KANO'S TRIDIMENSIONAL MODEL FOR QUALITY EVALUATION

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REZUMAT. Este foarte important pentru organizații, în special pentru cele care lucrează la dezvoltarea de noi produse şi servicii inovative, să cunoască nevoile şi cerințele clienților lor cât mai rapid. Abordarea „Crearea Calității Atractive", cunoscută şi sub numele de „Modelul Kano" a apărut ca urmare a punerii sub semnul întrebării a ideii tradiționale că acționând mai intens asupra unui produs sau serviciu atunci clientul va fi cu atât mai mulțumit. Dr. Noriaki Kano de la Universitatea Rika din Tokyo a susținut că performanța unui produs sau serviciu nu este egală în ochii clienților, în sensul că performanța unor anumite categorii de atribute ale produselor sau serviciilor, produce niveluri mai mari de satisfacție decât a altora. Prin adăugarea de noi dimensiuni Modelului Kano, apare posibilitatea cuantificării în termeni monetari a pierderilor suferite de clienți în cazul neîndeplinirii cerințelor acestora.

Cuvinte cheie: Kano, calitate, performanta, tridimensional, Taguchi.

ABSTRACT. It is very important for organisations, especially for those involved în developing new inovative products and services, to understand very quickly customer's nedds and requirements. „Creation of Attractive Quality" approach, also known as „Kano's Model" emerged due to questioning the more traditional idea that acting more intensily on a product or service then the customer will be happier. Dr. Noriaki Kano from Tokyo Rika University argues that a product's or service's performance is not equal în the customers eyes, meaning that the performance for some attribute categories of product's or service's induce greater satisfacțion

levels than other's. By adding new dimensions to Kano's Model, it arises the possibility to quantify în monetary terms the losses suffered by customers în the case that their requirements are not fulfilled.

Keywords: Kano, quality, performance, tridimensional, Taguchi.

1. INTRODUCTION

At the end of 70's, Dr. Noriaki Kano from Tokyo's Rika Univerity improved the quality definiton by adding a new dimewnsion to it. The previous definitions for quality, until that moment, were linear and one-dimensional (Fig.1). Dr. Kano integrated quality a two-dimensinal model (Fig. 2), by taking in account two dimensions: the way in which the product or service behave (X axis) and user/customer degree of satisfaction (Y axis).

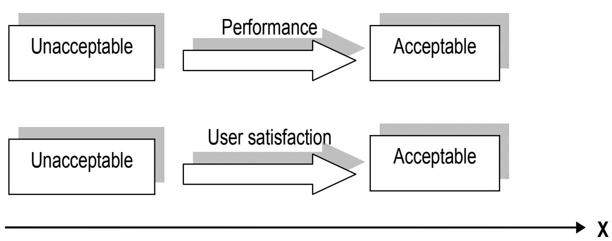

Fig. 1. One-dimensional Quality.

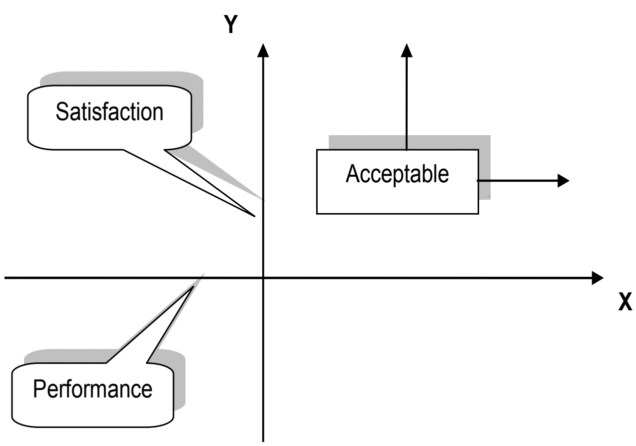

Fig. 2. Two-dimensional Quality.

The construction of Kano model begins with customers surveys, these being interviewed about product attributes and about their perception about both having them sufficiently as well as not sufficiently. A Kano type survey is asking 2 questions for each product's attribute, resulting the categories presented in table 1. An example given by Zultner and Mazur (2006) as a first question is „If the vehicle *has a good visibility* [**sufficient**], how do you feel?" [**neutral**]. Hence the „Physical State" is [**sufficient**] and the „User Perception" is [**neutral**]. The second question „If the vehicle ***doesn't*** *have a good visibility* [**insufficient**], how do you feel?" [**unsatified**]. Hence the „Physical State" is [**insufficient**] and the „User Perception" is [**unsatified**]. Thus, at the intersection of those two, from table 1, the version "Must Be" is obtained, meaning that a *good visibility* is expected by the customer for that type of vehicle.

