'Club of Economics in Miskolc' TMP Vol. 6., Nr. 2., pp. 37-47. 2010.

Separating the Measurement and Evaluation of Intellectual Capital Elements with Evaluator Functions

JÁNOS KÖVESI, Ph.D.
UNIVERSITY PROFESSOR

e-mail: kovesi@mvt.bme.hu

TAMÁS JÓNÁS
ASSISTANT PROFESSOR

e-mail: tamas.jonas@hu.flextronics.com

ZSUZSANNA ESZTER TÓTH, Ph.D.
ASSISTANT PROFESSOR

e-mail: tothzs@mvt.bme.hu

Department of Management and Corporate Economics, Budapest University of Technology and Economics

SUMMARY

The purpose of this study is to contribute to the use of evaluator and utility functions in order to increase the reliability of scorecard based intellectual capital measurement methods and to express and aggregate the utility of IC elements to the organization. The conducted field experiment integrates the results of interviews with 23 brand name customers through examining the customer satisfaction measuring practice of service provider companies. The main finding is that the adequately calibrated evaluator functions assign perceived customer satisfaction to its scorecard based measured values and mitigate the distortions of scorecard based measurements. The evaluator function interpreted as a kind of utility function reflects the utility of IC values derived from a scorecard based measurement method. Our research discusses the repertoire of aggregating the utility of IC elements as well.
Journal of Economic Literature (JEL) code: I32, E01, C01, C52

BACKGROUND

Measuring and valuing IC

Making IC elements visible within the assets of a corporation and measuring their contribution to corporate success arise as a natural demand. The existing methods (market capitalization, return on asset, direct intellectual capital and scorecard methods) offer different advantages and serve diverse purposes (Andriessen 2004; Marr et al., 2003; Sveiby, 1997; Sveiby, 2001-2005). Scorecard methods of intellectual capital measurement aim at apprehending unique and strategically relevant IC elements and embodying competitive advantages by emphasizing organization specific measures (Marr et al., 2004; Sveiby, 1997).
Andriessen (2004: 238) makes a clear distinction between IC measuring and valuing practices. If the criterion of value is defined in monetary terms, the method to determine value is a financial valuation method (see market capitalization methods, return on asset methods and direct intellectual capital methods). We can use a non-monetary criterion and translate it into observable phenomena, in which case the method is a value measurement method (see some of the scorecard methods, e.g., Balanced Scorecard). If the criterion cannot be translated into observable phenomena but instead depends on the evaluator's personal judgment, then the method is a value assessment method (none of the existing IC methods can be classified here). If the framework does not include a criterion for value but does involve a metrical scale that relates to an observable phenomenon, then the method is a measurement method (see some of the scorecard methods, e.g., Skandia Navigator, Intangible Asset Monitor, Intellectual Capital Index). As a conclusion Andriessen (2004) adds that a measurement method is not a method for valuation.
Our research is based on the scorecard methods of IC measurement focusing on assigning non-financial measures to intangible assets and dealing with the management issues of individual IC elements strategically.

The value lying in an organization's external relationships has both tangible and intangible aspects and both need to be developed and managed (Baxter and Matear, 2004). Customer capital as part of IC is about the knowledge embedded in relationships external to the organization and its development mainly relies on the support deriving from human and structural capital (see e.g., Homburg and Stock, 2004; Leliaert et al., 2003). As one of the most important indicators of customer capital, customer satisfaction is always a potential source of innovation, repeat sales, positive word-of-mouth and customer loyalty (Fornell et al., 1996; Johnsen et al., 2005). The study analyzes the nature of typical customer satisfaction measurement methods used by Service Provider (SP) companies, particularly by Electronics Manufacturing Services (EMS) providers.

Scorecard based measurement of customer satisfaction

The last decades have spawned numerous researches on customer satisfaction. Various studies show a wide range of applicable practices to understand the customers' voice and measure their satisfaction and loyalty (see e.g., Eshghi et al., 2007; Gustafsson, 2008; Gustafsson and Johnson, 2004; Iacobucci et al., 1995; Johnson and Fornell, 1991).
The common way of Customer Satisfaction (CS) measurement, which typical SP companies follow, is based on scorecard methods. The customers give regular feedbacks by using pre-agreed scorecards. The ultimate goal is to quantify the performance of the SP in areas such as quality, supply chain management, delivery accuracy, flexibility, customer communication etc. Finally, an aggregated artificial number characterizes the level of each customer's satisfaction. The company interprets this aggregated figure (i.e. its performance) in its own preference system. For example, an EMS company uses a scorecard that measures CS on a scale that goes from 0 to 100 and every time a customer company expresses its satisfaction the answer is a number between 0 and 100. This number and the company's preference system give the interpretation of CS similarly to the example given by Table 1.

Table 1. An example for CS evaluation

Score	Level of Customer Satisfaction
< 20	Very poor
20 ≤ and < 40	Poor
40 ≤ and < 60	Meets expectations
60 ≤ and < 80	Above expectations
80 ≤	Excellent

Certainly, the content of scorecards and the scoring criteria may vary from customer to customer but is fixed at one particular customer. Let us focus only on one customer and its scorecard to understand the above shown measurement and evaluation. At first sight it appears that if the scorecard is well defined and the customer has the right interpretation of scoring criteria, the measurement is accurate and consistent, the evaluation reflects the real level of customer satisfaction. Unfortunately, this is not necessarily so as there is a number of factors that may influence both the measurement and evaluation and cause uncertainties.

Uncertainties around the measurement

Our study investigates how scorecard based assessment methods can capture the enumerated contributors of customer satisfaction and how reliably these methods are able to reflect the customers' perceived satisfaction to SP companies.

