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Editorial

The aim of this thematic issue »Recent Advances in Systems, Decision Making, Business Intelligence and Learning« is to continue presenting the research achievement from the area of Systems Approach and Decision Support Systems for assessments of complex problems. The majority of the contributions were presented at the 23rd Conference on System Research, Informatics and Cybernetics, Baden-Baden, Germany, August 1-5, 2013, in the stream Simulation Based Decision Support, chaired by Miroljub Kljajić. The special issue includes papers dealing with the development of simulation methodology, modeling tools and practice for decision assessment, service systems, control and optimization and agriculture dynamics research. To address those issues above firm policies need to be established as a result of continues search for a sustainable future.

In that respect, the paper entitled »Weibull decision support systems in maintenance« addresses the Weibull distribution for the earliest decision support system for the assessment of a distribution for the parameters of the Weibull reliability model using expert information. The studies aimed to construct a distribution of the parameters of the Weibull reliability model and apply it in the domain of Maintenance Optimization. The parameters of the Weibull reliability model are considered as random variables and a distribution for the parameters is assessed using informed judgment in the form of reliability estimates from vendor information, engineering knowledge or experience in the field. The results are useful for the development of modern maintenance optimization models that can be embodied in decision support systems.

The paper »Fuzzy optimization for portfolio selection based on embedding theorem in fuzzy normed linear spaces« generalizes the results of embedding problem of fuzzy number space and its extension into a fuzzy Banach space. The main idea behind the approach consists of taking advantage of interplays between fuzzy normed spaces and normed spaces in a way to get an equivalent stochastic program. Inspired by this embedding theorem, the authors propose a solution concept of fuzzy optimization problem which is obtained by applying the embedding function to the original fuzzy optimization problem. The proposed method is used to extend the classical Mean-Variance portfolio selection model into Mean Variance-Skewness model in a fuzzy environment under the criteria on short and long term returns, liquidity and dividends. A fuzzy optimization problem can be transformed into a multiobjective optimization problem which can be solved by using an interactive fuzzy decision making procedure. Investor preferences determine the optimal multiobjective solution according to alternative scenarios.

The paper entitled »The development of sugar beet production and processing simulation model – a system dynamics approach to support decision-making processes« describes the system dynamics model for beet production development in order to support decision making. The sugar beet is the main field crop used for sugar production in the temperate climatic zone. The abolishment of the quota system will open new investment opportunities in countries that were forced to abandon sugar industry as the result of the reform in 2006. This paper describes the modeling of sugar beet production and its processing into sugar for the purpose of decision support. A system dynamics methodology was chosen to model impacts of regional sugar factory investment. The holistic model presents main feedback loops and dynamics of main elements in the case of regional investment into sugar industry. The factory model considered the specifics of the beet processing which is (a) limited period of beet processing and (b) initial adjustment to the production capacity at the start of the production season. The model seeks answers to strategic questions related to the whole sugar beet production and processing system and will be used for simulation of different scenarios for sugar production and their impact on economic and environmental parameters at an aggregate level.

The purpose of the paper entitled »Key Factors for Development of Export in Polish Food Sector« was an attempt to establish the current determinants for the possibility to increase the exports of the Polish food sector and to identify potential opportunities and potential threats in the future. It was also decided to give an answer to the question whether any of the group factors has a greater impact on the development of exports than the other, and which issues play only a minor role in the development of international exchange. The analysis used involved the review of the relevant literature and forming a group of expert to specify the key factor of success in the food sector export. Basing on the experts research the STEEPVL analysis was carried out. It turned out that apart from a number of organizational, financial and marketing factors the most important factors are: the level of the IT infrastructure and the fluctuation of the demand on the international markets for the goods offered by the sector.

The paper entitled »Extended Technology Acceptance Model for SPSS acceptance among Slovenian students of social sciences« has its aim in the development of a model for analysing the acceptance of the SPSS among university students of social sciences as one of the most widely used programs for statistical analysis in social sciences. The model is based on the widely known Technology Acceptance Model (TAM). The model *is tested using the web survey on the university students of social sciences from seven faculties at three Slovenian universities. The dependencies among the model components were studied and the significant dependencies were pointed out. The results of the empirical study prove that all external variables considered in the model are relevant, and directly influence both key components of the traditional TAM, »Perceived Usefulness« and »Perceived Ease of Use«. The obtained results are useful for educators, and can help them to improve the learning process.*

The guest editors hope that our selected topics display the state-of-the-art of the research efforts over the world coping with complex problem solving in a holistic way which is characteristic for modern Systems Research and Cybernetics! Moreover, we are very thankful to our journal Organizacija (Organization - Journal of Management, Information Systems and Human Resources) for having given us the opportunity and honour of hosting this special issue as a scientific project and service to the people on earth. We express our gratitude to the Editors of Organizacija, and hope that our special issue will well-demonstrate Organizacija being a premium journal and of a great scientific and social value!

The Guest Editors:
Miroljub Kljajić,
Gerhard Wilhelm Weber

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Weibull Decision Support Systems in Maintenance

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Background: The Weibull distribution is one of the most important lifetime distributions in applied statistics. Weibull analysis is the leading method in the world for fitting and analyzing lifetime data. We discuss one of the earliest decision support system for the assessment of a distribution for the parameters of the Weibull reliability model using expert information. We then present a different approach to assess the parameters distribution.
Objectives: The studies mentioned in this paper aimed to construct a distribution of the parameters of the Weibull reliability model and apply it in the domain of Maintenance Optimization.
Method: The parameters of the Weibull reliability model are considered random variables and a distribution for the parameters is assessed using informed judgment in the form of reliability estimates from vendor information, engineering knowledge or experience in the field.
Results: The results are the development of modern maintenance optimization models that can be embodied in decision support systems.
Conclusion: While the information management part is important in the building of maintenance optimization decision systems, the accuracy of the mathematical and statistical algorithms determines the level of success of the maintenance solution.

Keywords: Weibull Distribution, Reliability, Inference, Maintenance, Expert Opinion

1 Introduction

In maintenance optimization, a decision support system is a computer-based information system for the scheduling of events such as inspection, preventive maintenance, repair and replacement of operating equipment in manufacturing and industrial environments. The decisions are based on optimality criteria and involve the use of mathematical algorithms. The management of information is important and involves the collection of historical data. The second essential part is the set of mathematical and statistical algorithms used in the determination of optimal courses of actions. The accuracy and efficiency of these algorithms determines the level of success of the maintenance optimization routines. We present solutions to a mathematical computational problem and a statistical modeling problem needed in the solving of maintenance optimization problems. We focus on the Weibull distribution in Reliability and reintroduce one of the earliest Weibull Decision Support Systems in Reliability that incorporates expert opinion. We follow with the modern construction of a prior probability distribution for the parameters of the lifetime distribution for use in several maintenance optimization scenarios. In one of the maintenance problems, we point to the exact calculation of the renewal function in the case of an adaptive block replacement strategy. We illustrate the approaches with simulated results.

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1.1 The Weibull distribution for lifetime data

The Weibull distribution is one of the most important lifetime distributions in applied statistics. First identified by Fréchet (1927) and first applied by Rosin and Rammler (1933), it was described by Waloddi Weibull in 1937 and published for the first time in 1939 (Weibull, 1939) with the title 'A statistical theory of the strength of material.' It was written in order to explain the, at that time, well known but unexplained facts that the relative strength of a specimen decreases with increasing dimensions and that its bending strength is larger than its tensile strength (Weibull, 1981). Delayed by the Second World War and after an unsuccessful attempt to publish the result in a well-known British journal that deemed it to be interesting but of no practical importance, Weibull published his landmark paper in 1951 titled 'A statistical distribution function of wide applicability' (Weibull, 1951). Even then, the reaction to his paper in the 1950s was negative, varying from skepticism to outright rejection. Weibull's claim that the data could select the distribution and fit the parameters seemed too good to be true. However, pioneers in the field like Dorian Shainin and Leonard Johnson applied and improved the technique. The U.S. Air Force recognized the merit of Weibull's method and funded his research until 1975. Today, Weibull analysis is the leading method in the world for fitting and analyzing life data (Abernethy, 2006). For more than half a century the Weibull distribution has been used by statisticians in various fields and the research is ongoing (Sultan and Mahmoud, 2007; Pak et al., 2013). Together with the normal, exponential, χ^2, t and F distributions, the Weibull distribution is, without any doubt, the most popular model in modern statistics (Rinne, 2009). It is particularly true in Reliability and survival analysis, where the distribution is applied to the modelling of lifetime data. The Weibull is a useful failure model in both biomedical and engineering applications (Singpurwalla, 2006).

1.2 Reliability Assessment Incorporating Expert Opinion

In classical statistics, in order to fit a statistical model to a life data set, the analyst estimates the parameters of the lifetime distribution that most closely fits the data. The parameters control the scale, shape and location of the distribution function (ReliaSoft Corporation, 2014). Several methods have been devised to estimate the parameters. These include probability plotting, rank regression on x (RRX), rank regression on y (RRY) and maximum likelihood estimation (MLE). In Bayesian statistics, the approach is different. The parameters of the model are considered random variables and a distribution for the parameters is assessed. We consider the problem of the assessment of a distribution for the parameters of the Weibull reliability model. Using informed judgment in the form of reliability estimates from vendor information, engineering knowledge or experience in the

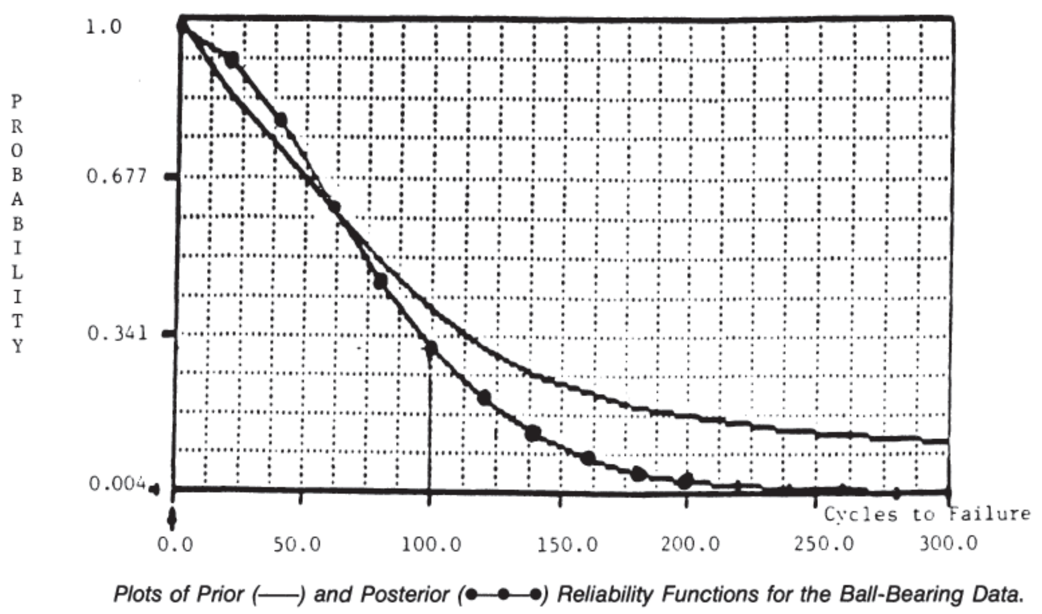

Figure 1: Plot of the reliability function in Singpurwalla (1988)

field, we look at building a probability distribution for the parameters (λ, β) of the Weibull distribution with reliability function $R(t/\lambda, \beta) = e^{(-\lambda t^{\beta})}$. Singpurwalla (1988) outlined the principles and discussed the development of such procedure for reliability assessment of items whose life lengths are described by the Weibull distribution, whose reliability function is shown in Figure 1. The software, *An Interactive PC-Based Procedure for Reliability Assessment* (IPRA), prepared by the first author of this article and cited in Goel (1988), is one of the earliest Weibull Decision Support Systems in Reliability that incorporates expert opinion. At the time, the graphics were very basic (Figure 2) and the program was still transported on a floppy disk. Aboura, Singpurwalla and Soyer (1989a, 1989b, 1989c) describe the software and the theory. Aboura and Soyer (1986) and Aboura and Campodonico (1992) provide users' manuals.

