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A FRAME PROCEDURE FOR MULTIPLE CRITERIA SELECTION OF IT PRODUCTS AND SERVICES

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Abstract

In an information society, the Information Technology (IT) infrastructure of enterprises is important for their performance. Since in the last few decades the Multiple Criteria Decision Making (MCDM) methods have already turned out to be very applicable in solving problems, this article explores the particularities of the frame procedure for MCDM by using the group of methods based on assigning weights in the selection of IT products and services in enterprises. Special attention is given to the methods for establishing the judgements on criteria's importance, based on the interval scale. The procedure is completed for considering interactions – synergies and redundancies – among criteria, which can strengthen the decision making basis in the selection of the most appropriate IT product or service. The applicability of the above mentioned frame procedure is illustrated via a real-life case – the selection of the most appropriate storage array.

Keywords: multiple criteria decision making, information technology, prescriptive approach, weight
JEL classification: C44, C81, D83, M15

1. INTRODUCTION

To assure competitive advantages on the European and global market, enterprises consider the following requirements for stimulating the economy in contemporary information society: information, including the Information and Communication Technology (ICT), and appropriate methodology, including the computer supported multiple criteria decision methods. European Union (EU) finds this topic critical. In the context of the Lisbon Strategy, ICT is recognized to be a main contributor to prosperity and growth in EU (European Commission – Information Society, 2007). Moreover, transition countries have faced considerable challenges in promoting ICT to enable innovation and new business creation (Bučar, 2002). In an information society, the communication infrastructure, as well as the Information Technology (IT) infrastructure of enterprises is important for their performance. For example, they need affordable and secure IT products and services that fit within their budgets, meet the needs of their growing business, and can support the inclusion in global economic processes. In the last few decades, Multiple Criteria Decision Making (MCDM) methods have already turned out to be very applicable in solving important holistic decision problems – see, for example, Belton and Stewart (2002), among them practical business problems regarding IT – see, for example, Čančer (2010), Moaven *et al* (2008), Sridhar *et al* (2008).

Considering the criteria of different level requirements for business informing, preparing the reliable business information is recognized as one of the main prerequisites for the successful use of multiple criteria models in complex business environment. In the sense of prescriptive approach to decision making (Raiffa, 1994), decision makers are encouraged to follow one of the MCDM procedures for holistic problem solving. Following the original procedures of multiple criteria methods, professional expertise and own experience, we have already built the frame procedure of MCDM for the group of methods based on assigning weights (Čančer, 2010). The frame procedure for MCDM was well verified in business problem solving, on the micro level in enterprises, for example in creditworthiness assessment, environmentally oriented business decision making, benchmarking of business processes, investment in production technology, information system selection, etc (Čančer, 2010).

The most common aggregation tool that is used in MCDM is the weighted arithmetic mean. Under the assumption of independence among criteria, it requires the assignment of a weight to each criterion. Interactions among criteria should be considered in measuring the global phenomena like globalization, sustainable development and (corporate) social responsibility. Because interactions among criteria should also be considered in the IT fields, for example, in decisions about sensor networks (Sridhar *et al*, 2008) and software architecture (Moaven *et al*, 2008), we adapted the frame procedure for MCDM to the selection of IT products and services. If there is interaction among the criteria, decision makers usually return to the hierarchy and redefine the criteria. They can also use other models to obtain the aggregated alternatives' values, e.g. the multiplicative (Goodwin and Wright, 1992) and the fuzzy ones (Grabisch and Labreuche, 2005). Some examples of the models for planning the information infrastructure in enterprises include the selection of the most suitable operating system in small- and medium sized enterprises, blade in medium-sized and large enterprises, and storage system in medium sized enterprises. MCDM by following the adapted frame procedure is illustrated with a real-life case: the selection of the most appropriate storage array together with an IT enterprise.

The organization of the article is as follows. The second chapter introduces the position of member states of the EU from the viewpoint of technological readiness as an efficiency enhancer of global competitiveness, as well as the role of ICT in national economies from the viewpoint of the World Economic Forum (WEF). It also addresses the role of ICT in the context of the strategy EUROPE 2020. The third chapter explores the particularities of the frame procedure for MCDM by using the group of methods based on assigning weights in the selection of IT products and services in enterprises. It shows that considering interactions among criteria in synthesis is possible, for example, by the concept of the fuzzy Choquet integral, adapted to the multiple criteria value theory. The fourth chapter illustrates the applicability of the above mentioned frame procedure via a real-life case – the selection of the most appropriate storage array. The last chapter delineates advantages and disadvantages of the Choquet integral in considering interactions among criteria. It also brings concluding remarks about the applicability of the presented decision making approach in the selection of IT products and services.