Measurement and valuation roles

The typical role setup of a scorecard based customer satisfaction measurement and evaluation at SP companies looks so that the customer provides the scores (does the measurement) and the service provider company evaluates them. With other words, the company receives numbers and believes that comparing these numbers to the evaluation criteria reflects how much the customer is satisfied. It means that the customer instead of giving feedback about its perceived satisfaction level quantifies the level of performance provided by the SP company.

Scaling

Is it really true that a customer is double satisfied when it gives 80 points (as customer satisfaction score) compared to giving only 40 points? Thinking about this question may make us worried about the consistency of this method, although SP companies widely use similar methods. The cause of this problem is the withheld assumption that a customer expresses its satisfaction on a linear scale (proportional scale), that is the score given by the customer is proportional to its perceived satisfaction. If it is not so, using linear evaluation regarding the level of customer satisfaction may be questionable.

Subjectivity

The customer organizations represent themselves by individuals, who may have influences on the feedbacks given by their organizations, even if they try to be objective with their best intentions. Unfortunately, their subjectivity is somehow always in the scores they give. If we consider the scorecards as measurement systems, the repeatability and reproducibility of these systems can be disputable (Burdick and Borror, 2005).

Evaluator functions

Our ultimate goal is to propose a solution by using evaluator functions that can mitigate the highlighted problems of CS measurement and evaluation. Evaluator functions are mathematical functions that translate the scorecard based CS measurement scores to an evaluation scale. Let variable m be the measured CS scores in the $[m_S, m_E]$ interval, where m_S and m_E is the start- and endpoint of the measurement scale. Using these notations an E evaluator function assigns the $E(m)$ CS value to every m measured CS value and meets the following basic criteria.

The $E(m)$ function is monotonously increasing, that is higher measured values correspond to higher perceived satisfaction level, even if the relationship between them is not linear.

The range carrier of $E(m)$ is the (0, 1) or [0,1] interval.

$E(m)$ represents the perceived satisfaction that the customer would assign to the measured m satisfaction.

These criteria determine just a loose frame for an evaluator function, but taking other experiential properties of customers' behavior and satisfaction perceptions into account, particular evaluator functions can be derived.

The Eω(m) evaluator function

In this study, we use the

$$E_{\omega, m_S, m_E, m_0, E_{m_0}, E_L, E_H}(m) =$$

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

function as evaluator function. This function is a linearly transformed version of Dombi's κ function introduced in the fuzzy theory as a membership function (Dombi, 1990), and a good approximation of a linearly transformed logistic function. For the details of choosing the ω parameter and the approximation see Jónás (2010). From this point onwards the simplified $E_{\omega}(m)$ notation will be used instead of the $E_{\omega, m_S, m_E, m_0, E_{m_0}, E_L, E_H}(m)$ long form.

METHODOLOGY

Practical use of the Eω(m) function

One of the problems with the commonly used CS evaluation is that the measurement (done by the customer) and the evaluation (done by the service provider) are separate process steps. This separation in itself would not cause any problem, if the evaluation could adequately reflect the customer's perception. In practice, there is a disconnection between customers' and service providers' evaluations. Now we have a mathematical tool that the customer can use to evaluate its satisfaction using the CS scorecard, but first the customer needs to set the parameters of the evaluator function so that it reflects the customer's satisfaction perception of the measured CS scores. The study presents a method here how to use the $E_{\omega}(m)$ evaluator function for customer satisfaction evaluation. The $E_{\omega}(m)$ function is a tool that corrects and improves the reliability of the scorecard based measurement. We call this method reliability-based customer satisfaction evaluation (RCSE) method.

Step 1.

The customer is asked to measure its satisfaction based on a common scorecard system used for all customers.

Step 2.

The customer needs to set the window parameters for the $E_{\omega}(m)$ function, which determine the domain of variability (the $[m_S, m_E]$ interval) and the lowest (E_L) and highest (E_H) satisfaction values of the $[0,1]$ evaluation scale.

Step 3.

Three further parameters: m_0, E_{m_0} and ω have to be specified to unambiguously determine the evaluator function. For this purpose the customer specifies two satisfaction levels on the evaluation scale in the (E_L, E_H) interval and assign them to two arbitrary chosen (but different both from m_S and m_E) points of the original CS measurement scale. Either of these two pairs can be directly used as the (m_0, E_{m_0}) pair, so one point of $E_{\omega}(m)$ is explicitly given. In practice, the selection of m_0 as the midpoint of the measurement scale is suggested since half of the maximum reachable score is a good characteristic point of the scale.

Step 4.

Let (m_a, E_{m_a}) note the other arbitrary chosen (measurement value, evaluation value) pair. As (m_a, E_{m_a}) is a point of the $E_{\omega}(m)$ curve, the $E_{m_a} = E_{\omega}(m_a)$ equation needs to be met. From this equation parameter ω can be calculated as

$$\omega = \frac{\ln\left(\frac{E_H - E_{m_a}}{E_{m_a} - E_L}\frac{E_{m_0} - E_L}{E_H - E_{m_0}}\right)}{\ln\left(\frac{m_E - m_a}{m_a - m_S}\frac{m_0 - m_S}{m_E - m_0}\right)}$$

Which point of the measurement scale is worth to be chosen as m_a? Each customer has a kind of a threshold value for the measured CS score. Certainly, these threshold figures vary from customer to customer. Basically that is why the standardized scorecard based measurement has limited capability to express the customer satisfaction appropriately. The customer specific evaluator functions allow the customers to assign their values of perceived satisfaction to the scores measured by a standardized scorecard method. Hence, setting m_a as the customer specific threshold value for the measured CS score for each customer is recommended.

