INTEGRATED QUALITY ASSESSMENT OF INVESTMENT

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The process of product evaluation becomes important in case of big investments like purchasing new production equipment by companies. A wide range of product parameters has to be evaluated according to different requirements of different interests groups inside and out the company. Therefore a new methodology of integrated product quality assessment was developed. In this method, all product parameters are divided into different groups based on the requirements and evaluated separately after that. Furthermore, all economical parameters are processed separately within financial simulations including processing of risk variables as well. The outputs of the financial simulations are the expected product value and risk of the investment. Then all even very different parameters are evaluated by specific quality index and an appropriate weight is assigned to them, to calculate the final product quality index. Resulting method can be used for the product selection process as well as for the product benchmarking.

risk management; product assessment, simulation; benchmarking

INTRODUCTION

Growing market requirements put pressure on companies to keep the production equipment in best condition. This is possible only by investing in new production technologies. However, these investments are affecting the company for a long time after its purchasing. High costs and long term aspect of any investment require careful selection of equipment. The selection process starts with definition and settings of requirements on the investment. After that, some alternatives have to be found and evaluated in order to find the best possible solution. Finally the best alternative is voted and realised.

The process of selection is very complicated; basically, there are two different ways of product selection used, one focuses on the financial aspects of purchasing production equipment and the second one focuses primary on technical aspects of the product and evaluates the product quality (L e g á t et. al, 2006).

The economical theories of optimal investment decision use static and dynamic methods for investment evaluation. The static methods (B l o h m et al., 2006; G ö t z e , 2006) evaluate investment according to average values as average costs or incomes, based on some average period of the product life. On the other hand, the dynamic methods concern the whole product life (H a b e r s t o c k , D e l l m a n n , 1971; K e r n , 1974; H a x , 1993; S c h n e i d e r , 1992; B l o h m et al., 2006; G ö t z e , 2006) and discount e.g. the incomes of whole product life time. This results in Nett Present Value (NPV) describing today's product value. Another type of dynamic method is the internal income method but H a b e r s t o c k and D e l l m a n n (1971) demonstrated that this method can be confusing under specific conditions.

Another method concerns the product quality. G a r v i n (1984) defined five major approaches to the definition of the quality: (1) the transcendent approach of philosophy, (2) the product-based approach of economics, (3) the user-based approach of economics, marketing and operations management; and (4) the manufacturing-based and value-based approach of operations management. Regarding to the product selection process, the user-based theory is closest to the customer evaluation. This theory defines that individual consumers are assumed to have different wants or needs, and those goods best satisfying their preferences are those having the higher quality (E d w a r d s , 1968).

Eight dimensions can be identified as a framework for thinking about the basic elements of product quality: performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality. Each of the approaches focuses implicitly of a different dimension of quality: the product-based approach focuses on performance, features and durability, the user-based approach focuses on aesthetics and perceived quality, and the manufacturing based approach focuses on conformance and reliability. However, the economical part is not considered here.

The aim of this study was to develop methodology of the integrated product quality assessment enabling processing of the customers requirements compared to the product features to get an integrated product quality index based on both- economical and technical aspects.

MATERIALS AND METHODS

The quality is defined as satisfaction of the customer preferences by the product features.

$$Quality = \frac{features}{preferences} \tag{1}$$

Therefore, the quality index is lower than one, when the preferences exceed the product features and higher than one, when the product features exceed customer requirements. Ideally, the index has to be equal to one, if the product features conform to the customer's preferences.

This relation is valid only when the relationship is linear. In reality, the relation can be more precisely represented by an exponential function. For the methodology, the product parameters are divided into (1) measurable and (2) non-measurable parameters.

Measurable parameters

Measurable parameters are further subdivided in:

(a) Optimal parameters i.e. any deviation of parameter and a given preference is unwanted. The quality index of optimal parameters is defined as:

$$Q_i = e^{-\left|\frac{P_i - P_o}{P_o}\right|} \quad (2)$$

where Q_i is the quality index of the parameter, P_i is real parameter value and P_o is the required value of the optimal parameter.

(b) Limited parameters i.e. parameters can be worse or better than required. The quality index of optimal parameters is defined as:

$$Q_i = e^{\pm\frac{P_i - P_m}{P_m}} \quad (3)$$

where P_m is the required value of limited parameter.

