Quality Management in Fashion Industries

Dr. Ferenc Schmél, MSc. Tech., PhD.

United Nations Industrial Development Organization (UNIDO)

Dictionaries and encyclopedias provide several dozens of definitions for the four keywords of the title: quality, management, fashion and industry. Everyday life uses the term of quality in various contexts. In the industry (including services) besides *productivity*, **quality** is recognized as the other important criteria for becoming or remaining competitive on the market. **Fashion** is generally regarded as formal (aesthetic) requirement that hardly can be approached by technical or scientific methods. Fashion industries are undergoing automation, high technology (CAD/CAM, robotics, body scanning, color measurement, membranes etc.) is widely used even in small-scale operations and therefore assessment of quality should also make maximum use of objective methods. The paper makes an attempt to formalize and even quantify quality aspects of fashion industry products so, that artistic features of these goods could equally be handled with those measured in laboratories or in the technology.

Terminology

Quality is an attribute, a property, a special feature or characteristic or a manner, a *style*.[1] Quality is fitness for use.[2] In other words quality is the set of product *features* or its freedom of deficiencies.[3] **Management** is the application of skill or care in the manipulation, use, treatment, or control of things or persons, or in the conduct of an enterprise, operation, etc.; the administration of (a group within) an organization.[1] Management is get things done through other people, or more officially is a *process* by which a cooperative group directs actions towards common goals.[4] Management is a distinct process consisting of activities of *planning*, *organizing*, *actuating* and *controlling*, performed to determine and accomplish stated objectives with the use of human beings and other resources.[5] **Fashion** is a particular make, shape, style, or pattern; specifically a particular *style of clothing*.[1] Particularly the fashion is the latest and most admired style in clothes and cosmetics and behavior.[6] A fashion consists of a current (constantly changing) trend, favored for *frivolous* rather than logical or intellectual reasons.[7] **Industry** is a particular form or branch of productive labour; a trade, a *manufacture*.[1] At the same time an industry is a basic category of *business* activity.[8]

Association of these terms adds to the meaning of the components. **Quality management** is concerned with getting things right.[9] ***Total* quality management**

(TQM) is a method that centers on quality and on the long-term success of the organization through the *satisfaction of the customers*, as well as the benefit of all its members and society.[10] (The term "total quality management" covers all elements of the traditionally used phrases and methods such as quality control, quality planning, quality assurance.) The **fashion industry** consists makers and sellers of fashionable *clothing*[11] such as textile apparel (including knitwear), leather products (including footwear, leather goods, gloves, leather garment), jewelry (including bijou).

From these definitions follows that while quality is associated with functionality and perfection, fashion is governed seemingly appreciations or perceptions. Product quality is defined by its *rational* features; fashion reflects virtually *irrational* aspects depending on timely valid formal properties.

Product Quality

Although product quality may be described by a set of physical, chemical, comfort, environmental etc. properties that can be established by appropriate laboratory tests, not all features (e.g. workmanship) can be expressed in numerical values. On the other hand fashion related characteristics (e.g. form, shape, color harmony) do not lend themselves for measuring at all. Products of fashion industries are valued by consumers in their integrity, i.e. both quality and fashion are considered – perhaps in different proportions in case of specific products – when purchased.

The quality of industrial products has several components[12] playing different roles in appreciating its value, namely:

- *Quality of the construction* or structure: set of product properties built in the design that becomes apparent both in the production process and use (e.g. grain of shoe upper or leather goods, composition of athletic footwear's soles).
- *Functional quality* expressed by the product's suitability for its intended use, reliability, security and comfort (e.g. geometry of travel goods vis-à-vis storage capacities, dimensions of shoe lasts, water-vapor permeability of shoes and gloves).
- *Production/execution quality* determined by workmanship and technology precision, absent of faults, realization of the (aesthetic) design (e.g. symmetry of left and right shoes and gloves, evenness of seams and overlaps, finishing consistency).
- *Realization/recognition quality* that plays extremely important role in marketing of fashion goods (e.g. compliance with avant-garde trends).

As a consequence of specialization and globalization the value chain is becoming increasingly fragmented and complex, whereas each participants – except ultimate consumers – acts both as buyer (in procuring materials and/or services) and supplier. In this relation quality arguments may arise around *adequacy* (compliance with order specification or sample), *functionality* (fitness for intended use), *reliability* (timeliness, adherence to agreed terms) and *consistency* (similarity within the batch).