AGGREGATED EVALUATION

Scorecard based measurement lays the foundation for evaluating the reliability-based customer satisfaction evaluation method. This is already an aggregate approach as its input variable is an aggregate score. Actually, a service provider company has multiple customers whose expectations may vary in a wide range. Even if the same service at the same performance level is provided, different customers may perceive very different satisfaction levels. The typical approach to handle this situation is the use of customer specifically structured, customized and weighted scorecards to measure the CS level. It means that different scorecards measure the performance of the same operation as different customers have different preferences. The SP company rightly wants to understand each customer and have an overall picture both about its performance and the customers' satisfaction level. How to aggregate and quantify the customer satisfaction levels in such cases?

The greatest advantage of using evaluator functions is that their range carrier is the same [0,1] interval regardless what their domains of variability are. Different scorecards with the same measurement scale can be used for different customers, but the evaluated CS is always expressed on the [0, 1] scale (or in one of its subsets). The evaluation scale is unified and the use of $E_\omega(m)$ functions can be interpreted as a common basis transformation. It allows us to aggregate the evaluated CS of multiple customers. The starting point is that each customer follows the same way of thinking and satisfaction perception as function of the CS score. Each of them can evaluate the CS by a suitably calibrated $E_\omega(m)$ function. Providing this, we can assume that the aggregated satisfaction has the same nature. The only remaining question is the calibration of the aggregated $E_\omega(m)$ function.

Let us assume that a SP company has n customers and there is a CS scorecard defined for each of them. Then by applying the $E_\omega(m)$ function every customer calibrates it according to the reliability-based customer satisfaction evaluation method. As discussed earlier, the $E_\omega(m)$ function has seven adjustable parameters: ω, m_S, m_E, m_0, E_{m_0}, E_L and E_H. In case of multiple clients there is an $E_\omega^{(i)}(m)$ evaluator function with $\omega^{(i)}$, $m_S^{(i)}$, $m_E^{(i)}$, $m_0^{(i)}$, $E_{m_0}^{(i)}$, $E_L^{(i)}$ and $E_H^{(i)}$ parameters for each customer, and

$$\omega^{(i)} = \frac{\ln\left(\dfrac{E_H^{(i)} - E_{m_a}^{(i)}}{E_{m_a}^{(i)} - E_L^{(i)}} \dfrac{E_{m_0}^{(i)} - E_L^{(i)}}{E_H^{(i)} - E_{m_0}^{(i)}}\right)}{\ln\left(\dfrac{m_E^{(i)} - m_a^{(i)}}{m_a^{(i)} - m_S^{(i)}} \dfrac{m_0^{(i)} - m_S^{(i)}}{m_E^{(i)} - m_0^{(i)}}\right)}$$

where the $\left(m_0^{(i)}, E_{m_0}^{(i)}\right)$ and $\left(m_a^{(i)}, E_{m_a}^{(i)}\right)$ pairs are the inputs of the ith customer to calibrate its evaluator function $(i = 1,2,..., n)$.

When the company is about to figure out the aggregate CS evaluator function, inputs of different customers can be considered with different importance and the company may consider the customer responses with different weights. Let w_i be the weight assigned to the i^{th} customer, that is the contribution of this customer to the aggregate CS level, where

$$\sum_{i=1}^{n} w_i = 1.$$

Without compromising the generality, assuming that the same measurement scale is used for all customers, the aggregate $m_S^{(A)}$ start- and $m_E^{(A)}$ endpoints of the measurement scales are the same for each evaluator function, that is $m_S^{(i)} = m_S^{(A)}$, and $m_E^{(i)} = m_E^{(A)}$ $(i = 1,2,..., n)$.

The $\omega^{(A)}$, $m_0^{(A)}$, $E_{m_0}^{(A)}$, $E_L^{(A)}$ and $E_H^{(A)}$ parameters of the aggregated evaluator function can be calculated as the weighted averages of the corresponding parameters:

$$\omega^{(A)} = \sum_{i=1}^{n} w_i \omega^{(i)}, \; m_0^{(A)} = \sum_{i=1}^{n} w_i m_0^{(i)},$$

$$E_{m_0}^{(A)} = \sum_{i=1}^{n} w_i E_{m_0}^{(i)},$$

$$E_L^{(A)} = \sum_{i=1}^{n} w_i E_L^{(i)}, \; E_H^{(A)} = \sum_{i=1}^{n} w_i E_H^{(i)}.$$

We call this construction parameter weighted aggregate customer satisfaction evaluation (PWACSE) method.

UTILITY POINT OF VIEW: ASSESSING THE VALUE OF IC ELEMENTS

The evaluated customer satisfaction represents the level of performance that our customers perceive. From the SP company's point of view customer satisfaction is a measure of performance, from the customer's perspective the level of satisfaction is the measure of the utility of services provided by the company. Therefore, the CS evaluator function can be interpreted as utility function as well. Since customer satisfaction can be considered as a specific element of intellectual capital, our aggregation results in the aggregated utility function of the chosen IC element.

The aggregated utility function as function of a measured m score gives a good overall indication of the utility (value) that a service provider gives to its customers. The aggregate utility function is invertible, therefore, a particular utility level can be translated to the m metric. Keeping in mind that the scorecard measurement has a known structure, the management can identify the actions required to achieve the necessary level of metric m. Doing so, the customers' inputs can be used for setting intellectual capital improvement goals.