With an aim to briefly describe the role of ICT in the world, European and national economy, the research methodology used in this article includes a search for and the compilation of relevant facts from contemporary official documents of the World Economic

Forum and European Commission. As the result of our exploratory and descriptive research, in terms of prescriptive approach, we adapt the frame procedure for MCDM by using the group of methods based on assigning weights to the selection of the most appropriate IT services and products. The work methodology used in the real-life case includes a step-by-step approach of the above-mentioned frame procedure for MCDM. The local alternatives' values are measured by pairwise comparisons, value functions and the direct method. The methods based on the interval scale (SWING and SMART), and the direct method are used to express the judgments about the criteria's importance. During synthesis, the additive model is used. The stability of the obtained solution is verified by the gradient sensitivity analysis. Interactions among criteria are considered by using the discrete Choquet integral. With alternative ranking, the most appropriate alternative is selected.

2. THE ROLE OF ICT IN THE WORLD, EUROPEAN AND NATIONAL ECONOMY

The Global Competitiveness Report 2011-2012 of the World Economic Forum (2011) explicitly treats ICT in two of twelve pillars of competitiveness: infrastructure and technological readiness. In the context of infrastructure is emphasized that, among other conditions, a well-developed communications infrastructure network is a prerequisite for the access of less-developed communities to core economic activities and services (World Economic Forum, 2011). The technological readiness pillar measures the agility with which an economy adopts existing technologies to enhance the productivity of its industries. A specific emphasis is given on its capacity to fully leverage ICT in daily activities and production processes for increased efficiency and competitiveness (World Economic Forum, 2011).

Therefore ICT access and usage are key enablers of countries' overall technological readiness. According to the ninth pillar of the Global Competitiveness Index 2011-2012 – technological readiness (World Economic Forum, 2011), even five national economies from EU ranked among top ten of 142 studied national economies, these are: Sweden, Denmark, Netherlands, United Kingdom and Luxemburg (Table no. 1). For each EU member, we extracted the technological readiness score and its rank among all studied national economies; and determine its rank among EU member countries in Table no. 1. For example, Table no. 1 shows that with respect to technological readiness, the Czech Republic was ranked on the 31st place, Slovenia on the 32nd place and Slovakia on the 37th place among 142 national economies. Among EU member countries, these national economies were ranked on the 16th, 17th and 20th place. EU member states with the lowest technological readiness are Romania, Bulgaria, Poland, Greece and Latvia.

Table no. 1 Technological readiness of the EU member states

EU member state	Score*	Rank in the world*	Rank in EU
Austria	5.4	15	10
Belgium	5.8	11	6
Bulgaria	4.11	50	26
Cyprus	4.36	41	21
EU member state	**Score***	**Rank in the world***	**Rank in EU**

Czech Republic	4.82	31	16
Denmark	6.2	4	2
Estonia	4.95	27	14
Finland	5.75	12	7
France	5.63	13	8
Germany	5.61	14	9
Greece	4.21	47	24
Hungary	4.55	36	19
Ireland	5.34	17	11
Italy	4.34	42	22
Latvia	4.26	46	23
Lithuania	4.7	34	18
Luxemburg	6	9	5
Malta	5.05	26	13
Netherlands	6.13	5	3
Poland	4.18	48	25
Portugal	5.31	19	12
Romania	3.76	60	27
Slovakia	4.54	37	20
Slovenia	4.76	32	17
Spain	4.95	28	15
Sweden	6.29	2	1
United Kingdom	6.08	8	4

Sources: [*World Economic Forum, 2011; own]

In a strategy for smart, sustainable and inclusive growth EUROPE 2020, insufficient use of ICTs was recognized as one of the main causes that Europe's average growth rate has been structurally lower than that of EU's main economic partners (European Commission, 2010). In the context of the strategy EUROPE 2020, smart growth means strengthening knowledge and innovation as drivers of future growth (European Commission, 2010). Besides improving the quality of education, strengthening research performance, promoting innovation and knowledge transfer throughout the EU, this requires making full use of ICTs and thus enabling that ideas can be developed into innovations – new products and services. One of the main European Commission's initiatives tackles digital society. At EU level, the Commission will work to increase support in the field of ICTs; it is expected that ICTs will help reinforce Europe's technology strength in key strategic fields and create the conditions for high growth small and medium-sized enterprises (SMEs) to lead emerging markets and to stimulate ICT innovation across all business sectors. Namely, the global demand for ICTs was a market worth € 2 000 billion, but only one quarter of this came from European firms (European Commission, 2010).