Singpurwalla and Song (1986) also presented an approach for the analysis of Weibull lifetime data using expert opinion. While many authors in the Bayesian literature use expert opinion on the values of the parameter vector (see Bousquet, 2006), Singpurwalla (1988) and Sinpurwalla and Song (1988) introduced a slightly different approach and assumed that an expert was able to provide information about the median lifetime and give an estimate of its prior mean. Fixing the marginal prior distribution of the shape parameter β, they obtained a complete prior on (λ, β). For a literature review on the use of expert opinion in probabilistic risk analysis see Ouchi (2004).

1.3 Estimation using initial reliability estimates

There are two main difficulties using the Weibull distribution (Bousquet, 2010). First, its only conjugate prior distribution is continuous-discrete (Soland, 1969) and remains difficult to justify in real problems (Kaminskiy and Krivtsov, 2005). Second, the meanings of the scale parameter and the shape parameter greatly differ. Their values and correlation remain hard to assess by non-statistician experts (Bousquet, 2010). To alleviate this difficulty, and following on the idea of asking expert quantile information, Aboura (1995) introduced a prior elicitation procedure which uses expert opinion on the reliability of the item rather than on the parameters directly. In concept, Aboura (1995) can be viewed as an extension of the use of the median by Singpurwalla (1988) and Sinpurwalla and Song (1988). However they differ in the construction of the expert model and the resulting priors

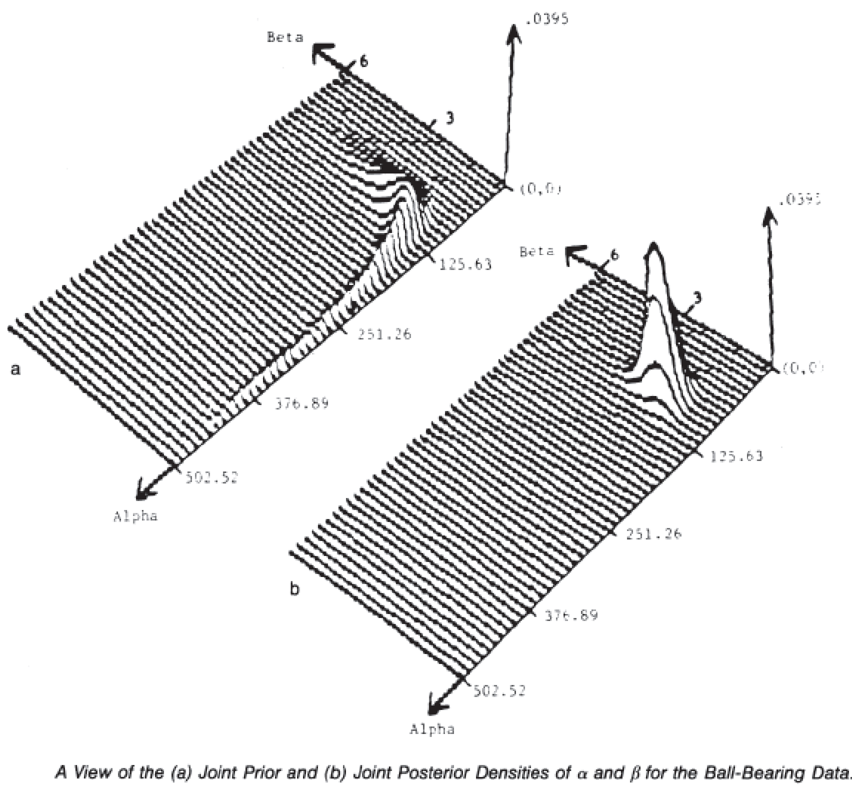

Figure 2: 3D plots in the IPRA software (Singpurwalla, 1988)

for the Weibull parameters. In doing so, it also extends a result by Mazzuchi and Soyer (1996) who used Soland's distribution (Soland 1969) for the parameters of the Weibull lifetime distribution. The approach of Aboura (1995) is used in Aboura and Agbinya (2013) and Aboura and Robinson (2013) in the context of maintenance optimization.

2 Research Methods in Maintenance Optimization

The purpose of the reliability procedures discussed in the previous section is often their incorporation in maintenance optimization decision support systems. While the information management part is important in building maintenance optimization decision support systems, the accuracy of the mathematical and statistical algorithms determines the level of success of the maintenance software. In their maintenance optimization solution, Mazzuchi and Soyer (1996) used Soland's (1969) distribution for the parameters of the Weibull lifetime distribution. A discretized Beta distribution is used for the parameter β. Although such a use of Soland's distribution does provide a starting prior joint density, one could dispute the feasibility of collecting any direct information about β from an expert, the abstract model parameter β not having any physical meaning. One can also argue about the arbitrariness used by Mazzuchi and Soyer (1996) to select the range of the discretized Beta distribution for β, unless this range is made to cover most of the likely values of β. Aboura and Agbinya (2013) and Aboura and Robinson (2013) remedy to these shortfalls by constructing a prior density for (λ, β) using estimates of observables. The range of β and the dependence structure of (λ, β) result naturally from an initial reliability estimation. The distribution of Soland (1969) is extended to include dependence and fitted through moments to the prior distribution.

2.1 Maintenance optimization procedure using initial reliability estimates

Upon the introduction of new equipment or at the start of a study, reliability estimates are often available in the form of vendor information or informed judgment from maintenance operators. As failure and survival data are collected, a better assessment of the life length characteristics of the items becomes possible, allowing a more effective estimation procedure. Consider a structure of M identical items operating independently of each other under similar conditions. At prescribed points in time T_1, T_2, ..., etc., all items are replaced by new ones. An item that fails before the next replacement time remains failed. We let T_0 be time 0. As failures accumulate between the replacement times, two types of data collection are possible; (1) the exact failure times are recorded (complete data) and (2) the numbers of failures per time interval are recorded (interval censored data). Aboura and Agbinya (2013) treat both cases and consider only the case of the numbers of failures between replacement times in case (2). That is the interval censored data consist of the number of failures in $[T_{i-1}, T_i)$, $i = 1, 2,$ ...The more general case of interval censored data involves inspection points in $[T_{i-1}, T_i)$ where the numbers of failures are recorded between the inspection points. The extension to the inspection case is straightforward given that the inspection times are fixed. A further extension would be to consider the inspection times as decision variables in the setting of an optimal maintenance strategy. Let T be the lifetime of the item under consideration. We assume that reliability estimates $r^{(n)} = (r_1, r_2, ..., r_n)$ are provided for different mission times t_i, $i = 1, 2, ..., n$, with, $r_n + 1$ being a lower bound on the reliability of the item. Assuming a Weibull model for the lifetime T with reliability function, the prior distribution of (λ, β) is constructed in Aboura and Agbinya (2013) and the maintenance optimization solutions provided. For example, in the Penalty Cost Model I of Aboura and Agbinya (2013), the model assumes an increasing cost function $c_f(j)$ for the failure of j items. Various functions may be chosen to model c_f (j) depending on the application. The maintenance optimization problem at time at time T_{i-1} is

$$min_{\Delta T_i > 0} \quad \frac{c_p + \sum_{j=0}^{M} c_f(j)\, Prob(N_i = j/D_{i-1})}{\Delta T_i}$$

where

$$Prob(N_i = j/D_{i-1})$$
$$= \sum_{\beta} \int_{\lambda} \binom{M}{j} (1 - e^{-\lambda \Delta T_i{}^{\beta}})^j (e^{-\lambda \Delta T_i{}^{\beta}})^{M-j}\, g(\lambda, \beta / r^{(n)}) d\lambda.$$

$g(\lambda, \beta / r^{(n)})$ is the prior distribution constructed with the expert opinion using the initial reliability estimates. It can be shown that for an appropriate choice of the penalty function c_f, an optimal solution ΔT_i obtains for each stage $i = 1, 2,$ …, etc.

2.2 Maintenance optimization procedure using the renewal function

In Aboura and Robinson (2013), the maintenance scenario differs and requires the computations of the renewal function for the Weibull distribution. The maintenance optimization procedure consists of determining at each planned replacement time, T_{i-1} the next preventive replacement time T_i, $i = 1, 2, \ldots$. In between the prescribed times T_1, T_2, ..., replacement by a new item is made upon failure of the operating item/system. The maintenance procedure applies the well-known Block Replacement protocol in which the item under consideration is replaced at predetermined points in time by a new item (or by an item repaired and brought back to the 'new' state), regardless of the age of the failed item. In the traditional Block Replacement approach, the time intervals between planned replacements are equal and determined at the start of the operations. In the approach by Aboura and Robinson (2013), the replacement times are determined only a stage ahead. The adaptive nature of the policy introduced reduces considerably the loss due to a Block Replacement protocol, as it reaches for an optimal replacement time. At time T_{i-1}, $i = 1, 2, ..., \Delta T_i = T_i - T_{i-1}$, is determined as the solution of

$$min_{\Delta T_i > 0} \frac{c_p + c_f M(\Delta T_i / D_{i-1})}{\Delta T_i}$$

c_p is the replacement cost, c_f is the cost per failure and $D_{i-1} = \{f^{(m)}, s^{(l)}\} \cup D_0 . f^{(m)} = (f_1, f_2, ... f_m)$ and $s^{(l)} = (s_1, s_2, ... s_l)$ are the failure and survival times respectively, observed in $(T_0, T_{i-1}]$. D_0 is the set of all relevant information known prior to and at time T_0 In this case, $D_0 = \{r^{(n)}, t^{(n)}, b\}$ (see Aboura and Robinson, 2013). $M(\Delta T_i / D_{i-1})$ is obtained by averaging over (λ, β),

$$M(\Delta T_i / D_{i-1}) = \sum_{j=1}^{k} \int_0^{\infty} M(\Delta T_i / \lambda, \beta_j)\, p(\lambda, \beta_j / D_{i-1}) d\lambda$$

where $p(\lambda, \beta_j / D_{i-1})$ is the prior distribution of (λ, β) for $i = 1$ and the posterior distribution of (λ, β) at time T_{i-1} for $i > 1$, derived from the same prior distribution at time T_0 used in Aboura and Agbinya (2013).

To solve the maintenance optimization problem, the renewal function for the Weibull distribution must be computed accurately. Let $N(t)$ be the number of failures (and renewals) in the time interval $(0, t]$, then the renewal function, $H(t) = E(N(t))$ is the expected number of renewals in that time interval. The expected number of renewals between successive times T_i and T_{i-1} is defined by, where $\Delta(T_i) = T_i - T_{i-1}$ is the optimal time interval to be determined. For the Weibull lifetime model with distribution function $F(t) = 1 - e^{-\lambda t^{\beta}}$, the renewal function $H(t/\lambda, \beta)$ is available in series form (Smith and Leadbetter, 1963) but becomes impracticable to calculate for most $t > 1$, $\beta > 1$. One can use a simple approximation due to Smeitink and Dekker (1990), but Aboura and Robinson (2013) provide a more accurate solution, due to Constantine and Robinson (1997), for computing the Weibull renewal function and its derivative $h(t/\lambda,\beta)=dH(t/\lambda, \beta)/dt$. Another method due to Robinson (1997) can also be used to compute the renewal function to any desired degree of accuracy. That method solves directly the integral equation expression for $H(t/\lambda, \beta)$ (see e.g. Cox (1962) for general renewal theory) in terms of multi time-segment Chebyshev polynomial series. It is a method suitable for a wide range of probability density functions, both parametric and nonparametric. However, the quicker method of Constantine and Robinson (1997), dedicated to the Weibull renewal function is used to provide accurate results. The methodology can be extended with similar accuracy to the case of the Generalised Gamma lifetime distribution (Robinson, 1998) and to a wide range of lifetime distributions.