Quality Analysis

Analysis is the resolution or breaking up of something complex into its various simple elements.[1] As shown above quality is no doubt a complex phenomena. *Quality analysis* is a business practice (within a company, [sub]sector or trade) aiming at improving quality of products and/or services.[13] In any case quality analysis is a process attempting to determine the actual level in order to find ways and means resulting in quality improvement.

The most traditional methods of quality analysis are based on **(mathematical) statistics**. Expressing share of rejects in percentage of the total (productions, products), showing the distribution of grades (e.g. of raw hides and skins, [semi]finished leather) are typical statistical approaches. The *Pareto diagram* provides a simple and obvious method for reducing the number of quality components (parameters) to the controllable volume (*Fig. 1*). Another well-known method is the *statistical quality inspection* whereby (e.g. destructive) test results gained from a small sample are extrapolated fro the entire population (material or product batch or supply). Two-step sampling is particularly efficient and economic, but unfortunately it is practically not used in fashion industries (*Fig. 2*). More sophisticated statistical quality assessment is done by using *control cards* (*Fig. 3*) which can be constructed and operated using computer spreadsheets.

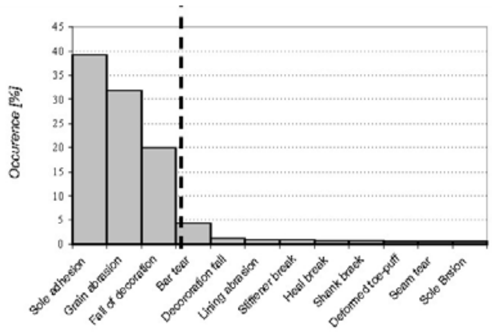


Fig. 1

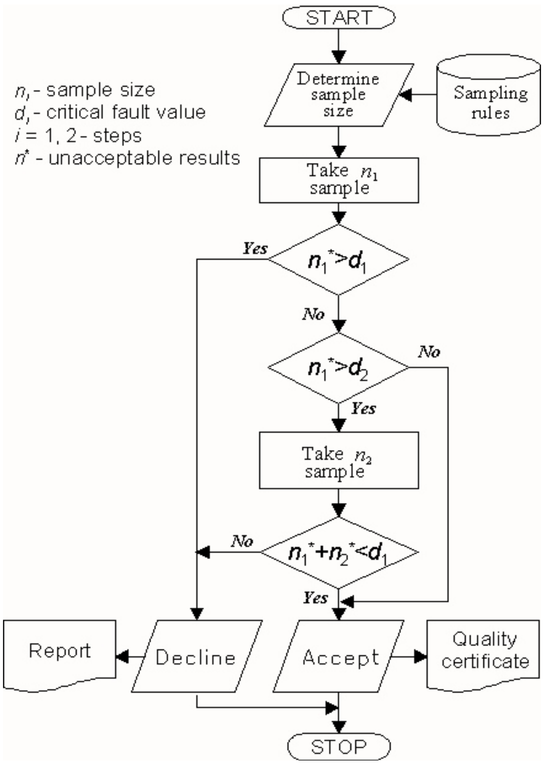

n_i - sample size
d_i - critical fault value
i = 1, 2 - steps
n^* - unacceptable results
START
Determine sample size
Sampling rules
Take n_1 sample
Yes
$n_1^*>d_1$
No
$n_1^*>d_2$
No
Yes
Take n_2 sample
No
$n_1^*+n_2^*<d_1$
Yes
Report
Decline
Accept
Quality certificate
STOP

