Mathematical models for decision-making about ISO 9001 and/or ISO 14001 under risk and fuzziness

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***Abstract* —** Quality decision-making is currently one of the most important managerial activities of each enterprise. Every day decisions differ only by their importance and complexity. Companies are facing strong competitive environment on their markets and they meet with problems based on uncertainty or fuzziness of the information during decision-making processes. If companies want to make their decision precise they must find the way how to work with this uncertainty. Rapidly growing and changing development generates significant pressure on the companies. This pressure is based on never ending competitiveness and challenges. Companies can gain stronger competitive position by implementation of the ISO norms 9001 and the ISO 14001. ISO certification in quality and environmental management has grown noticeably in several last years. ISO certification is becoming more and more obvious than just an exceptional. Number of certified organizations growth rapidly in last two decades. The evolution in the Czech Republic copied the rapid evolution and in the last years Czech Republic reached leading position in ISO implementations of quality and environment.

The key element of ability how to make quality decision is to find the way how to work with uncertainty, how to express or use obtained knowledge and information. Crossing the border between certainty and uncertainty, this moves our decisions on higher level and gives us the key competitive advantage. In our contribution we will demonstrate the application of decision-making model based on fuzzy information. Fuzzy decision model (game against nature) will be used for the choice of the best decision for the following real problem: Management has to decide if implement ISO 9001 (Quality management system) and/or implement ISO 14001 (Environmental Management Systems). Finding out if customers are oriented towards the ISO 9001 or the ISO 14001 is based on the progress of number of certified companies. Model contains fuzzy states of nature and pay-off of possible alternatives.

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I. Introduction

CONTEMPORARY economic decision-making is a very complex and complicated process which has an important impact on firm competitiveness. Interests of the most managers are mostly focused on reaching positive economic results and as well as on extending of the approaches how to reach these economic results. Large attention is now giving to quality production and to environment.

During the ends of 80s World Commission on Environment and Development (United Nations) published report, in which they have noted, that subsequent development of society, if the global environment will not be threatened, has to continue based on a new type of economic development. This development was called as “Sustainable development” [19]. Sustainable development has three dimensions – economic, social and environmental.

If in the past decades was sufficient aim our concentration only on quantitative and economical aspects of managements, nowadays it is necessary to manage qualitative and time aspects as well. It is not sufficient supply relevant amount of products in specified price, but it is also necessary guarantee required quality and delivery time. Production quality is not only a marketability condition of the product, but quality or we can better say non-quality in a form of defective production does not have insignificant impacts on effectiveness of manufacture. Losses from defective production could be significant item in financial statements. This significant item can come up to several percents [21]. During 80s appeared first signals which lead towards responsibility of producers in products quality. New universal standards in quality were introduced in form of norms ISO 9001. Quality management system (QMS) is more and more oriented on requirements of establishing ISO 9001 into the practice.

On the other side, environmental care also belongs among the important international problems of present days. Existing experiences show us, that social and especially technological development had basically negative impact on the environment. In this context it is necessary reach sustainability of technological development. Environmental management system (EMS) became relevant since second half of 90s in

connection with acceptance of new ISO norms 14001. Organizations whose productions have impact on the environment have opportunities to obtain competitive advantages thanks to the ISO 14001. EMS includes organizational structure, planning activities, responsibilities, practices, procedures and sources which they can use for develop, implement, reach, revision and sustentation of environmental policy [21].

Establish and routine sustentation of management systems of quality and environment in organizations creates environment, which will generate standard managerial and operational practices. Certificate in form of certification is becoming decisive signal (guarantee) especially for customers, employees and relevant companies around, that the company is able to manage their processes. Sambasivan and Fei [16] noted that with the progressively widespread adoption of the ISO 14001 standards, it is not surprising that, in the near future, the implementation of an environmental management system (EMS), through registration with ISO 14001, will be the norm rather than the exception. We can fully agree with this conclusion in ISO 9001 implementation.

In this article we will analyze decision problem of the company, if establish (implement) or not ISO norms (ISO problem). This problem will be solved by classical decision-making model under the risk with using EMV (Expected Monetary Value) criterion and then with decision-making model under fuzziness.