Table 1. **Kano's category resulted through paired questions**

Physical State	**Sufficient**			
	User perception	**Unsatisfied**	**Neutral**	**Satisfied**
Insufficient	**Unsatisfied**	Skeptic	Must be	One-dimensional
	Neutral	Reverse	Indifferent	Attractive
	Satisfied	Reverse	Reverse	Skeptic

As can be seen from table 1, there are 5 categories of requirements. Thus, „**Attractive**" category, also named „**Exciting**", refers to requirements generally not known to the customer, which doesn't mention them when being interviewed, but like them when they detect them. Category „**Indifferent**", refers to to the fact that the customers simply doesn't care about indifferent requirements. Category „**One-dimensional**", also named „**Desired**", refers to the fact that the relation between the degree of fulfillment (Physical State) and the degree of satisfaction, is a linear one. More performance brings proportionally more satisfaction. „**Desired**" requirements appear usually when the customers are asked about what they desire. The customers are usually willing to accept compromises regarding more performance of one of the elements against other element. Category „**Must Be**", also named „**Expected**", refers to requirements assumed by the customers and are not mentioned (are mentioned only if being recently dissapointed). Category „**Reverse**", refers to the requirements which the customers prefer not to have, being even ready to pay for not having them. Their presence generates revolt and their lack of presence, generates satisfaction. Kano names the category „**Skeptic**", refering to the fact that there is some uncertainty regarding the customer responses. Other evaluators consider that this may fit the responses obtained when assessing levels of performance on either the customer does not care whether they accept any of them. An example for the first situation is: "How would you feel if your salary increases by 10 lei [**sufficient**], or 5 lei [**insufficient**]?, and for the second situation: "How would you feel if you had a salary of 9000 lei [**sufficient**], or 6000 lei [**insufficient**]? Note that the client will assess the question always keeping in mind a certain level of performance. Kano follows these categories with "quality elements", meaning a high level functional requirements. Thus these categories relate to the attributes of a product or solution and not the customer needs.

In Table 2 are shown examples of responses to Kano's categories on elements of a vehicle and in Figure 3 are presented graphically five categories, Kano noting that the neutral area is the one in which Attractive Quality starts and Necessary Quality ends.

Table 2. **Examples of answers to Kano's categories, refering to the elements of a vehicle** (source: Zultner and Mazur (2006))

Quality element	*Expected*	*Desired*	*Excited*	*Indifferent*	*Reverse*
Good visibility	●				
Spacious interior		●			
Enhanced traction system			●		
Adventurous image				●	
6 gear manual transmission					●

Another possibility to distinguish between types of requirements that influence customer satisfaction, is to answer in 5 different ways to each pair of questions for each element of the product or service, according to Sauerwein et. al. (1996), is presented in Table 3 and the evaluation of responses to the paired questions is given in Table 4. It is noted that for the given example to the classic model, the category "**skeptic**" is replaced with the category "**questionable**", which allows additionally to identify wrongfully asked questions.

Tabelul 3. **Functional and non-functional questions in Kano's survey**

Functional form of the question *How do you feel if the vehicle does have a good visibility?*	1. I like it in this way 2. It must be in this way 3. I am neutral 4. It is acceptable in this way 5. I don't like it in this way
Non-functional form of the question *How do you feel if the vehicle doesn't have a good visibility?*	1. I like it in this way 2. It must be in this way 3. I am neutral 4. It is acceptable in this way 5. I don't like it in this way

2. KANO TRIDIMENSIONAL MODEL

Juxtaposition of performance parameters respectively of satisfying the users in the 2 axes, created the possibility to define quality in a more sophisticated and holistic way (Ungvári 1999). Linking quality of the 2 axes (Fig. 4), led to 3 unique definitions of quality, namely: *Base Quality* (BC), *Performance Quality* (PQ) and *Excitement Quality* (EQ).