Fig. 2

Fig. 3

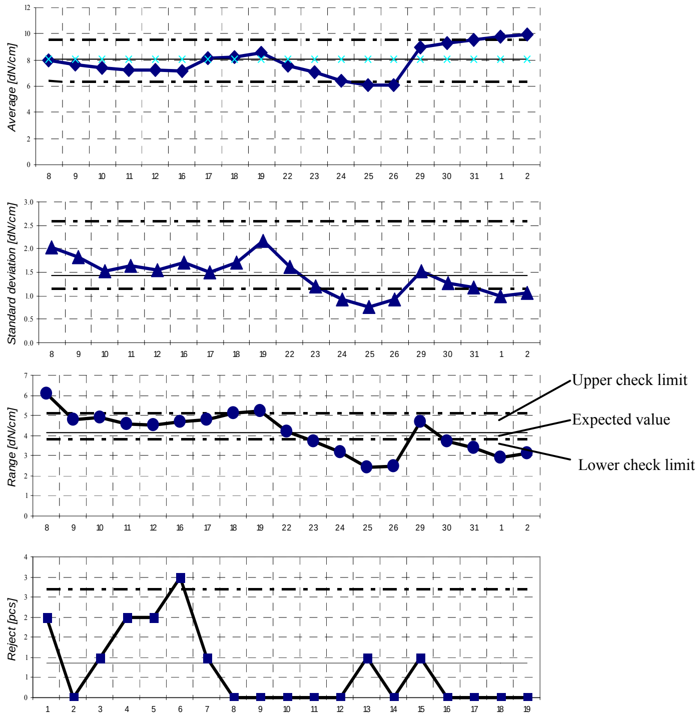


Fig. 3

The other group of accessories supporting quality assessment are based on **graphic representation** of components (parameters). The *cause-effect* (or as it shape implies: *fishbone diagram* reveals links between groups and individual factors affecting the product quality (*Fig. 4*). Probably the most comprehensive and concise way of summarizing product design (quality planning) technical information is the application of the so-called *quality house* (*Fig. 5*).

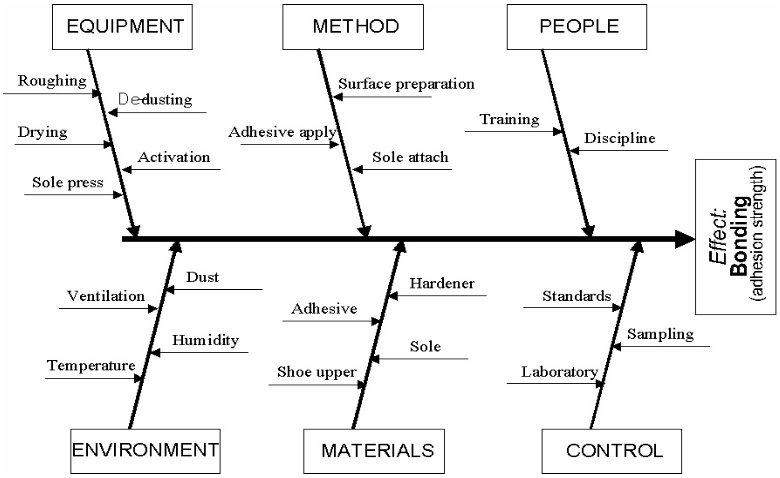

EQUIPMENT
METHOD
PEOPLE
Roughing
De-dusting
Drying
Activation
Sole press
Surface preparation
Adhesive apply
Sole attach
Training
Discipline
Effect:
Bonding
(adhesion strength)
Dust
Ventilation
Humidity
Temperature
Hardener
Adhesive
Sole
Shoe upper
Standards
Sampling
Laboratory
ENVIRONMENT
MATERIALS
CONTROL

Fig. 4

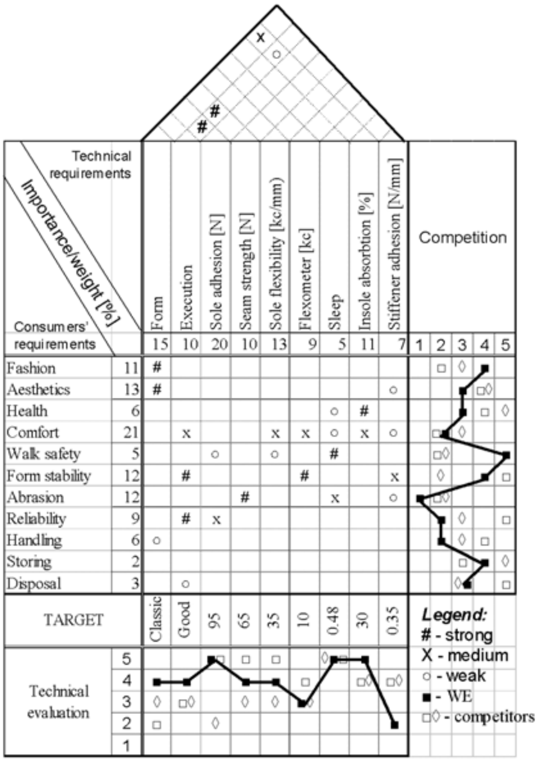


Fig. 5

These techniques have been around for decades are well-known,[14] because of their clear logical and especially graphic interface lend themselves for using in industries such as the clothing and leather products trade, but their application is lagging well behind their potential.