II. Benefits, Barriers and Impacts of ISO Implementation

Implement ISO norm of quality should lead towards to higher companies' profit and towards to increasing competitiveness by optimizing processes with a particular focus on the costumers. Cagnazzo et al. [4] described the main impacts of ISO 9001 on companies' performance. The impacts on business performances have been classified as external and internal.

- The external impacts are divided by impact on:

1) International trades,
2) Suppliers,
3) Customers,
4) Stakeholders, and
5) Market.

- The internal impacts are divided by impact on:

1) Quality system,
2) Product/service,
3) Competitiveness,
4) Financial performance, and
6) Human resource/organizational climate.

From Cagnazzo et al. survey [4] we see that the perception of the impact is mostly seen in improving operating efficiency (almost 70 % of all votes in internal impacts compare to better control of business operations with 21 %). The perception of external impacts is mostly given to costumers' satisfaction (more than 30 %), then improvement of company image (26 %). We can see that implementation of ISO 9001 has a huge impact on each company who wants to adopt quality management concept.

We can fully agree with that. The similar survey, in condition of the Czech Republic, was published by Šnajdr et al. [20]. They mentioned that the main assets from implementation are stronger position on the market, increasing of the market share, increasing competitiveness, acquirement of costumers' satisfaction, costumers' loyalty etc.

On the other side we should mention that there exist several barriers or pitfalls as well. Cagnazzo et al. [4] describes five main barriers from the company's side. They are

1) Short-sighted goal for "getting certified",
2) Over-expectation on ISO standard,
3) Mandatory requirement in some industries,
4) Following others (the trend) in certification, and
5) Lack of necessary guidance for certification.

We can compare these barriers with barriers which are important for Šnajdr et al. [20]:

1) Bad communication between company's departments,
2) Low interest of employees',
3) Unwillingness to responsibility, and finally
4) Low potential of companies' innovation.

Obviously we can also find several benefits for implementation of ISO 14001 as well. Most of them correspond with benefits regard to ISO 9001. For Sambasivan and Fei [16] the more important benefits are:

1) Gain entry into the global market
2) Maintain and gain competitive position in the global market,
3) Improve the company's image,
4) Improve the company's operations, and
5) Provide a clean environment through clean operations.

Many organizations seem as a main problem of implementation of EMS difficulties in determining the tangible and intangible benefits or impacts considering the cost incurred [16].

III. Tendency to ISO implementation

We already discussed benefits and barriers in ISO implementation. Each management has to weight if the implementation will be an advantage for their company or if it will not. Now let us find out what the trends in ISO 9001 and ISO 14001 are.

Quality management had a significant growth in the last 15 years. There are a few reasons for this growth. Firstly there has been a huge competition on the markets. Markets were flooded by many products and prices are in many cases pressed down to the minimum. Secondly consumers expect more than just a low price. There was a space for better quality production. Table 1 summarizes the number of ISO 9001 implementation on the World. Since 1993 Europe is consequently the leader in

Quality management system implementation. It is a noteworthy mention the growth of Far East in the last decade. Europe and Far East have regional share 47 % and 37,4 % respectively (Table 2).

Table 1. ISO 9001 – Quality management system – Requirements - overview

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TOTAL	46571	70364	127349	162701	223299	271847	343642	457834	510349	561767	497919	660132	773867	896929	951486	982832	1064785
Africa / West Asia	1272	1855	3378	6162	8668	12150	17307	20183	19800	23627	20124	31443	48327	71438	78910	73104	77408
Central / South America	140	475	1220	1713	2989	5221	8972	10805	14409	13679	9303	17016	22498	29382	39354	39940	36551
North America	2613	4915	10374	16980	25144	33550	45166	48296	50894	53806	40185	49962	59663	61436	47600	47896	41947
Europe	37779	55400	92611	109961	143674	166255	190247	269332	269648	292878	242455	320748	377196	414232	431479	455332	500319
Far East	1583	3091	9240	18407	29878	37920	56648	81919	126779	148573	163061	220966	247091	300851	345428	356559	398288
Australia / New Zealand	3184	4628	10526	9478	12946	16751	25302	27299	28819	29204	22791	19997	19092	19590	8715	10001	10272