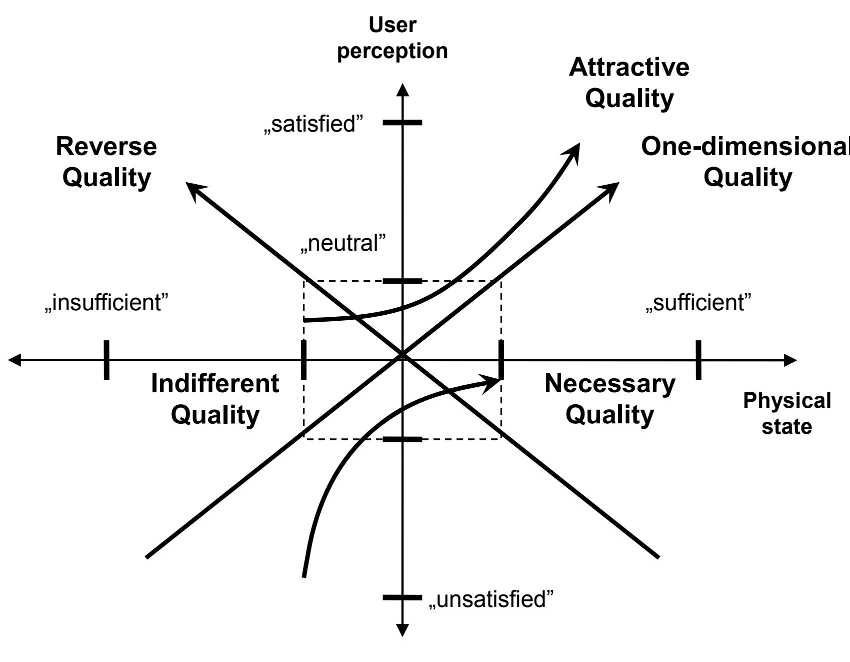

Fig. 3. Kano Model (source: Zultner and Mazur (2006)).

Table 4. **Evaluation mode of the paired questions answers**

Customer requirements		Non-functional questions (negative)				
		1.Satisfied	**2. Must be**	**3. Neutral**	**4. Acceptable**	**5. Unsatisfied**
Functional questions	**1. Satisfied**	*Questionable*	*Attractive*	*Attractive*	*Attractive*	*One-dimensional*
	2. Must be	*Reverse*	*Indifferent*	*Indifferent*	*Indifferent*	*Must be*
	3. Neutral	*Reverse*	*Indifferent*	*Indifferent*	*Indifferent*	*Must be*
	4. Acceptable	*Reverse*	*Indifferent*	*Indifferent*	*Indifferent*	*Must be*
	5. Unsatisfied	*Reverse*	*Reverse*	*Reverse*	*Reverse*	*Questionable*

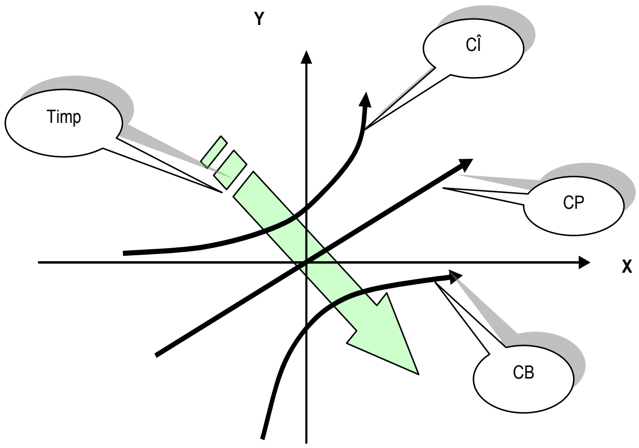

Fig. 4. Kano's Model for defining quality i.

Basic Quality dynamics (BQ) indicates that if the requirements of customers are not satisfied then creates major dissatisfactions and if they are met then create effects limited only to their satisfaction. Failure to fulfill the Basic Quality is expressed through the complaints of customers and complaints. In the industry, the "measure" for basic quality can be expressed through customer complaints, warranty data, service data etc.

A second type of requirements of customers' satisfaction generates satisfaction proportionally to the product or service performance. Attributes of Performance Quality (PQ) causes generally a linear response, high degrees of satisfaction being caused by high degrees of fulfillment. Customers express their desires freely relative to quality performance, this type of information being called "Voice of the Customer" (VOC), because those are things that the customer wishes to speak about. In general one can say that as the performance is better, the satisfaction is greater.

The third type of quality generates positive satisfaction at every level of execution. Excitement is generated by the fact that the customer receives certain items which it has not expected, required or thought about. In general, customers do not define the elements of delight in the questionnaires because they do not know that they want them. To generate excitement and customer loyalty to the brand, companies must use creative resources to identify ideas and possibilities for innovation. The Excitement Quality (EQ) becomes the main reason why customers make from a particular organization, the basic choice in relation to competition. The excitement elements causes an exponential response, small improvements in providing elements of excitement and their accumulation is causing increases in satisfaction of customers.

Quality dynamic shows that customers' requirements are changing over time (Fig. 4). Sources of excitement tend to be "expected" as the market becomes saturated and familiar with them. The excitement element becomes one of performance and possible, in time, a basic one.