Quality Assessment

Any definition of quality is implies relativity, i.e. quality (of products) can be described or assessed only in relation with some reference such as requirements, specifications, samples, standards or other (similar) products. This relation is established by measuring; using specific techniques makes possible the comparison of product characteristics with some references. The task of quality assessment (measuring) is especially complex in case of fashion goods as quite some of their features are either irrational (e.g. form harmony, color combination, compliance with trends) or cannot be expressed in numbers (e.g. fit, comfort).

The lack of available objective numerical values for describing the market value of fashion articles does not mean that application of numerical methods would be impossible in determining the value of fashion goods. We should remember *Galileo Galilei*'s words: "Measure what can be measured, and make measurable what cannot be measured." From quality management point of view this means that "we cannot manage what we cannot measure".[15]

Transformation is the process assigning scale values to actual properties. In fact measuring physical, chemical, comfort etc. properties of products in laboratories by using appropriate equipment (testing apparatus) normally results in values corresponding to a point of the measurement (linear) scale: e.g. sole adhesion at the toe-part is a value on scale having the unit of N (Newton). After measuring this property of each member of the sample of population (products), a scale may be constructed within zero (0) and the maximal value (a_{max}), i.e. assigning 100 to the maximum occurrence of that particular property, all other measured values can be expressed in proportion of the maximum and thus will range between 0 and 100.[*] Applying this transformation technique to all other measured properties we get a set of comparable parameters as this way the effect of different measurement units is eliminated. *Table 1* shows a simple example[**] comparing two parameters of seven different simulated genuine leather materials used for shoe uppers.

Table1

Computation of scale values

Material	Surface weight		Elongation at tear	
	g/m²	*Scale*	*%*	*Scale*
PPPP	732	58.0	45.3	37.3
RRRR	654	43.0	**92.8**	**100.0**
SSSS	789	68.9	61.4	58.5
TTTT	**951**	**100.0**	80.4	83.6
VVVV	*430*	*0.0*	60.2	56.9
XXXX	706	53.0	22.9	7.7
ZZZZ	593	31.3	*17.1*	*0.0*
Average	694		54.3	

[*] The mathematical algorithm of computing scale values is given in the *Appendix*.
[**] Examples are taken from real quality assessment of various materials and products of footwear manufacturing. In order to avoid references to any brands and to maintain confidentiality of test results actual product names are changed to symbolic notations throughout this paper.

Standard deviation	162	28.0
Minimum	*430*	*17.1*
Maximum	**951**	**92.8**
Range	521	75.7

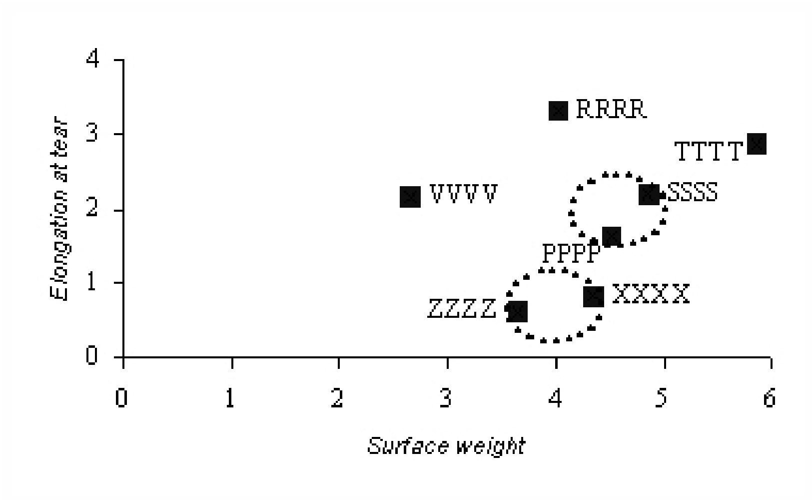
Individual properties are usually not equally important in view of the product's functions and/or marketability. Weighing is the most natural way to describe the priority of each characteristic. It can be done just by assigning numeric values to properties, whereas they are determined by experts. To increase the reliability of weight factors special techniques were developed.[16] Thus the weighed average (mean) of product properties is considered as the *generalized scale values*. The comparative evaluation of products' quality needs only ranking according to their generalized parameters. To illustrate this technique six shoe upper leather samples were tested on their acceptability for export: *Annex 1* lists the 16 selected laboratory tests that provide numerical results. Based on generalized scale values JJJJJ appears to be the best, but even this is just near "half way" to the perfection set by test results of the inspected sample. It also shows that GGGGG, HHHHH and LLLLL are of fairly similar quality.