3 Research Results

In Aboura and Agbinya (2013), several optimization models were studied. For example in their Constant Cost model, there is no dollar value associated with the failure of an

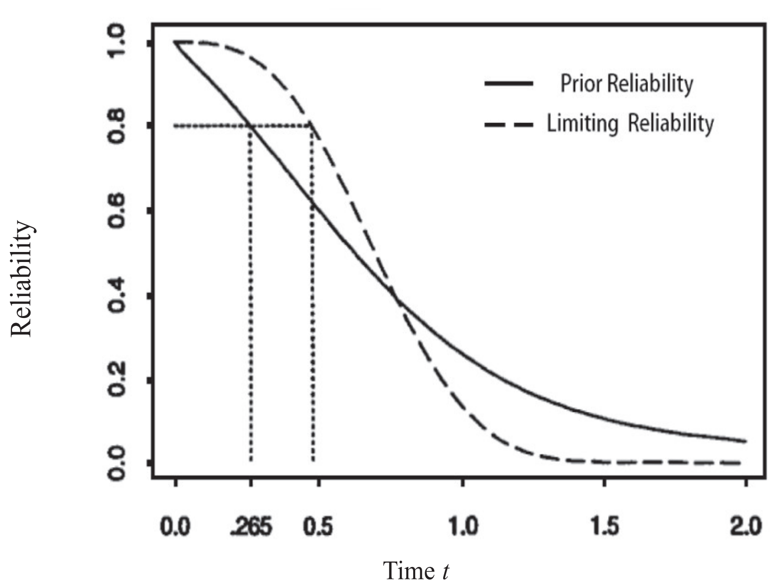

Figure 3: The first replacement time $\Delta T_1 = 0.265$ *and the optimal interval* $\Delta T_\infty = 0.481$

item. The range of possible time intervals before the next replacement is limited by a constraint on the expected number of failures in the considered interval. The maintenance optimization problem is solved for both collection data protocols and simulation is conducted to show the convergence of the solution. In a simulated example where $\lambda = 2$, $\beta = 3$ and $K/M = 0.2$ they assume that reliability estimates $r^{(5)} = (.99, .95, .60, .05, .01)$ for mission times $t^{(5)} = (.2, .4, .75, 1, 1.2)$ are given by an expert or taken from some other knowledgeable source. M is the number of operating items and K is a constraint on the number of failed items (see Aboura and Agbinya, 2013). The optimal value for the first replacement time T_1 is obtained as the time t at which the prior reliability $R(t/D_0)$ is equal to $1 - K/M = 0.8$. Therefore in the example the first replacement of all items is to occur at time $T_1 = \Delta T_1 = 0.265$. The prior reliability function t/D_0) is shown in Figure 3 with the resulting optimal first time interval $\Delta T_1 = 0.265$. The dashed line function in the graph of Figure 3 is e^{-2t^3} with the corresponding limiting optimal time interval $\Delta T_\infty = (-ln(1-.2)/\,2)^{1/3} = 0.481$.

At the successive times T_{i-1}, $i = 2, 3, ...$ the optimal time intervals ΔT_i are obtained as the solution of $R(\Delta T_1/D_{i-1}) = 1 - K/M$. In the case of complete data, $R(\Delta T_1/D_{i-1})$ obtains in a closed form while it must be computed numerically in the case of interval censored data. The optimal time intervals between replacements, ΔT_i, $i = 1, 2 \ldots, 20$, are plotted in Figure 4 for a 20 stages simulation of the maintenance routine. The exact failure times are recorded between the replacement times. The horizontal dashed line in Figure 4 marks the limiting optimal time interval $\Delta T_\infty = 0.481$. As data is gathered between the replacement times, the optimal time intervals improve to finally stabilize around the limiting value.

Although Aboura and Robinson (2013) provide an accurate approach for implementing the maintenance optimization procedure, a simple and practical approach can be substituted that makes use of Maximum Likelihood Estimates at each planned replacement stage. If initial expert information is available in the form of reliability estimates such as ($r^{(n)}$, $t^{(n)}$), Least Squares Estimates can be used to produce the first replacement time T_1. Maximum Likelihood Estimates will then be used at the next stages for producing the optimal planned replacement times. The MLE approach is attractive in that it eliminates the need for averaging over a prior/posterior distribution, reducing the number of times the renewal function is computed. In an example, Figure 5 shows optimal replacement time intervals ΔT_i for $i = 1, ..., 20$ as dictated by the MLE based maintenance optimization procedure (Aboura and Robinson, 2013). In this example, the limiting optimal replacement time interval is 0.452. In their study, Aboura and Robinson (2013) show the behaviour of the optimal replacement time interval ΔT_i, $i = 1, 2, ..., 11$, for 100 simulated replications. The first replacement time interval ΔT_1 is set arbitrarily to 1. They also display the boxplot of the 10 stages and plot the average optimal replacement time interval, the average taken over the 100 replications. They also compare the average optimal replacement time interval over 10 stages, stage 2 to stage 11, for the case of 10 and 20 items operating independently. The average of the replacement time interval is taken over 100 simulated replications for the first case (10 items) while

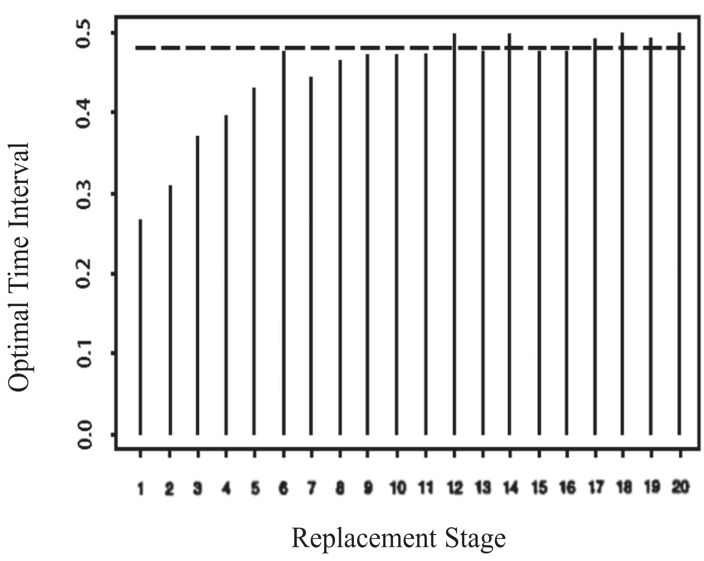

Figure 4: The optimal time intervals ΔT_i, $i = 1, 2 \ldots, 20$

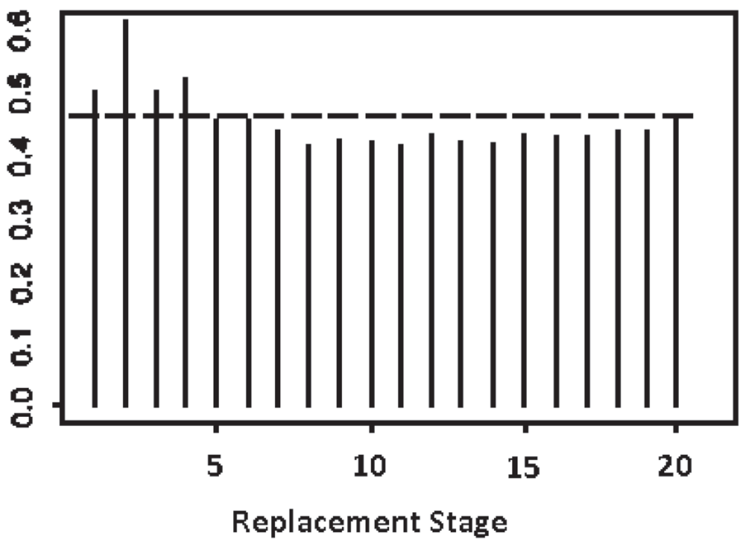

Figure 5: Optimal replacement intervals (Aboura and Robinson, 2013)

it is taken over 50 simulated replications for the second case (20 items).

4 Discussion

A variety of optimization models where replacement takes place require statistical modeling and accurate resolution of the optimization problems that ensue. Once these issues are addressed, effective decision support systems can be developed. Adaptive procedures for the optimal replacement of identical items operating under similar conditions are outlined. In Aboura and Agbinya (2013), two data collection scenarios are considered. The procedure was demonstrated and its convergence shown in both data collection cases in simulated examples. The procedure is easy to implement and can result in substantial savings. The adaptive nature of the procedure is a modern feature that permits an updating of the lengths of times between replacements as failure information is gathered. The methodology was developed following technical discussions with an electricity company. Of particular importance in some maintenance scenarios, is the resolution of problems such as the computation of the renewal function. Robinson (1997) solved the Weibull problem. The solution was extended to the Generalized Gamma distribution through the result of Robinson (1998). A whole range of optimization models can be established on the basis of these results. Aboura and Robinson (2013) demonstrate the accurate application of probabilistic updating to the maintenance optimization problems. To avoid excessive computations, the Maximum Likelihood Estimates can be used, as illustrated through simulation.

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Sistem za podporo odločanju vzdrževanja na podlagi Weibullove porazdelitve

Ozadje: Weibullova porazdelitev je ena od najbolj pomembnih na področju porazdelitev življenjske dobe v uporabni statistiki. Ona je vodilna metoda za oceno in analizo podatkov na področju življenjske dobe. V prispevku razpravljamo o enem od prvih sistemov za podporo odločanju za oceno porazdelitve parametrov zanesljivosti Weibull-ovega modela na podlagi razpoložljive informacije. Nato smo predstavili drugačen pristop za oceno porazdelitve parametrov .
Cilji: Cilj študije je zgraditi model porazdelitve parametrov zanesljivosti Weibullove porazdelitve in ga uporabiti na področju optimizacije vzdrževanja.
Metoda: Parametri modela Weibullove zanesljivosti obravnavamo kot naključne spremenljivke katerih distribucija je ocenjena z strani ekspertov v obliki zanesljivosti s pomočjo informacij prodajalca z inženirskim znanjem in izkušnjami na tem področju.
Rezultat: Rezultati so razvoj sodobnih optimizacijskih modelov za vzdrževanje kot sistem za podporo odločanju vzdrževanja.
Zaključek: Medtem ko je del za upravljanje informacij pomemben pri gradnji sistemov za podporo odločanja optimizacije vzdrževanja, zanesljivost matematičnih in statističnih algoritmov določa stopnjo uspešnosti rešitev za vzdrževanje.

Ključne besede: Weibullova porazdelitev, Zanesljivost, Vzdrževanje, Sklepanje, Ekspertno znanje

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Fuzzy optimization for portfolio selection based on Embedding Theorem in Fuzzy Normed Linear Spaces

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Background: This paper generalizes the results of Embedding problem of Fuzzy Number Space and its extension into a Fuzzy Banach Space $C(\Omega) \times C(\Omega)$, where $C(\Omega)$ is the set of all real-valued continuous functions on an open set Ω.
Objectives: The main idea behind our approach consists of taking advantage of interplays between fuzzy normed spaces and normed spaces in a way to get an equivalent stochastic program. This helps avoiding pitfalls due to severe oversimplification of the reality.
Method: The embedding theorem shows that the set of all fuzzy numbers can be embedded into a Fuzzy Banach space. Inspired by this embedding theorem, we propose a solution concept of fuzzy optimization problem which is obtained by applying the embedding function to the original fuzzy optimization problem.
Results: The proposed method is used to extend the classical Mean-Variance portfolio selection model into Mean Variance-Skewness model in fuzzy environment under the criteria on short and long term returns, liquidity and dividends.
Conclusion: A fuzzy optimization problem can be transformed into a multiobjective optimization problem which can be solved by using interactive fuzzy decision making procedure. Investor preferences determine the optimal multiobjective solution according to alternative scenarios.