One of the laws of systems evolution is the *Law of Dynamicity* which says that a system will become more flexible and dynamic over time (even Kano model is such an example). *Law of transition to supersystems* (MONO-BI-POLI) says that the *monosystems* will be combined with other *monosystems* to form *bi-systems*. Combining quality, as expressed in the Kano model, with the synergistic effect of TRIZ and Taguchi Method in a tridimensional model (Fig. 5) comply with this law. The advantage of a *bi-system* is that it provides a functionality and efficiency with a consumption of resources lower than the *monosystems* separate. As Kano model is composed of 3 elements (BQ, PQ, EQ), TRIZ +Taguchi interface is composed of 3 independent but complementary subsets: 1) AFD + FMEA, 2) Classical means of TRIZ + Taguchi and 3) DE.

2.1. Basic quality (BQ) and AFD + FMEA

The Basic Quality addresses to the functions which are "asked" by the customer while albeit they are "unspoken until violated". This seems contradictory but in reality BQ is considered to be so obvious that its nomination is considered redundant. *If BQ is present, then the customer is neutral*.

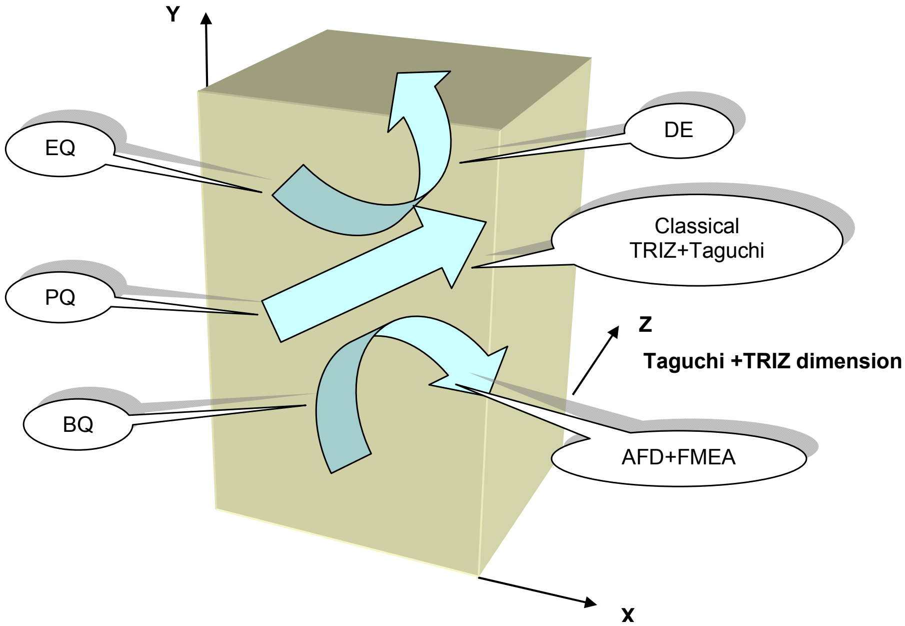

Fig. 5. The tridimensional model of quality.

Traditional methods of indicating of failures, FTA-Fault Tree Analysis, HAZOP-Hazards and Operations Analysis, and in particular FMEA-Failure Mode and Effect Analysis used in the Taguchi method, are constructed to answer the question "*What can go wrong*?". The problem is that this approach follows traditional failures scenarios that lack structural validity because they are subject to psychological inertia. A designer will explore the situation only from his point of view, this constraint limiting failures analysis only to a certain region of the total available failures space. Whereas, AFD - Anticipatory Failure Determination, reverses the question asking "*How can the system be destroyed*?" There are two major benefits resulting from the "reversed problem", namely on the one hand a new perspective on the system and on the other hand, TRIZ techniques can be used. *The combination of AFD and FMEA adds a new dimension to CB through the mode of approaching the problems and synergistic effect of the techniques provided by TRIZ and Taguchi methods.*

2.2. Performance Quality (PQ) and Taguchi + TRIZ

Performance Quality is characterized by the ability to achieve desired levels of fulfillment. *If PQ is absent, then the customer will be dissatisfied and vice versa.* Given the linear nature of PQ, it is clear that achieving higher levels of performance in particular in an efficient way in terms of costs (Taguchi's quality loss function) creates differentiation between product ensuring competitive advantages. Understanding the way to overcome barriers to increased performance at low costs is the key to overcome competition. On the other hand, products performance is limited by the conflicts inherent in the system. Typical conflicts, called in TRIZ terms *contradictions*, can be solved by synergistic effect of TRIZ and Taguchi methods. *Combining Taguchi's quality loss function with synergistic effect of TRIZ and Taguchi methods in approaching and solving contradictions within the system, adds a new dimension CP.*

2.3. Calitatea de încântare (CÎ) şi ED

Excitement Quality addresses to "dormant" or unfulfilled customers' needs. TRIZ interface for creating the third dimension is DE - Directed Evolution, which is the last stage of the "Technological Forecasting" which is based on "The Laws of Technological Evolution". These laws describe the natural progression of products (S curves) and were completed with "Lines of Evolution" that allow organizations to "see" possible future derivative products. These products may be natural or may be "directed" to appear as part of organization strategy of development new products. *If EQ is absent, the customer will be neutral or it will not be dissatisfied. If it is present and properly implemented, the customer will be delighted.*

➢ BQ and PQ are not elements. An element is a particular solution or a way to satisfy a requirement.