Source: ISO 2009 survey [10]

Table 2. ISO 9001 – Quality management system – Requirements – regional share in %

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TOTAL	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Africa / West Asia	2,7%	2,6%	2,7%	3,8%	3,9%	4,5%	5,0%	4,4%	3,9%	4,2%	4,0%	4,8%	6,2%	8,0%	8,3%	7,4%	7,3%
Central / South America	0,3%	0,7%	1,0%	1,1%	1,3%	1,9%	2,6%	2,4%	2,8%	2,4%	1,9%	2,6%	2,9%	3,3%	4,1%	4,1%	3,4%
North America	5,6%	7,0%	8,1%	10,4%	11,3%	12,3%	13,1%	10,5%	10,0%	9,6%	8,1%	7,6%	7,7%	6,8%	5,0%	4,9%	3,9%
Europe	81,1%	78,7%	72,7%	67,6%	64,3%	61,2%	55,4%	58,8%	52,8%	52,1%	48,7%	48,6%	48,7%	46,2%	45,3%	46,3%	47,0%
Far East	3,4%	4,4%	7,3%	11,3%	13,4%	13,9%	16,5%	17,9%	24,8%	26,4%	32,7%	33,5%	31,9%	33,5%	36,3%	36,3%	37,4%
Australia / New Zealand	6,8%	6,6%	8,3%	5,8%	5,8%	6,2%	7,4%	6,0%	5,6%	5,2%	4,6%	3,0%	2,5%	2,2%	0,9%	1,0%	1,0%

Source: ISO 2009 survey [10]

Table 3. Top 10 countries for ISO 9001 growth in 2009

1	Russian Federation	37101
2	China	32460
3	Italy	11757
4	Japan	5738
5	Romania	5128
6	Czech Republic	3942
7	Vietnam	3362
8	Poland	1742
9	Israel	1214
10	Iran	1090

Source: ISO 2009 survey [10]

In this contribution we focus on European countries and mainly on the Czech Republic. When we consider economic development in Czech Republic during the last two decades we would say that this development has been significant. Czech Republic adopted principles of western European countries in quality and environment. In the field of Quality management system it increased a lot in a few last years.

Table 3 shows us that Czech Republic reached top 10 in ISO 9001 growth in 2009. Czech companies, mostly with foreign owners, understand very well that in globalization time it is necessary to improve their competitiveness and Quality management system in ISO 9001 standard is an effective way.

Our contribution is focused on implementation of Environment management system based on the principles of ISO 14001 as well. So let us talk now about the evolution of environment thinking in global environment and European too.

Table 4 and Table 5 describe the evolution of ISO 14001. The evolution is similar like in ISO 9001 standard. During last decade the main roles have played Europe and Far East. They regional share is 40 % for Europe and approximately 50 % for Far East.

ISO 14001 is not globally extended as much as ISO 9001 is. This standard is in the most occasions implemented as an enlargement for Quality management system. There is considerably less cases when company implements previously ISO 14001 before ISO 9001. Many authors [5] pointed out that the number of ISO 9001 certificates in a given country is one of the factors explaining the number of ISO 14001 certificates issued in the same country.

Explanation of their shares would be explained due to large extension among companies and awareness among customers. Other regions would have other standards which their domestic companies preferred. But ISO standards are getting more popular and more internationally accepted.

Table 4. ISO 14001 – Environment management system – Requirements - overview

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TOTAL	13994	22847	36464	49440	64996	90554	111163	128211	154572	188815	223149
Africa / West Asia	337	651	924	1357	2002	2999	3994	4832	5586	7682	8813
Central / South America	309	556	681	1418	1691	2955	3411	4355	4260	4654	3923
North America	975	1676	2700	4053	5233	6743	7119	7673	7267	7194	7316
Europe	7253	10971	17941	23305	30918	39805	47837	55919	65097	78118	89237
Far East	4350	7881	12796	17744	23747	35960	46844	53286	71458	89894	112237
Australia / New Zealand	770	1112	1422	1563	1405	2092	1958	2146	904	1273	1623

Source: ISO 2009 survey [10]

Table 5. ISO 14001 – Environment management system – Requirements – regional share in %