Keywords: Embedding problem, Fuzzy optimization, Fuzzy Banach Space, Portfolio selection.

1 Introduction

Based on the fact that in many situations the distance between two points is in exact rather than a single real number, Kaleva and Seikkala initiated the concept of a fuzzy metric space by describing the distance of points as s fuzzy real number. Since each usual metric space and each Menger probabilistic metric space can be considered as s special case of fuzzy metric space, the study for the fuzzy metric space has been attracted many authors, and several results for nonlinear mappings have been given in some literatures. The concept of a fuzzy norm on a linear space is of comparatively recent origin. It was Katsaras, who while studying fuzzy topological vector spaces, was the first to introduce in 1984 the idea of fuzzy norm on a linear space. Following his pioneering work, Felbin offered in 1992 an alternative definition of a fuzzy norm on a linear space with an associated metric of the Kaleva and Seikkala type. A further development along this line of inquiry took place when in 1994; Cheng and Mordeson evolved the definition

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of a further type of fuzzy norm having a corresponding metric of the Kramosil and Michalek type. Since these results apparently also constitute various types of fuzzy norms, the further line of inquiry that obviously suggests itself pertains to the determination of relations, if any, among these fuzzy norms. In 2007, an attempt was made to find such relation by making a comparative study of the fuzzy norms defined by Katsaras, Felbin and Bag and Samanta. It has been observed that the fuzzy norm defined by Bag and Samanta is similar to that of Katsaras who defined it in a different way. On the other hand, Felbin's type fuzzy norm corresponds to a pair of which one is a fuzzy norm in our sense and the other is a fuzzy anti-norm. It is as important the concept of Menger probabilistic normed linear space introduced by Serstnev and moreover, each usual classical normed space and Menger probabilistic normed spaces is special cases of fuzzy normed linear spaces. The authors (Sadeqi I, Solatikia F. 2010; Weber G.-W., Solatikia F. 2013) showed that each of the category of fuzzy normed space and Menger probabilistic normed space is isomorphically a subcategory of the category of topological vector spaces and all results and theorems of topological vector spaces apply to fuzzy normed space and Menger probabilistic normed space in general, also as a new result they showed that $C(\Omega)$, is a fuzzy normed space then Menger probabilistic normed space, while it is not classically norm able. So, if we replace the normed space $C[0,1]$ by the fuzzy normed linear space $C(\Omega)$, then we get an important result in fuzzy normed linear space, while the same statement does not hold true in classical analysis.

Portfolio optimization is the process of allocating budget between assets and managing the assets within it. The modern portfolio theory has been proposed by Markowitz (1952) that considers expected return and risk for a portfolio selection problem where variance is used as risk measure. Markowitz's mean–variance model is the central source for a single period portfolio selection problem, from where the efficient frontier model with beta market risk and risk free return can be exploited. As a common standard portfolio model it is used the determine the performance of financial investments and serves as a hedge instrument with encompassing specifications. A wide range of fuzzy model applications are derived from the initially proposed Markowitz model. Genetic algorithms with applications of portfolio selection models in a fuzzy framework are analyzed by Gupta et al. (2012), Bermúdeza et al. (2012), Li and Xu (2013), Khalili-Damghani et al. (2013). Gupta analyze a multiobjective credibilistic model with fuzzy constraints of the portfolio selection problem. A hybrid intelligent algorithm that integrates fuzzy simulation with a real-coded genetic algorithm is contructed. They claim for more efficiency where fuzzy parameters are characterized by general functional forms. Bermúdeza proposed genetic algorithms transfering applications from their traditional domain of optimization to fuzzy ranking strategy for selecting efficient portfolios of restricted cardinality. A special focus is put on the ambiguity of the trapezoidal fuzzy number which represents the uncertainty on the return. A hybrid multiobjective framework integrates and synthesizes a genetic based machine learning method to design an alternative fuzzy ranking system for comparison purposes based on the results from a data mining model with the results from a data envelope analysis model. Metaxiotis and Liagkouras (2012), and Khalili-Damghani et al. (2013) use evolutionary algorithms to evaluate fuzzy portfolio models. Metaxiotis and Liagkouras present a portfolio management model with the support of multiobjective evolutionary algorithms. They utilize this framework to gain an understanding of the current state of areas related to applications in the portfolio management research field. Khalili-Damghani develop an evolutionary algorithm to design the structure of fuzzy rule based multiobjective system. Tsaur (2013), Li and Xu (2013), Huang and Qiao (2012) put their focus on a behavioral aspect of portfolio selection. Investor behaviors can be classified as risk averse, risk neutral or risk affine. Tsaur conducts a behavioral analysis of the investor in the fuzzy portfolio model. They examine different investor risk preferences to discover an efficient method for fuzzy portfolio selection. In this relation, a probabilistic mean–standard deviation model is applied to fit the risk attitudes of investors. In an application of a multiobjective portfolio selection model with fuzzy random returns Li and Xu use experts' opinions and judgments and investors' different attitudes in the portfolio selection process, such that the investor's individual preference on return, risk and liquidity are considered by the help of a genetic algorithm. A similar model is proposed by Huang and Qiao to enable the users to solve a problem with currently available programming tools. In addition, a method of obtaining the uncertainty distributions of the security returns is described based on experts' evaluations and presented illustratively. A TOPSIS compromised programming approach is designed by Liu et al. (2012) to transform a portfolio selection problems in fuzzy environment into single objective models. The model includes return, transaction cost, risk and skewness of the portfolio as decision parameters.

Wu (2004) develops models with fuzzy space and special spaces such as Banach spaces. In particular, Wu and Ma (1991) provide a specific Banach space that the set of all fuzzy real numbers, which was introduced by Zadeh (1965) and plays the most fundamental role in the theory of fuzzy analysis, can be embedded into a Banach space $C[0,1] \times C[0,1]$, where $C[0,1]$ is the set of all real-valued bounded functions on $[0,1]$ such that it is left-continuous for any $t \in (0,1]$ and right-continuous at 0, and has a right limit for any $t \in (0,1]$. In 2011, Bhattacharyya and Kar extend the classical Mean-Variance portfolio selection model into Mean Variance Skewness model in fuzzy environment under the criteria on short and long term returns, liquidity and dividends. The embedding theorem is used to convert the fuzzy MVS model into crisp multi-objective constrained optimization problem. They proposed a convenient tool for deep research of fuzzy analysis. It seems therefore reasonable to think if the concept of Fuzzy optimization problems based on the embedding theorem and also Multiobjective fuzzy optimization for portfolio selection can be extended to probabilistic normed spaces and in that case enquire how the basic properties are affected.

In this paper, the embedding theorem from the set of all fuzzy numbers into a Banach space $C[0,1] \times C[0,1]$, is extended to more general case, i.e., from fuzzy number space into a Fuzzy Banach space $C(\Omega)$, where $C(\Omega)$ is the set of all real-valued continuous functions on an open set Ω, to propose a solution concept of fuzzy optimization problem which is obtained by applying the embedding function to the original fuzzy optimization problem.

2 Preliminaries

For readers convenience, in this section we briefly recall some concepts and results from Menger probabilistic normed spaces theory used in the paper.

Definition: A mapping $\eta : \Re \to [0,1]$ is called a fuzzy real number, whose $\alpha-$ level set is denoted by $[\eta]_\alpha$, i.e., $[\eta]_\alpha = \{t : \eta(t) \geq \alpha\}$, if it satisfies two axioms:

($N1$) There exists $t_0 \in \Re$ such that $\eta(t_0) = 1$.

($N2$) For each $\alpha \in (0,1] : [\eta]_\alpha = [\eta_\alpha^-, \eta_\alpha^+], -\infty < \eta_\alpha^- \leq \eta_\alpha^+ < +\infty$.

The set of all fuzzy real numbers denoted by $\Re(I)$. If $\eta \in \Re(I)$ and $\eta(t) = 0$ whenever $t < 0$, then η is called a non-negative fuzzy real number and $\Re^*(I)$ stands for the set of all non-negative fuzzy real numbers. The number 0 stands for the fuzzy number satisfying $0(t) = 1$ if $t = 0$ and $0(t) = 0$ if $t \neq 0$ clearly $0 \in \Re^*(I)$. The set of all real numbers can be embedded in $\Re$ because if $r \in (-\infty,+\infty)$, then $r \in \Re(I)$ satisfies $r(t) = 0(t - r)$. According to Puri and Ralescu in 1986, we define the metric $d_{\{F\}}$, when $\eta_1, \eta_2 \in \Re(I)$ as:

$d_{\{F\}}([\eta_1]_\alpha, [\eta_2]_\alpha) = \sup_{0<\alpha<1} \max\{|\eta_{1\{\alpha\}}^- - \eta_{2\{\alpha\}}^-|, |\eta_{1\{\alpha\}}^+ - \eta_{2\{\alpha\}}^+)|\}$.

Definition: Let X be a real linear space; L and R be symmetric and non-decreasing mapping from $[0,1] \times [0,1]$ into $[0,1]$ satisfying $L(0,0) = 0$, $R(1,1) = 1$. Then $\|.\|$ is called a fuzzy norm and $(X, \|.\|, L, R)$ a fuzzy normed linear space if $\|.\|: X \to \Re^*(I)$ satisfies the following axioms, where $[\|x\|]_\alpha = [\|x\|_\alpha^-, \|x\|_\alpha^+]$ for $x \in X$ and $\alpha \in (0,1]$:

(A)1 $\|x\| = \bar{0}$ if and only if $x = 0$,

(A)2 $\|rx\| = |r| \|x\|$ for all $x \in X$ and $r \in (-\infty, \infty)$,

(A)3 For all $x, y \in X$:

($A3L$) whenever $s \leq \|x\|_1^-, t \leq \|x\|_1^-$ and $s + t \leq \|x + y\|_1^-$, then $\|x + y\|(s + t) \leq R(\|x\|(s), \|y\|(t))$,

($A3R$) whenever $s \geq \|x\|_1^-, t \geq \|y\|_1^-$ and $s + t \geq \|x + y\|_1^-$, then $\|x + y\|(s + t) \leq R(\|x\|(s), \|y\|(t))$.

Definition: Let X be a vector space. A fuzzy subset N of $X \times \Re$ is called a fuzzy norm on X if the following conditions:

N1) $N(x, t) = 0$; $\forall t \in \Re$ with $t \leq 0$,

N2) $N(x, t) = 1$; $\forall t \in \Re$, $t > 0$ iff $x = 0$,

N3) $N(cx, t) = N(x, \frac{t}{|c|})$; $\forall t \in \Re$, $t > 0$ and $c \neq 0$,

N4) $N(x + y, t + s) \geq \min\{N(x, s), N(y, t)\}$; for all $x, y \in X$ for all $s, t \in \Re$,

N5) $N(x,.)$ is a non -decreasing function on $\Re$, and $\lim_{t\to\infty} N(x,t) = 1$.

The pair (X, N) is said to be a fuzzy normed space.

Definition: Let X and Y be topological spaces. An embedding function of X into Y is a function $e : X \to Y$ which is a homeomorphism when considered as a function from X onto $e(X)$. A function $e : X \to Y$ is an embedding function if and only if it is continuous and one-to-one and for every open set V in X there exists an open subset W of Y such that $e(V)$ is the intersection of W and Y.

3 Main results

Theorem: Let $(X, N_1, *)$ and $(Y, N_2, *)$ be two fuzzy normed spaces. Let $(x, y) \in X \times Y, t \in \Re$, and $N((x, y), t) = \min\{N_1(x,t), N_2(y,t)\}$. Then $(X \times Y, N, *)$ is a fuzzy normed space on $X \times Y$.