Using the RICEE and PWAICEE methods

The approach of the RCSE method can be applied to any IC element and this generalized method is called reliability-based intellectual capital element evaluation (RICEE) method. Similarly, the logic of PWACSE method under the name of parameter weighted aggregate intellectual capital element evaluation (PWAICEE) can be used as a possible way to aggregate multiple utility (evaluator) functions for the same IC element, if the same scorecard metric is used as independent variable for the various utility (evaluator) functions. By this means, in case of multiple IC elements as many aggregated utility functions can be derived as many IC elements are chosen. For this the individual utility (evaluator) functions are to be calibrated one by one following the same way introduced earlier.

Evaluator functions and the aggregate evaluator function are tools that can correct biased scorecard based measurements on an IC element in order to express its utility to the organization more reliably. Having an actual (aggregated) measured score the (aggregated) evaluator function determines its value on the evaluation scale. This latter is a number from the [0,1] interval representing the actual utility of the examined IC element to the organization. Following this approach, one utility figure can be assigned to each IC element and all these figures are from the [0,1] interval. It means that by giving importance weights to IC elements it allows us to aggregate the current utility figures into one utility value. Figure 1 illustrates the generic use of the RCSE and PWACSE methods for n IC elements.

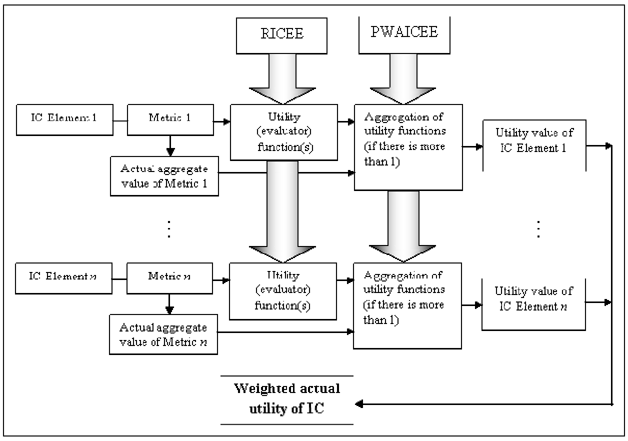

Figure 1. The scheme of aggregated utility of IC by using the RICEE and PWAICEE methods

A practical application of the RCSE and PWACSE methods

A site of a service provider company uses a scorecard with the following categories to collect information about the satisfaction of its 23 customers: quality of products and services, delivery accuracy, strategic value-added, operational performance, cost competitiveness, customer communication, materials management, reporting of operational metrics, program/project management, quotation process, supply chain performance, e-Business/ IT, documentation management, business start-up process, new product introduction/prototype, technology development.

Each customer has given a weight to each assessment category (the sum of weights is 100%). The weights represent the importance of the different measurement categories to the customers. Table 2 shows this weighting system.

Table 2. Customers' weighting of assessment categories

Customized scorecards / Weights																	
Assessment category																	
Customer	Quality of Products and Services	Delivery Accuracy	Strategic Value Added	Operational Performance	Cost Competitiveness	Customer Communication	Materials Management	Reporting of Operational Metrics	Program / Project Management	Quotation Process	Supply Chain Performance	e-Business / Information Technology	Documentation Management	Business Start-up Process	New Product Introduction / Prototype	Technology Development	Sum of weights
1	12	12	12	11	10	6	8	5	4	3	3	4	3	3	2	2	100
2	20	20	4	10	5	6	5	5	4	3	3	4	3	5	2	1	100
3	10	25	10	10	15	5	5	3	4		3	4	2	3	1		100
4	10	5	5	10	25	6	5	5	10	1	3	2	2	10		1	100
5	30	15	15	15	15	5	1	1	1	1	1						100
6	5	20	10	10	5	3	25	5	3		4	4	3	3			100
7	5	5	5	5	5	5	25	5	4		25	4	4	3			100
8	10	15	10	10	5	10	5	5	5	5	5		5	5	5		100
9	12	15	13	15	10	3		2	5			15	5	5			100
10	5	5	5	5	30	10	5	5	5		5	5	5	5		5	100
11	45	10	5	10	5	5			5			10		5			100
12	30	10	20	10	10	5					10					5	100
13	10	45		10	10		5	5	10		5						100
14	22	13	5	10	10	3	6	7	10		3		3	5		3	100
15	10	5	5	5	20	5	5	5	5	5	5	5	5	5	5	5	100
16	5	10	5	10	40	5		10								15	100
17	5	35	5	10	10	5	5	5	5		5		5			5	100
18	25	15	15	10	5	5			5			15		5			100
19	10	12	12	8	8	8	8	4	4	4	5	3	5	5	2	2	100
20	15	15	15	10	5	5	5					10	10	10			100
21	50	3	3	3	8	3	3	3	3	3	3	3	3	3	3	3	100
22	10	45	7	7	5	6	6	2	3	2	3	3	1				100
23	35		20	20	10			5				10					100

The company uses a scale from 0 to 100 to measure the customers' satisfaction. The measurement works so that each customer gives its scores category by category and the weighted average as aggregate score (weighted aggregate score) of the given scores is calculated for each customer (Table 3).

