MŰEGYETEM 1782

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Modeling Reliability of Business Processes

Theses of PhD dissertation

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Budapest, 2010

Contents

1. Scientific background and objectives of researches

Understanding the processes related to operations of enterprises is a key to their competitiveness. Nowadays, the continuous and conscious maximization of efficiency of operational processes is a basic requirement in the business world. Our expectation towards the resources of a company is that they serve the company with their best efficiency.

The resources of an enterprise are the "engines" of its processes, and so by improving the goodness and reliability of resources yields better and more reliable processes. In order to improve the processes we need to consider them in a broad sense, thus we need to take into account not only the core manufacturing or service processes, but the processes related to support activities as well. All those processes – including the support ones too – that contribute to the output of an enterprise, we consider as business processes. With other words, the concept of *business processes* includes both the core operational (manufacturing or service) and support processes.

In most of the cases, the goodness characteristics of the core operational processes can be quantified by using methods of mathematics, physics, chemistry and technological sciences. Contrary to this, quantification of goodness or reliability of business processes is much more difficult, as those are much influenced by various "soft" factors. Good examples for such processes are the human performance evaluation, the customer satisfaction evaluation, or the valuation of a company's intellectual capital. These examples illustrate well how difficult is the quantification of goodness and reliability of such processes but on the other hand, we need to handle and manage the "soft" factors as well.

Focus of my researches is on the interpretation, measurement and evaluation of goodness and reliability of business processes impacted by "soft" factors. Starting point of my investigations is that the goodness or reliability of business processes is measured and expressed by artificial *indices*.

In my dissertation, I study how much the traditional index-based measurement methods (scorecard methods) are able to reflect the perceptions of an enterprise on the goodness and reliability of its business processes, and what are the causes of the observable differences between the perceptions and the reflections by the measured indices. I introduce the application of novel quantitative methods that render it possible to adequately express the goodness and reliability of index-based measured business processes.

Chapter 2 of my theses introduces the traditional concept and definitions of reliability (Gnyegyenko et al., 1970; Balogh et al., 1980:277; Gaál és Kovács, 2000) as well as it shortly discusses the fundamental questions of reliability as a fuzzy concept in the technical reliability theory (Kai-Yuan Cai, 1996). After this, I summarize the conclusions of the studies I made on the index-based measurement methods of business process reliability, and I introduce the concept of *reliability based evaluation*. The essence of the reliability based evaluations is that these methods result in numerical results which express the perceptions of the evaluator entity on the business process reliability much better than the measured values of the corresponding indices themselves. I point it out that the evaluation of business process reliability based on the traditional set theory does not harmonize with the rationality of everyday's business practice. Using the fuzzy set theory, I introduce the interpretation of *reliable business processes as fuzzy sets*. I consider the membership functions, which define these fuzzy sets, as *evaluator functions that transform the index-based measurement results from the measurement scale to the [0,1] evaluation scale*.

After these, I give a short insight into the applications of fuzzy theory in various fields of business sciences such as operations management (Guiffrida and Nagi, 1998), planning of human resources (Guerry, 1999), health system financing (Chernichovsky et al., 2003), project management (Shipley et al. 1996; Wang, 1999), selection of suppliers (Ng et al., 2002), marketing (Varki et al., 2000) preparation of business decisions (Hauszmann, 2006). The books of Ragin (2000), Smithson and Verkuilen (2006), and Zopounidis et al. (2001) give a comprehensive picture of applications of fuzzy theory in social, economic and management sciences.

I study the adequateness of application of the so-called *logistic evaluation* in businesses, and give the constructions of the logistic function (Csaba, 1978; Lewandowski, 1974; Balakrishnan, 1992) and its approximants the $E_{\omega}(m)$ functions (Dombi and Gera, 2005), and describe the *quasi logistic evaluation*. I show how these functions can be used for reliability based evaluation.