The key products and services of the ICT sector are as follows: Telecommunication equipment, Telecommunication services, IT services, Hardware, Software, Equipment distribution, and Web services. We will set bounds of the next chapters on IT. For example, among 27 leading home and foreign-owned enterprises in the ICT sector in Slovenia in 2010, a quarter of them were dealing primarily with IT services and products (JAPTI, 2011).

3. PARTICULARITIES OF THE FRAME PROCEDURE FOR MCDM IN THE SELECTION OF IT SERVICES AND PRODUCTS

When solving problems with MCDM methods, decision-makers are encouraged to follow one of the MCDM procedures – see an outline of the steps for the AHP (Saaty, 1999) and for SMART (Goodwin and Wright, 1992). We adapted the original procedures created for a particular MCDM method so that they can be used for more MCDM methods that are based on assigning weights. Furthermore, we adapted the frame procedure for MCDM by using the group of methods based on assigning weights to the selection of the most appropriate IT services and products. Let us only summarize the main characteristics of each step of the framework procedure of MCDM based on assigning weights – for a detailed description see (Čančer, 2010), and emphasize some particularities when using it in the selection of IT services and products:

a. *Problem definition.* When defining a problem, relevant criteria and alternatives should be described. Alternatives are characterized by several attributes. In the process of, for example, generating and developing innovations, creative thinking methods (for example, morphological analysis, and brainstorming) can be used to develop alternatives (Čančer and Mulej, 2010). However, the selection of the most appropriate IT services and products can usually be considered narrower - possible alternatives are known and these problems can be well defined by specialized experts and interested stakeholders.

b. *Elimination of unacceptable alternatives.* We assess all possible alternatives; some of them do not fulfil the requirements for the goal fulfilment and should therefore be eliminated. For example, when choosing the most appropriate IT products for SMEs, the ones created for large enterprises should not be taken into consideration in the steps that follow.

c. *Problem structuring*. When the problem is accurately described, this step transforms into *hierarchy structuring* (Saaty, 1999): each problem consists of a goal, criteria, very often some level of sub-criteria, and alternatives. Let us define attributes as the criteria on the last hierarchy level. The law of requisite holism (Mulej and Kajzer, 1998) should be followed when structuring the problem.

d. *Measuring local alternatives' values*. On the basis of the expressed judgments about the preferences to alternatives, the values of the alternatives with respect to each criterion on the lowest level (these are so-called local values), are calculated. The local values of alternatives can be measured by value functions, pair-wise comparisons or directly (Belton and Stewart, 2002). When measuring the local values of alternatives, professionals of several fields that are capable of interdisciplinary co-operation should be involved; namely, skills in their own professions as well as the ability of interdisciplinary co-operation are of great importance when making pair-wise comparisons or defining value functions. In making judgments about preferences to alternatives – IT products and services, IT engineers in enterprises, financiers, users in several departments or customers, vendors etc. should be involved. It is a great advantage if at least one member of a decision group has knowledge about MCDM methods for measuring alternatives' values with respect to attributes.

e. *Criteria weighting*. The most common aggregation tool used in MCDM has been the weighted arithmetic mean (Marichal and Roubens, 2000). Under the assumption of independence among criteria, it first requires the assignment of a weight to each criterion (Kojadinovic, 2004). This step is usually carried out by the decision makers and thus reflects their point of view on the multiple criteria decision problem (Kojadinovic, 2004). Since, in practical applications, decision makers very often tell the relative importance of criteria directly with difficulty, the criteria's importance can be expressed by using several methods (Belton and Stewart, 2002). The criteria's importance can be expressed by using the methods based on ordinal (for example, SMARTER), interval (for example, SWING and SMART) and the ratio scale (AHP), or by direct weighting (Belton and Stewart, 2002). In this article, special attention is given to the use of the methods for establishing the judgements on criteria's importance, based on the interval scale. In SMART, a decision maker is first asked to assign 10 points to the least important criterion change from the worst criterion level to its best level, and then to give points (≥ 10, but ≤ 100) to reflect the importance of the criterion change from the worst criterion level to the best level relative to the least important criterion change (Systems Analysis Laboratory, 2002). In SWING, a decision maker is asked first to assign 100 points to the most important criterion change from the worst criterion level to the best level, and then to assign points (≤ 100, but ≥ 10) to reflect the importance of the criterion change from the worst criterion level to the best level relative to the most important criterion change (Systems Analysis Laboratory, 2002). In SMART and SWING (Systems Analysis Laboratory, 2002), the weight of the j^{th} criterion, w_j, is obtained by:

