

Quality Assessment of Electrical Equipment

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Abstract. c

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1. The Quality Concept

“Quality” term comes from Latin language, where “qualis” has the meaning of “way of being”. Quality refers to a part of environment, called product or entity. For this entity are identified significant elements, named characteristics.

The qualitative characteristics can be various: basic characteristics, process characteristics or utilization characteristics. In order to determine the qualitative characteristics, it is necessary to identify the stakeholders for the product. These stakeholders are the manufacturer, the beneficiary and the society. Definition: Quality is the image of an entity, image created by the qualitative characteristics of the entity.

The qualitative characteristics give the differences between the products of a class. The basic characteristics of a product are the characteristics with direct role in the functionality of the product and these characteristics can be estimated in the moment of buying of the product.

The utilization characteristics are describing the behavior of the product in time. Examples for these characteristics are: reliability, maintainability and availability.

Reliability is the probability that the product is functioning a certain period of time without faults.

Maintainability is the probability that the product is repaired in a specified time period.

Availability is the probability that the product is functioning at a certain moment.

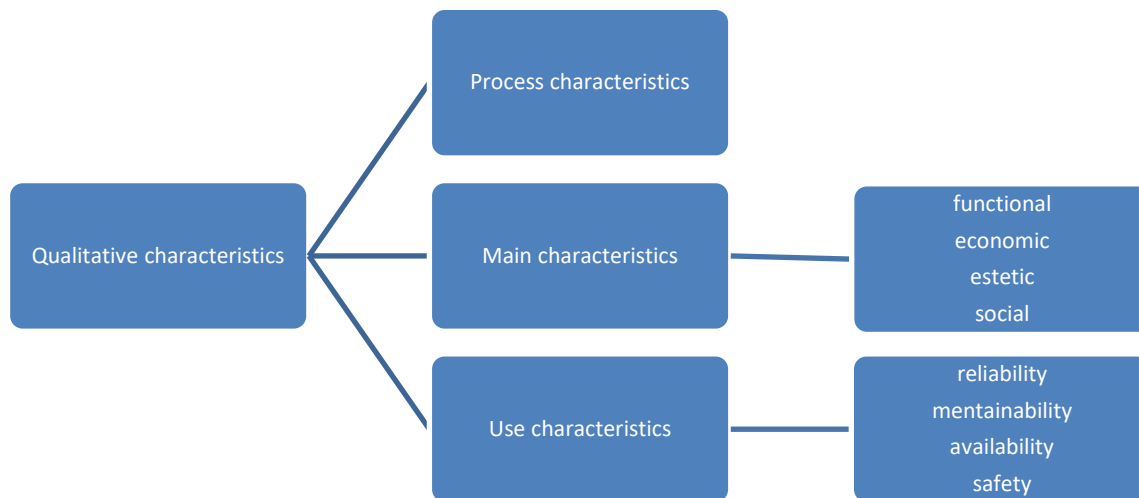


Fig.1 Qualitative characteristics

2. Quality assessment of electrical equipment

In order to perform the quality assessment of electrical equipment one has to have prior knowledge, skills and expertise in the field of electrical engineering since the objective characteristics and some of the subjective characteristics involved in the quality of the electrical equipment rely on the technical data sheets, technical specifications and on the technology used to build the respective electrical equipment.

The final user of the respective electrical equipment may know what he /she wants and expects from the equipment, but he/she does not know what technical aspects related to the equipment determine the respective expectations and features related to the subject electrical equipment.

The quality assessment measures the difference between the real and the expected performance, in order to identify the opportunities of quality improvement.

2.1 Quality of data used in the quality assessment

The quality of the data used in the quality measurement is of great importance.

The dimensions or characteristics of data quality are in accordance with some authors [5], the following:

Completeness: every fact of the real world is represented

Relevance: every piece of information stored is important in order to get a representation of the real world.

Reliability: the data stored is trustworthy, i.e. it can be taken as a true information.

Amount of data: the number of facts stored

Consistency: there is no contradiction between the data stored.

Correctness: every data set stored represents a real world situation

Timeliness: data is updated in time; update frequency is adequate.