One of the simplest ways of quantifying all observed or considered properties is to assign *grade values* – the same way teachers evaluate the pupils' performance in schools. Obviously this approach is applicable for any kind of properties – including those, which cannot be measured by laboratory equipment. It is quite easy to handle properties where the maximum or the minimum or a specific optimum value corresponds to the "best" or "excellent" quality. Similarly the scale for transferring test results to grades may or may not be linear. The first thing usually opposed in such grading or ranking is the role of subjective judgment. One should, however, not forget that the selected set of properties used for specifications, as well as the requirements or standards – whether they are absolute, relative, desired or planned – are not absolute either. E.g. the left side of *Annex 2* presents a set of grading criteria.

Combination of measured and graded quality parameters is fairly easy, as grade values – being numerical – can be used as kind of measurements of respective otherwise not quantifiable properties. The table in *Annex 2* shows an example how this approach can be used in case of four different men boots produced by different manufacturers, tested and assessed according to a standard set of properties. The following aspects of this table deserve special attention:

a) the set of properties include measurable (laboratory tested) and graded characteristics;

b) each property has a weight factor to express its importance within the set of tested/assessed parameter set – for convenience these weights are expressed in percentage, i.e. their sum is exactly 100;



c) although exactly 50 properties are listed, some of them was considered as not applicable in case of the given product type (e.g. heel fastness and top-piece where because all tested samples had unit soles), therefore the corresponding weight factors are set to zero;

d) grades are given according to test results or expert's evaluation using rules presented in the left side of the table;

e) the right column of each product shows weighted generalized grade values: their sum may be interpreted as the degree of perfection and as such can be compared with other products.

The final ranking of the four sample men boots is shown in the last row of the table. From this the following statement can be made:

- product BBBB is the "best" (its generalized scale value is 80.85%), while AAAA is of the lowest quality (75.80%);
- the difference between BBBB (No. 1) and DDDD (No. 2) is 80.85%-79.73%=1.12% somewhat larger than between DDDD and CCCC (No. 3) and between CCCC and AAAA (no. 4) which are 79.73%-77.74%=1.99% and 77.74%-75.80%=1.60% respectively.

In reality this simple method has two features: it quantifies the consolidated quality of the product and offers the possibility of *multidimensional comparison* (co-measuring) of different products (entities).

Cluster Analysis

A further question is how could we establish similarities among different properties taking into account their complete set of properties and how could they be grouped? From the foregoing one can suggest to represent each product as a point in the *m*-dimensional space (where *m* is the number of properties). However relative locations of points (products) depend not only on their properties, but also on the scale selected for the axis, which is normally determined by the unit of measurement used. To exclude the effect of scales, the basic data are *normalized*, i.e. each property is divided by the standard deviation of that particular property. Applying this to the two parameters used in *Table 1* will result in the scatter plot shown on *Fig. 6*. It is clearly seen that materials denominated PPPP and SSSS, also XXXX and ZZZZ are fairly similar, while all other are more different – of course on the basis of these selected two properties. To create groups circles may be drawn, whereas the number of groups will depend on the cirle's radius (the larger the span of compasses the less groups are created) and on the location of the center of circles. In our example the radius r=0.45 will produce five groups: ***I*** – PPPP+SSSS, ***II*** – XXXX+ZZZZ, ***III*** –RRRR, ***IV*** – TTTT, ***V*** – VVVV. Techniques used for generating groups of elements using their complex (multidimensional) characteristics are known in the literature as *cluster analysis* or *automatic classification*.