$$w_j = \frac{t_j}{\sum_{j=1}^{m} t_j}, \tag{1}$$

where t_j corresponds to the points given to the j^{th} criterion, and m is the number of criteria. When the criteria are structured in two levels (which is the case in the practical example dealing with in this article), the weight of the s^{th} attribute of the j^{th} criterion, w_{js}, is in SMART and SWING obtained by:

$$w_{js} = \frac{t_{js}}{\sum_{s=1}^{p_j} t_{js}}, \tag{2}$$

where t_{js} corresponds to the points given to the s^{th} attribute of the j^{th} criterion, and p_j is the number of the j^{th} criterion sub-criteria. Again, professionals of several fields that are capable of interdisciplinary co-operation should be involved in this step. They can respond the questionnaires and then co-ordinate their judgments with other respondents. Because very often the decision makers are not aware of the relationships among different factors taken into account for the goal fulfilment, intuition and experience from the past come into forefront when establishing the judgments on importance.

f. *Synthesis*. During synthesis, the additive model is usually used, in which the reciprocal preferential independence of criteria is assumed. When the criteria are structured in one level only, the aggregate alternatives' values are obtained by:

$$v(X_i) = \sum_{j=1}^{m} w_j v_j(X_i),\ i = 1, 2, \ldots, n, \tag{3}$$

where $v(X_i)$ is the value of the i^{th} alternative, w_j is the weight of the j^{th} criterion and $v_j(X_i)$ is the local value of the i^{th} alternative with respect to the j^{th} criterion. When the criteria are structured in two levels, the aggregate alternatives' values are obtained by:

$$v(X_i) = \sum_{j=1}^{m} w_j \left(\sum_{s=1}^{p_j} w_{js} v_{js}(X_i) \right),\ i = 1, 2, \ldots, n, \tag{4}$$

where p_j is the number of the j^{th} criterion sub-criteria, w_{js} is the weight of the s^{th} attribute of the j^{th} criterion and $v_{js}(X_i)$ is the local value of the i^{th} alternative with respect to the s^{th} attribute of the j^{th} criterion.

If the criteria can interact with each other, then not only should the weights of each criterion (i.e. the criterion of the lowest hierarchy level – attribute) be considered, but also the weighting on subsets of criteria as well. A suitable aggregation operator, which generalizes the weighted arithmetic mean, is the discrete Choquet integral. Following Grabisch (1995) and Marichal (2000), this integral is viewed here as an m-variable aggregation function; let us adopt a function-like notation instead of the usual integral form, where the integrand is a set of m real values, denoted by $v = (v_1, \ldots, v_m) \in \Re^n$. The (discrete) Choquet integral of $v \in \Re^n$ with respect to w is defined by:

$$C_w(v) = \sum_{j=1}^{m} v_{(j)} \left[w(K_{(j)}) - w(K_{(j+1)}) \right], \tag{5}$$

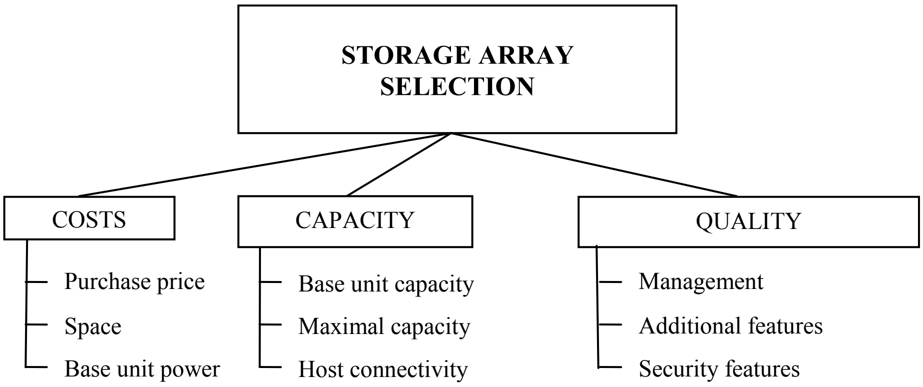
where $(\cdot)$ is a permutation on K – the set of criteria, such that $v_{(1)} \le \ldots \le v_{(m)}$. Also, $K_{(j)} = \{(j), \ldots, (m)\}$.