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Africa / West Asia	2,4%	2,8%	2,5%	2,7%	3,1%	3,3%	3,6%	3,8%	3,6%	4,1%	3,9%
Central / South America	2,2%	2,4%	1,9%	2,9%	2,6%	3,3%	3,1%	3,4%	2,8%	2,5%	1,8%
North America	7,0%	7,3%	7,4%	8,2%	8,1%	7,4%	6,4%	6,0%	4,7%	3,8%	3,3%
Europe	51,8%	48,0%	49,2%	47,1%	47,6%	44,0%	43,0%	43,6%	42,1%	41,4%	40,0%
Far East	31,1%	34,5%	35,1%	35,9%	36,5%	39,7%	42,1%	41,6%	46,2%	47,6%	50,3%
Australia / New Zealand	5,5%	4,9%	3,9%	3,2%	2,2%	2,3%	1,8%	1,7%	0,6%	0,7%	0,7%

Source: ISO 2009 survey [10]

Now let us focus on the Czech Republic again. The evolution in case of ISO 14001 is similar like in case of ISO 9001. Czech companies have adopted this standard due to requirements for stronger competitiveness on the European market or global market respectively. Table 6 shows us that Czech Republic is in TOP 10 countries worldwide in ISO 14001 implementations. If we consider that Czech Republic is globally a small country it is a very interesting situation. Czech Republic has reached its position thanks to successful implementation in 2009 (Table 7).

The popularity increased during the last years when Czech companies saw the big advantages which they gained from successful Quality management system implementation. This situation has confirmed their belief that this implementation will have a positive impact onto their competitiveness. Another important issue is joined to increasing global environmental care. Most governments, European are not an exception, pay a bigger attention to the environment projects and to the environmental behaviour. Environmental management system is currently an important requirement for those organizations wishing to sell their products in the context of the global market [6]. Implementation may affect on company's capability sell products globally.

Table 6. ISO 14001 – top 10 countries

1	China	55316
2	Japan	39556
3	Spain	16527
4	Italy	14542
5	United Kingdom	10912
6	Republic of Korea	7843
7	Romania	6863
8	Germany	5865
9	USA	4684
10	Czech Republic	4684

Source: ISO 2009 survey [10]

However there is a large dissemination of both standards, we have seen a certain drop in the number of certificates in several of the countries which had historically been leaders in these areas [5]. Potentially there could be a saturation of implementation of ISO 9001 or ISO 14001.

Table 7. Top 10 countries for ISO 14001 growth in 2009

1	China	16121
2	Japan	3983
3	Romania	2979
4	Italy	1620
5	United Kingdom	1457
6	Czech Republic	1366
7	France	1196
8	Thailand	930
9	Russian Federation	783
10	Republic of Korea	710

Source: ISO 2009 survey [10]

IV. Reasons of Decision-Making in ISO Implementation

In our opinion all of the main barriers have similar reasons. In companies where implementation of ISO norms was not successful, there exists low stress on the communication between departments and adequate expectations.

When company has to consider all of those barriers, impacts and benefits, there is a significant reason, why company should think about decision-making method as a tool for the right decision.

The implementation of the ISO norms can be considered, in some sense, as an innovative behaviour. Pekovic and Galia [12] investigated the impact of quality system of ISO 9001 on innovation. They pointed out that ISO 9000 certification seems to be positively associated with innovation performance (correlation between ISO 9000 and innovation is positive and significant concerning products, processes and innovation). In order to increase profits from implementation the ISO norms, i.e. higher production quality and increase of awareness of company's environmental care, it is appropriate to include key customers and suppliers into the company's innovative suggestions. We see marketing research as an insufficient compare to ISO implementation's impact.

Pitra [13] mentioned relation between quality management system and innovations. Implementation ISO norms and effective function of quality management is necessary condition for successful development of innovative activities. Innovations are positively joined with knowledge of the company itself. Lee [11] pointed out the usage of ISO 9001 to reach the knowledge application of the business.