Table 3. Customers' Scores

Scores																	
Assessment category																	
Assessment category	Quality of Products and Services	Delivery Accuracy	Strategic Value Added	Operational Performance	Cost Competitiveness	Customer Communication	Materials Management	Reporting of Operational Metrics	Program / Project Management	Quotation Process	Supply Chain Performance	e-Business / Information Technology	Documentation Management	Business Start-up Process	New Product Introduction / Prototype	Technology Development	Weighted aggregate score
1	68	70	92	72	50	90	85	92	90	95	80	92	95	88	95	82	78.88
2	82	95	93	92	70	76	92	82	84	85	85	87	68	92	63	82	85.74
3	95	90	92	90	88	80	91	85	85		95	95	90	90	85		89.90
4	85	95	90	95	85	92	95	92	90	90	95	85	80	90		95	89.37
5	80	85	75	75	60	80	82	80	85	75	80						76.27
6	92	95	88	95	80	95	95	93	93		91	95	92	88			92.78
7	85	80	88	83	75	85	82	83	85		75	77	68	92			80.16
8	76	92	88	72	92	77	75	75	73	82	73		88	85	87		81.60
9	92	91	90	88	94	91		97	91			91	91	93			91.06
10	83	82	74	82	81	82	88	91	82		80	81	87	89		91	83.00
11	77	69	65	72	69	71			72			75		69			73.55
12	82	67	91	90	92	85					84					85	84.60
13	91	90		88	97		92	93	91		89						90.90
14	78	77	62	51	82	90	91	87	86		92		91	90		88	79.05
15	88	92	94	94	81	91	88	89	87	82	82	92	91	92	93	95	88.10
16	95	78	92	97	83	99		76								76	84.00
17	92	77	91	72	73	75	69	71	74		68		73			75	75.85
18	78	87	88	91	97	92			89			89		91			86.65
19	94	63	78	79	79	65	64	62	78	88	83	76	76	72	77	72	75.21
20	65	62	68	61	72	71	78					63	62	67			65.60
21	89	97	95	98	92	93	95	91	89	94	93	92	91	92	92	93	91.01
22	72	68	69	69	71	70	70	82	75	75	72	81	78				70.17
23	93		85	83	82			91				87					87.60

The method introduced so far represents the company's traditional method of customer satisfaction measurement. On top of customers' score inputs the following three additional questions were asked from the clients.

What would be your perceived satisfaction level on the (0,1) scale, if you scored our company at 50 on the measurement scale? Please, use 2 digit numbers.

What would be your perceived satisfaction level on the (0,1) scale, if you scored our company at 90 on the measurement scale? Please, use 2 digit numbers.

What is your current perceived satisfaction level on the (0,1) scale?

By answering Question (1) and (2) the customer calibrates its utility function, while question (3) as a control question compares the calculated utility of actual aggregate CS score to the customer's perceived satisfaction that it assigns to the aggregate score.

The same measurement scale was used for each customer, that is $m_S^{(i)} = 0$ and $m_E^{(i)} = 100$. In order to simplify the procedure, $E_L^{(i)} = 0$ and $E_H^{(i)} = 1$ were chosen for each customer. According to question (1) and (2) all customers have used $m_0^{(i)} = 50$, $m_a^{(i)} = 90$ scores for the calibration of their utility functions $(i = 1,...,23)$. The customers' inputs and the calculations done by the SP company using the RCSE and PWACSE methods are summarized in Table 4.

Table 4. Customers' inputs and calculations based on RCSE and PWACSE methods

Cust.	WAS	$E_L^{(i)}$	$E_H^{(i)}$	$m_S^{(i)}$	$m_E^{(i)}$	$m_0^{(i)}$	$E_{m_0}^{(i)}$	$m_a^{(i)}$	$E_{m_a}^{(i)}$	ω	CW (%)	CCPS	CUAS	LTWAS
1	78.88	0	1	0	100	50	0.05	90.00	0.90	2.34	4.35	0.50	0.5347	0.7888
2	85.74	0	1	0	100	50	0.1	90.00	0.85	1.79	4.35	0.75	0.7336	0.8574
3	89.90	0	1	0	100	50	0.05	90.00	0.95	2.68	4.35	0.95	0.9486	0.8990
4	89.37	0	1	0	100	50	0.2	90.00	0.80	1.26	4.35	0.80	0.7859	0.8937
5	76.27	0	1	0	100	50	0.1	90.00	0.98	2.77	4.35	0.75	0.7385	0.7627
6	92.78	0	1	0	100	50	0.15	90.00	0.90	1.79	4.35	1.00	0.9445	0.9278
7	80.16	0	1	0	100	50	0.1	90.00	0.85	1.79	4.35	0.60	0.5748	0.8016
8	81.60	0	1	0	100	50	0.2	90.00	0.80	1.26	4.35	0.65	0.6209	0.8160
9	91.06	0	1	0	100	50	0.1	90.00	0.95	2.34	4.35	0.95	0.9621	0.9106
10	83.00	0	1	0	100	50	0.1	90.00	0.95	2.34	4.35	0.80	0.8195	0.8300
11	73.55	0	1	0	100	50	0.4	90.00	0.90	1.18	4.35	0.70	0.6913	0.7355
12	84.60	0	1	0	100	50	0.3	90.00	0.85	1.18	4.35	0.75	0.7603	0.8460
13	90.90	0	1	0	100	50	0.35	90.00	0.95	1.62	4.35	0.95	0.9574	0.9090
14	79.05	0	1	0	100	50	0.25	90.00	0.90	1.50	4.35	0.70	0.7096	0.7905
15	88.10	0	1	0	100	50	0.4	90.00	0.87	1.05	4.35	0.85	0.8450	0.8810
16	84.00	0	1	0	100	50	0.3	90.00	0.95	1.73	4.35	0.90	0.8823	0.8400
17	75.85	0	1	0	100	50	0.2	90.00	0.95	1.97	4.35	0.70	0.7046	0.7585
18	86.65	0	1	0	100	50	0.4	90.00	0.95	1.52	4.35	0.95	0.9203	0.8665
19	75.21	0	1	0	100	50	0.35	90.00	0.85	1.07	4.35	0.70	0.6387	0.7521
20	65.60	0	1	0	100	50	0.3	90.00	0.95	1.73	4.35	0.50	0.5663	0.6560
21	91.01	0	1	0	100	50	0.2	90.00	0.95	1.97	4.35	0.95	0.9599	0.9101
22	70.17	0	1	0	100	50	0.1	90.00	0.85	1.79	4.35	0.30	0.3393	0.7017
23	87.60	0	1	0	100	50	0.25	90.00	0.90	1.50	4.35	0.85	0.8622	0.8760
Agg.	82.65	0	1	0	100	50	0.22	90.00	0.90	1.75	4.35	0.76	0.7609	0.8265

Figure 2 shows the assemblage of curves of the calibrated utility functions and the aggregate utility function generated using the PWACSE method.

