetry fall into three types, namely rigorous, approximate and short cut.

Rigorous methods depend on cutting-edge scientific research, which helps to obtain minimum-error estimates permitted by the state of the art. Short-cut methods work with maximum tolerable error. Approximate methods are halfway between rigorous and short cut methods in terms of calculation error. Obviously, a smaller calculation error means greater labour intensity and vice versa.

The method used herein, because of a very limited time allowed for its development, is a short-cut one.

*The Type of Comparability Inherent in the QEM*

All methods of qualimetry in terms of comparability of their results are separated into three kinds: those ensuring functional comparability; those ensuring time comparability; and those ensuring formal comparability.

When applied to franchising, functional comparability means the ability to compare franchises relating to all businesses, even quite disparate ones. Temporal comparability means that franchises can be compared at different times. With formal comparability franchises can only be compared if they were evaluated in an identical rating scale. Any resulting information lacks the properties of either functional or temporal comparability.

This QEM ensures functional and formal comparability but not temporal comparability.
The Scale to Present QEM Results

Decision-making theory, operations research and qualimetry commonly use two scales to quantify their findings, one being the rank scale (otherwise known as the ordinal scale) and the other being the ratio scale.

With the rank scale one can order objects (e.g., franchises) by any characteristic such as success, but cannot decide to what extent (still less how many times) one object, is better or worse than another. This kind of information can only be obtained if results are expressed in the ratio scale.

This QEM makes it possible to obtain quantitative information expressed in the rank (ordinal) scale but not in the ratio scale.

Labour and Time Inputs into Scoring for Eight Competing Brands

With six human calculators (who may also act as experts) and all the initial data available the labour input will be approximately nine men-days (not counting the QEM Designer’s time outlays).

QEM Frequency of Application (Multiple or One-off)

If the method is applied only once all calculations can be made by formulas, which is the case with this QEM. If the intention is to use the QEM more than once it makes sense to develop calculation diagrams or use special-purpose computer programs such as MS Excel.

The foregoing questions, which the QEM Designer expects to be answered at the Evaluation Context Definition step, are more numerous than shown herein. Their number depends on the complexity of the evaluation object, and they have been enumerated in more detail in other works on qualimetry, e.g., in [21].
2. The Criteria Tree Used in Evaluating the Golden Brand National Competition Nominees

This tree, built according to the general tree derivation rules set forth in Section 2.6 above, takes into account the evaluation context described in the previous section. The Golden Brand competition is designed to identify the most efficient franchising business. To this end the 19 criteria used in the scoring are grouped in the shape of an incomplete tree (see Figure 27). The totality of these criteria is based on the information made available to the QEM Designer by the competition organisers.

![Figure 27. Criteria tree characterising the success / efficiency of a nominee franchise enterprise](image)

3. Determining the Values of a Criterion WF

*The tier* $WF, G_i$, is a weight factor such that it characterises the importance of a criterion in relation to another criterion that is a member not just of the same group but also of the same tier; even in relation to another property belonging to another tier of the tree.
WFs are always normalised, i.e., \( 0 \leq G < 1 \).

Besides, within any tier \( \sum G_i = 1 \) is always achieved.

Properties in the tree are numbered as shown in Figure 27.

The general approach to determining WF values favours the analytical technique. If however the evaluation context prohibits it or makes it too complicated (because of time or data limitations), the expert method is then applied.

The WFs of the 19 criteria listed in the tree above (Figure 27) had to be determined by the QEM Designer working under time pressure to design a QEM for the Golden Brand competition. For this reason the QEM Designer decided to determine WF values by the expert method using an expert group of seven members (see Table 6). WFs were determined for summary properties Nos 1—11 (placed at the last, topmost tier of the tree) and for intermediate properties Nos 12—19.

Note that the expert survey and the processing of its results relied on an appropriate procedure described, e.g., in [21]. Table 7 lists only summary WF values for eight intermediate and eleven final criteria at the top tier of the tree shown in Figure 27.
Table 7. Summary of an expert-based determination of the group $G_i$s

4. Determining Absolute, Reference and Reject Values of Indices

For the key concepts used to determine the values of $q^{\text{ref}}$ and $q^{\text{rej}}$ for criterion indices by the documentary and expert methods, see Section 2.9 above.

Absolute criterion index $Q$, a quantitative characteristic of a criterion, which determines its degree of manifestation in a criterion-specific measuring scale; for example, the number of franchise agreements concluded.

Value of the absolute criterion index $q$, a particular numeric value that $Q_{ij}$ can assume in the $i^{\text{th}}$ ($i=1,2,\ldots,11$) criterion of the $j^{\text{th}}$ competition nominee ($j = 1,2,\ldots, 8$); for example, the number of franchise points $Q = 5$.