So why is there a reason for decision-making methods? Companies have to be for hundred percent sure that there will be a positive impact. By positive impact we mean not only a bigger profit or stronger competitiveness position. We already mentioned above that in ISO 14001 implementation is difficult to recognize tangible and intangible benefits. Decision-making model is a one of the tools which we can use for solving this problem, for answer the question if there will be a significant profit (benefit) for organization. We can calculate all possible future events. Future events as high or low customer preferences in the ISO norms, costs and profit impact of implementation etc.

V. ISO Problem Formulation and Solving – Implement ISO 9001 and/or ISO 14001?

The real company in the Czech ICT market, which does not wish to be designated, provides complex spectrum of services in the field of system integration. Currently the company is looking for new opportunities how to increase their competitiveness. First possible way is establish Quality management system based on ISO 9001 and/or establish Environmental management system based on ISO 14001. It is going to be decision-making under the risk, because there is much information (reports) which include forecasts of the future trend (progression) on the market [7]. Another reason why it is going to be a decision-making under risk can be due to the points which we described in chapter II and corresponding to [4] and [20].

Uncertainty in this problem comes primarily through the manner of definition of the states of nature in the model. We will construct model with fuzzy states of nature and crisp alternatives, but the evaluation of each combination alternative-fuzzy states of nature will be crisp values. This model is compared with decision-making model under risk.

A. Decision-Making under Risk

Decision model helps to choose the best decision alternative ([1], [14], [17]). In fact, it is a model of games against nature. The decision maker selects one of alternatives that are available. Their effect depends on possible future states of nature and its probability. Payoffs are associated with each combination alternative – state of nature. The general format of a decision model is in a decision table (Table 1).

Table 8. Decision table with crisp states of nature

		States of nature			
		S_1	S_2	.....	S_n
Alternatives	A_1	v_{11}	v_{12}	...	v_{1n}
	A_2	v_{21}	v_{22}	...	v_{2n}
	.....	...	...	...	...
	A_m	v_{m1}	v_{m2}	...	v_{mn}
Probability	***P***	p_1	p_2	.....	p_n

where A_i is the i-th alternative, i = 1, ..., m,
S_j is the j-th state of nature, j = 1, ..., n,
v_{ij} is the payoff of alternative A_i and state of nature S_j combination, and
p_j is probability of state of nature S_j.

The appropriated alternative is selected according to the decision criterion; typically the best alternative maximizes the payoff value. Commonly used criterion is Expected monetary value criterion (EMV), the alternative A_I is selected, if it has the maximal mean value of payoff (1).

$$EMV_i = \sum_{j=1}^{n} p_j v_{ij} \quad i = 1, ..., m$$
$$A_I: \quad EMV_I = \max_{i=1,...,m} EMV_i \tag{1}$$

The decision theory and decision models enable the decision-maker to make rational decisions. There are many principles for decision model solving, but all of them need crisp data assessing. This may often lead to unsatisfactory results because of the accuracy of data estimation ([2], [3], [7], [8], [9]).

B. Decision-Making under Fuzzy

The decision theory and decision models can be used also in the case of so called soft defined problems when the decision-maker is not able to make a crisp definition of problem [15].

For this reason some methods exist for decision model solving whenever the crisp formalization and quantification is difficult or impossible. One possible way of softening decision model is including fuzzy information into model construction.

Suppose now that we are not able to set exact definition of states of nature. In this situation we have to define elements of universe of states of nature, than fuzzy state of nature and values of membership function of elements of universe into all fuzzy states of nature and probability of elements of universe [15]. Fuzzy decision table has to be enlarged comparing it to crisp decision table ([8], [14]). It has to include all these data and information. The decision model with fuzzy state of nature is described in a following decision table (Table 9). Sirbiladze et al. [18] shows an application of fuzzy methods in optimization model including expert knowledge and comparison between crisp approach and fuzzy approach according to the application of the optimal choice of candidates.