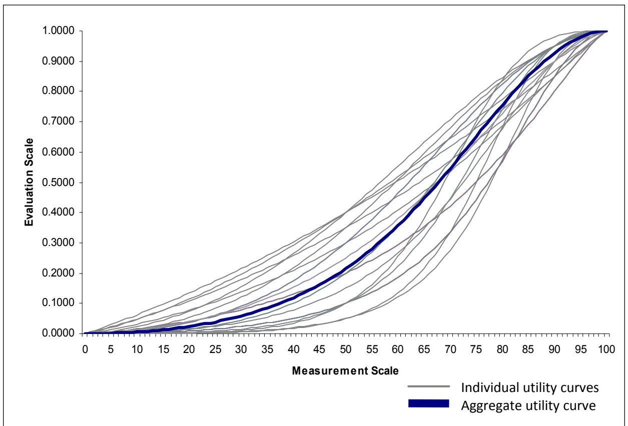

Figure 2. Assemblage of curves of the calibrated utility functions and the aggregate utility function

Statistical analyses

In order to characterize the goodness of the introduced methods, we calculated the difference between the customer's current perceived satisfaction (CCPS) and the calculated utility of aggregate score (CUAS) for each customer. If the measured scores are converted to the evaluation scale (the [0,1] interval) using a simple linear transformation, we get the linearly transformed weighted average score (LTWAS) for each customer. The CCPS-CUAS and CCPS-LTWAS differences are used to analyze statistically the data collected and calculated in our case study in order to see how well the RCSE method works. Table 5 shows the CCPS-CUAS and CCPS-LTWAS differences.

Table 5. The CCPS-CUAS and CCPS-LTWAS differences

Customer	CCPS-CUAS	CCPS-LTWAS
1	-0.0347	-0.2888
2	0.0164	-0.1074
3	0.0014	0.0510
4	0.0141	-0.0937
5	0.0115	-0.0127
6	0.0555	0.0722
7	0.0252	-0.2016
8	0.0291	-0.1660
9	-0.0121	0.0394
10	-0.0195	-0.0300
11	0.0087	-0.0355
12	-0.0103	-0.0960
13	-0.0074	0.0410
14	-0.0096	-0.0905
15	0.0050	-0.0310
16	0.0177	0.0600
17	-0.0046	-0.0585
18	0.0297	0.0835
19	0.0613	-0.0521
20	-0.0663	-0.1560
21	-0.0099	0.0399
22	-0.0393	-0.4017
23	-0.0122	-0.0260
Aggr.	0.0022	-0.0635

The descriptive statistics (see Table 6) and the Boxplot charts (see Figure 3) for the CCPS-CUAS and CCPS-LTWAS differences show that the estimated mean of CCPS-CUAS is closer to zero than the estimated mean of CCPS-LTWAS and the standard deviation for CCPS-CUAS is much less than for CCPS-LTWAS.

Table 6. Descriptive statistics for CCPS-CUAS and CCPS-LTWAS

Variable	Mean	StDev	Median	Range
CCPS-CUAS	0.00216	0.02885	0.00143	0.12756
CCPS-LTWAS	-0.0635	0.1198	-0.0355	0.4852