g. *Ranking.* With alternative ranking, we can select the most appropriate alternative(s), eliminate the alternative(s) with the lowest aggregate value, or compare the alternatives with respect to their aggregate values. In decision making about IT services and products, the first of the above mentioned purpose usually comes into forefront.

h. *Sensitivity analysis.* Several types of sensitivity analysis enable decision makers to investigate the sensitivity of the goal fulfilment to changes in the criteria's weights (for example, gradient and dynamic sensitivity) and to detect the key success or failure factors for goal fulfilment (for example, performance sensitivity and head-to-head sensitivity).

4. REAL-LIFE CASE

Let us illustrate how the frame procedure for MCDM, based on assigning weights, was followed in the selection of the most suitable storage array together with an IT enterprise with the aim of presenting possible solutions to their current and potential customers: medium-sized enterprises. The storage arrays that can be offered to medium-sized enterprises are described as alternatives: Sun Storage 6580 Array (Alternative 1) (Oracle, 2011), HP EVA 4400 (Alternative 2) (HP, 2011), IBM Storwize V7000 Unified Disk System (Alternative 3) (IBM, 2012) and E7900 Storage System (Alternative 4) (NetApp, 2011). These alternatives are characterized by the attributes presented in Table no. 2. The criteria hierarchy includes the costs (Purchase price, Space, Base unit power), capacity (Base unit capacity, Maximal capacity, Host connectivity), and quality attributes (Management, Additional features, Security features). The structure in Figure no. 1 does not include cultural, social and political factors neither several aspects of human factors (e.g. psychological, sociological and philosophical aspects) because the model was built by decision makers and experts in the considered IT enterprise to suggest medium-sized enterprises, i.e. final users, the most appropriate storage array.



Source: [own]

Figure no. 1 Criteria structure for the selection of the most appropriate storage array

The data and experts' evaluations about the alternatives with respect to the considered attributes are collected in Table no. 2. The last column in Table no. 2 shows the methods that were used together with decision makers in the considered IT enterprise to measure local alternatives' values with respect to the attributes. To evaluate alternatives with respect to space, engineers in the considered IT company compared preferences to alternatives by pairs. They evaluated the considered storage arrays with respect to purchase price and base unit power by using decreasing value functions, and with respect to base unit capacity and maximal capacity by using increasing value functions (Table no. 2). Verbal evaluations of the considered alternatives with respect to the quality attributes ant to host connectivity were attributed numerical values and measured by the direct method.

Table no. 2 Alternatives' data with respect to the attributes

Attribute	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Measuring local alternatives' values
Purchase price (measurement unit: €)	*105000*	*110000*	*87000*	*80000*	*Value function, LB: 60000, UB: 150000*
Space (measurement unit: U)	*7*	*7*	*4*	*8*	*Pair-wise comparisons*
Base unit power (measurement unit: W)	*940*	*697*	*615*	*1721*	*Value function, LB: 600, UB: 2000*

Attribute	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Measuring local alternatives' values
Base unit capacity (number of discs)	*28*	*24*	*48*	*60*	*Value function, LB: 24, UB: 60*
Maximal capacity (measurement unit: TB)	*256*	*330*	*360*	*960*	*Value function, LB: 100, UB: 960*
Host connectivity (verbal evaluation)	*Good*	*Very good*	*Very good*	*Very good*	*Direct method*
Management (verbal evaluation)	*Good*	*Advanced*	*Good*	*Advanced*	*Direct method*
Additional features (verbal evaluation)	*No*	*Good*	*Excellent*	*Excellent*	*Direct method*
Security features (verbal evaluation)	*Basic*	*Advanced*	*Basic*	*Basic*	*Direct method*

Symbols: € – Euro, W – Watt, U – standard height, TB-terabyte, LB – lower bound, UB – upper bound; Alternative 1 – Sun Storage 6580 Array, Alternative 2 – HP EVA 4400, Alternative 3 – IBM Storwize V7000 Unified Disk System, Alternative 4 – E7900 Storage System