Table 9. Decision table with fuzzy states of nature

		Fuzzy states of nature				
		$\tilde{\tilde{F}}_1$	$\tilde{\tilde{F}}_2$	...	$\tilde{\tilde{F}}_n$	***P***
Universum	S_1	$\mu_{\tilde{\tilde{F}}_1}(s_1)$	$\mu_{\tilde{\tilde{F}}_2}(s_1)$	...	$\mu_{\tilde{\tilde{F}}_n}(s_1)$	P_1
	S_2	$\mu_{\tilde{\tilde{F}}_1}(s_2)$	$\mu_{\tilde{\tilde{F}}_2}(s_2)$	...	$\mu_{\tilde{\tilde{F}}_n}(s_2)$	P_2
	...	...	...	...	...	...
	S_r	$\mu_{\tilde{\tilde{F}}_1}(s_r)$	$\mu_{\tilde{\tilde{F}}_2}(s_r)$	...	$\mu_{\tilde{\tilde{F}}_n}(s_r)$	P_r
Alternatives	A_1	v_{11}	v_{12}	...	v_{1n}	
	A_2	v_{21}	v_{22}	...	v_{2n}	
	...	...	...	...	...	
	A_m	v_{m1}	v_{m2}	...	v_{mn}	

where A_i is the i-th alternative, $i = 1, ..., m$,

$\tilde{\tilde{F}}_j$ is the j-th fuzzy state of nature, $j = 1, ..., n$,

S_k is element of universum of fuzzy states of nature, $k = 1, \ldots, r$

$\mu_{\tilde{\tilde{F}}_j}(s_k)$ is membership function of elements S_k in $\tilde{\tilde{F}}_j$

v_{ij} is the payoff of alternative A_i and state of nature $\tilde{\tilde{F}}_j$ combination.

P_k is probability of S_k.

All fuzzy states of nature are defined on a universe of numerical rates. The fuzzy states $\tilde{F}_j$ will be required to be orthogonal fuzzy sets. This orthogonality condition means that for the fuzzy states membership function values will be hold

$$\sum_{j=1}^{n} \mu_{\tilde{F}_j}(x_k) = 1 \quad k = 1,...,n \tag{2}$$

The first step in process of the best alternative selection by fuzzy Bayesian decision method is to calculate expected pay-off of crisp alternative A_i:

$$EMV_i = \sum_{j=1}^{n} \mu_{ij}\, p(\tilde{F}_j) \tag{3}$$

where

$$p(\tilde{F}_j) = \sum_{j=1}^{n} \mu_{\tilde{F}_j}(x_k)\, p(x_k) \tag{4}$$

The best alternative will be chosen as

$$A_I : \quad EMV_I = \max_{i=1,...,m} EMV_i \tag{5}$$

C. Additional information

In many decision situations we are asking, if we can obtain more information, which could help us make decision-making process more precise. Make final decision later when we will have more information or we will know more, it is not always possible regard to company's changing environment (prices, inflation etc.). In fact of this problem we are trying to obtain additional information which would confirm our forecasts or fill them in and lowered potential risks. We can obtain new useful information for the states of nature from research, experiments etc.

Additional information can be used for upgrading original probabilities. Firstly we considered probabilities as the crisp values. In this situation additional information will be used as a weight for them. Decision-making process will continue as normally, but at the end we will compare both results and if the result with additional information will be higher than without additional information, this information has own utility.

Next we can consider additional information as a fuzzy value. It means that additional information can be joined with uncertainty. This uncertainty can exist wherever around us. Additional information will be a universe of discourses suitable for new information. Next step is creation of fuzzy states of nature on this information as a "good information", "average information" or "bad information". All fuzzy information will have member-ship function.

D.Crisp ISO Problem - The Best Alternative under Risk

Analysis of solve decision problem result in the following definition of crisp ISO problem. There are three possible strategies:

- A_1 no ISO norm establish
- A_2 establish only ISO 9001
- A_3 establish ISO 9001 and ISO 14001

Universe of all possible (crisp) states of nature is divided into following five subsets – crisp defined states of nature:

- S_1 no preference of ISO norms by consumers
- S_2 low preference, market begins orient onto ISO 9001
- S_3 average preference, market requires ISO 9001
- S_4 higher preference, market requires ISO 9001 and tends also onto ISO 14001
- S_5 absolute preference, market requires both ISO 9001 and ISO 14001

Profit in the sector of system integration was evaluated around 500 million Czech crown. Our company has market share 25 %. We will consider company's profit in the amount 125 million Czech crowns. Estimation of expenses necessary for implementation managerial approaches corresponds to customer's satisfaction, i.e. current probabilities of states of nature. Into the expecting profits were calculated costs needed for implementation ISO norms. These costs are:

1) Costs for implementation from external company,
2) Costs for internal and external audit,
3) Running costs, and
4) Control audit from Certification Company ([7], [8], [9]).