Generally in case of *m* properties the geometric model is represented in the *m*-dimensional space, moreover each property may have its own weight in order to express importance in the product quality. The clustering process is based on construction of a square matrix size $n*n$ (where *n* is the number of products/materials to be grouped) in showing weighted and normalized[**] distances (in the *m*-dimensional space) between each pair of products (obviously this matrix will be symmetric as $d_{AB}=d_{BA}$). If we take the maximum of these distances as a critical value then no doubt all products will fall in one group (all other pairs will have less distance). In the other extreme if the critical distance is set to the smallest of the entire set, then each product will form its own group with one member only. Taking any value in between the largest and the smallest distances will result at least one group with minimum two members. The best approach is to span the range of all distances with some preset increment, find the corresponding clustering situation for each and see if the result is acceptable to our requirements. In practice it means that we preset the target number of groups within reasonable limits (e.g. 5 and 10), start with the first calculated critical distance, generate corresponding groups and repeat the process with increasing critical distances until the produced number of groups fall within our expected limits.[17] It is proven that after several iterations this will happen, the process is stopped.[18] (Of course some groups may have only one

---

[***] In this case normalization is made by dividing each (property) parameter by the standard deviation of the entire set of that characteristic.

member.) The computational process is easily programmable: the respective mathematical algorithm of this automatic classification is attached in the *Appendix*.)

A computer program (CITAX) was developed to undertake all computations required for automatic classification of products which quality is represented by a large number or properties. This software produces the required number of groups in three possible ways: on the basis of entered data (natural property values and/or ranges), scale values (automatically generated) and range values. It also offers hierarchical classification, as well as numeric and graphic representation (Fig. 7) of results.[19] Several other computer programs have been created for analyzing complex systems that may be used for quality measurement, product ranking and/or clustering: PATTERN (**P**lanning **A**ssistance **T**hrough **E**valuation of **R**elevance **N**umbers from HONEYWELL), MARSAN, ELECTRE, SORK (**SOR**TRAN**K**ING), the Hungarian KIPA, TEXIMEI-REM, CADM, RANG-64 just to name a few.[20] Another set of algorithms and computer software is available for the Internet – including commercial (e.g. CLUSTAN, IBM INTELLIGENT MINER, POLYANALYST, VISIPOINT) and even (e.g. CLUTO, PROXIMUS, RECKLESS, SNOB, STARPROBE) freeware program packages.[21] Furthermore some data mining systems also offer clustering functions (e.g. TANAGRA[22], EDM[23]).