Let $(X, \|.\|, L_1, R_1)$ and $(Y, \|.\|, L_2, R_2)$ be two fuzzy normed spaces by the above definition, where $R_1(x, y) \leq \max(x, y)$, *and* $R_2(x, y) \leq \max(x, y)$. Then $(X \times Y, \|.\|, L, R)$ is a fuzzy normed space where $R = \max$ and $L = 0$,

$$\|(x, y)\|(t) = \begin{cases} 1, \\ \max\{\|x\|(t), \|y\|(t)\}, \end{cases}$$

$t \in [\min\{\|x\|_1^-, \|y\|_1^-\}, \max\{\|x\|_2^+, \|y\|_2^+\}]$,

otherwise.

By applying the induction method, we conclude that the Cartesian product of fuzzy normed spaces, $X_1 \times X_2 \times .... \times X_n$ is also fuzzy normed space. We have also same result in Menger probabilistic spaces.

Let $(X, \|.\|)$ be a classical real normed space. Felbin and Samanta have been shown that classical real normed space can be considered as fuzzy normed linear spaces (Felbin's type and Samanta's type). In the following we bring an example of a fuzzy normed space which is not a real normed space in the classical sense. Therefore the spectrum of the category of fuzzy normed linear spaces is broader than the category of normed spaces. This is why the study of fuzzy normed linear spaces (Felbin's type and Samanta's type) is of great importance.

Let Ω be a nonempty open set in some euclidean space. It is well known that Ω is the union of countably sets $K_n \neq \emptyset$, which can be chosen so that K_n lies in the interior of K_{n+1} ($n = 1, 2, 3, ...$). The linear space $C(\Omega)$, is the vector space of all complex valued continuous functions on Ω, topologized by the family of non-decreasing classical seminorms $p_n(f) = \sup\{| f(x) | \ ; x \in K_n\}$. In the following results, we will prove that $C(\Omega)$ is fuzzy normable but it is not so in classical analysis, where $\Omega \subset \Re^n$ is an open subset.

Theorem: The linear space $C(\Omega)$ is fuzzy normable in general. For $\alpha \in (0,1]$, there exists $n \in \mathrm{N}$ such that $\frac{1}{n+1} < \alpha \leq \frac{1}{n}$. Let $f \in C(\Omega)$ define

$f_\alpha^- = \sup\{| f(x) | \ ; \ x \in K_1\}$ and

$f_\alpha^+ = \sup\{| f(x) | \ ; \ x \in K_{n+1}\}$. Then $\{[f_\alpha^-, f_\alpha^+] \ ; \ \alpha \in (0,1]\}$ is a family of nested bounded closed intervals. We define the fuzzy norm map $\| . \|$ on $C(\Omega)$ as:

$\forall t \in \Re \ , \ \| f \| (t) = \sup\{\alpha \in (0,1] \ ; \ t \in [f_\alpha^-, f_\alpha^+]\}$.

It is easy to see that for $f \in C(\Omega)$, $\| f \|$ is a fuzzy real number. Now we show that $(C(\Omega), \| . \|, \min, \max)$ is a fuzzy normed space. Also by definition

$$\rho_n(f,t) = \begin{cases} 0, & t \leq \rho_n(f), \\ 1, & t > \rho_n(f). \end{cases}$$

We have shown that that $\rho_n(f,t)$ is a fuzzy seminorm for all $n \in N$ and $P = \{\rho_n ; n \in N\}$ is the separating family of seminorms on $C(\Omega)$. According to the above theorem we can define a fuzzy norm on $C(\Omega)$ as

$$N(f,t) = d(f,0,t) = \sum_{i=1}^{\infty} 2^{-i} \rho_n(f,t).$$

Then, $(C(\Omega), N)$ is a fuzzy normed space. But $C(\Omega)$ is not normable in classical analysis, where Ω is an open subset of $\Re^n$.

Furthermore, $C(\Omega) \times C(\Omega)$ is also a Fuzzy Banach space with the norm where $(f,g) \in C(\Omega) \times C(\Omega)$ and $t \in \Re$ defined by

$$N((f,g),t) = \min\{N(f,t), N \ (g,t)\},$$

and

$$\| (f,g) \| (t) = \begin{cases} 1, \\ \max\{\| f \| (t), \| g \| (t)\}, \end{cases}$$

$t \in [\min\{\| f \|_\alpha^-, \| g |_\alpha^-\}, \max\{\| f \|_\alpha^+, \| g \|_\alpha^+\}]$, otherwise.

Definition: [Wu and Ma (1991)] let η be a fuzzy number in $\Re(I)$ and we write $\eta^-(\alpha) = \eta_\alpha^-$ and $\eta^+(\alpha) = \eta_\alpha^+$ as the function of $\alpha \in [0,1]$, then the function $\pi : \Re(I) \to C(\Omega) \times C(\Omega)$ defined by $\pi(\eta) = (\eta^-(\alpha), \eta^+(\alpha))$ is injective. Now, we prove that each element in $\Re(I)$ can be identified with an element $(\eta^-(\alpha), \eta^+(\alpha))$ in $C(\Omega) \times C(\Omega)$, where $\eta^-(\alpha) = \eta_\alpha^-$ and $\eta^+(\alpha) = \eta_\alpha^+$, and this identification is isometric and isomorphic.

An important problem in topology is embedding problem. Theorems asserting the embedding of a space into some other space which is more manageable than the original space are known as embedding theorems.

Theorem: (Embedding Theorem). The function $\pi : \Re(I) \to C(\Omega) \times C(\Omega)$ be defined by $\pi(f) = (f^+(\alpha), f^-(\alpha))$, if $\alpha > 0.5$, and $(f^-(\alpha), f^+(\alpha))$, if $\alpha < 0.5$. Then, the following properties hold true:

(i) π is injective.

(ii) $\pi((1_{\{s\}} \otimes f_1) \oplus (1_{\{t\}} \otimes f_2)) = s\pi(f_1) + t\pi(f_2)$ for all $\eta_{11}\eta_2 \in \Re(I)$, $s > 0$ and $t > 0$.

(iii) $d_{\{F\}}(f_1, f_2)(t) = N(\pi(f_1) - \pi(f_2), t) = \sup\{\alpha \in (0,1], \quad t \in [f_\alpha^-, f_\alpha^+]\}$. That is to say, $\Re(I)$ can be embedded into $C(\Omega) \times C(\Omega)$ isometrically and isomorphically.

Proof: *(i)*: Let f_1, f_2 be two distinct fuzzy numbers such that $\pi(f_1) = \pi(f_2)$. Then $(f_{1\alpha}^-, f_{1\alpha}^+) = (f_{2\alpha}^-, f_{2\alpha}^+)$, i.e. $(f_1^-(\alpha), f_1^+(\alpha)) = (f_2^-(\alpha), f_2^+(\alpha))$. Then $f_1^-(\alpha) = f_2^-(\alpha)$, and $f_1^+(\alpha) = f_2^+(\alpha)$, because the two real open intervals are equal which contradicts our assumption and consequently the mapping π is injective. *(ii)*: By the definition of fuzzy number and function of π we have:

$$\pi((1_{\{s\}} \otimes f_1) \oplus (1_{\{t\}} \otimes f_2)) = ([(1_{\{s\}} \otimes f_1) \oplus (1_{\{t\}} \otimes f_2)]_\alpha^-, [(1_{\{s\}} \otimes f_1) \oplus (1_{\{t\}} \otimes f_2)]_\alpha^+) =$$
$$([(1_{\{s\}} \otimes f_1)]_\alpha^- \oplus [(1_{\{t\}} \otimes f_2)]_\alpha^-, [(1_{\{s\}} \otimes f_1)]_\alpha^+ \oplus [(1_{\{t\}} \otimes f_2)]_\alpha^+) =$$
$$([(1_{\{s\}}]_\alpha^- \otimes [f_1)]_\alpha^- \oplus [(1_{\{t\}}]_\alpha^= \otimes [f_2)]_\alpha^-, [(1_{\{s\}}]_\alpha^+ \otimes f_1)]_\alpha^+ \oplus [(1_{\{t\}}]_\alpha^+ \otimes f_2)]_\alpha^+) =$$
$$((s[f_1)]_\alpha^- \oplus t[f_2)]_\alpha^-, s[f_1)]_\alpha^+ \oplus t[f_2)]_\alpha^+) = s\pi(f_1) + t\pi(f_2).$$

$$(iii): \quad d_{\{F\}}(f_1, f_2) = \sup_{0<\alpha<1} \max\{| f_{1\alpha}^- - f_{2\alpha}^- |, | f_{1\alpha}^+ - f_{2\alpha}^+ |\} = \max[\sup_{0<\alpha<1} | f_{1\alpha}^- - f_{2\alpha}^- |, | f_{1\alpha}^+ - f_{2\alpha}^+ |] =$$
$$= \max\{\sup\{\alpha \in (0,1] \quad t \in [f_{1\alpha}^-, f_{1\alpha}^+], \sup\{\alpha \in (0,1] \quad t \in [f_{2\alpha}^-, f_{2\alpha}^+]\}\} = \max\{\| \pi(f_1) \| (t), \| \pi(f_2) \| (t)\}$$
$$= \| \pi(f_1), \pi(f_2) \| (t) = N(\pi(f_1) - \pi(f_2), t).$$

Therefore, we proved that the set of all fuzzy numbers can be embedded into a Fuzzy Banach space isometrically and isomorphically. Inspired by this specific Banach space, a fuzzy optimization problem can be transformed into a multiobjective optimization problem which can be solved by using interactive fuzzy decision making procedure. Under this setting, the fuzzy optimization problem is transformed into a biobjective programming problem by applying the embedding theorem and the optimal solution of the crisp optimization problem obtained from the fuzzy optimization problem is also an optimal solution of the original fuzzy optimization problem under the set of core values of fuzzy numbers.

Now, we consider a class of optimization problems which have multiple objective functions subject to a set of fuzzy relation equations.

The general form of a Banach application to fuzzy logic portfolio selection model can be described as follows:

$$\begin{aligned} &\text{maximize} \quad Z = r_1x_1 \oplus r_2x_2 \ldots \oplus r_nx_n \\ &\text{such that} \quad \tilde{a}_1x_1 \oplus \tilde{a}_2x_2 \oplus \ldots \tilde{a}_nx_n \oplus \le \left(\tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_n\right), \\ &\qquad x_i \ge 0 \;\; (i = 1,2,\ldots,n). \end{aligned} \tag{1}$$

A more approximative style to implement a numerical solution to a portfolio selection is described as an application such as in Eqn. (2) or in Eqn. (3). In the following section we present optimization models which illustrate the solution to multiobjective portfolio selection models in a fuzzy optimization environment.

$$\begin{aligned} &\text{maximize} \quad E[\sum_{i=1}^{n} r_i x_i] \\ &\text{and} \quad \text{minimize } \mathrm{Var}[\sum_{i=1}^{n} r_i x_i] \\ &\text{such that} \quad \sum_{i=1}^{n} x_i = 1, \quad x_i \ge 0 \quad (i = 1,2,\ldots,n); \end{aligned} \tag{2}$$

$$\begin{aligned} &\text{maximize} \quad Z_r = E[\sum_{i=1}^{n} r_i x_i] \\ &\text{and} \quad \text{minimize} \quad Z_v = \mathrm{Var}[\sum_{i=1}^{n} r_i x_i] = \sum_{i=1}^{n} x_i^2 \mathrm{Var}(r_i) + 2 \sum_{1 \le i \le j \le n} x_i x_j \mathrm{Cov}(r_i, r_j) \\ &\text{such that} \quad \sum_{i=1}^{n} x_i = 1, \quad x_i \ge 0 \quad (i = 1,2,\ldots,n). \end{aligned} \tag{3}$$

4 FNLP technique for solution of Multiobjective Programming Problem (MONLP)

Consider the following general Multiobjective Nonlinear Programming (MONLP) optimization problem:

$$\begin{aligned} &\text{minimize} \quad (f_1(x), f_2(x), \ldots, f_k(x))^T \\ &\text{such that} \quad x \in X = \{x \in R_+^n;\; g_j(x) \le 0 \;\; (j = 1,2,\ldots,m)\}, \\ &l_i \le x_i \le u_i \;\; (i = 1,2,\ldots,n) \end{aligned} \tag{4}$$

Step 1: In order to solve the MONLP problem in (12) we solve the problem as only one objective while disregarding the other ones. The procedure is successively repeated to find the ideal solution.