Precision: data is stored with the precision required to characterize it

Unambiguous: each piece of data has a unique meaning

Accuracy: each piece of data stored is related to a real world datum in a precise way

Objectivity: data is objective, i.e. it does not depend on the judgement, interpretation or evaluation of people

Conciseness: the real world is represented with minimum information required for the goal it is used for

Usefulness: the stored information is applicable for the organization

Usability: the stored information is usable by the organization.

In accordance with some other authors [4], the dimensions of data quality are the following:

- Accessibility: the extent to which data is available, or easily and quickly retrievable
- Appropriate amount of data: the extent to which the volume of data is appropriate for the task at hand
- Believability: the extent to which the data is regarded as true and credible
- Completeness: the extent to which data is not missing and is of sufficient breadth and depth for the task at hand
- Concise representation: the extent to which data is compactly represented
- Consistent representation: the extent to which data is presented in the same format
- Ease of manipulation: the extent to which data is easy to manipulate and apply to different tasks
- Free-of-error: the extent to which data is correct and reliable
- Interpretability: the extent to which data is in appropriate languages, symbols and units, and the definitions are clear
- Objectivity: the extent to which data is unbiased, unprejudiced and impartial
- Relevancy: the extent to which data is applicable and helpful for the task at hand
- Reputation: the extent to which the data is highly regarded in terms of its source of content
- Security: the extent to which access to data is restricted appropriately to maintain its security
- Timeliness: the extent to which the data is sufficiently up-to-date for the task at hand
- Understandability: the extent to which the data is easily comprehended
- Value-added: the extent to which data is beneficial and provide advantages from its use

The steps in the evaluation of the quality of data:

1. Choose the interesting dimensions taking into account that not all the dimensions are relevant in every situation.
2. Choose or define the questions that characterize the dimensions: each dimension has several aspects that characterize it. Not every aspect is important in every situation.
3. Choose and define the metrics and techniques to answer each question: depending on the system implementation, the resources deadlines, etc, one technique or another should be selected to answer the same question
4. For each metric define values or ranges representing good and bad quality data
5. If subjective metrics have been chosen, define appropriate data collecting forms and data collection procedures
6. Collect the information using data collection forms
7. For each metric, determine if data quality is acceptable or not, and take the appropriate corrective actions
8. Store the obtained results

2.2 Preferences and utility

John von Neumann and Oskar Morgenstern presented in 1947 the four axioms of rationality, such that any agent satisfying the axioms has an utility function.

The four axioms of rationality are the following:

- a) Completeness: between any two states (of preference) L and M exact one of the following holds: $L > M$ or $M > L$ or $L = M$
- b) Transitivity: for L, M and N preferences, if $L < M$ and $M < N$ then $L < N$
- c) Continuity: if $L < M < N$, then there exists a p probability such that: $pL + (1-p)N = M$
- d) Independence: if $L < M$, then for any N and probability p : $pL + (1-p)N < pM + (1-p)N$

2.3 The decision theory

In order to assess the quality many ideas and concepts can be taken from the decision theory.

The foundation of the decision theory is the theory of games with two players, precisely the theory of games against „nature“. The game against „nature“ assumes that one of the players – nature – has not the purpose that the other player loses, respectively nature is not playing to maximize its profit.

In this particular case of the games against „nature” the decisions are:

- Certainty decisions, with known future conditions
- Uncertainty decisions with no information about the probabilities of realization of nature’s states
- Risk decisions with known probabilities of the realization of the nature’s states

The certainty decisions could correspond to the situation when the quality has only measurable (objective) characteristics.

The risk decisions could model the situation when the quality shows both, objective and subjective characteristics. Thus, choosing of an unique strategy from a set of alternatives (options) corresponds to the situation when a hierarchy must be made, between more products with both, objective and subjective characteristics.

2.4 Quality measuring

The quality characteristic of a product, process or system represents a distinctive intrinsic feature of the product relative to a certain requirement. Measuring of a characteristic has as result a numerical value which express the absolute value of the measured characteristic.