Sources: [HP, 2011; IBM, 2012; NetApp, 2011; Oracle, 2011; own]

On the bases of experiences and detailed data from the principal, engineers in the considered IT enterprise responsible for pre-sales support expressed their judgments about the criteria's importance. The first level criteria weights were determined directly. The importance of the capacity attributes was assessed with the SWING method. 100 points were given to the change from the worst to the best base unit capacity, which is considered the most important criterion change. With respect to this change importance, 80 points were given to the change from the lowest to the highest maximal capacity, and 20 points were given to the change from the worst to the best host connectivity level. The importance of the quality attributes were assessed with the SMART method. 10 points were given to the change from the worst to the best management, which is considered the least important criterion change. With respect to this, 30 points were given to the change from the lowest to the highest additional features, and 60 points to the change from the worst to the best security features. The importance of the costs attributes was assessed by using the SMART method, as well. The weights of the attributes – second level criteria, and the first level criteria are presented in Table no. 3.

Table no. 3 The criteria structure and the weights for the selection of storage arrays

First level criteria	**Weights of the first level criteria**	**Second level criteria**	**Weights of the second level criteria**
Costs	$w_1 = 0.25$	Purchase price	$w_{11} = 0.6$
		Space	$w_{12} = 0.3$
		Base unit power	$w_{13} = 0.1$
Capacity	$w_2 = 0.4$	Base unit capacity	$w_{21} = 0.5$
		Maximal capacity	$w_{22} = 0.4$
		Host connectivity	$w_{23} = 0.1$
Quality	$w_3 = 0.35$	Management	$w_{31} = 0.1$
		Additional features	$w_{32} = 0.3$
		Security features	$w_{33} = 0.6$

Source: [own]

The alternatives' values with respect to the first level criteria and the aggregate alternatives' values, obtained by (4) in synthesis, are shown in Table no. 4. The comparison of the alternatives' values with respect to the first level criteria can let us report that the key success first level criteria of Alternative 4 are capacity and quality; Alternative 3 has the highest value with respect to costs; the key success first level criterion of Alternative 2 is quality, while the failure sphere of this alternative are costs; Alternative 1 has the lowest level with respect to capacity and quality. Table no. 4 shows that Alternative 4 has the highest aggregate value. The results of gradient sensitivity analysis can let us conclude that the final solution shown in Table no. 4 is highly stable. Namely, with reasonably small (< 0.1) changes of weights, the rank of the first and the second alternative is not changed.

The customers' managers that make the storage array purchase decisions are interested in the interactions among the first level criteria. On the bases of experiences and detailed data from the principal, engineers in the considered IT enterprise responsible for pre-sales support evaluated that there is synergy between capacity and quality. In the concept of the Choquet integral, the directly evaluated synergy between capacity and quality means: $w_{2,3} > w_2 + w_3$; $w_2 + w_3 = 0{,}75$ (Table no. 3), and $w_{2,3} = 0{,}90$. They also evaluated that there is synergy between costs and quality: $w_{1,3} > w_1 + w_3$; $w_1 + w_3 = 0{,}6$, and $w_{1,3} = 0{,}7$, and redundancy between costs and capacity: $w_{1,2} < w_1 + w_2$; $w_1 + w_2 = 0{,}65$, $w_{1,2} = 0{,}55$. Table no. 4 presents the Choquet integrals, obtained by (5). For instance, for Alternative 4, where $v_3 < v_1 < v_2$ (Table no. 4), we have:

$$C_w(v_1, v_2, v_3) = v_3\left[w_{3,1,2} - w_{1,2}\right] + v_1\left[w_{1,2} - w2\right] + v_2 w_2\,, \tag{6}$$

where $w_{3,1,2} = 1$. Following (5), the Choquet integral for other alternatives was expressed. The values of Choquet integral C in Table no. 4 let us report that considering synergies and redundancies among the first level criteria did not change the rank of the observed alternatives. In this case, considering synergies and redundancies among the first level criteria can therefore confirm the priority of the alternative with the highest aggregate value obtained by the additive model.