The third chapter of my theses summarizes how the theoretical results of Chapter 2 can be applied in practice. I introduce the *calibration methods of the evaluator functions*. These methods are to set the parameters of the logistic and $E_{\omega}(m)$ functions so that they appropriately reflect the perceived business process reliability in the [0,1] evaluation scale. After the introduction of theoretical background of the methods, I study how these methods can be applied to index-based evaluation of human performance, customer satisfaction and organizational intellectual capital. I point it out how the evaluator functions can be interpreted as utility functions, how those can be used to quantify the business utility of measured indices, and furthermore, how the aggregation of these utilities is possible at organizational level by using the *parameter-weighted reliability based aggregation method*. The introduced case studies and their results prove that the evaluation methods, based on the evaluator functions, can model the business process reliability better than just the measured indices themselves. A further example in Chapter 3 of my work demonstrates how fuzzy intervals can be used for evaluation of suppliers' performance.

In the first three chapters of my theses I study the index-based measurement and evaluation methods of business process reliability, and I tacitly consider the indices as ones that are constant in time. In practice, most of the *quality and reliability indices change in time, and these changes are related to the lifecycle of the business process in point*. In Chapter 4, I summarize the results of my studies on the changes of aggregate quality and reliability indices during the introduction phases of manufacturing and service processes. The aggregate approach allows us to interpret the changes of the aggregate indices as a result of the organizational learning of the business process. In this interpretation, the changes of aggregate indices are learning curves determined by technology and operational culture of the enterprise. The introduced models allow us to quantify the determining roles of technology and operational culture, and numerically compare ramp-up curves. The ramp-up curves become comparable based on their parameter sets. The related case studies introduce the applications of the developed methods in practical cases.

2. Research methods

For studying business process reliability and changes of aggregate quality and reliability indices as function of time, I mainly used *quantitative approach*. I endeavored to prove the adequateness of the introduced methods through company case studies.

The index-based business process reliability evaluation methods, *the logistic and quasi logistic evaluations* discussed in Chapter 2 of my theses, *are founded upon my previous researches on the sigmoid functions*. Results of these researches were summarized in my Scientific Students' Association Conference Paper titled "The sigmoid function and its applications" and in my M.Sc. theses titled "Approximations and applications of the logistic function".

In Chapter 3 of my dissertation, I used *data and samples* from real business life to demonstrate through case studies how the introduced methods are applicable in practice. Results of the case studies were verified by *statistical methods* (tests, confidence intervals). By studying the utility theory of economics, I deduced that the evaluator functions can be interpreted as utility functions.

Based on the *literature study* on process ramps, and on the theoretical results from my researches related to the logistic function and its approximations, I worked out the restricted linear logistic regression method and the $R_\omega(t)$ approximation to model the changes of aggregate indices. These studies were supported with industrial data, and based on the data collected, I introduced the following three case studies.

- Change of quality yield during the introduction of a manufacturing process;
- Improvement of the MPU[1] ratio during the ramp up period of a repair process;
- Change of the OEE[2] index in ramp up period of a manufacturing process.

[1] MPU: Minutes Per Unit index that measures the amount of human labour built into one product.

[2] OEE: Overall Equipment Efficiency.

3. Summary of new scientific results

In the followings, I shortly summarize my scientific results, and introduce the theses of my dissertation. The publications related to the theses are referenced based on the numbering used in Chapter 6 of this booklet.

3.1. Interpretation of reliability of business processes

When reliability of business processes needs to be studied, the classic definitions of reliability theory are not, or just hardly applicable. In such cases, under the concept of reliability we mean a kind of goodness, or a performance result compared to a target performance level. In practice, it means that measurable indices that can numerically characterize a process are associated to it, and through these indices the reliability of the process can be measured and evaluated. Measurements of characteristics and attributes – based upon the need for measurability – are widely used tools of the management. First hypothesis (H1) of my researches relates to these measurements.

H1: The index-based measurement methods of business process characteristics usually have such attributes, and are based on such conditions which make the reliability, and goodness of this methods and the interpretation of their results questionable.

In case of measurement of indices, we need to count with the following uncertainties and distortions.