➢ A *basic requirement* represents the substrata for an element. The customer requires a particular benefit and not necessarily the particular mode in which this is offered.

➢ The way to find information about what the customer expects in terms of performance requirements is by asking "Why?". Thus is determined the element (elements) that the customer asks for through the *basic requirement*. Once obtained, the *performance requirements*, can be classified then as BQ, PQ or EQ.

3. QUALITY LOSS FUNCTIONS BASED ON KANO MODEL

"Quality Loss Function" is one of the major contributions brought by Genichi Taguchi (Alexis 1999). Speaking in simple terms, „The Quality Loss Function" is a way to show how each defective product is resulting in a loss for the individual, firm, company. Dr. Edwards W. Deming (1982), page 141 states that: "A minimum loss to nominal value and an eternal increase of the loss with remoteness in both directions. Genichi Taguchi defines quality as a feature that avoids the loss of money both for the manufacturer during the manufacturing process and, for the user and the overall society.

Taguchi Quality Loss Function. According to the concept of Genichi Taguchi (Fig. 6), the loss occurs not only if the product quality characteristic is outside the specified limits but also when is inside them.

It is obvious that the difference between a P_1, declared acceptable (good) at the lower limit of tolerance and a P_2, declared unacceptable (rejected) to the same limit is insignificant. The difference is more important between the P_1 and a P_3, also declared acceptable, but being at the upper limit of tolerance. The best product is P_0 which is exactly at the specified nominal value (target). In other words, this approach is different from what is called *defective fraction*, which implies that all products are within specified limits of tolerance are alike good (not defective), while if they are outside these limits are considered *equally defective*. In reality, only products whose responses are exactly on the target provide the best performance, as the response deviates more from the target it becomes "worse" progressively. It follows that minimizing the quality loss is not the fixing of good/bad limits but in reducing variations in relation to the nominal values (target).

Quality loss function, as loss induced to the society because of the characteristic deviation from its target value, aims to quantify the economic consequences of variations in relation to prescribed values. Mathematical expression of the quality loss function differs depending on the types of quality criteria to be optimized: target criterion (optimum is the nominal value), the criterion to be minimized (the lower the better) and criterion to be maximized (the higher the better).

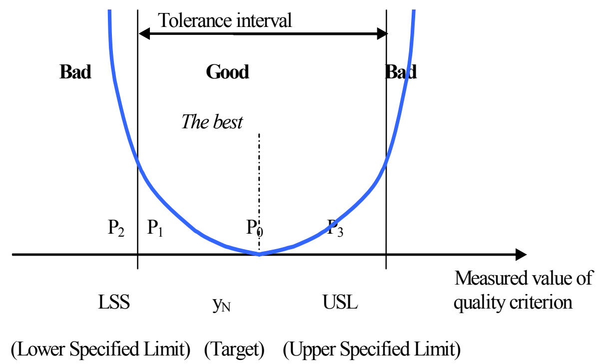

Fig. 6. Quality Loss Function concept.

Mathematical expression of Taguchi quadratic loss function. A technical definition of the Taguchi loss function is given by William Duncan "*A parabolic representation which considers loss expressed in monetary units resulting when the quality characteristic deviates from the target, the cost of this deviation increasing quadratic as the characteristic departs more and more from the target value*".

It notes with Y a characteristic that has value target y_N. A continuous symmetrical quadratic loss function is presented in Fig. 7 and which is in fact a simplifying assumption of Genichi Taguchi that loss is proportional to the square characteristic deviation with respect to the fixed value.