In quality measuring we distinguish between the objective and subjective quality characteristics. The objective characteristics are those characteristics of the product which are directly measurable. In opposition to the objective characteristics, the subjective characteristics cannot be measured directly, and these subjective characteristics are in relation with the perception of the people (for example: design, shape a.s.o.)

2.4.1 Measuring quality for products showing only objective characteristics

The products which show only objective characteristics are representing a particular situation, since the great majority of products have both objective and subjective quality characteristics.

For this kind of products, a global quality indicator can be calculated starting from the logical criteria which must be fulfilled by a such indicator.

Logical criteria:

- a) Comparability
- b) Discrete elements calculus, the values of the characteristics must be used
- c) Expression of a structure
- d) Expression of weights of characteristics
- e) Interchangeability of certain characteristics
- f) Pointing of the favorable direction of the evolution of the characteristics

Using the mentioned logical criteria the global quality indicator of the product (i) related to the reference product (I) is:

$$Q_i = K * \prod_{j=1}^n \left(\frac{x_{ij}}{x_{Ij}} \right)^{\pm y_j}$$

In this relation the notations are following:

K – constant which defines the technical level of the reference product (I), usually K=1000

I – the product considered as reference product

i – the analyzed product

x_{ij} – value of j characteristic for the i product

y_j – the weight of j characteristic

+/- sign of the weight, depending of the proportionality of characteristic j with the quality

2.4.2 Measuring quality for products showing both, objective and subjective characteristics

The Scoring model used in the decision theory for the assessment of alternatives can be proposed for the situation when the product has both objective and subjective characteristics.

As a starting point, measuring the quality of the product results through summation of the indicators (partial utilities) for individual quality characteristics, taking into account the degree of fulfillment for each characteristic. The importance of the characteristics (the vector of preference of the importance of characteristics) is to be determined by questioning a chosen population. Eventually the partial quality scores or partial utilities for each of the characteristics are to be calculated and then the total quality score (index) or total utility results through summation of these partial utilities represented by the partial quality scores.

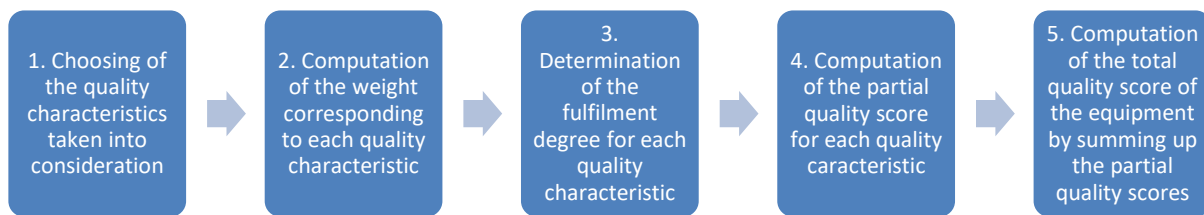


Fig.2 Quality assessment using the scoring model

The model is described by the following steps:

1. defining of the quality characteristics

At beginning the quality characteristics of the analyzed product must be defined. These characteristics can be goals, requirements, functions or properties of the product.

2. calculation of the weights related to each characteristic

The quality characteristics usually do not have the same importance. That is why, for each characteristic (C_{ij}) of the analyzed product, the weight of the characteristic is calculated. The calculation of the related weights (PC_{ij}) results from the vector of preferences related to the characteristics. The vector of preferences sorts the characteristics by their importance, taking into account the questioning of population. Based on the vector of preferences the matrix of preferences is developed. Dividing the row sums of the preference matrix by the total sum of the elements of preference matrix, the weights are thus calculated.

For the n characteristics related to a product (i) the following holds:

$$\sum_{j=1}^n PC_{ij}=1 \text{ or } \sum_{j=1}^n PC_{ij}=100\%$$

3. determination of the fulfillment degree of each characteristic

For each analyzed product (i) is determined the degree of fulfillment of each characteristic (GIC_{ij}). For this purpose can be used an evaluation of the fulfillment degree which is independent of the number of the characteristics (for example from 1 to 5, “1- very poor degree of fulfillment of the characteristic”...”5- very good degree of fulfillment of the characteristic”). An evaluation depending of the number of characteristics (n) such that the product with the characteristic with the best degree of fulfillment receives the degree n , the product with the characteristic with second best degree of fulfillment receives the degree $(n-1)$ and so on, can be also used.