- *Subjective elements of the measurement*;
- *Repeatability and reproducibility problems with the measurement system*;
- *Differences between the measured values and the values perceived by the company's organization.*

In my dissertation, it is discussed that the measured indices themselves are not able to adequately reflect that reliability of business processes which the company's organization perceives. This is summarized in the second hypothesis (H2).

H2: In practice of enterprises, the measurement of business process characteristics in itself is not enough, further evaluation methods are needed that can evaluate the measured figures so that the evaluation results reflect the goodness and reliability of processes perceived by the evaluator entity.

I call these methods *reliability based evaluation methods*. The *evaluator entity* is the person or organization that makes the evaluation. In my work, I evaluate the reliability of a business process based on the next sequence.

1.) Selection of the process characteristic or attribute

2.) Assign an index to the characteristic or attribute

3.) Measure the assigned index

4.) Reliability based evaluation of the measured values of the index

3.2. Fuzzy reliability of business processes

Let m be an index that is used to measure a characteristic or an attribute of a business process. As discussed earlier, usually, there are uncertainties around the measurement of such an index. On the other hand, we *also need to take into account that the human evaluations, due to their nature, are also impacted by uncertainties*. The uncertainty of evaluation can be handled in two ways. The traditional approach is based on the classic set theory methods, while another possible approach is interpreting the reliability as a fuzzy concept.

3.2.1. Traditional approach

Let M be the set of possible values of m. The traditional approach relies on defining a sharp boundary between the reliable and unreliable domains (sets). In this approach the M_R set as set of the reliable processes can be given by its $\mu_{M_R}(m) \rightarrow \{0; 1\}$ characteristic function (Szendrei, 1996):

$$\mu_{M_R}(m) = \begin{cases} 0, & \text{ha } m \notin M_R \\ 1, & \text{ha } m \in M_R \end{cases},$$

where M is the domain of variability of function $\mu_{M_R}(m)$. The range carrier of $\mu_{M_R}(m)$ is the $\{0; 1\}$ set, and $\mu_{M_R}(m)$ has the value of 1, if $m \in M_R$, and it has value of 0, if $m \notin M_R$. The $\{0; 1\}$ set is an *evaluation set* that has two elements, so the membership to the M_R set is sharply defined.

3.2.2. Fuzzy approach

In the business life, we can find at every step qualifying statements such as "reliable supplier", "strategic partner", "business with medium level profit", "efficient production process”, “medium level performance”, or “acceptable profit”. In despite of these classifications are imprecise and superficial, these are broadly used and accepted by everybody. When we try to assign measurable indices to the above mentioned characteristics in order to measure them, we hope for better exactness. This better exactness does not fully come through as our world is basically fuzzy, imprecise, and so *the traditional evaluation based on the characteristic function is too restrictive* (Zimmermann, 2001). Based on the fuzzy approach that arise from the human nature (Kosko, 1993), we tend to quantify the membership to the set of reliable processes not only with the values of 1 and 0, but *with any value from the [0,1] continuous scale so that greater values represent greater membership to the set.*

Zadeh (1965) has introduced the fuzzy sets and the membership functions that define them and doings so has created a better interpretation of information which harmonizes better with the human concepts and languages than the traditional approach that is based on the sharply defined sets.

The $M_R^{(F)}$ fuzzy set of reliable processes defined on the M set according to Retter (2006: 21-23.) is

$$M_R^{(F)} = \left\{\left(m, \mu_{M_R}^{(F)}(m)\right) \middle| m \in M\right\},$$

where

$$\mu_{M_R}^{(F)}: M \to [0,1].$$

The $\mu_{M_R}^{(F)}$ function is the *membership function of the* $M_R^{(F)}$ fuzzy set. It can be considered as a generalization of the

$$\mu_{M_R}: M \to \{0; 1\}$$

characteristic function, which means a transition from the binary evaluation to the evaluation in the $[0,1]$ interval. The $M_R^{(F)}$ fuzzy set consists of $\left(m, \mu_{M_R}^{(F)}(m)\right)$ ordered pairs, and by this means each m element of set M has a $\mu_{M_R}^{(F)}(m) \in [0,1]$ membership to the $M_R^{(F)}$ set.