Non-measurable parameters

Non-measurable parameters have to be evaluated by experts only. The final quality index of such parameters is an average value of indexes given to the parameter by different experts. It is defined as:

$$Q_i = \frac{1}{n}\sum_{j=1}^{n} Q_{ij} \quad (4)$$

where Q_{ij} is a quality index of parameter-i, determined by the expert-j.

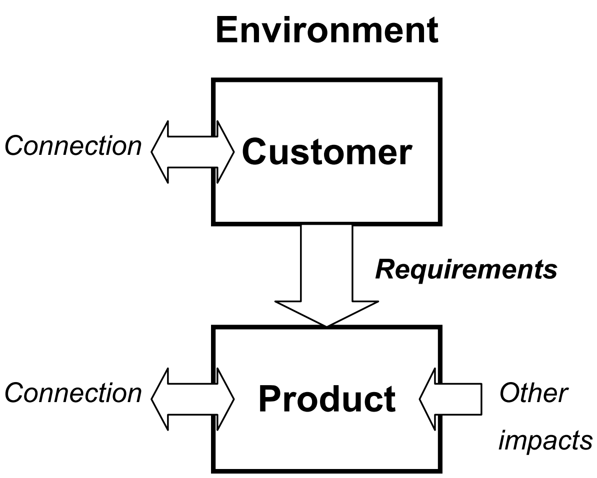

Fig. 1. Relation between the product and environment

Total product quality index

The total product quality index Q_t can be now calculated as follows:

$$Q_T = \frac{1}{n}\sum_{i=1}^{n} Q_i \quad (5)$$

This equation is valid only if all parameters are comparable. In reality, the importance of each parameter differs. Therefore specific weight of each parameter has to be assigned. Parameter weight can be either defined directly by the experts or indirectly by comparing every two parameters separately. When the weight M of each parameter is defined, the quality index equation becomes:

$$Q_T = \frac{\sum_{i=1}^{k} M_i}{\sum_{i=1}^{k} \frac{M_i}{Q_i}} \quad (6)$$

As could be seen in this definition, the quality of the product is not specified only by the product features; however it is defined mostly by the environment where the product is evaluated. The environment affects not only the requirements of the customer, however the product features as e.g. service availability as well. Therefore, the product quality index is not constant and objective value, but differs depending on the environment and customer preferences. Fig. 1 shows the relation between the product and environment.

There are seven different dimensions of quality determined for the quality assessment, which have to be evaluated separately. Each of these dimensions is specified by different parameters. Therefore the evaluation methods differ, too. Following dimensions are defined:

1. Financial incomes and expenditures
2. Performance and features
3. Reliability
4. Conformance
5. Durability
6. Serviceability
7. Aesthetics and perceived quality

Financial incomes and expenditures

The main goal of each company by purchasing of any investment is to secure or even enhance the economical profit. In this aspect the financial evaluation becomes most important in the process of quality assessment. The investment cash flow can be calculated as follows:

$$cf = (c_t - m_t - mat_t).x_t - o_t \quad (7)$$

Where the cash flow cf is calculated as the product income per product (i.e. product price c_t in a time period t reduced by personal m and material costs mat) is multiplied by the amount of sold products x and reduced by "other" costs o.

To simplify the financial calculations, one interest tariff i for credit and deposit is used. Then, based on the Fischer separation (F i s c h e r , 1930) the economic goals of the company (maximising of incomes and maximising of residual value) can be considered as equivalent. Finally, to compare expected company profit, net present value (NPV) is used. For the non-linear interest tariff, the NPV can be calculated as follows:

$$NPV = \sum_{t=0}^{T} cf_t \prod_{\tau=0}^{t} \left(1 + i_{\tau-1,\tau}\right)^{-1} \quad (8)$$

The input variables are the problem of this calculation. The NPV is calculated based on the future alias unsafe parameters. To reduce the risk of the calculation, the method of risk management is used. So, the expected distribution of NPV is calculated using computational simulations (H e r z , 1964). In this method, for each unsafe variable a range of values is generated from estimated values of this variable and its distribution. Then, based on the random values generated before, the NPV distribution is simulated. The mean value of this distribution defines the expected value of NPV and the mean deviation of the distribution defines the risk of the investment. Finally, the NPV calculation becomes:

$$NPV_R = \sum_{t=0}^{T} E\left(\tilde{P}\right)_t \prod_{\tau=0}^{t} \left(1 + i_{\tau-1,\tau}\right)^{-1} \quad (9)$$

where NPV_R is the expected net present value and $E(P)$ is the cash flow simulated using generated random values.