4. determination of the partial quality score (index) or partial utility of each characteristic

The partial utility indicator of the characteristic j of the product i , results by multiplication of the weight of the j characteristic (PC_{ij}) by the degree of fulfillment of the characteristic (GIC_{ij}).

So that the indicator of the partial utility Q_{ij} has the value:

No.	Coffee machine brand	Coffee tank	Capacity	Power	Tea prep function	Integrated coffee grinder	Price
1	Bosch TAS 4012 Tassimo	1	5	3.91	5	1	4.13
2	Philips Saeco HD8323 Poemia Focus	1	1	2.09	1	1	4.32
3	Gaggia Classic	1	5	2.82	1	1	2.29
4	Philips Saeco HD8751 Intelial Focus	5	3	5	1	5	1.96
5	Bosch TAS 4013 Tassimo	1	5	3.91	5	1	4.36
6	Philips Saeco HD8743 Xsmall	5	1	3.18	1	5	2.62
7	DeLonghi EC330	1	1	2.09	1	1	3.92
8	Rohnson R 955	1	2.2	1.73	1	1	4.53
9	ZASS ZEM 05	1	1	1	1	1	5
10	BOSCH TES50129RW	5	3.8	3.91	5	5	1

Table 1

The total quality score or index for each of these items results by summing up all the partial quality scores or utilities of the quality characteristics for each product, and thus the total quality index for each of the items is:

– Coffee machine 1:	Total quality score:	3,91
– Coffee machine 2:	Total quality score:	2,29
– Coffee machine 3:	Total quality score:	2,63
– Coffee machine 4:	Total quality score:	3,24
– Coffee machine 5:	Quality score:	3,98
– Coffee machine 6:	Quality score:	2,60
– Coffee machine 7:	Quality score:	2,16
– Coffee machine 8:	Quality score:	2,49
– Coffee machine 9:	Quality score:	2,22
– Coffee machine 10:	Quality score:	3,27

One can easily see that the coffee machines in positions 1 and 10 are regarded as the most qualitative ones since they have the highest quality scores, whereas the seventh and the ninth coffee machines are regarded as the ones with the poorest quality, since they have the lowest quality scores.

The computer subroutine “Qeval” below, using the Octave environment, allows the computation of the total quality scores by using the scoring model presented above. The same subroutine, with some slight modifications can be adapted to work in the Matlab environment

“Qeval”: Octave computer subroutine use to compute total quality scores (indices) according to the scoring model

```
function [ ret ] = Qeval ()
    ##load the names of the I/O files
    fid=fopen("Date.csv","r");
    disp("Fisierele utilizate sunt:");
    a=fgetl(fid);
    disp(a);
    b=fgetl(fid);
    disp(b);
    c=fgetl(fid);
    disp(c);
    d=fgetl(fid);
    disp(d);
    fclose(fid);
    ##load the vector of preferences
    p=csvread("vectorpref_in.csv");
    disp("Vectorul de preferinte este:");
    disp(p);
    ##load the matrix of fulfilling of characteristics
    q=csvread("GIC_in.csv");
    n=rows(q); disp("Numarul de produse este:"); disp(n);
    disp("Gradele de indeplinire a caracteristicilor pentru cele n produse sunt:");
    disp(q);
    disp("Matricea de preferinta este:");
    nc=columns(p);
    for i=1:nc
        for j=1:nc
            if (p(i)>p(j))
                pref1(i,j)=2.0;
            elseif (p(i)==p(j))
                pref1(i,j)=1.0;
            else
                pref1(i,j)=0.0;
            endif;
        endfor;
    endfor;
    disp(pref1);
    s=sum(pref1,2);
    disp("sumele liniilor matricei de preferinte sunt:");disp(s);
    disp("suma elementelor matricei de preferinte este:");disp(t=sum(s));
    disp("ponderile sunt:");disp(s/t);

    disp("Indicii de calitate pentru cele n produse sunt:");
    for i=1:n
        Q(i)=q(i,:)*(s/t);
        disp(q(i,:)*(s/t));
    endfor;
    dlmwrite("evaluare_out.csv",Q);
endfunction
```

Factorial Analysis and Principal Component Analysis for the quality characteristics of a batch of electrical equipment

The factorial analysis is a statistical tool designated to reduce a larger number of variables to a smaller number of latent variables, by taking into consideration their relative importance.