Table no. 4 The alternatives' values

	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**
Value with respect to costs v_1	0.431	0.415	0.679	0.516
Value with respect to capacity v_2	0.178	0.187	0.534	0.980
Value with respect to quality v_3	0.220	0.450	0.430	0.450
Aggregate alternative's value v – additive model	0.256	0.336	0.534	0.678
Choquet integral C	0.260	0.359	0.523	0.672
Rank	4.	3.	2.	1.

Source: [own]

5. CONCLUSIONS

Considering synergies and redundancies among criteria can strengthen the decision making basis in the selection of the most appropriate IT product or service. Due to the ranking of the alternative's values with respect to the criterion on the observed level, some of the synergies and redundancies might not be considered when using the Choquet integral approach. In the above presented real-life case it was not possible to include the synergy between capacity and quality in (5). Moreover, the ranking of the alternative's values can differ for each of the considered alternatives, which results in adapting (5) to each alternative. Considering synergies and redundancies can confirm the priority of the alternative with the highest aggregate value obtained by the additive model – which is the case in the presented real-life problem. On the other hand, it can also considerably change the values and the ranks of the alternatives in other problems. That depends upon the ranks of the alternative's values with respect to the criteria on the observed level.

The presented decision making approach has proved appropriate – it is explored by considering the theoretical foundations of MCDM, own experience of author and the experiences of experts in business practice that have already applied it in solving problems. The frame procedure for MCDM for the methods based on assigning weights has already been applied in several real-life applications on micro and macro level (Čančer, 2010). However, the model built for the selection of the most appropriate IT infrastructure can be adapted regarding the considered IT product or service. Moreover, when the model is being used in an IT enterprise over time, customer needs and rapid developments in the IT sector cause the need for changing the set of alternatives appearing in the market.

In the real-life case described in this article, the presented frame procedure for MCDM was applied by multi-vendor systems integrator with the aim of presenting possible solutions to their current and potential customers. However, it can also be used directly by their customers when evaluating their own needs and preparing tenders for IT products and services. The adapted frame procedure was also tested by three potential users – medium-sized enterprises that wanted to perform MCDM about the most appropriate storage array by themselves. The steps of the described frame procedure for MCDM were followed. Although IT experts, managers and end users in several departments employed in these enterprises were included in the decision-making teams, they were faced with the lack of expertise in the field of storage arrays. When defining the problem, potential users considered less relevant alternatives than the multi-vendor systems integrator because, for example, they preferred their current vendor or they considered only their current needs. Objective elimination of unacceptable alternatives based on holistic expertise was therefore not possible. When measuring the local values of alternatives by using value functions, the lack of the alternatives' data with respect to the attributes resulted in the upper and lower bounds, different from the ones in Table no. 2, and consequently in the alternatives' values, different from the ones presented in Table no. 4. The methods based on interval scale SMART and SWING turned out to be helpful in criteria weighting, and synthesis and sensitivity analysis were well supported by appropriate user friendly computer programs. However, potential users did not consider synergies and redundancies among criteria because of the lack of experience and knowledge in the field of storage arrays. Moreover, not all of potential users are able to acquire the aggregation operators, suitable for considering interactions among criteria. It can be concluded that systematic procedures cannot compensate for the lack of knowledge or limited abilities of decision makers. Again, professionals of several fields that are capable of interdisciplinary co-operation should be involved in MCDM about the most appropriate IT products and services.

References

Belton, V. and Stewart, T. J., 2002. *Multiple Criteria Decision Analysis: An Integrated Approach*. 3rd Edition. Boston, Dordrecht, London: Kluwer Academic Publishers.

Bučar, M., 2002. Informacijska tehnologija kot razvojna priložnost za Slovenijo. *Naše gospodarstvo* , 48(1-2), pp. 1-9.

Čančer, V., 2010. A Frame Procedure for Multi-criteria Decision-making: Formulation and Applications. In: V. Boljunčić, L. Neralić and K. Šorić, eds. *KOI 2008 Proceedings*. Pula, Zagreb: Croatian Operational Research Society, pp. 1-10.

Čančer, V. and Mulej, M., 2010 The Dialectical Systems Theory's Capacity for Multi-Criteria Decision-Making. *Systems research and behavioral science,* 27(3), pp. 285-300.

European Commission – Information Society, 2007. *i2010 in context – ICT and Lisbon Strategy*. [online] Brussels: European Commission. Available at: <http://ec.europa.eu/information_society/eeurope/i2010/ict_and_lisbon/index_en.htm> [Accessed 26 February 2012].