Performance and features

The design defines the product performance and features. The performance refers to the primary operating characteristics of a product and features as secondary characteristics supplement the product's basic functioning. These dimensions of quality combine elements of product and user-based approaches (Garvin, 1984). Measurable product attributes are involved, and products can usually be ranked objectively on at least one dimension of performance. The performance of the product would correspond to its objective characteristics, while the relationship between performance and quality would reflect individual reactions. The features and performance are mostly measurable variables, so they can be evaluated using equations 2 and 3.

Reliability

Reliability reflects the probability of a product's failing within a specified period of time. Among the most common measures of reliability are the mean time to first failure (MTFF), the mean time between failures (MTBF), and the failure rate per unit time. Because these measures require a product to be in use for some period, they are more relevant to durable goods than they are to products and services that are consumed instantly. Other possibility to measure the product reliability is the comparison within the financial simulations. This idea is based on the fact, that all product failures are affecting the costs. Therefore, the estimated failures can be simulated as costs within the cash flow calculation. For this purpose, the failures have been subdivided into three groups on (1) small, (2) middle and (3) big failures. Where the big failures occur sporadic and are distinguished by very high costs caused by requirement of external service and expensive spare parts. On the other side, the small failures occur often and are mostly removed directly by the staff. In the methodology, reliability is evaluated as risk costs within the financial calculations.

Conformance

The product conformance is the degree, to which a product's design and operating characteristics match preestablished standards. Within the factory, conformance is commonly measured by the incidence of defects: the proportion of all units that fail to meet specifications, and so require rework or repair. In the field, data on conformance are often difficult to obtain and proxies are frequently used. Two common measures are the incidence of service calls for a product and the frequency of repairs under warranty. These measures, while suggestive, neglect other deviations from standard, such as misspelled labels or shoddy construction that do not lead to service or repair. Therefore, the conformance deviations with an impact on product failure are evaluated in terms of reliability as product costs within the financial calculations as mentioned above and the other parameters as perceived quality, which will be discussed later.

Durability

Durability as a measure of product life has both economic and technical dimensions. Technically, durability can be defined as the amount of use one gets from a product before it physically deteriorates. For two-stage products, where the repair is impossible, product is used under constant conditions until its physical life. When repair is possible, durability becomes more difficult to interpret. Then the concept takes on an added dimension, for product life will vary with changing economic conditions. Each time a product fails, customer has two choices. He has weight the expected costs of future repairs against the investment and operating expenses of a newer model. In these circumstances, a product's life is determined by repair costs. In terms of presented methodology, durability affects primary the product costs and is considered within financial simulations as time-variable.

Serviceability

The speed, courtesy, and competence of repair are called serviceability. Customer concerns not only about product breaking down, but also about the elapsed time before service is restored. The timelines, with which serv-