As noted in the figure, quality loss denoted by $L(y)$ is equal to 0 when the quality characteristic is exactly on target ($Y = y_N$), quality loss increases as the quality characteristic departs from the target in both directions. An each limit of tolerance (specification), quality loss is equal to A (M.U.), deviation of Y from y_N in any direction being therefore considered undesirable. In the general case, it is considered that for the quality characteristic Y, the loss function L(y) represents the monetary value of loss induced to an arbitrary customer by a product unit. For approximately determination of this function, the function evaluated in y_N is developed in Taylor series function evaluated y_N up to terms of order II, the terms higher order being neglected, according to relation (1.1).

$$L(y) = L(y_N + y - y_N) = \\ = L(y_N) + \frac{L'(y_N)}{1!}(y - y_N) + \frac{L''(y_N)}{2!}(y - y_N)^2 + \ldots \quad (1.1)$$

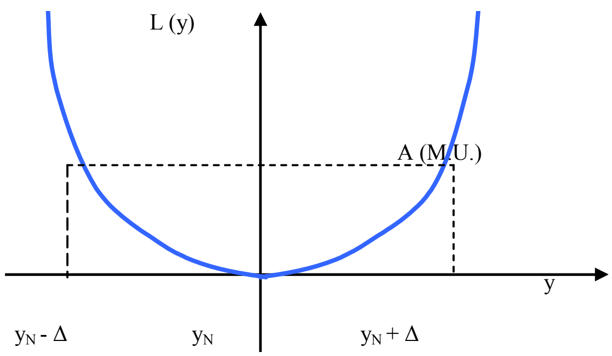

Fig. 7. Continuous symmetrical quadratic loss function.

It is noted that $L(y_N) = 0$, and because the minimum value o the function is at y_N, the first derivative of the function evaluated at this point is equal to 0, i.e. $L'(y_N) = 0$. Then relation (1.1) can be rewritten as (1.2).

$$L(y) = \frac{L''(y_N)}{2!}(y - y_N)^2 = k(y - y_N)^2 \quad (1.2)$$

where k is a constant named *coefficient of quality loss.*

It is oobvious that the quality characteristic Y varies from unit to unit and also in time and is practical to represent variation by a probability distribution function. It is assumed that the probability density function of Y is $f(y)$. Given the quality loss function $L(y)$ and probability density function $f(Y)$, the expected loss can be written in general form (1.3).

$$E[L(y)] = \int_{-\infty}^{+\infty} L(y) \cdot f(y)\mathrm{d}y \quad (1.3)$$

In quadratic loss function case, $L(y)$ from equation (1.2) can be directly substituted in equation (1.3).

$$E[L(y)] = \int_{-\infty}^{+\infty} k(y - y_N)^2 f(y)\mathrm{d}y = \\ = k\left[\sigma_y^{\ 2} + (\mu_y - y_N)^2\right] \quad (1.4)$$

where μ_y şi $\sigma_y^{\ 2}$ are mean and variance of Y respectively.

Taguchi quadratic quality loss function in target criteria case. It is applied to characteristics which have a specified nominal value, the target criterion being exactly the nominal value. The mathematical expression for a single product case is:

$$L(y) = k(y - y_N)^2 \quad (1.5)$$

where: $L(y)$ is the unitary loss value expressed in monetary units; y – measured quality characteristic value; y_N – specified nominal value (target value); k – constant for quantifying financial losses.

In order to evaluate the average quality for a product batch, average of $(y_i - y_N)^2$ can be used, named also MSD (mean square deviation), obtaining finally the expression of quality loss function for a product batch given in relation (1.6)

$$L(y) = k\left[\sigma^2 + (m - y_N)^2\right] \quad (1.6)$$

If considered a sample of n products upon which the measurements are being taken, then the estimated value of the mean $\bar{y}$ and standard deviation s are used, resulting for quality loss function relation (1.7).

$$L(y) = k\left[s^2 + (\bar{y} - y_N)^2\right] \quad (1.7)$$

Taguchi quadratic quality loss function in criteria to be minimized case. It is applied to characteristics having the nominal value equal to este zero ($y_N = 0$), criterion to be minimized being: *smaller the better*. Quality loss function is:

$L(y) = ky^2$ – for a single product; (1.8)

$L(y) = k(s^2 + \bar{y}^2)$ – for a batch of products. (1.9)

Graphical representation of quality loss function in criteria to be minimized is a half of parabola, as presented in Fig. 8.

Taguchi quadratic quality loss function in criteria to be maximized case. It is applied to characteristics having the target value theoretically infinite, criterion to be maximized being: *bigger the better*. Quality loss function is:

$L(y) = \frac{1}{y^2}$ – for a single product; (1.10)

$L(y) = k\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^{\ 2}}$ – for a batch of products. (1.11).

Becase relation (1.11) is relatively difficult to utilizet, for average quality evaluation of a product batch mean of $\frac{1}{y_i^{\ 2}}$ is utilized, named also MSD (mean square deviation).