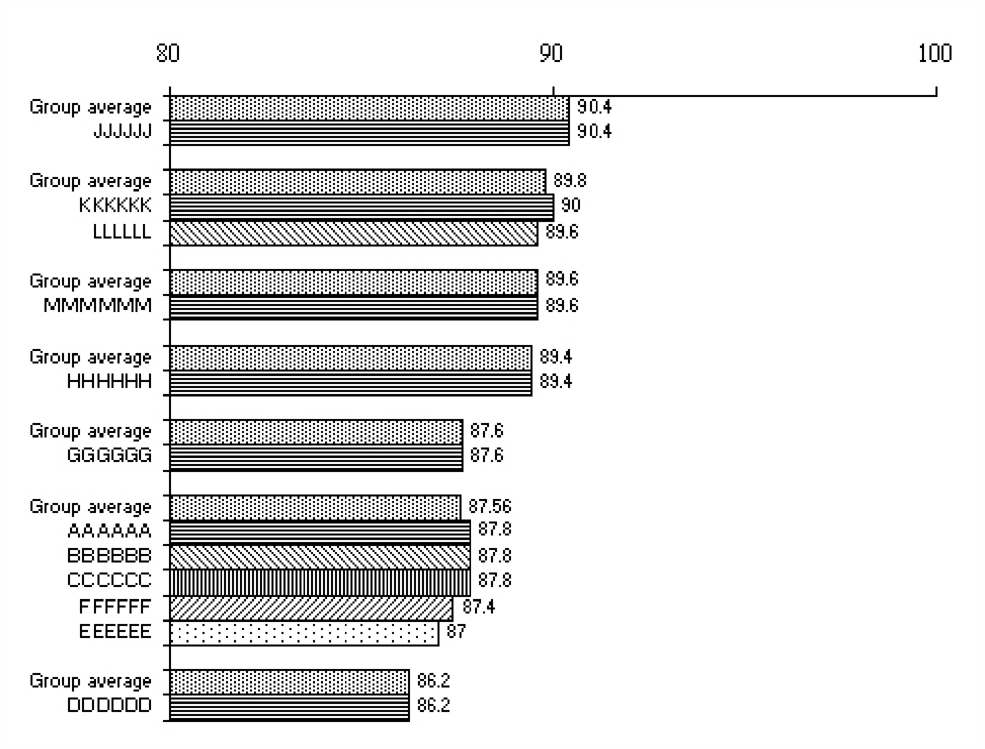


Fig 7

Clustering or automatic classification of materials or (industrial) products may be used for determining coherent groups (e.g. for interchangeability of materials or suppliers, defining market position, identifying quality improvement needs and simulate their effect). It can also be a useful tool when difference (in quality or property terms) between product and/or groups should be objectively and quantifiably reported.

Conclusions

Formal (i.e. aesthetic and/or visual) properties of fashion articles may be quantified and thus they will become integral part of the quality management. Several methods mentioned above feature graphic interpretation assessment of results (sometimes based on rather complicated computation algorithms): this is far more informative for those involved in range building, product design and development, marketing than usual analytical (numeric) representation of quality-related characteristics, so these methods contribute to strengthening the corporate climate and team cohesion within the company.

Generating scale values, assigning grades, ranking or clustering (fashion) products is only one of the available techniques and components used in total quality management; other approaches (e.g. metrology, ISO 9000) are also playing important roles in ensuring production of goods of required or expected quality level and attributes. All these methods – along with other management and business tools – together can assist manufacturers to meet challenges of the globalized world and to participate in the (international) trade.

References

[1] Oxford Talking Dictionary. THE LEARNING COMPANY, INC., London, 1998.
[2] *Juran, J. M.:* Juran's Quality Control Handbook (4th edition). MCGRAW-HILL, New York, 1988.
[3] *Juran, J. M.:* Juran on Quality by Design – The New Steps for Planning Quality into Goods and Services. THE FREE PRESS, New York, 1992.
[4] *Massie, J. L.:* Essentials of Management (Fourth edition). PRENTICE-HALL OF INDIA PRIVATE LTD., New Delhi, 1994.
[5] *Terry, G. R. – Franklin, S. G.:* Principles of Management (Eighth edition). ALL INDIA TRAVELLERS BOOKSELLERS, Delhi, 1994.
[6] The Free Dictionary. http://www.thefreedictionary.com/fashion
[7] http://www.free-definition.com/Fashion.html
[8] http://www.investorwords.com/2447/industry.html
[9] http://www.ogc.gov.uk/sdtoolkit/reference/deliverylifecycle/quality_mgmt.html
[10] http://www.kwaliteg.co.za/tqm/Total%20Quality%20Management.htm
[11] http://www.webster-dictionary.org/definition/fashion%20industry
[12] *Schmél, F.:* A minőség mérése I. (Measuring the quality I.). BŐR- ÉS CIPŐTECHNIKA, No. 3, (XLIII) 1991.
[13] Total Quality. KOGAN PAGE LIMITED, London, 1992.
[14] *Schmél, F.:* A minőség mérése II.– A minőség elemzésének módszertana. (Measuring the quality II. – Methodology of quality analysis). BŐR- ÉS CIPŐTECHNIKA, No. 5, (XLIII) 1991.
[15] *Blanton, A. G.:* The Tough Stuff. http://www.qualitydigest.com/sept97/html/qmanage.html
[16] *Kindler, J. - Papp, O.:* Komplex rendszerek vizsgálata. MŰSZAKI KÖNYVKIADÓ, Budapest, 1977.
[17] *Schmél F.:* A minőség mérése III. – A minőség mérésének elmélete. (Measuring the quality III. – Theory of quality measurement). BŐR- ÉS CIPŐTECHNIKA, No. 7, (XLIII) 1993.
[18] *Párniczky, G.:* A statisztikai informatika alapjai. STATISZTIKAI KIADÓ VÁLLALAT, Budapest, 1976.
[19] *Schmél F.* A minőség mérése IV. – A számítógépes minőségmérés gyakorlata. (Measuring the quality IV. – Practice of computerized quality measurement). BŐR- ÉS CIPŐTECHNIKA, No. 12, (XLIII) 1993.
[20] *Dobó, A.:* Számítógépes összehasonlító minőségértékelési módszerek. MINŐSÉG ÉS MEGBÍZHATÓSÁG No. 5, 1987.
[21] http://www.kdnuggets.com/software/clustering.html
[22] http://chirouble.univ-lyon2.fr/~ricco/tanagra/en/tanagra.html