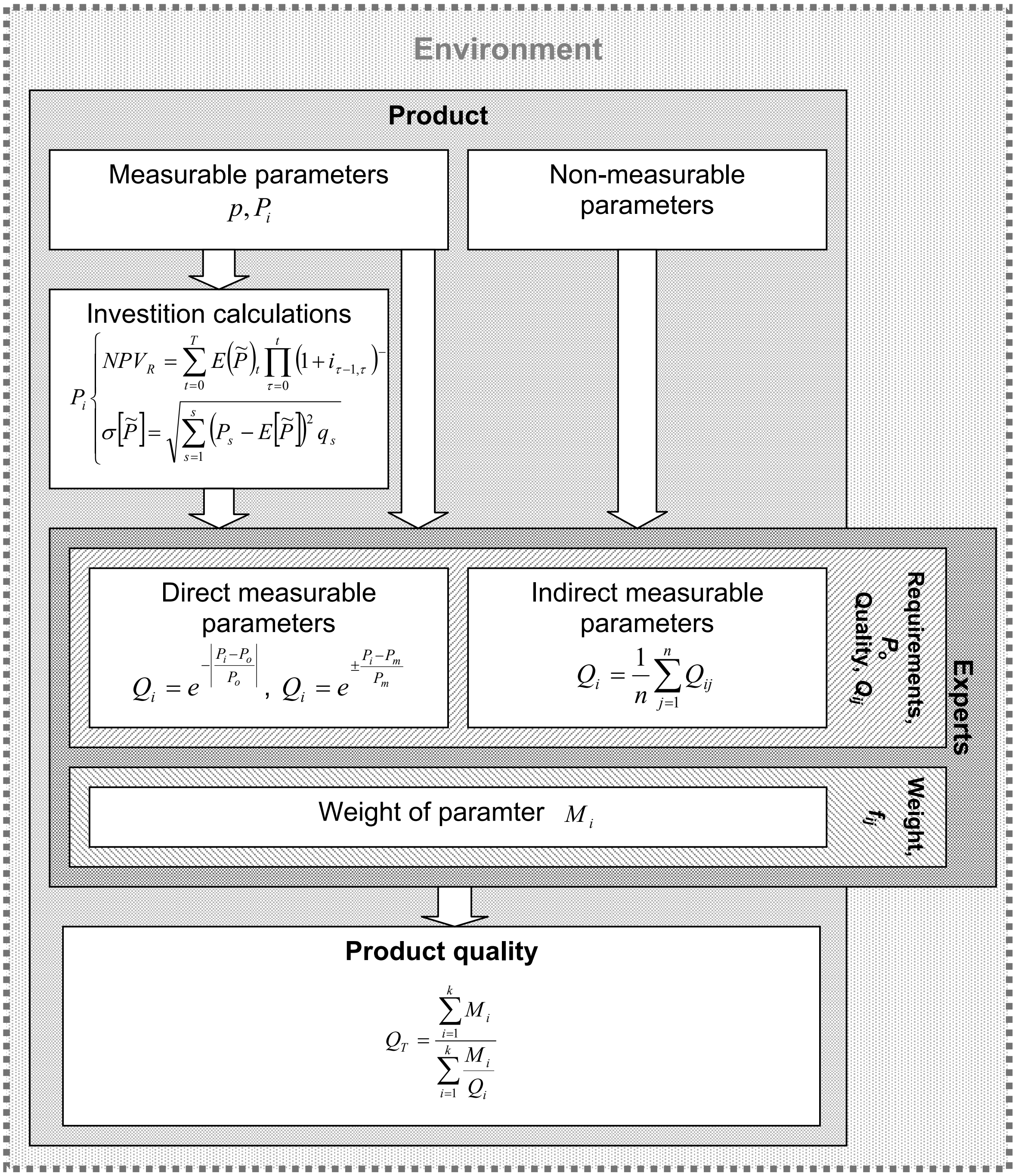

Fig. 2. Methodology of the integrated product quality assessment

ice appointments are kept, the nature of their dealings with service personnel, and the frequency, with which service calls or repairs rail to resolve outstanding problems can by partially measured quite objectively, others reflect differing personal standard of what constitutes acceptable service. Serviceability of the product is given by three aspects: the product design, the preventive maintenance system and the maintenance after failure. Product features as diagnostics or availability of lubrication places are given in the design stage. So they can be evaluated as features alias measurable or non-measurable parameters (Eq. 2–4). The preventive maintenance can be planned and affect first of all the costs. Therefore, the impact of preventive maintenance is evaluated within the financial simulations. Finally the maintenance after failure has two dimensions; one meets the costs and was discussed within reliability, second dimension is the communication with the service department of the producer and has to be evaluated as a non-measurable product parameter (Eq. 4)

Aesthetics and perceived quality

The final two dimensions of quality are the most subjective. Both aesthetics and perceived quality are closely related to the user-based approach. In these circumstances, products are evaluated less on their objective characteristics than on their images, advertising and personal feelings. These dimensions have evaluated as non-measurable parameters (Eq. 4) in term of the quality assessment.