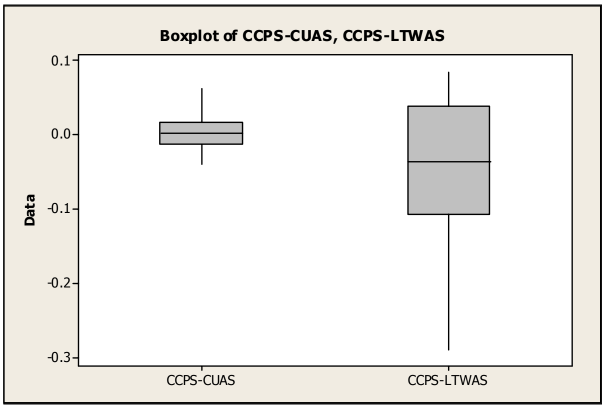

Figure 3. Boxplot charts for CCPS-CUAS, CCPS-LTWAS

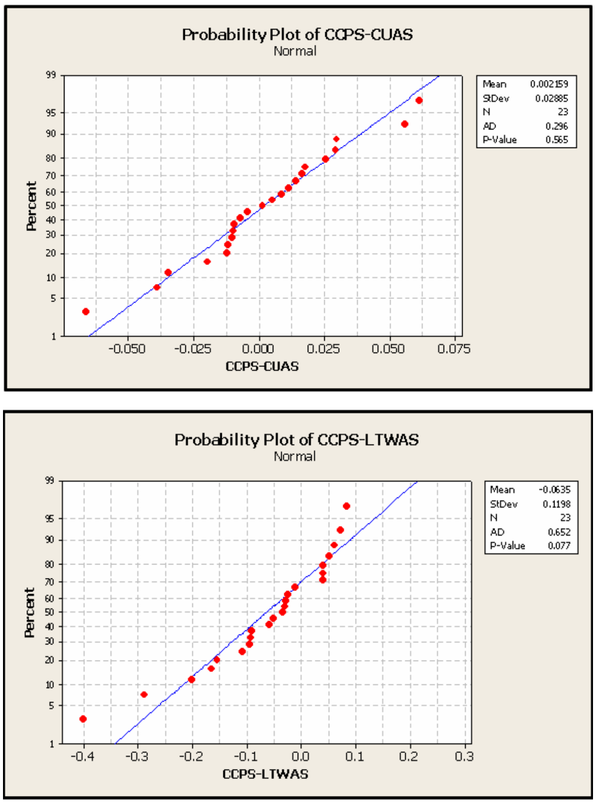

Figure 4. Probability plots of CCPS-CUAS and CCPS-LTWAS

The p-values of Anderson Darling normality tests applied to CCPS-CUAS and CCPS-LTWAS were greater than the significance level 0.05. This means the hypothesis that both CCPS-CUAS and CCPS-LTWAS are normally distributed random variables can be accepted, however, the probability plot charts suggest that probability distribution of CCPS-CUAS fits to a normal distribution better than the probability distribution of CCPS-LTWAS (see Figure 4).

Our hypothesis that the variance of CCPS-CUAS is significantly less than the variance of CCPS-LTWAS was proven by using F-test and Levene's test at significance level of 0.05. F-test was applicable as both of the variables passed the normality test at significance level of 0.05. Levene's test was used to reinforce the result from the F-test as although CCPS-LTWAS passed the normality test, but showed a relatively weak fit to a normal distribution. Figure 5 shows the results of F- and Levene's test.

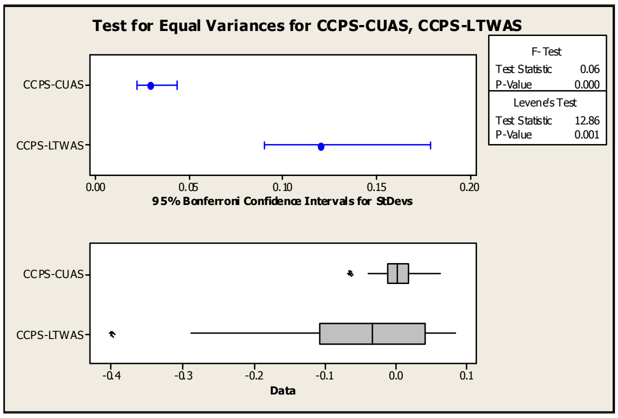

Figure 5. F-test and Levene's tests for equal variance for CCPS-CUAS and CCPS-LTWAS

Both tests resulted in p-values less than the chosen significance level, and so the null-hypothesis of equal variances of CCPS-CUAS and CCPS-LTWAS was rejected, thus there is a significant difference between them, namely, the variance of CCPS-CUAS is significantly less than the variance of CCPS-LTWAS. This statistical conclusion proves that the logistic-type evaluation based RCSE method is able to reflect the perceived customer satisfaction more reliably than the simple linear transformation of measured scores.

CCPS-LTWAS passed the normality test, but showed a relatively weak fit to a normal distribution, and so the Mann-Whitney test was used to compare the medians of the two variables instead of comparing their means. The test at significance level of 0.05 resulted in p-value of 0.0369. So the null-hypothesis that the two medians are equal was rejected (see Table 9). Based on this results and the descriptive statistics, it can be concluded that the median of CCPS-CUAS (0.00143) is closer to zero than the median of CCPS-LTWAS (-0.0355) and the same is valid for the mean figures.

Moreover, if we look at the differences between the aggregate CCPS and CUAS values and between the aggregate CCPS and LTWAS values, it can be stated that

the aggregate CUAS figure (0.7609) generated by using the PWACSE method is much closer to the aggregate CCPS (0.76) figure than the aggregate LTWAS (0.8265) figure.
The application of the RCSE and PWACSE methods require some extra work both from the customers (e.g., the three additional questions they need to answer) and from the service provider company. On the other hand, if both parties understand what the methods are about and how they can lead to a more reliable evaluation, they will recognize that the methods are worthwhile to use.