The decision-making model is evaluated with profit estimation as it is shown below (Table 10).

Table 10. Decision model of crisp ISO problem

Profit	S_1	S_2	S_3	S_4	S_5
A_1	125	120	115	110	100
A_2	131	140	136	137	135
A_3	120	126	132	144	150
Probability	0,1	0,3	0,4	0,1	0,1

Next elements are probabilities of all states of natures. Currently customers (market) do not overly require ISO certification, i.e. their orientations onto certificated systems are average or rather lower. In this fact, higher probabilities will be situated in states of nature S_2 and S_3. It is outlined in Table 10.

The best alternative according to the EMV criterion is the second variant A_2 with the highest EMV value (Table 11). The alternative A_3 yields also a good value of EMV.

Table 11. EMV criterion values using formula (1)

A_1	EMV_1	115,5
A_2	EMV_2	**136,7**
A_3	EMV_3	132

E. Fuzzy ISO Problem - The Best Alternative Under Fuzzy

Analysis of decision problem and its soft character result in the following definition of fuzzy ISO decision-problem. Our alternatives or possible strategies are again:

- A_1 no ISO norm establish
- A_2 establish only ISO 9001
- A_3 establish ISO 9001 and ISO 14001

Universe of discourses of all possible states of nature is divided into following five subsets – crisp defined states of nature as above:

- S_1 no preference of ISO norms by consumers
- S_2 low preference, market begins orient onto ISO 9001
- S_3 average preference, market requires ISO 9001
- S_4 higher preference, market requires ISO 9001 and tends also onto ISO 14001
- S_5 absolute preference, market requires both ISO 9001 and ISO 14001

On this universe we will describe four fuzzy states of nature:

- $\tilde{F}_1$ market non-oriented onto ISO norms
- $\tilde{F}_2$ market oriented only onto ISO 9001
- $\tilde{F}_3$ market oriented only onto ISO 14001
- $\tilde{F}_4$ market oriented simultaneously onto ISO 9001 and ISO 14001

Next step is a definition of probabilities of each states of nature from universe. Currently our customers are not a lot satisfied in certification of ISO norms. It means that their orientation for certificated systems is rather low-average (according our states of nature). Due to this situation bigger probabilities will be at states S_2 and S_3

$$\boldsymbol{P} = (0{,}1 \quad 0{,}3 \quad 0{,}4 \quad 0{,}1 \quad 0{,}1)$$

Company's profit or model pay-offs are estimated using same principle as above. The decision model will be constructed as it is shown below (Table 12, Table 13).

Table 12. ISO problem with fuzzy states of nature

Profit	$\tilde{F}_1$	$\tilde{F}_2$	$\tilde{F}_3$	$\tilde{F}_4$
A_1	125	115	115	100
A_2	131	140	138	135
A_3	120	130	140	150

The following step is defining of membership function values for each fuzzy states of nature. Evaluation of

membership function is based on expert estimation of weight of S_k according to the description of $\tilde{F}_j$ For example fuzzy is defined on the combination of S_1 and S_2 in proportion 0,4 and 0,7. The proportion of splitting of all fuzzy states of nature corresponds to the similarities among them and universe of discourses. The fuzzy sets in Table 13 satisfy the orthogonal condition due to (2).

Table 13. Membership values for fuzzy states

	$\tilde{F}_1$	$\tilde{F}_2$	$\tilde{F}_3$	$\tilde{F}_4$	$\boldsymbol{P}$
S_1	1	0	0	0	0,1
S_2	0,6	0,4	0	0	0,3
S_3	0	0,7	0,2	0,1	0,4
S_4	0	0	0,4	0,6	0,1
S_5	0	0	0	1	0,1

Probabilities for fuzzy states of nature are calculated by using formula (4) and are shown in Table 14:

Table 14. Probabilities of fuzzy states of nature

$p(\tilde{F}_1)$	0,28
$p(\tilde{F}_2)$	0,4
$p(\tilde{F}_3)$	0,12
$p(\tilde{F}_4)$	0,2

The biggest expected mean value (EMV) we will gain if we will choose alternative A_2 (Table 15). Company's profit will increase from 125 million to 136,24 million Czech crowns (included all expenses). Almost the same result we can gain from alternative A_3 (132,4 million). Alternative A_1 is the worst and lead to lower potential profit than is current company's profit. This trend corresponds with expectations which we discussed in chapter II.