RESULTS AND DISCUSION

The process of integrated product quality assessment occurs in the following steps:

1. Determination of product requirements
2. Collecting of product parameters and input values
3. Financial simulations
4. Setting of quality indexes for each parameter
   a) Evaluation of each parameter based on the requirements
   b) Assigning of weight to each parameter
5. Calculating of total product quality index

In the first step, the product requirements are determined by the company. These are the fundamental for the product evaluation. In the next step, the product parameters are collected. The source is either the producer of the product, the company's internal sources and or the company's environment. As written above, environment determines the product features directly and indirectly (e.g. service availability) as well as the company's requirements. Financial simulations are an important part of the quality definition. The simulations put together all economic variables, affecting incomes and expenditures meeting the product, and transform them into (a) expected net present value and (b) expected risk of the investment. These two parameters are finally evaluated like other measurable parameters; however their weight should be very high. Furthermore, financial simulations include the variables evaluating product durability. All described methods provide very objective results; however the quality index of non-measurable parameters as well as weight assigned to each parameter are set individually by experts and makes the method and the final result very subjective.

If the company requirements in this method will be subset by best possible parameters of competitive products, this method can serve for benchmarking of products as well. Fig. 2 shows schematically the process of the integrated product quality assessment.

CONCLUSION

The process of product evaluation becomes on importance in case of big investments like purchasing new production equipment by companies. A wide range of product parameters has to be evaluated according to different requirements of different interests groups inside and out the company. Therefore, a new methodology of integrated product quality assessment was developed. In this method, all product parameters are divided into separate groups based on the requirements and evaluated separately after that. Furthermore, all economical parameters are processed separately within financial simulations including processing of risk variables as well. The outputs of the financial simulations are the expected product value and risk of the investment. Then all even very different parameters are evaluated by specific quality index and an appropriate weight is assigned to them, to calculate the final product quality index. Resulting method can be used for the product selection process as well as for the product benchmarking. However, this method offers always a subjective result, given by the requirements on one site and by the individual evaluation and parameter weight setting on the other site.

The method presented in this paper enables exact processing of all inputs; however it can not secure the best solution to its user. Then the final decision about purchasing of the investment will be always an individual decision of responsible persons.

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Výběr a pořízení nových výrobních zařízení v podniku je spojen s velkým výdajem finančních prostředků a ovlivňuje podnik po dlouhou dobu. Z tohoto důvodu je třeba při výběru takových zařízení postupovat velmi pečlivě. Především je nutné si uvědomit, že na výběr takovýchto zařízení je kladena celá řada nároků a požadavků nejen ze strany podniku, ale i z vnějšího prostředí, jako je legislativa, bezpečnost práce či ochrana životního prostředí. Metodika integrovaného hodnocení jakosti produktu popsaná v tomto článku umožňuje podrobné zpracování řady požadavků na investiční celek na straně jedné a parametrů produktu na straně druhé do jednoho konečného indexu jakosti. Metodika nejprve rozděluje hodnocené proměnné do skupin, v jejichž rámci jsou jednotlivé parametry hodnoceny samostatně. Na základě váhy určující důležitost jednotlivých parametrů jsou tyto na závěr integrovány do jednoho souhrnného ukazatele jakosti. Nově navrhovaná metodika využívá především finančních simulací ke zpracování příjmů a výdajů z investice a vyhodnocení rizika, vyplývajícího z dlouhodobosti investice. V rámci této metody jsou nejprve určeny nejisté příjmy a výdaje, pro které jsou určeny očekávané budoucí hodnoty a pravděpodobnost výskytu těchto hodnot. Na základě těchto údajů jsou vygenerovány proměnné hodnoty, které jsou následně využity při finančních simulacích. Tímto způsobem je vytvořena řada očekávaných příjmů a čistá současná hodnota investice. Na základě rozdělení jednotlivých výsledků je určena průměrná hodnota, představující příjem z investice s nejvyšší pravděpodobností výskytu a dále směrodatná odchylka souboru, určující rizikovost investice. Tyto hodnoty jsou zpracovány spolu s ostatními parametry. Navržená metodika tak představuje nástroj pro komplexní zpracování údajů o jakosti investičního celku do formy doporučení, které slouží v procesu výběru při pořízení investičního celku.

pořízení investic; management rizik; investiční výpočty; benchmarking

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