Step 2: Once all optimal solutions for each objective are solved, a pay-off matrix for each single objective can be obtained. The obtained pay-off matrix is described as follows:

$$\begin{array}{c} \\ x^1 \\ x^2 \\ \cdots \\ x^k \end{array} \begin{array}{c} \begin{array}{cccc} f_1(x) & f_2(x) & \cdots & f_k(x) \end{array} \\ \begin{bmatrix} f_1^*(x^1) & f_2(x^1) & \cdots & f_k(x^1) \\ f_1(x^2) & f_2^*(x^2) & \cdots & f_k(x^2) \\ \cdots & \cdots & \cdots & \cdots \\ f_1(x^k) & f_2(x^k) & \cdots & f_k^*(x^k) \end{bmatrix}. \end{array} \tag{5}$$

Optimal solutions for each objective function $f_1(x), f_2(x), \ldots, f_k(x)$ are given as $x^1, x^2, \ldots, x^k$. From this computation we derive the upper and lower bounds of each objective function $f_n(x)$ $(n = 1,2,\ldots,k)$. The upper and lower bounds are given in the following says:

$$\begin{aligned} U_n &= \max\{f_n(x_1), \;\; f_n(x_2), \;\; \cdots \;\; , f_n(x_k)\}, \\ L_n &= \max\{f_n(x_1), \;\; f_n(x_2), \;\; \cdots \;\; , f_n(x_k)\}. \end{aligned} \tag{6}$$

Step 3: Fuzzy set: characteristic function μ_n of crisp set to each member in X with $\mu_n : X \to [0,1]$. The assigned values is called a *membership function* and the set $A = \{(x, \mu_n(x)) : x \in X\}$, defined by $\mu_n(x)$ for $x \in X$ is called afuzzy set. Membership function, crisp problem the membership function μ_k and v_k are used respectively to solve the maximization of objective function $f_1(x)$ and minimization of objective function $f_2(x)$. We note:

$$\mu_k(Z_k(\overline{X})) = \begin{cases} 1, & \text{if } Z_k(\overline{X}) \le L_k, \\ \dfrac{U_k - Z_k(\overline{X})}{U_k - L_k}, & \text{if } L_k \le Z_k(\overline{X}) \le U_k, \\ 0, & \text{if } Z_k(\overline{X}) \ge U_k, \end{cases}$$

$$v_k(Z_k(\overline{X})) = \begin{cases} 1, & \text{if } Z_k(\overline{X}) > U_k, \\ \dfrac{Z_k(\overline{X}) - L_k}{U_k - L_k}, & \text{if } L_k \le Z_k(\overline{X}) \le U_k, \\ 0, & \text{if } Z_k(\overline{X}) \le L_k. \end{cases}$$

With w_1 and w_2 being crisp weights for portfolio returns and portfolio variance, then the previous model can be formulated as follows:

$$\begin{aligned} &\text{maximize } \alpha \text{ such that } \; w_1 \circ \left(\frac{Z_r - Z_r^l}{Z_r^u - Z_r^l}\right) \ge \alpha, \\ &w_2 \circ \left(\frac{Z_v^u - Z_v}{Z_r^u - Z_r^l}\right) \ge \alpha, \\ &\sum_{i=1}^{n} x_i = 1, \quad 0 \le \alpha \le 1, \quad w_1 + w_2 = 1, \end{aligned} \tag{7}$$

where »°« is the composition operator for a function w, and a multiplication symbol for our applied exanple in the following section.

Step 4: Solve crisp nonlinear programming to get optimal solution of the MONLP by application of various proposed well-known methods.

Crisp Weights:

Crisp relative weights measure the preferences for objective goals and reflect their relative importance. The positive crisp weights w_1 ($i = 1, 2, .., m$). for the crisp model are normalised as $\sum_{i=1}^{m} w_i = 1$. In alternative scenarios we propose different weights to reflect investors alternative preferences. Hence, a higher weight value gives evidence for more importance of the objective goal. In our fuzzy non-linear programming models, we tested various related scenarios.

Fuzzy Weighted Model:

$$\text{maximize } \alpha \text{ such that } \mu_{w_1} \circ \left(\frac{Z_r - L_k}{U_k - L_k} \right) \geq \alpha,$$

$$v_{w_2} \circ \left(\frac{U_k - Z_v}{U_k - L_k} \right) \geq \alpha,$$

$$\sum_{i=1}^{n} x_i = 1, \qquad 0 \leq \alpha \leq 1. \tag{8}$$

5 Numerical Illustration

This section gives an illustrative example to present optimal solutions to MONLP models. We selected six stock exchange shares which are traded in the Frankfurt DAX stock exchange market. The daily data ranges between January 2011 and January 2014. We selected each share from different sectors to account for alternative portfolio investments. Table 1 shows expected return and variance of the alternative shares. The companies are as follows: Deutsche Bank (DB), Daimler AG (DM), Henkel AG (HK), E.ON. (EON), BASF AG (BASF), Allianz AG (AL).

The covariance matrix for the selected data sample is given in Table 2.

In Table 3, the *pay-off matrix* indicates the optimal results of each single objective.

Weighted Portfolio Selection:

Table 4 shows the optimal solution values according the relative investor preferences.

Finally, we derive the Fuzzy weighted model solution in Table 5.

6 Conclusion

The optimal solution of the crisp optimization problem deduced from the fuzzy optimization problem by using embedding theorem is an optimal solution of the original fuzzy optimization problem under the set of core values of fuzzy real numbers. In a portfolio selection problem, the expected return, risk, liquidity cannot be predicted accurately. So the investor generally makes his portfolio choice according to his knowledge and his economic wisdom. Thus, deterministic portfolio selection is not a sensible option for the investor. Because of the existence of several non-stochastic factors in a stock market, fuzzy portfolio selection models have been proposed by model within fuzzy

Table 1: Expectation and variance for selected stocks (in growth).

	DB	DM	HK	EON	BASF	AL
Expected Return	1.00	1.00	1.00	0.99	1.00	1.00
Variance	0.00061	0.000395683	0.000181948	0.000348582	0.000289541	0.000360242

Table 2: Covariance matrix.

	DB	DM	HK	EON	BASF	AL
DB	0.22349517	0.223058336	0.223346256	0.222815933	0.222994258	0.22296937
DM	0.223058336	0.223449288	0.223118822	0.222894143	0.223114491	0.223061775
HK	0.223346256	0.223118822	0.223689574	0.222889422	0.223063648	0.223015952
EON	0.222815933	0.222894143	0.222889422	0.222987418	0.222826304	0.222803293
BASF	0.222994258	0.223114491	0.223063648	0.222826304	0.223347778	0.222988255
AL	0.22296937	0.223061775	0.223015952	0.222803293	0.222988255	0.222985648

Table 3: Pay-off matrix signifying optima.

	Zr	ZVar
(DB,DM,HK,EON,BASF,AL)1	1.000994	0.1885714E-03
(DB,DM,HK,EON,BASF,AL)2	0.1885714E-03	1.000994

Note. The model is solved as in Step 2. The optimal values are obtained by iteratively solving and combining the single objective functions Zr and ZVar.

Table 4: Relative preferences of the investors.

Case	W1	W2	SOLRETURN	SOLVAR	ALPHA
1	0.5	0.5	1.001174	0.000000	0.5000942
2	0.6	0.4	0.6675093	0.000000	0.4000754
3	0.4	0.6	1.501671	0.000000	0.6001131

*Note.*The abbreviations are as follows: w1, weight for return maximizing objective, w2, weight for variance minizing objective, SOLRETURN, solution value for return objective, SOLVAR, solution value for variance objective, alpha, solution value for final multiobjective optimal solution.

Table 5: Optimal solutions in the fuzzy weighted model.

Case	FW1	FW2	SOLRETURN	SOLVAR	ALPHA	W1	W2
1	[0.4, 0.5]	[0.6, 0.7]	1.667149	0.000000	0.7001319	0.5000000	0.7000000
2	[0.6, 0.7]	[0.4, 0.5]	1.261565	0.000000	0.5000942	0.7000000	0.5000942
3	[0.5, 0.6]	[0.7, 0.8]	1.470387	0.000000	0.8001507	0.6000000	0.8000000
4	[0.7, 0.8]	[0.5, 0.6]	1.168285	0.000000	0.6001131	0.8000000	0.6000000

Note. See Table 4. FW1 and FW2 denote the fuzzy weights.

norm. This paper extends the classical Banach spaces into fuzzy Banach and Menger probablistic Banach spaces model in fuzzy environment. This embedding theorem can be used for multiobjective decision making and has successfully been applied to optimization problems. We tried out various scenarios for portfolio selection which are pointing out different investor preferences. In Case 1 (See Table 4), the investor treats both objectives equally. In Case 2, the investor put more weight on portfolio return. In Case 3, the investor prefers to put more weight on the portfolio variance. We observe that different investor preferences determine the optimal solution to multiobjective fuzzy portfolio selection models according to alternative scenarios.

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Mehka optimizacija za izbiro portfelja na osnovi vstavljenega (vgrajenega) izreka v mehko normiran linearni prostor

Ozadje: Članek posploši rezultate problema vgrajenega mehkega številskega prostora in njegovih razširitev v mehki Banachov prostor , kjer je množica vseh realnih kontinuirnih funkcij na odprti množici Ω.

Cilji: Poglavitna ideja v ozadju našega pristopa je izrabiti prednost medsebojnega vpliva mehkih normiranih prostorov in normiranih prostorov na način, da dobimo ekvivalenten stohastičen program. Tako se laže izognemo tveganju zaradi prevelikega poenostavljanja realnosti.
Metoda: Vgrajeni izrek pokaže, da množico vseh mehkih števil lahko vgradimo v mehki Banach-ov prostor. Izhajajoč iz tega izreka predlagamo rešitev koncepta mehkega optimizacijske problema, ki se pojavi, kadar uporabimo vgrajeno funkcijo na prvotnem mehkem optimizacijskem problemu.
Rezultati: Predlagano metodo smo uporabili, da smo razširili klasičen model (srednja varianca) za izbiro portfeja na model v mehkem okolju (srednja varianca z nesimetrično porazdelitvijo) ob kriteriju dolgoročnih in kratkoročnih dobičkov na vlaganja, likvidnosti in dividend.
Zaključek: Problem zabrisane optimizacije je mogoče pretvoriti v problem večkriterijske optimizacije, ki ga je mogoče rešiti z uporabo interaktivnega mehkega postopka odločanja. Investitorjeve preference določajo optimalno večkriterijsko rešitev glede na alternativne scenarije.

Ključne besede: Vgrajeni problem, Mehka optimizacija, Mehki Banach-ov prostor, izbira portfelja

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The Development of Sugar Beet Production and Processing Simulation Model – a System Dynamics Approach to Support Decision-Making Processes

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Background: The sugar beet is the main field crop used for sugar production in the temperate climatic zone. The abolishment of the quota system will open new investment opportunities in countries that were forced to abandon sugar industry as the result of the reform in 2006. Present paper describes the modeling of sugar beet production and its processing into sugar for purpose of decision support.
Methods: A system dynamics methodology was chosen to model impacts of regional sugar factory investment. We present two basic concepts of system dynamics models at causal loop diagram level. The first holistic model deals with regional planning of new product development and the second one deals with factory model.
Results: The holistic model presented main feedback loops and dynamics of main elements in the case of regional investment into sugar industry. The factory model considered the specifics of the beet processing which is a) limited period of beet processing and b) initial adjustment to the production capacity at the start of the production season
Conclusions: The model seeks answers to strategic questions related to the whole sugar beet production and processing system and will be used for simulation of different scenarios for sugar production and their impact on economic and environmental parameters at an aggregate level.