This reduction is explained by the fact that very often, many of the variables exhibited by a certain item are correlated to each other.

In the case of quality assessment and analysis, these variables are the quality characteristics of the equipment themselves.

The main idea on which this method is based upon is that behind the quality characteristics, which are in fact observable variables, lie latent factors which are influencing them.

The factors represent linear combinations of the values of quality characteristics, the coefficients of those linear combinations being named saturations or “charges” of the factors.

Let us now consider the following table having in its cells the degrees of fulfillment of the quality characteristics for a batch of ten coffee machines.

No.	Coffee machine	Coffee tank	Capacity	Power	Tea prep function	Integrated coffee grinder	Price
1	Bosch TAS 4012 Tassimo	1	5	3.91	5	1	4.13
2	Philips Saeco HD8323 Poemia Focus	1	1	2.09	1	1	4.32
3	Gaggia Classic	1	5	2.82	1	1	2.29
4	Philips Saeco HD8751 Intelia Focus	5	3	5	1	5	1.96
5	Bosch TAS 4013 Tassimo	1	5	3.91	5	1	4.36
6	Philips Saeco HD8743 Xsmall	5	1	3.18	1	5	2.62
7	DeLonghi EC330	1	1	2.09	1	1	3.92
8	Rohson R 955	1	2.2	1.73	1	1	4.53
9	ZASS ZEM 05	1	1	1	1	1	5
10	BOSCH TES50129RW	5	3.8	3.91	5	5	1

Table 2

The steps used in the factorial analysis are:

1. The above characteristics/product table matrix can be normalized and thus the transformed matrix Z is obtained:

$$Z = \frac{x - E(x)}{s}$$

Where E(x) represents the average values of the in the columns of the r characteristics/product table matrix, whereas s represents the standard deviations of the columns in the characteristics/product table matrix.

No.	Coffee machine	Coffee tank	Capacity	Power	Tea prep function	Integrated coffee grinder	Price
1	Bosch TAS 4012 Tassimo	-0.62	1.23	0.76	1.45	-0.62	0.54
2	Philips Saeco HD8323 Poemia Focus	-0.62	-1.00	-0.71	-0.62	-0.62	0.68
3	Gaggia Classic	-0.62	1.23	-0.12	-0.62	-0.62	-0.84
4	Philips Saeco HD8751 Intelia Focus	1.45	0.11	1.64	-0.62	1.45	-1.09
5	Bosch TAS 4013 Tassimo	-0.62	1.23	0.76	1.45	-0.62	0.71
6	Philips Saeco HD8743 Xsmall	1.45	-1.00	0.17	-0.62	1.45	-0.59
7	DeLonghi EC330	-0.62	-1.00	-0.71	-0.62	-0.62	0.38
8	Rohnson R 955	-0.62	-0.33	-1.00	-0.62	-0.62	0.84
9	ZASS ZEM 05	-0.62	-1.00	-1.59	-0.62	-0.62	1.19
10	BOSCH TES50129RW	1.45	0.56	0.76	1.45	1.45	-1.81

Table 3

2. Computation of the correlation matrix of the quality characteristics:

$$Cor = \frac{1}{n-1} Z'Z$$

Quality characteristic	Coffee tank	Capacity	Power	Tea prep function	Integrated coffee grinder	Price
Coffee tank	1.00	-0.08	0.59	0.05	1.00	-0.80
Capacity	-0.08	1.00	0.61	0.69	-0.08	-0.29
Power	0.59	0.61	1.00	0.53	0.59	-0.63
Tea prep function	0.05	0.69	0.53	1.00	0.05	-0.13
Integrated coffee grinder	1.00	-0.08	0.59	0.05	1.00	-0.80
Price	-0.80	-0.29	-0.63	-0.13	-0.80	1.00