DISCUSSION

Key findings, managerial implications and further research directions

By showing that a distinction can be made between financial valuation methods, value measurement methods, value assessment methods and measurement methods, Andriessen (2004) warns that more research is needed into the nature of the problems, strength and weaknesses that valuation and measurement addresses.
The focus of this article is on the organizational ability to separate the measurement and valuation of intellectual capital elements. As a kind of organizational resource the perceived values of IC are of great importance, which are then compared to the measured values. The heart of the matter is how and to what extent IC can contribute to the execution of strategically relevant goals which means the evaluation of IC elements and the assessment of their utility in the company's own preference system. Expressing the value of an IC element through scorecard based measurement may result in distorted information and so it is not able to reflect the real utility of the examined IC element to the organization correctly. The adequately calibrated $E_\omega(m)$ evaluator functions are suitable tools to assign perceived customer satisfaction to its scorecard based measured values, and thus the application of these functions mitigates the distortion effects of scorecard based measurement methods. Besides customer satisfaction the reliability-based intellectual capital element evaluation method can be generally applied to any IC element.
An $E_\omega(m)$ evaluator function can be interpreted as a utility function reflecting the utility of measured intellectual capital values derived from a scorecard based measurement method. The parameter weighted aggregate intellectual capital element evaluation method can be used for aggregating multiple utility (evaluator) functions for the same IC element, if the same scorecard metric is used as independent variable for the various utility (evaluator) functions. Using the utility functions, the current utility of each identified intellectual capital element can be expressed on the common [0,1] scale and having importance weights given to the elements their current utility values can be aggregated into one utility value.
By choosing key success indices from human, structural and customer capital aligned to strategic goals, the presented approaches can be used for setting measurement against evaluation, enhancing the reliability of measurement, and expressing and aggregating the utility of IC elements to the organization.
Utility functions can convert the figures derived from financial valuation and scorecard based measurement, the methods presented here allow the joint use of these two approaches in the same performance management system.
One implication of this research relates to the application of RICEE and PWAICEE methods for other intellectual capital elements such as employee satisfaction, technology transfer, labor recruitment, training programs and to signal the value of intellectual capital to stakeholders (see e.g., Andriessen, 2004; Mouritsen et al., 2003, Narayanan et al., 2000; Ndofor and Levitas, 2004; Roos et al., 1997). The findings of this study also contribute to an improvement of awareness of how the measurement and evaluation of intellectual capital elements as an input can be built into organizational decision making processes. In addition, future lines of research could be geared to establish how the targeted value of intellectual capital elements could be deducted from organizational strategic goals.

REFERENCES

ANDRIESSEN, D. (2004): IC valuation and measurement. Journal of Intellectual Capital, 5(2): 230-242.

BAXTER, R. – MATEAR, S. (2004): Measuring intangible value in business-to-business buyer-seller relationships: An intellectual capital perspective. Journal of Business Research, 33(6): 491-500.

BURDICK, R. K. – BORROR, C. M. – MONTGOMERY, D. C. (2005): Design and Analysis of Gauge R&R Studies. Philadelphia: SIAM

DOMBI, J. (1990): Membership function as an evaluation. Fuzzy Sets and Systems, 35(1): 1-21.

ESHGHI, A. – HAUGHTONA, D. – TOPIA, H. (2007): Determinants of customer loyalty in the wireless telecommunications industry. Telecommunications Policy, 31(2): 93-106.

FORNELL, C. – JOHNSON, M. D. – ANDERSON, E. W. – CHA, J. – BRYANT, B. E. (1996): The American customer satisfaction index: nature, purpose and findings. Journal of Marketing, 60(4): 7-18.

GUSTAFSSON, A. – JOHNSON, M. D. (2004): Determining Attribute Importance in a Service Satisfaction Model. Journal of Service Research, 7(2): 124-141.

GUSTAFSSON A. (2008): Customer satisfaction with service recovery. Journal of Business Research, 62(11): 1220-1222.

HOMBURG, C. – STOCK, R. M. (2004): The link between salespeople's job satisfaction and customer satisfaction in a business-to-business context: a dyadic analysis. Journal of the Academy of Marketing Science, 32(2):. 144-158.

IACOBUCCI, D. – OSTROM, A. – GRAYSON, K. (1995): Distinguishing Service Quality and Customer Satisfaction: The Voice of the Consumer. Journal of Consumer Psychology, 4(3): 277-303.

JOHNSEN, T. – PHILIPS, W. – CALDWELL, N. – LEWIS, M. (2006): Centrality of customer and supplier interaction in innovation, Journal of Business Research, 59(6): 671-678.

JOHNSON, M. D. – FORNELL, C. (1991): A framework for comparing customer satisfaction across individuals and product categories. Journal of Economic Psychology, 12(2): 267-286.

JÓNÁS, T. (2010): Aggregált megbízhatósági és minőségi mutatók változásainak modellezése. Minőség és Megbízhatóság, 3. 140-150. o.

LELIAERT, P. J. C. – CANDRIES, W. – TILMANS, R. (2003): Identifying and managing IC: a new classification. Journal of Intellectual Capital, 4(2): 202-214.

http://www.oecd.org/dataoecd/16/22/1947894.pdf, (accessed January 2008)

MARR, B. – GRAY, D. – NEELY, A. (2003): Why do firms measure their intellectual capital? Journal of Intellectual Capital, 4(4): 441-464.

MARR, B. – SCHIUMA, G. – NEELY, A. (2004): Intellectual capital – defining key performance indicators for organizational knowledge assets. Business Process Management, 10(5): 551-569.

MOURITSEN, J. – BUKH, N. – ROSENKRANDS, M. – LARSEN, H. T. – NIELSEN, C. – HAISLER, J. – STAKEMANN, B. (2003): Intellectual Capital Statements – The new guideline. Danish Ministry of Science, Tecnhology and Innovation. Available at: http://www.urjc.es/innotec/tools/IntellectualCapitalStatements-TheNewGuideline.pdf, (accessed October 2007)

NARAYANAN, V. K. – PINCHES, G. E. – KELM, K. M. – LANDER, D. M. (2000): The influence of voluntarily disclosed qualitative information. Strategic Management Journal, 21(7): 707-722.

NDOFOR, H. A. – LEVITAS, E. (2004): Signaling the strategic value of knowledge. Journal of Management, 30(5): 685-702.

ROOS, J. – ROOS, G. – DRAGONETTI, N. C. – EDVINSSON. L. (1997): Intellectual Capital: Navigating the New Business Landscape. London: Macmillan

SVEIBY, K. E. (1997): The New Organizational Wealth. San Francisco: Berrett-Koehler Publishers

SVEIBY, K. E. (2001-2005): Methods for Measuring Intangible Assets.
Available at: http://www.sveiby.com/Portals/0/articles/IntangibleMethods.htm, (accessed January 2008)