Keywords: Sugar beet, system dynamics, simulation, model

1 Introduction

The 2007 European Union (EU) Sugar Reform turned the EU from a major sugar exporter into a major sugar importer, significantly changing the dynamics of the EU sugar market. High international sugar prices have been undercutting the EU's attraction as a favored export destination, while the increased productivity resulting from the reform has led to record EU sugar production beyond quota (Polet, 2012).

Sugar beet is the main field crop used for sugar production in the temperate climatic zone. According to Food and Agriculture Organization data, the area under sugar beet has decreased as result of technical advances and higher yields (Steinrücken, 2005; Ćurčić et al., 2009). The expected elimination of the sugar quota system in 2017, in the final reform, presents new business opportunities for farmers and investors in countries that have abandoned sugar beet production and the sugar industry as a whole. Greater competitiveness

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and deregulation in agribusiness and the food industry require new forms of co-ordination between farmers and their clients to increase the efficiency and profitability of the supply chain. Processing firms use various co-ordination processes to control the quantity and quality of their raw material (Gaucher et al., 2003). Since the investments in the sugar industry are long-term and financially demanding, there is a clear need for the use of modern decision support tools and models in order to ensure good decision support before the investment is made (Rozman et al., 2013).

According to Vandendriessche and Van Ittersum (1995), models for the sugar beet crop have been developed for a variety of purposes: (i) sugar yield forecasting with regard to campaign planning and marketing strategies; (ii) integration of scientific knowledge and hypothesis testing; and (iii) decision support, particularly in tactical and operational decisions at the farm level. It is difficult to satisfy these three objectives with one model; each aim requires its own model. Available sugar beet models can be divided into two types, descriptive and explanatory, and they integrate various processes. The former type is primarily used for prediction, the latter for research. For decision support and the management of a sugar beet crop at the farm level, a combination of descriptive or explanatory crop models, databases, and expert systems may be used.

A variety of models are used for decision support or forecasting in sugar beet production and processing. For example, Jones et al. (2003) studied the impact of future climate change on sugar beet yields over Western Europe using future (2021–2050) climate scenario data from a general circulation model, and the Broom's Barn simulation model of rain-fed crop growth and yield. Tzilivakis et al. (2005) assessed 13 sugar beet production scenarios that represent those used throughout the UK. They differed in soil type, nutrients applied (inorganic and organic), crop protection (chemical and cultural), and use of irrigation. The assessment included an evaluation of inputs (nutrients, pesticides, and energy) and their impact on the environment. A net margin for each scenario was also calculated to provide an economic assessment. Gohin and Bureau (2006) simulated the effects of the 2006 reform of the EU sugar regime and the effects of a ban on sugar export subsidies with the use of the general equilibrium model.

Stöckle et al. (2003) presented CropSyst as a multi-year, multi-crop, daily time step cropping systems simulation model developed to serve as an analytical tool to study the effect of climate, soils, and management on cropping systems productivity and the environment. CropSyst simulates the soil, water, and nitrogen budgets, crop growth and development, crop yield, residue production and decomposition, soil erosion by water, and salinity.

Models of sugar factories have also been developed. Henke et al. (2006) described the application of the Sugars™ program for modeling and simulation of a sugar factory with subsequent production of bioethanol and animal fodder. The designed scheme was further adjusted and verified using data from the Czech sugar industry (i.e., processing of 10.000 tons of sugar beet per day, 17% of sucrose in sugar beet, 2.5% of impurities, and 98% effectiveness of ethanol fermentation).

Rozman et al. (2013) developed a spreadsheet technologic economic model for feasibility analysis of the sugar beet plant. This model is used for the (1) assessment of sugar beet production costs, (2) sugar beet processing costs and factory cash flow projections, and (3) complete analysis of required field area necessary for the planned sugar factory.

System dynamics (SD) is one of the possibilities for employing computer simulation in order to support the decision-making process in sugar beet processing (Forrester, 1958, 1994). The system dynamics was successfully applied in several similar cases (Rehan et al., 2014; Martinez-Moyano and Richardson, 2014; Rozman et al., 2013). This paper discusses the problem of sugar beet processing using causal loop diagram (CLD) and SD methodology for holistic decision support.

2 System approach to regional planning of new product development

As stated in the introduction, investment in a new factory may have many advantages for a region; tradition, culture, land availability, and unemployment. However, due to the effects of the financial crisis and ecology sensitivities on the investment impact on ecology, a local authority must consider a number of factors, not only economics, in planning future development. Therefore, we decided to use SD methodology for such analyses, as one powerful method of decision support. Figure 1 shows a causal loop diagram (CLD) of a new sugar production factory with all relevant implications for development in the region.

We can observe several main feedback loops reinforcing and balancing in Figure 1. The reinforcing loops R1, R2, R3, and R4 are typical developmental loops. The investment in sugar production represents a new employment opportunity and increases workforce demand. That means that investment in the sugar factory, and power from the electrical biogas-based power plant, provides new employment opportunities and workforce demand in the sugar production and electrical plant sectors, which, at some time following investment, makes a final impact on regional development. This is also expressed in the demand for special agricultural custom machine services, such as sugar-beet harvesting, cleaning-loading, and transport. The sugar industry also contributes to employment in other sectors that support the sugar industry with production inputs (such as use of lime and fuel), as well as input for sugar beet production in the

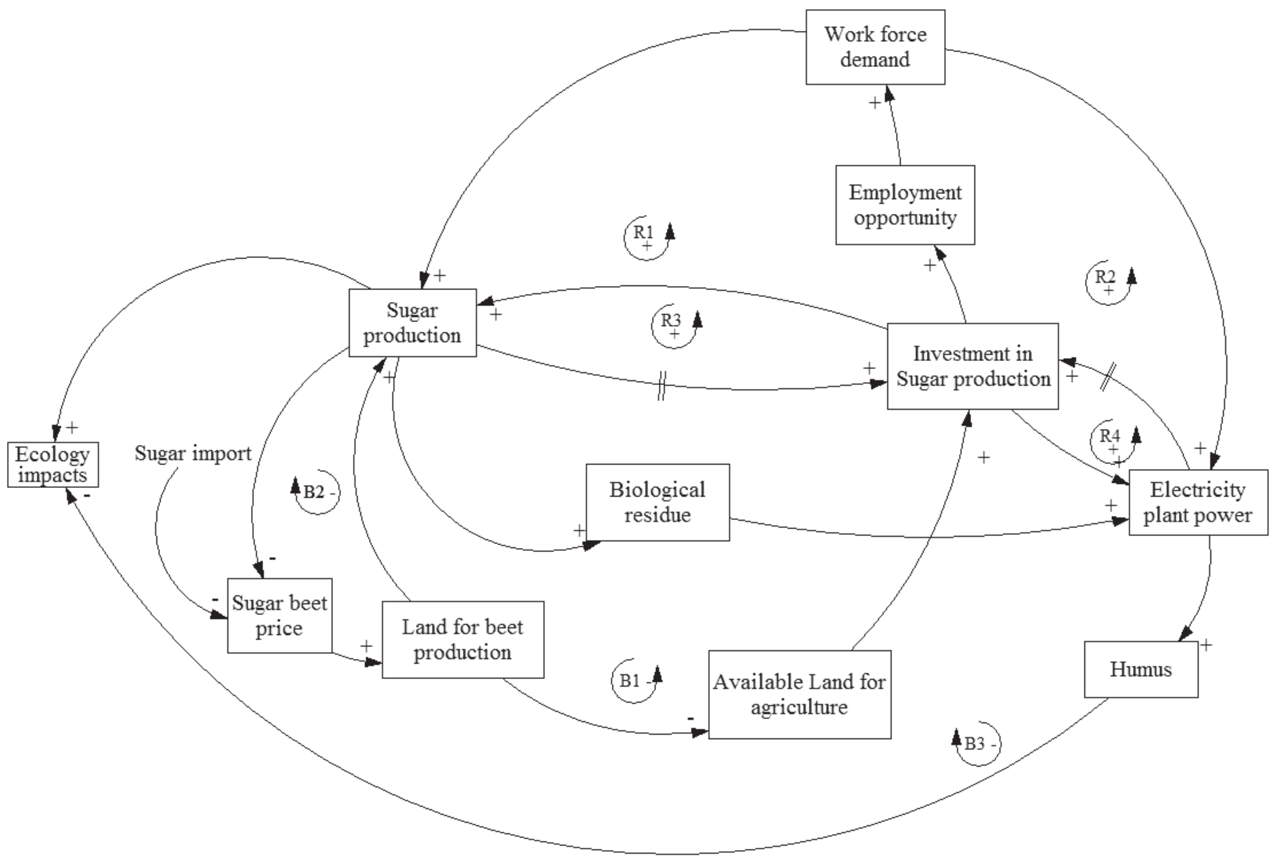

Figure 1: Holistic model of regional development of new product (sugar)

field. According to Rozman et al. (2013), a factory with a capacity for 7,500 tons of beet/day requires around 30 full time equivalents (FTE) during the campaign for transport alone. Of course, all of this depends on the market price of sugar and electricity. However, the new sugar plant requires land for sugar beet production. Therefore, available land for field crop production is decreased, and this influences the capacity of the new plant (balancing loop B1). The sugar beet production area is limited by crop rotation rules (recommended share of sugar beet in the crop rotation is 20%, higher shares can cause a decrease in yields and sugar content, and can also lead to more serious pest problems). There is also balancing loop B2 with a variable sugar price, which influences the decision-makers. Namely, increased sugar production and/or import of sugar from a free market leads to a decrease in sugar price negatively influencing the sugar beet prices, which can negatively impact the farmers' motivation for sugar beet growing and consequently result in the decrease of land for the sugar crop area and also decrease production level. These two loops, B1 and B2, are the basis for the planning of potential capacity of both plants. Biological remains (such as green mass and soil that come to the factory with the beet) can affect the environment; therefore a biogas plant that results in electric energy and additional employment opportunities should be built. In this manner, the negative influence on the environment is decreased (balancing loop B3). The reduction of the negative effect on the environment through loop B3 is also expressed in:

- The use of waste lime (a result of the carbonation sugar-cleaning process in one of the stages of sugar production). Waste lime is one of the most effective lime-based fertilizers, and, importantly, its use by sugar beet-producing farmers contributes to a decrease in soil acidity.
- The remains from the biogas plant can also be used as fertilizer. Furthermore, biogas production is usually combined with liquid manure from animal farms. Liquid manure is the source of methane CH_4 that is an even more damaging green-house gas than carbon dioxide (CO_2). In the biogas plant, the methane (produced through methagenic fermentation in the biogas plant reactor) is transformed to less damaging carbon dioxide

and water in the gas engine powering the electric generator.

Figure 1 is qualitative, and provides important causal loop relationships between relevant factors when deciding on investment. This can be incorporated into the holistic model in Figure 1; however, several other elements must be considered in further model development, such as annual climatic factors, world sugar production, and price. In the next chapter we focus only on sugar production; because of investment limitation, a biogas electrical plant is on our long-term planning horizon.

3 SD Model of sugar production

Figure 2 shows the CLD as the basis for the SD model of the sugar beet industry. We used the standard stock-inventory model as a basis.