By interpreting the reliability of business processes as a fuzzy concept, we have a mathematical tool that can be used for expressing the reliability of business processes measured based on indices. Based on these, the third hypothesis (H3) of my researches is as follows.

H3: Interpretation of business process reliability as a fuzzy set renders it possible to evaluate the index-based measured reliability values of these processes so that on one hand we handle the uncertainties of the measurement, and on the other hand the evaluation results are in line with the perceived values of company's organization.

3.3. Evaluator functions

A membership function that defines the set of reliable business processes is an *evaluator function*, too. The evaluator functions are mathematical transformations from the M measurement scale to the $[0,1]$ evaluation scale. A generic E evaluator function over the M set is defined as

$$E: M \to [0,1]$$

$$m \longmapsto E(m).$$

The E evaluator function represents a reliability based evaluation, if it assigns such $E(m)$ value of the $[0,1]$ interval to each value of m that the evaluator entity would assign to the measured value of m. In my dissertation, I introduce constructions of such evaluator functions that can be used for reliability based evaluation of business process reliability. The fourth hypothesis (H4) of my work is as follows.

H4: The logistic function and its approximant, the $E_\omega(m)$ function can be used as evaluator functions that embody reliability based evaluation of business process reliability.

My dissertation discusses how the *concept of logistic evaluation* harmonizes with the rationality of business thinking and with the concept of reliability based evaluation. In case of logistic evaluation the $E(m)$ evaluator function meets the

$$\frac{dE(m)}{dm} = \lambda[1 - E(m)][E(m) - 0]$$

logistic differential equation, where λ is a non-zero coefficient. If $\lambda > 0$, then $E(m)$ is increasing, if $\lambda < 0$, then $E(m)$ is decreasing. Solving the equation considering the

$$E(m_0) := E_{m_0},$$

condition results in

$$E(m) = S_{\lambda,m_0,E_{m_0}}(m) = \frac{1}{1 + \frac{1 - E_{m_0}}{E_{m_0}} e^{-\lambda(m - m_0)}},$$

and introduction of the

$$a = m_0 + \frac{1}{\lambda} \ln \frac{1 - E_{m_0}}{E_{m_0}}$$

substitution results in

$$E(m) = S_{\lambda,a}(m) = \frac{1}{1 + e^{-\lambda(m-a)}}.$$

The $S_{\lambda,m_0,E_{m_0}}(m)$ and $S_{\lambda,a}(m)$ functions are the so-called *logistic functions*. These two functions represent the same evaluation concept with different parameter sets. In my work, from the $S_{\lambda,m_0,E_{m_0}}(m)$ and $S_{\lambda,a}(m)$ *logistic evaluator function* forms, I always use the one that is more suitable for the particular case.

The logistic evaluator function does not carry the values of 0 and 1 on the $[m_S, m_E]$ scale. In my dissertation, I introduce that the

$$E_{\omega,a,m_S,m_E}(m) = \frac{\left(\frac{m - m_S}{m_E - m_S}\right)^{\omega}}{\left(\frac{m - m_S}{m_E - m_S}\right)^{\omega} + \left[\frac{a - m_S}{m_E - a}\left(1 - \frac{m - m_S}{m_E - m_S}\right)\right]^{\omega}},$$

$\left(a \in (m_S, m_E)\right)$, and the

$$E_{\omega,m_0,E_{m_0},m_S,m_E}(m) = \frac{\left(\frac{m - m_S}{m_E - m_S}\right)^{\omega}}{\left(\frac{m - m_S}{m_E - m_S}\right)^{\omega} + \frac{1 - E_{m_0}}{E_{m_0}}\left[\frac{m_0 - m_S}{m_E - m_0}\left(1 - \frac{m - m_S}{m_E - m_S}\right)\right]^{\omega}}$$