Quality loss function for a product batch, in criteria to be maximized case, is given in relation (1.12).

$$L(y)=k\frac{1}{m^2}\left[1+3\frac{\sigma^2}{m^2}\right] \qquad (1.12)$$

If m and σ are repalced with their estimations $\bar{y}$ and s, relation (1.13) is obtained:

$$L(y)=k\frac{1}{\bar{y}^2}\left[1+3\frac{s^2}{\bar{y}^2}\right] \qquad (1.13)$$

Graphical representation of the quality loss function for the criteria to be maximized is a hyperbola as in Fig. 9. Criterion is more sensitive to the mean value than to the dispersion of measured values average and it is preferable to obtain an average value as big as possible even if standard deviation is larger than vice versa. As noted above, the quality loss function (QLF) is a mechanism to assess quality on a monetary scale when the product (process) deviates from a target value identified by the customer. A desired quality characteristic has a nonnegative value loss (Teeravaraprug 2002) and the loss is minimal compared to the target identified by the customer (even zero). Then it may make the assumption that there is a target value identified by the customer and which is the one by which the customer is "*totally satisfied*", not having reasons to be "*delighted*". According to Kano's model when the client receives performance as expected, it is satisfied and there is no loss for him. Also if the client receives a better performance than expected he is "*delighted*" and there are some benefits for him. It may be said in this case, according to Kano model, that loss may be "*negative*". It may be said that each type of *quality requirement* must be converted into *performance requirement* (Fig.10).

Quality loss function in PQ case. In PQ case, the converted quality performances can be divided in 3 types.

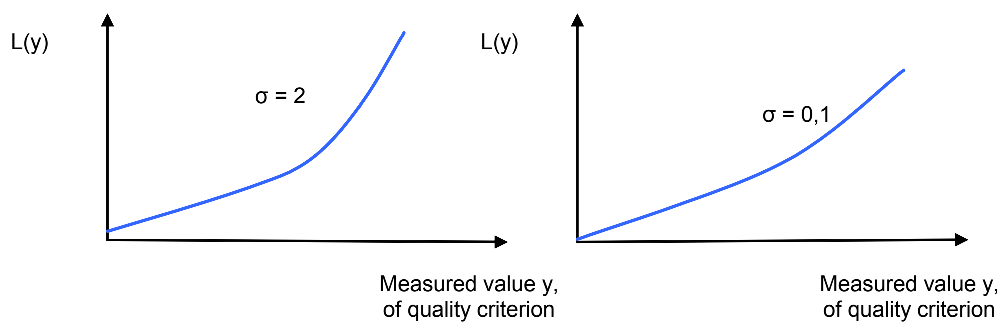

Fig. 8. Quality loss function for a criterion to be minimized.

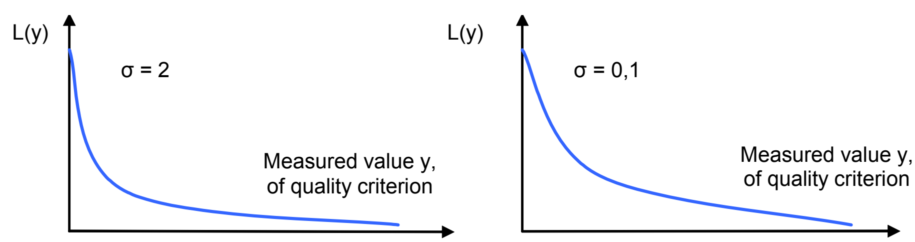

Fig. 9. Quality loss function for a criterion to be maximized.

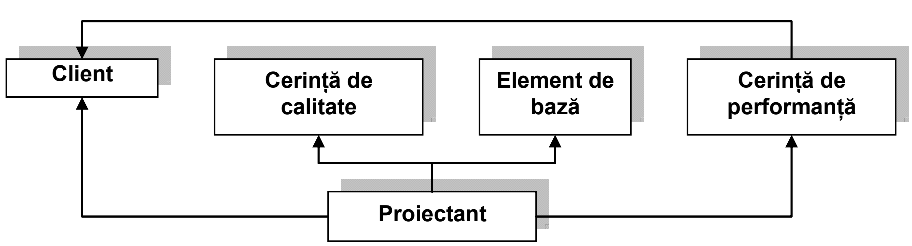

Fig. 10. Conversion of quality requirements into performance rerquirements.