Particular values of $i^{\text{th}}$ criteria were determined from data supplied
to the Organising Committee (and made available to the QEM Designer) by every $j^{th}$ nominee; they are listed in Table 10.

**Reference value of the absolute criterion index** $q_{ref}^i$ is the best value of a criterion’s absolute index achieved in the world (as of the time of brand assessment) as applied to similar franchises in operation anywhere in the world; for example, the number of franchise points is 115.

**Acceptable value of the absolute criterion index** $q_{acc}^i$ is the worst yet acceptable value of the absolute index of the criterion (as of the time of brand assessment) as applied to similar objects (franchises) in operation anywhere in the world. For example, current sales volume of any franchising operation today is unlikely to be less than $1000; any smaller amount can be neglected. Therefore, the acceptable value for this criterion $q_{acc}^i = 1000$.

**Rejection value of the absolute criterion index.** This value ($q_{rej}^i$) is taken to be the worst value of the criterion index that is the nearest to $q_{acc}^i$. As applied to sales volume we can assume the rejection value $q_{rej}^i = 990$.

The methods that were used to determine the Values of $q_{ref}^i$ and $q_{rej}^i$ for measurable criterion indices and those lacking units of measurement are described in Section 2.8 above.
Table 8. Reference and rejection index values for the tree in Figure 27

Table 9. Weight factors, reference and rejection values for Figure 27 property (criterion) tree
Table 10. Absolute measures of $Q_{ij}$ ($i^{th}$ criteria passed by $j^{th}$ nominees to the Organising Committee and made available to the QEM Designer)

<table>
<thead>
<tr>
<th>Criterion number and name in the Figure 27 tree</th>
<th>Unit of measurement</th>
<th>Values of $i^{th}$ criteria for $j^{th}$ nominees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No. of franchisees who opened more than one franchise point in the period under review</td>
<td>pcs</td>
<td>36.0 0.0 1.0 5.0 35.0 2.0 11.0 9.0</td>
</tr>
<tr>
<td>2. Total franchisees</td>
<td>pcs</td>
<td>68.0 63.0 13.0 25.0 143.0 20.0 51.0 178.0</td>
</tr>
<tr>
<td>3. Prevalence by region (no. of cities in which franchisees operate)</td>
<td>pcs</td>
<td>68.0 10.0 12.0 21.0 90.0 16.0 37.0 94.0</td>
</tr>
<tr>
<td>4. No. of franchises dissolved in the period under review</td>
<td>pcs</td>
<td>0.0 0.0 1.0 1.0 50.0 0.0 50.0 3.0</td>
</tr>
<tr>
<td>5. Ratio of dissolved to total franchise sin the period under review</td>
<td>%</td>
<td>0.0 0.0 7.9 7.7 4.0 3.5 0.0 9.8 1.7</td>
</tr>
<tr>
<td>6. Total franchise sales in the period under review</td>
<td>mln rubles</td>
<td>3866.7 28.0 30.0 350.0 2109.1 70.0 216.6 2714.0</td>
</tr>
<tr>
<td>7. Franchiser’s franchise promotion costs in the period under review</td>
<td>mln rubles</td>
<td>5.0 6.0 2.5 3.5 277.8 5.0 3.8 74.4</td>
</tr>
<tr>
<td>8. Franchiser’s franchisee assistance costs in the period under review</td>
<td>mln rubles</td>
<td>4.7 0.0 1.0 0.2 152.3 2.0 2.9 152.3</td>
</tr>
<tr>
<td>9. Franchiser losses from franchise agreement dissolution in the period under review</td>
<td>mln rubles</td>
<td>0.0 0.7 0.7 0.7 0.0 0.0 0.0 0.0</td>
</tr>
<tr>
<td>10. Share of goodwill promotion costs in franchiser’s total promotional costs</td>
<td>%</td>
<td>6.1 100.0 40.0 11.1 5.8 5.8 47.7 5.8</td>
</tr>
<tr>
<td>11. Share of franchise costs in an enterprise’s total promotional costs</td>
<td>%</td>
<td>4.0 60.0 50.0 10.0 63.0 20.0 18.5 20.0</td>
</tr>
</tbody>
</table>

5. Determining Relative Values of Indices (Criteria)

As it can be seen from Table 10, the absolute measures $Q_{ij}$ (criteria by which Golden Brand entrants are evaluated) use different units of measurement and are thus incommensurable. To make them commensurable we convert absolute measures of varying dimensionality into relative measures of the same dimensionality. To this end we use the normalisation formula (see Section 2.9.2 above):
where $Q_{ij}$ is found from Table 10, and $q_i^{\text{rej}}$ and $q_i^{\text{ref}}$ are found from Table 9. The values of $K_{ij}$ thus obtained are entered in Table 11.