[23] http://www.data-miner.com/

Appendix

Mathematical algorithm

of multidimensional comparison and classification of objects

(such as fashion industry products)

Scaling and grading

The **generalized quality parameter** of the *i*-th product is computed as follows:

$$p_i = \frac{\sum f_i v_{ij}}{\sum w_j} \quad \textbf{(1)}$$

where w_j - the weight of the *j*-th property, $j \in [1, m]$, *m* - the number of properties used for description of the product quality, v_{ij} - percentage value of performance of *i*-th product in relation of *j*-th property, $j \in [1, n]$, *n* - the number of products to be compared. If the grading is made on a scale having *r* clusters (*r*>1 and integer), then where g_{ij} - the grade value given for the *i*-th product regarding the *j*-th property.

If all properties of products are measured on linear scales and the optimum values are the extremes (e.g. elongation, specific weight, hardness), a more objective approach may be followed. Assume that the minimal value of the *j*-th property

$$v_{ij} = \frac{100\, g_{ij}}{r} \quad \textbf{(3)}$$

$$v_{ij} = 100 \frac{q_{ij} - a_j}{b_j - a_j} \quad \textbf{(2)}$$

among the *n* product was a_j and similarly the maximum value was b_j. The performance value then
where q_{ij} - the measured property. Using these v_{ij} the formula (1) is applied for the computation of the **generalized scale value**.

Cluster analysis

Basic notations

m - number of properties involved in the quality measurement;
n - number of products to be compared and classified;
x_{ij} - the value of *j*-th property in case of *i*-th product;
x_j - the average (mean) of *j*-th property values:
$j \in [1,n]$
$i \in [1,m]$

$$x_j = \frac{\sum x_{ij}}{m} \tag{4}$$

s_j - standard deviation of *j*-th property in the sample composed of the

$$s_j = \sqrt{\frac{\sum (x_{ij} - x_j)^2}{m-1}} \tag{5}$$

products analyzed:
w_j - the weight of the *j*-th property.

The computational algorithm

The weighed and normalized difference of the *l*-th and the *k*-th products (i.e. their Euclidean distance in the *m*-dimensional space):

$$d_{lk} = \sqrt{\frac{w_i}{s_j^2}(x_{lj} - x_{jk})^2} \tag{6}$$

There are

$$\binom{n}{2} = \frac{n!}{2(n-2)!} \tag{7}$$

distances between all points. Let us arrange all these distances in quadratic matrix **D**. The matrix is of size $n*n$ and will be symmetric having zero values in its diagonal. Now select a critical distance value d_c

$$\max\{d_{lk}\} \le d_c \le \min\{d_{lk}\} \tag{8}$$

and create a quadratic Boolean matrix **A** of the same size as **D**, where

$$a_{lk} = 1 \qquad \text{if} \qquad d_{lk} \leq d_c$$

$$a_{lk} = 0 \qquad \text{if} \qquad d_{lk} > d_c \qquad\qquad \textbf{(9)}$$

$$a_{kk} = 1$$

According to the method of transitive completion (closedown) let us multiply the **A** matrix by itself, whereas the multiplication and addition operations on the elements of matrices is to be done according to the Boolean algebra:

$$\mathbf{B} = \mathbf{A} \, . \, \mathbf{A} \qquad\qquad \textbf{(10)}$$

If $\mathbf{B} \neq \mathbf{A}$, repeat the multiplication:

$$\mathbf{C} = \mathbf{B} \, . \, \mathbf{A} = \mathbf{A} \, . \, \mathbf{A} \, . \, \mathbf{A} \qquad\qquad \textbf{(11)}$$

until the produced matrix appears unchanged. (It is proved that after a definite number of steps the process terminates, and the final Boolean matrix will certainly be symmetric). By simple permutation of rows and columns the result matrix may be transformed into a block-diagonal matrix, whereas the blocks indicate the groups created on the basis of critical d_c distance.

If $d_c = \min\{d_{lk}\}$ then the number of groups created will be equal to the number of products (i.e. each product forms a group by itself). Similarly if $d_c = \max\{d_{lk}\}$ then all products will belong to the same group (i.e. only one cluster will be generated).