$\left(m_0 \in (m_S, m_E), E_{m_0} \in (0,1)\right)$ functions defined over the $[m_S, m_E]$ interval are good approximants of the $S_{\lambda,a}(m)$, and $S_{\lambda,m_0,E_{m_0}}(m)$ functions, if

$$\omega = \frac{\lambda(m_E - a)(a - m_S)}{(m_E - m_S)},$$

and

$$\omega = \frac{\lambda(m_E - m_0)(m_0 - m_S)}{(m_E - m_S)},$$

and $E_{\omega,a,m_S,m_E}(m)$ and $E_{\omega,m_0,E_{m_0},m_S,m_E}(m)$ have the 0 and 1 values in the start- and endpoint of the measurement scale depending on sign of ω.

In Chapter 2 of my dissertation, hypotheses H1, H2, H3 and H4 get verified, and the theoretical research results are summarized in Thesis 1. The $E_\omega(m)$ notation stands for the $E_{\omega,a,m_S,m_E}(m)$ and $E_{\omega,m_0,E_{m_0},m_S,m_E}(m)$ functions that are called *quasi logistic functions*.

3.4. Thesis 1

The uncertainties and distorting effects that appear during index-based characterizations of reliability and goodness of business processes can be handled by the logistic and its approximant $E_\omega(m)$ functions as fuzzy membership and evaluator functions. The membership to the reliable, good sets is definable in fuzzy sense, and the reliability based evaluation of index-based measurements is realizable, and so the consistence of management decisions can be improved.

Publications related to Thesis 1 are: P1, P2, P3, P8, P9, P10.

3.5. Application of evaluator functions

In order to make the logistic or quasi logistic evaluator function adequately reflecting the perceptions of the evaluator entity on the measured values, the evaluator functions need to *be calibrated*.

3.5.1. Calibration of evaluator functions

Calibration of the logistic and $E_\omega(m)$ functions is the adjustment of their parameters in such a way that the evaluation results given by the evaluator functions on the evaluation scale are in line with the values that the evaluator entity would assign to the measured values of the examined index. The fifth hypothesis (H5) of my work summarizes this.

H5: Calibration of logistic and quasi logistic functions results in evaluator functions that make the logistic and quasi logistic type evaluations suitable to reflect on the evaluation scale the evaluator entity's perceptions of the measured index values.

Setting up of parameters of the functions can be done based on two approaches. One possibility is to specify that many points of the function curve as many parameters it has. This is the *analytical approach*. The other way is based on a set of

$$(m_1; E_{m_1}), (m_2; E_{m_2}), \ldots, (m_n; E_{m_n})$$

pairs given by the evaluator entity. Having a sample like this, the parameters of the evaluator function can be determined by application of a *regression method*. This is the *statistical approach*.

3.5.2. Human performance evaluation

In Chapter 3.2. of my work, I introduce how the logistic evaluation can be used for evaluating the index-based measurement of human performance. The starting point of my investigations is the hypothesis 6 (H6) that I verify by a particular case study.

H6: By application of the logistic evaluator function, and by separation of measurement and evaluation, the measured human performance figures can be evaluated so that the evaluation results give a better characterization of the real human performance than just the measured values of the examined index themselves.

3.5.3. Evaluation of customer satisfaction and intellectual capital

I study the application of quasi logistic functions to customer satisfaction and intellectual capital evaluation in Chapter 3.3. of my theses. These studies are based on the H7, H8 and H9 hypotheses.

H7: An appropriately calibrated $E_{\omega}(m)$ evaluator function is suitable to express the perceived customer satisfaction as function of the measured customer satisfaction so that – by mitigating the measurement distortions – it embodies a reliability based customer satisfaction evaluation.

H8: If the $E_{\omega}(m)$ evaluator function is used for customer satisfaction or intellectual capital evaluation, then the function can also be interpreted as a utility function that expresses the utility of the examined customer satisfaction or intellectual capital to the company on the [0,1] evaluation scale. Analogically, logistic evaluation of human performance represents the utility of the measured human performance to the company.