Table 4

3. Diagonalization of the correlation matrix of quality characteristics and choosing of the factors:

$$Cor = U * S * V'$$

The factors' matrix is: $Y = U * \sqrt{S}$

No.	Quality characteristic	F1	F2
1	Coffee tank	-0.88	0.45
2	Capacity	-0.38	-0.86

3	Power	-0.86	-0.34
4	Tea prep function	-0.39	-0.79
5	Integrated coffee grinder	-0.88	0.45
6	Price	0.89	-0.17

Table 5

Taking into account that the sum of the first two eigenvalues divided through the trace of the diagonal matrix S is $(\lambda_1 + \lambda_2)/\text{tr}(S) = 0,8815$, these two chosen factors are accountable for and hence explain 88.15% from the total variance.

“Qevalpca”: Octave computer subroutine use to compute the factors, according to the principal component analysis theory

```
function [ ret ] = Qevalpca ()
    ##load the names of the I/O files
    fid=fopen("Date.csv","r");
    disp("Fisierele utilizate sunt:");
    a=fgetl(fid);
    disp(a);
    b=fgetl(fid);
    disp(b);
    c=fgetl(fid);
    disp(c);
    d=fgetl(fid);
    disp(d);
    fclose(fid);
    ##load the matrix of fulfilling of characteristics
    q=csvread("GIC_in.csv");
    n=rows(q); disp("Numarul de produse este:"); disp(n);
    m=columns(q);
    ##disp("Gradele de indeplinire a caracteristicilor pentru cele n produse sunt:");
    ##disp(q);
    for j=1:m
        for i=1:n
            t(j)=sum(q(:,j))/n;
            k(j)=std(q(:,j));
            z(i,j)=(q(i,j)-t(j))/k(j);
        endfor
    endfor
    disp("miu si (q-miu)/std")
disp(t); disp(z);
    disp("matricea de corelatie este:")
    cor=(z'*z)/(n-1)
    disp(cor)

    disp("diagonalizarea este:")
    [u,s,v]=svd(cor)
    y=u*sqrt(s);
    disp("factorii sunt:")
disp(y)
    disp("y*y'")
    disp(y*y')
    dlmwrite("factors_out.csv",y)
    dlmwrite("z_out.csv",z)
    dlmwrite("cor_out.csv",cor)
endfunction
```

Conclusions

The scoring model together with its adjacent decision theory and its methods can be successfully used in the assessment and determination of the quality of electrical equipment, especially when this equipment exhibits both, objective and subjective characteristics, which is the most general situation of an analyzed product.

The results of the scoring model depend however the quality characteristics of each electrical equipment chosen.

The results of the scoring model depend on the preferences' system of the population questioned with regard to the both, weights of the quality characteristics and fulfilment degree of the quality characteristics, in order to assess a certain electrical equipment.

Often times, the buyer or the end user of the respective electrical equipment is not familiar with the design and the construction of the respective electrical equipment. His expectations from and his preferences regarding the electrical equipment are closely related to technical specifications and intrinsic features of the equipment, which are understood either by the technical staff in the electrical field or by the staff involved in the design and in the construction of the respective equipment.

This is why in order to perform the quality assessment of electrical equipment one has to have prior knowledge, skills and expertise in the field of electrical engineering since the objective characteristics and some of the subjective characteristics involved in the quality of the electrical equipment rely on the technical data sheets, technical specifications and on the technology used to build the respective electrical equipment.

Regarding the application of the factorial analysis and principal component analysis of the quality characteristics, one has to be aware of the utility and importance of the computation of the correlation matrix in the reduction of the number of quality characteristics, since many times this reduction of factors, based on the correlations between quality characteristics serves to a better understanding of an equipment quality.

In the case study presented to factorial analysis tool the F1 and F2 are the main factors which are accountable and explain 88.15% of the total variance. Also, as a main result of this analysis, one can state that the price is not a consequence of the other quality characteristics, which leads to the conclusion that in this case is either about the "fashion" or about the "brand", or some of the positive quality characteristics should be reconsidered.

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