European Commission, 2010. *Communication from the Commission: EUROPE 2020: A strategy for smart, sustainable and inclusive growth*. Brussels: EU European Commission, 2010.

Goodwin, P. and Wright, G., 1992. *Decision Analysis for Management Judgment*. Chichester: John Wiley & Sons.

Grabisch, M., 1995. Fuzzy integral in multicriteria decision making. *Fuzzy Sets and Systems*, 69(3), pp. 279-298.

Grabisch, M. and Labreuche, Ch., 2005. Fuzzy Measures and Integrals in MCDA. In: J. Figueira, S. Greco and M. Ehrgott, eds. *Multiple Criteria Decision Analysis*. New York: Springer, pp. 563-608.

HP, 2011. *Disk Storage Systems*. [online] HP. Available at: <http://h18006.www1.hp.com/storage/disk_storage/index.html> [Accessed 28 January 2013].

IBM, 2012. *IBM Storwize V7000 Unified Storage*. [online] IBM. Available at: <http://www-03.ibm.com/systems/storage/disk/storwize_v7000/overview.html> [Accessed 28 January 2013].

JAPTI, 2011. *Key figures 2010*. [online]. Ljubljana: JAPTI, 2011. <http://www.investslovenia.org/en/industries/ict/> [Accessed 26 January 2013].

Kojadinovic, I., 2004. Estimation of the weights of interacting criteria from the set of profiles by means of information-theoretic functional. *European Journal of Operational Research*, 155(3), pp. 741-751.

Marichal, J. L., 2000. An Axiomatic Approach of the Discrete Choquet Integral as a Tool to Aggregate Interacting Criteria. *IEEE Trans. Fuzzy Systems*, 8(6), pp. 800-807.

Marichal, J. L. and Roubens, M., 2000. Determination of weights of interacting criteria from a reference set. *European Journal of Operational Research*, 124(3), pp. 641-650.

Moaven, S., Ahmadi, H., Habibi, J. and Kamandi, A., 2008. A Fuzzy Model for Solving Architecture Styles Selection Multi-Criteria Problem. In: D. Al-Dabass, A. Nagar, H. Tawfik, H. Abraham and R. Zobel. *Proceedings of the Second UKSIM European Symposium on Computer Modeling and Simulation*. IEEE Computer Society, pp.388-393.

Mulej, M. and Kajzer, Š., 1998. Ethics of Interdependence and the Law of Requisite Holism. In: M. Rebernik, M. and M. Mulej, eds. *STIQE '98, Proceedings of the 4th International Conference on Linking Systems Thinking, Innovation, Quality, Entrepreneurship and Environment*. Maribor: Institute for Entrepreneurship and Small Business Management, at Faculty of Economics and Business, University of Maribor, and Slovenian Society for Systems Research, pp. 129-140.

NetApp, 2011. *E7900 Storage Systems*. [online] NetApp. Available at: <http://www.netapp.com/us/products/storage-systems/e7900/> [Accessed 11 February 2012].

Oracle, 2011. *Enterprise Disk Storage: Sun Storage 6000 Array Series – Sun StorageTek 6580*. [online] Oracle. Available at: <http://www.oracle.com/us/products/servers-storage/storage/san/fc/overview/index.html>. [Accessed 11 February 2012].

Raiffa, H., 1994. The Prescriptive Orientation of Decision Making: A Synthesis of Decision Analysis, Behavioral Decision Making, and Game Theory. In: S. RIOS, ed. *Decision Theory and Decision Analysis: Trends and Challenges*. Boston: Kluwer Academic Publishers.

Saaty, T. L., 1999. *Decision Making for Leaders.* 3rd Edition. Pittsburgh: RWS Publications.

Systems Analysis Laboratory, 2002. *Value Tree Analysis*. [online] Helsinki: Systems Analysis Laboratory, Helsinki University of Technology. Available at: <http://www.mcda.hut.fi/value_tree/theory>. [Accessed 9 March 2013].

Sridhar, P., Madni, A. M. and Jamshidi, M., 2008. Multi-Criteria Decision Making in Sensor Networks. *IEEE Instrumentation & Measurement Magazine.* 11(1), pp. 24-29.

World Economic Forum, 2011. *The Global Competitiveness Report 2011-2012*. [online] World Economic Forum. Available at: <http://www.weforum.org/reports/global-competitiveness-report-2011-2012>. [Accessed 9 March 2013].