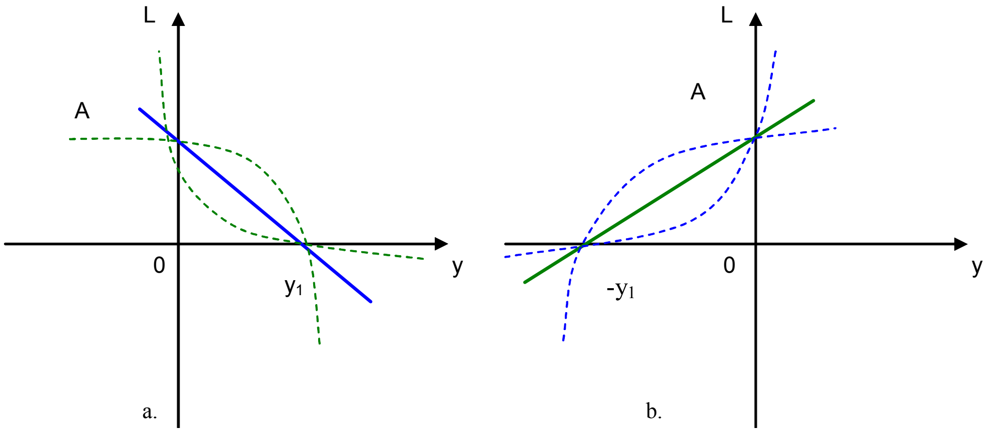

Fig. 11. Quality loss function based on Kano Model in PQ case:
$a - L_{KLTB}$; $b - L_{KSTB}$.

a) ***LTB type ("bigger the better").*** This type LTB, means that the customer wants a large quantity of performance requirements. The ideal performance value is approaching + ∞ and the loss of quality is approaching 0, however the customer having a specific value for which is satisfied. In this case the customer is satisfied when this value is reached and will be delighted if it is exceeded. Based on the concept of Taguchi's quality loss, when the customer is neutral there is no loss, when unsatisfied there is a loss and when delighted the loss will be negative (Fig. 11 a)

b) ***STB type („smaller the better").*** This type, STB, means that the customer is more satisfied as the value decreases. Ideal value is obtained as the performance is approaching - ∞ and the loss is closer to 0. As in the previous case the customer has an expected value and when this value is reached there is no loss for the customer. Based on the concept of Taguchi's quality loss, when the customer is neutral there is no loss, when the performance is greater than the expected value than there is a loss and when performance is less than expected, the customer is delighted and the loss will be negative (Fig. 11 b).

c) ***NTB type („nominal is the best").*** This type NTB, means that the customer has an expected value and at this one yhe loss is 0. When performance deviates from the expected (nominal) value, a loss incurs to the customer. Loss 0 is the lowest loss for the customer (Fig. 12).

Quality loss function in BQ case. As noted previously, BQ is a quality requirement expected to be always present. BQ acts as a "Go – Not go" gauge and therefore whether is present, the customer is neutral and if missing will be dissatisfied. It follows that the loss will occur only if the BQ is missing, loss being equal to 0 in the presence of BQ (Fig. 13).

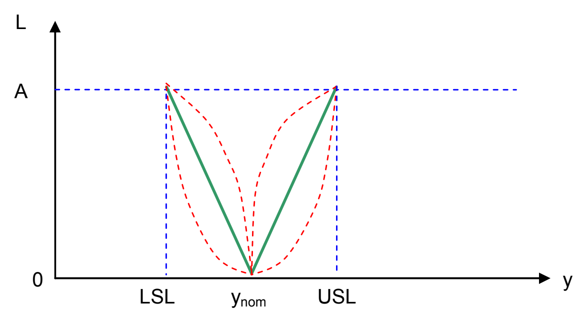

Fig. 12 Quality loss function based on Kano Model in PQ case: L_{NTB}.

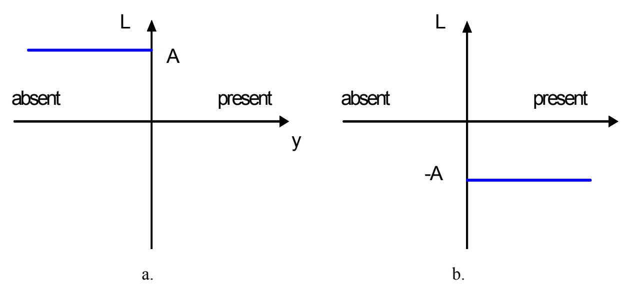

Fig. 13. Quality loss function based on Kano Model in BQ and EQ cases:
$a - L_{KBQ}$; $b - L_{KEQ}$.

Quality loss function in EQ case. And in this case EQ acts as a "Go – Not go" gauge, but in a different manner than in the previous case. If EQ is not present then the customer will be neutral and the loss will be equal to 0 if it is present then the customer will be delighted and the loss is negative (incurs a benefit) (Fig. 13 b).

4. CONCLUSIONS

Combining quality, as expressed in the Kano model, with the synergistic effect of TRIZ and Taguchi methods, leads to a tridimensional model of quality.

The third dimension added to the quality by the synergistic effect of TRIZ and Taguchi methods, allows the exploration, improvement and optimization of technological solutions for each type of quality described by Kano model.

Kano model provides a general class of loss functions similar to Taguchi loss functions for LTB, STB and NTB cases but with greater flexibility.

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