H9: As the [0,1] evaluation scale is used for expressing the utility of each intellectual capital element, and so the utility of each element can be individually determined – independently of the used indices and measurement units – and aggregated into one utility value.

The case study in Chapter 3.3.8 of my work discusses the application of quasi logistic function as utility function to reliability based customer satisfaction and intellectual capital evaluation. This case study and the case study about the human performance evaluation verify the H5, H6 and H7 hypotheses, and based on these, Thesis 2 (T2) of my dissertation is the following.

3.5.4. Thesis 2

The measured values of an aggregate index that characterizes a business process or attribute can be evaluated by application of adequately calibrated logistic and quasi logistic functions – as evaluator functions – and by separation of measurement and evaluation, so that the values assigned to the measured index values by the evaluation result in a better characterization of goodness of the business process or attribute than the measured values of the index itself. The evaluations by the logistic and $E_\omega(m)$ functions can be effectively applied as reliability based evaluations of index-based measurements of human performance, customers satisfaction and organizational intellectual capital.

Publications related to Thesis 2 are: P1, P2, P3, P8.

3.5.5. Utility point of view and aggregate evaluation

In Chapter 3.3.6. of my work, I give the interpretation of evaluator functions as utility functions, while Chapter 3.3.7. discusses the fundamentals of the *aggregate evaluation,* and Chapter 3.3.8. introduces the *parameter weighted evaluation method* that can be used to aggregate the utilities derived from reliability based evaluations. Based on the findings and conclusions, hypotheses H8 and H9 are verified, and the results are summarized in Thesis 3 and Thesis 4.

3.5.6. Thesis 3

The evaluator functions, which are suitable to evaluate index-based measurements of a business process or attribute on the [0,1] evaluation scale, can also be interpreted as utility functions that assign the company utility of the index-based measurements of a business process or attribute to its index-based measurement values.

Publications related to Thesis 3 are: P3, P5, P6, P8.

3.5.7. Thesis 4

The parameter weighted aggregate evaluation method renders it possible to determine the company utility of a business process or attribute that is index-based measured, and evaluated by an evaluator function, in those cases, when the measurements are done on a fixed scale but derived from various sources or entities.

Publications related to Thesis 4 are: P3, P5, P6, P8.

3.6. Modeling change of aggregate reliability and quality indices

In practice, most of the reliability and quality indices change over time, and these changes are connected to the lifecycle of the examined business process. Chapter 4 of my theses summarizes the results I found by studying how aggregate reliability and quality indices change during the introduction phase of manufacturing and service processes. My researches are based on hypotheses H10, H11 and H12.

H10: The restricted linear logistic regression method and the $R_\omega(t)$ approximation can be used to model the change of an aggregate reliability or quality index (R(t)) of a manufacturing or service process during its introduction (ramp-up) phase.

H11: Use of these models allows us to quantify the determining role of technology and operational culture in ramp-up of manufacturing and service processes.

H12: Using this approach, ramp-up curves separated in a manner of time or space can be compared on quantitative basis.

In Chapter 4 of my work, the

$$R(t) = S_{\lambda,a,R_I,R_T}(t) = R_I + (R_T - R_I)\frac{1}{1 + e^{-\lambda(t-a)}}$$

model and the

$$R_{\omega,a,t_S,t_E,R_I,R_T}(t) = R_I + (R_T - R_I)\frac{\left(\frac{t - t_S}{t_E - t_S}\right)^\omega}{\left(\frac{t - t_S}{t_E - t_S}\right)^\omega + \left[\frac{a - t_S}{t_E - a}\left(1 - \frac{t - t_S}{t_E - t_S}\right)\right]^\omega}$$

$t_E < a < t_S$ function, which is a good approximant of $S_{\lambda,a,R_I,R_T}(t)$, if

$$\omega = \frac{\lambda(t_E - a)(a - t_S)}{t_E - t_S},$$

are discussed as *change models*. The $R(t)$ function represents the change of the R aggregate index from its initial R_I value to its R_T terminal value as function of time that is measured in the $[t_S, t_E]$ interval.