The calculated results of the Golden Brand prize competition (for the Figure 27 tree) for eight nominees are listed in Table 11, where for every $i^{\text{th}}$ criterion its $g_i$ taken from Table 2 is factored in. For reasons of privacy protection the names of nominee companies in Table 11 were replaced with the serial numbers 1 to 8.

The above ranking technique can be used in situations other than a competition. It is perfectly suited for cases where one has to make the best selection from a number of options, with each option characterised by any number of criteria (their nature not constrained in any way).

As can be seen from Table 11 the top three places in the Golden Franchise category of the Golden Brand national prize competition went to nominees Nos. 1, 2 and 7.
Table 11. Calculated results of the Golden Brand national prize competition (Golden Franchise category) for the criteria tree in Figure 27.

<table>
<thead>
<tr>
<th>Nominee 1</th>
<th>Nominee 2</th>
<th>Nominee 3</th>
<th>Nominee 4</th>
<th>Nominee 5</th>
<th>Nominee 6</th>
<th>Nominee 7</th>
<th>Nominee 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>( O_L )</td>
<td>( K_a )</td>
<td>( K_c^a )</td>
<td>( G_i )</td>
<td>( O_L )</td>
<td>( K_a )</td>
<td>( K_c^a )</td>
<td>( G_i )</td>
</tr>
<tr>
<td>1. No. of franchisees who opened more than one franchise point in the period under review</td>
<td>36.0</td>
<td>0.923</td>
<td>0.058</td>
<td>0.0</td>
<td>0.000</td>
<td>0.000</td>
<td>1.0</td>
</tr>
<tr>
<td>2. Total franchisees</td>
<td>68.0</td>
<td>0.035</td>
<td>0.001</td>
<td>63.0</td>
<td>0.032</td>
<td>0.003</td>
<td>11.0</td>
</tr>
<tr>
<td>3. Prevalence by region (No. of cities in which franchisees operate)</td>
<td>68.0</td>
<td>0.171</td>
<td>0.020</td>
<td>10.0</td>
<td>0.023</td>
<td>0.003</td>
<td>12.0</td>
</tr>
<tr>
<td>4. No. of franchisees dissolved in the period under review</td>
<td>0.0</td>
<td>1.000</td>
<td>0.072</td>
<td>5.0</td>
<td>0.688</td>
<td>0.050</td>
<td>1.0</td>
</tr>
<tr>
<td>5. Ratio of dissolved to total franchisees (at their mean value in Russia) in the period under review</td>
<td>0.0</td>
<td>1.000</td>
<td>0.086</td>
<td>7.9</td>
<td>0.921</td>
<td>0.079</td>
<td>7.7</td>
</tr>
<tr>
<td>6. Total franchise sales in the period under review</td>
<td>38667</td>
<td>0.139</td>
<td>0.028</td>
<td>28.0</td>
<td>0.001</td>
<td>0.000</td>
<td>30.0</td>
</tr>
<tr>
<td>7. Franchisees' franchise promotion costs in the period under review</td>
<td>5.0</td>
<td>0.997</td>
<td>0.091</td>
<td>6.0</td>
<td>0.997</td>
<td>0.093</td>
<td>2.5</td>
</tr>
<tr>
<td>8. Franchisees' franchise assistance costs in the period under review</td>
<td>4.7</td>
<td>0.984</td>
<td>0.096</td>
<td>0.0</td>
<td>1.000</td>
<td>0.097</td>
<td>1.0</td>
</tr>
<tr>
<td>9. Franchisees' losses from franchise agreement dissolution in the period under review</td>
<td>0.0</td>
<td>1.000</td>
<td>0.028</td>
<td>0.7</td>
<td>0.954</td>
<td>0.026</td>
<td>0.7</td>
</tr>
<tr>
<td>10. Share of goodwill promotion costs in franchise's total promotional costs</td>
<td>6.1</td>
<td>0.001</td>
<td>0.006</td>
<td>100.0</td>
<td>1.000</td>
<td>0.105</td>
<td>40.0</td>
</tr>
<tr>
<td>11. Share of franchise costs in an enterprise's total promotional costs</td>
<td>4.0</td>
<td>0.060</td>
<td>0.070</td>
<td>66.0</td>
<td>0.400</td>
<td>0.023</td>
<td>50.0</td>
</tr>
</tbody>
</table>

Calculated value of \( K_c^a \), \( G_i \) for nominees 1, 2, 5, 6, 7, 8.
References


19. GOST 23554.1 — Expert Methods for Evaluation of the Quality of Industrial Products.


Mechanical Engineers. — Moscow: Moscow Automobile and Road Institute Publ., 2005.