Now we would like to discuss the further results of analyzed decision alternatives of implementing ISO norms. As we mentioned above in the previous chapters there is a constant pressure to the production quality and to the environmental care. If we consider development of market situation it is legitimate to consider the change of the probabilities of states of nature in both decision models.

Table 15. EMV criterion values using formula (3)

A_1	EMV_1	114,8
$\boldsymbol{A_2}$	$\boldsymbol{EMV_2}$	**136,24**
A_3	EMV_3	132,4

F. Possible further development of market situation

In the Czech Republic there is a given weight to Quality management system and to Environmental management system. The initial probabilities were set as follows

$$\boldsymbol{P} = (0{,}1 \quad 0{,}3 \quad 0{,}4 \quad 0{,}1 \quad 0{,}1)$$

It described a situation where consumers pay low-average attention to ISO 9001 and minimal to ISO 14001. Due to the increasing amount of successful implementation of ISO 14001 (Table 7), the probabilities will be changed toward the preference of both ISO norms. Higher expectation will be put to state of nature S4 (higher preference, market requires ISO 9001 and tends also onto ISO 14001) and to state of nature S5 (absolute preference, market requires both ISO 9001 and ISO 14001).

The new estimation of probabilities vector for description of the future situation could be estimated as follows

$$\boldsymbol{P} = (0{,}05 \quad 0{,}05 \quad 0{,}25 \quad 0{,}4 \quad 0{,}25)$$

This change leads to the different result of both crisp and fuzzy decision-making model which show the increasing profit in relation with ISO certification.

Table 16. EMV criterion values for crisp and fuzzy model

		Crisp model	Fuzzy model
A_1	EMV_1	110	108,075
A_2	EMV_2	136,1	136,285
$\boldsymbol{A_3}$	EMV_3	**140,4**	**141,6**

These results do not chose as a best alternative A_2 (establish only ISO 9001) which expected profit did not be changed. The alternative A_3 (establish ISO 9001 and ISO 14001) becomes the best alternative because its expected profit is increasing from 132 mil CZK to 140,4 resp. 141,6 mil CZK.

We must also consider that implementation ISO standards is not an easy and cheap issue. Implement both standards would be difficult. So companies who have already adopted Quality management system (ISO 9001) should pay their attention towards implementation of Environmental management system (ISO 14001). Companies who have not adopted the ISO 9001 yet, should pay their attention towards the Quality management system.

VI. Conclusion

This contribution shows an application of fuzzy decision-making model and its comparison with classical decision-making model. The decision-making models were calculated for the real problem where Czech ICT company wanted to solve the ISO implementation problem. First model which was situated on the present days give us for crisp and fuzzy version very similar results. The best alternative is A_2 - establish only ISO 9001. The second alternative A_3 could be also selected as a good one if we consider that the difference between these

two alternatives is not significant. Due to the Czech increasing numbers in ISO 9001 and ISO 14001 certifications we proceeded to modify the probability vector. The possibilities moved from lower costumer orientations on ISO certification to the higher orientation on both managerial systems. After this modification as the best alternative was calculated by both form of models A_3 - establish ISO 9001 and ISO 14001 with expected monetary value more than 140 mil. CZK. And finally we can say that the implementation (certification) of ISO 9001 and ISO 14001 is getting more and more important and companies without these certifications will probably not be successful in the near future. It is not certain what the future economic trends will be but it is certain that the competitors will be stronger and competitive advantage will play the main role. Due to this conclusion companies should focus on the implementation of system QMS and EMS.

We suppose further testing and implementing of soft decision-making models for solving of various decision problems. Especially we want to adopt fuzzy pay-offs and analyze the difference among models with fuzzy, probabilistic and interval pay-offs. We will also consider additional fuzzy information.

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