In Chapter 4.2. of my theses, I introduce the *restricted linear logistic regression method* that is based on the $S_{\lambda,a,R_I,R_T}(t)$ function, and discuss how this regression model can be approximated with the $R_{\omega,a,t_S,t_E,R_I,R_T}(t)$ function.

The cases studies in Chapter 4.3. of the dissertation prove that the introduced models are suitable for practical applications. Based on this conclusion the H10, H11 and H12 hypotheses are verified, and the results are summarized in Thesis 5.

3.6.1. Thesis 5

Changes of an aggregate reliability or quality index assigned to a production or service process can be modeled by the restricted linear logistic regression and the $R_\omega(t)$ approximation during the introduction phase of the examined process. By this means, the determining role of technology and operational culture in organizational learning of a production or service process can be quantified through the parameters of regression functions, and so the learning processes (curves) can be compared on quantitative basis.

Publications related to Thesis 5 are: P1, P4, P7.

4. Practical utilization of results and further research plans

Based on the studies on how to interpret, measure and evaluate reliability and goodness of business processes, I have developed quantitative methods which rely upon the concept of reliability based evaluation, and provide new, alternative tools to manage attributes and processes that are impacted by “soft” factors. For evaluation of index-based measurements of characteristics and attributes, I have applied the fuzzy sets theory, the logistic function and its adequate approximants, and have introduced the logistic and quasi logistic evaluations that render it possible to match the evaluation results with the perceptions of the evaluator entity on reliability and goodness of business processes. By this means, I have given an interpretation of business processes reliability as a fuzzy concept. Interpreting the introduced evaluator functions as utility functions allows us to express the business utility of measured indices as well as these utilities can be aggregated at organizational level. The *positive experiences with practical applications of the elaborated methods to index-based evaluation of human performance, customer satisfaction and intellectual capital have proven the usability of these methods*.

Investigations of how the introduced methods can be used for evaluation of employee satisfaction, new technology introduction and training programs are subjects of my further research plans. Another area for further researches is studying of how the intellectual capital measurement and evaluation results can be used as inputs for company decisions, and how the necessary actions to reach a sufficient level of intellectual capital can be deduced from the company goals.

As most of the quality, reliability and goodness indices of business processes change by the time according to the lifecycle of the business processes, I have separately studied how the aggregate reliability and quality indices change over the time during the introduction phase of new processes. The aggregate approach allows us to interpret the changes of the investigated indices as a learning curve of the company’s organization on the process being introduced. In this interpretation, the learning curve is determined by the technology at company’s disposal, and the company’s operational culture taken in a broad sense. *With help of the restricted linear logistic regression and the $R_\omega(t)$ models, the determining role of technology and company culture can be quantified, and learning curves can be compared on quantitative basis. The positive results from real applications at companies, discussed in the case studies, prove the practical usability of the developed methods and models*. As part of my further researches, I wish to study how the technology and company culture impact on the parameters of the introduced models, and on the shape of ramp-up curves. For example, a possible question is how different geographical regions impact on ranges of the function parameters, and how the ramp-up phases of different companies can be compared. Another area to be studied is the comparison of goodness of processes through ramp-up curves. I also wish to study practical cases in which the ramp-up of an index can be expressed with ramp-up curves that are not symmetric about their inflection point.

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6. List of publications related to the dissertation

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Journal papers in English

P1. Jónás T.: *Sigmoid Functions in Reliability Based Management*. Periodica Polytechnica-Social and Management Sciences 15:(2), 2009. pp. 67-72.

P2. Jónás T., Kövesi J.: *Reliability based Customer Satisfaction Evaluation*. Periodica Polytechnica-Social and Management Sciences, 2010. (Accepted for publication.)

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P3. Jónás T., Kövesi J.: *Értékelő függvények a megbízhatóság alapú menedzsmentben* (Evaluator Functions in Reliability Based Management). Minőség és megbízhatóság XLIII:(6) 2009. pp. 311-320.

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