Figure 2 shows the CLD of production capacity, estimated demand, and stock of sugar production. The primary driving variable in the model is »demand«, which determines the operation of the entire system. According to the »demand«, the sales diminish the »sugar stock«. In contrast, the »demand« influences the »desired production«. One may observe the delay mark from »demand« to »desired production«; if »demand« increases, then »desired production« is higher than it would otherwise have been. Here, it is important that the impact of the delay from »demand« to »desired production« is as short as possible, and also that the »demand« estimates are correct. Another link that influences »desired production« is »sugar stock« control link. If the »sugar stock« increases, the »stock shortage«, which is dependent on the »desired stock«, decreases. Here, we compare the »desired stock« and actual stock, which is named »sugar stock« in our case. If the »stock shortage« increases,

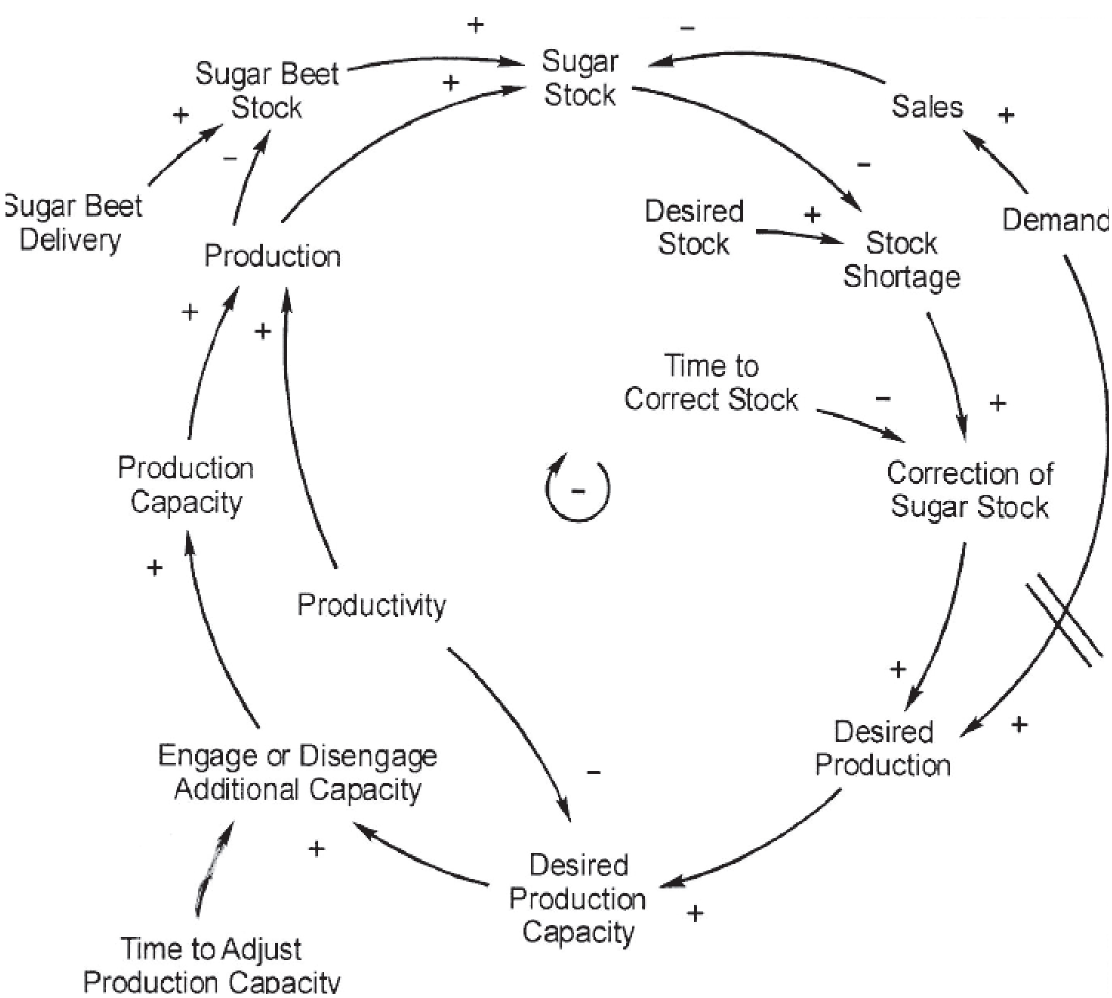

Figure 2: CLD of production capacity, estimated demand and stock of sugar production

the »correction of sugar stock« also increases. The response is determined by the »time to correct stock«; if the »time to correct stock« is longer, it will take longer to perform proper control action. The »correction of sugar stock« positively influences the »desired production«, which is the sum of »demand« values and the shortage of stock in our case, whereby proper control action is determined by the »correction of sugar stock«. »Desired production« determines the »desired production capacity«, which is dependent on the »productivity« of the production means. If the »productivity« is greater, fewer production means are required, therefore the »desired production capacity« is lower. If the »desired production capacity« increases, the »engagement or disengagement of additional capacity« is higher than it would otherwise have been. This is also dependent on the »time to adjust production capacity«. »Engagement or disengagement of additional capacity« determines the »production capacity«, which determines the »production« by additional consideration of »productivity«. The »sugar beet stock« is dependent on the »sugar beet delivery«, which increases the »sugar beet stock«, and, conversely, the intensity of the »production« decreases the »sugar beet stock«.

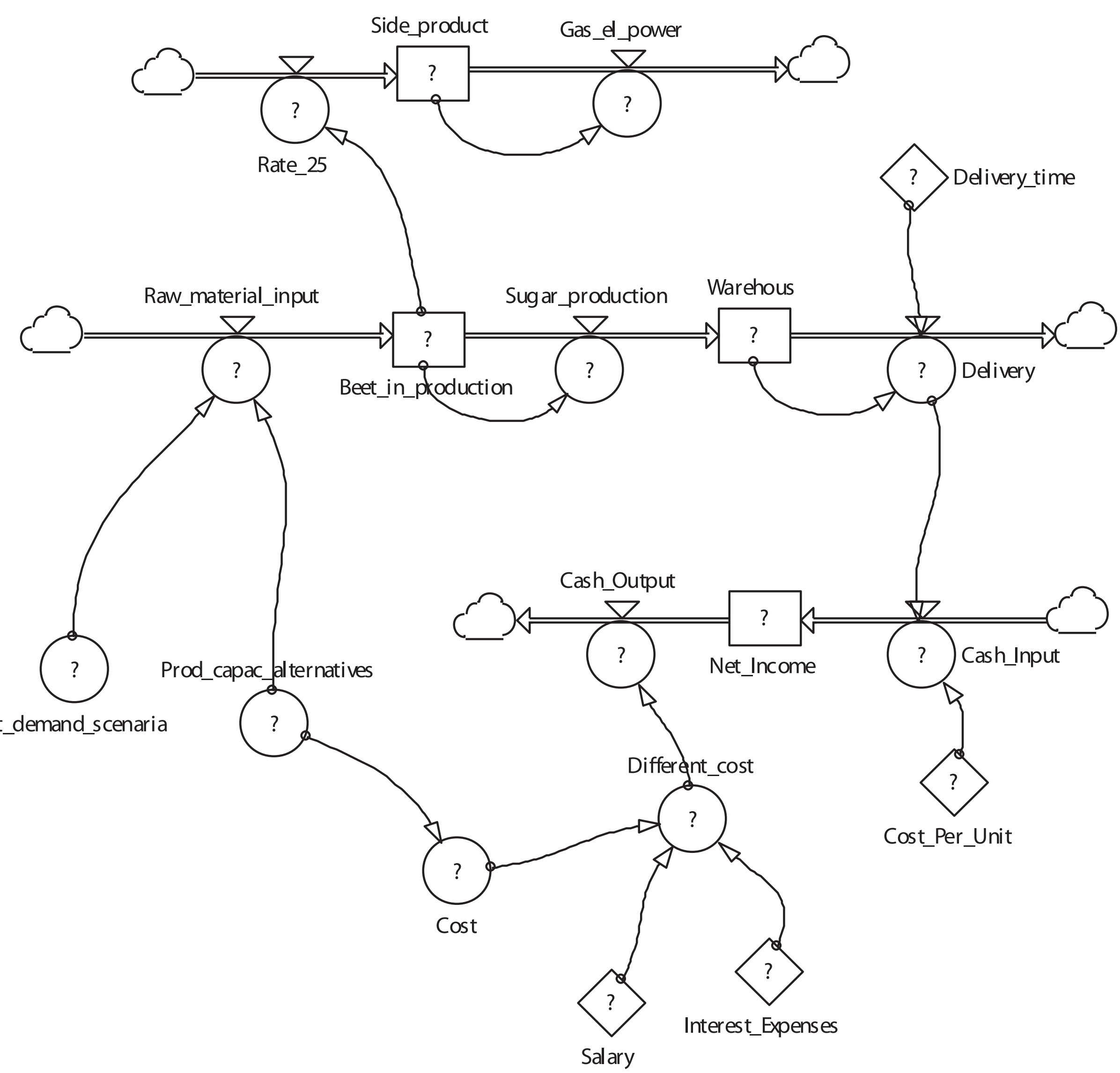

Figure 3: Preliminary SD model for investment decision support

»Sugar stock« is therefore dependent on the »production«, as well as on the capability to provide proper »sugar beet stock« supply. The structure represents a negative feedback loop with reference, which is primarily determined by the sugar »demand«.

The system can be modeled with a simple SD model, as shown in Figure 3.

The financial aspects of a new investigation were modeled in Powersim, as a continuous simulation model based SD methodology. The model will be used to test different business strategies in order to define the appropriate mix of price and costs for anticipated market demand with respect to production constraints.

The difference equation for net income (*NI*), from Figure 3, takes the following form:

$$NI_{ij}(k+1) = NI_{ij}(k) + \Delta t(CI_{ij}(k) - CO_{ij}(k)) \quad (1)$$

where, $NI_{ij}(k+1)$ represents net income at a future time; $NI_{ij}(k)$ is net income at the present time for the j-th alternative (type of technology) at the i-th scenario (Market demand); Δt is the solution time interval set to the value of 1 month, $CI_{ij}(k)$ is cash input, $CO_{ij}(k)$ is cash output and $k = 0, 1, 2, ...$ represents simulation time. Cash input and cash output are defined as follows:

$$CI_{ij}(k) = CPU_{ij} * SD_j \quad (2)$$

$$CO_{ij}(k) = IE_j + S_j + PC_j + Others \quad (3)$$

where *i, j* represents the j-th alternative and the i-th scenario, PPU_{ij} is price per unit, which is determined according to the market,
SD_j is rate of sugar delivered,
IE_j is interest expenses and other financial expenses, which represent different investment arrangements of the production alternatives, such as depreciation, administrative expenses, fixed costs, etc.). With adequate modification equation 1 will be used as decision criteria for analysis.

An expert group should determine unit sale price and market demand function, according to the different production scenarios and properties of alternatives. Scenarios are defined as a set of parameters: unit sale price, unit production costs, market demand, and other operating expenses. Market demand was formulated as a prediction function of demand and existing orders, which was determined by the regional expert group in the form of external scenarios. In equation 2, we did not consider invest into gas electrical plant and humus production.

4 Conclusions

In this paper, we attempted to employ a preliminary SD model in order to simulate the sugar beet processing process. The presented SD model enables simulation of different policies, and it is comprehensible to a wide range of users in the decision-making process. The holistic model presented main feedback loops and dynamics of main elements in the case of regional investment in the sugar industry. This way we can simulate effects of the investment into sugar factory on regional economy (work force) and environment. The factory model considered the specifics of the beet processing, which are a) limited period of beet processing, and b) initial adjustment to the production capacity at the start of the production season. In addition, the main feedback loops, which enable proper control, were identified, and this is important for the management of the considered system. Further consideration must be given to the interaction between elements in the main feedback loop in the system, which determines the system performance and provides the means for proper definition of control strategy. The main advantage of the SD model is its capability to assess strategy changes and the response of target variables over time. Such model can be useful tools for decision-makers to use in sugar-beet processing for the efficient organization of regional sugar industry systems. Likewise, the consideration of longer time periods and sugar prices will be accounted for in further model development.

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Razvoj modelov sistemske dinamike za podporo odločanju pri pridelavi in predelavi sladkorne pese

Ozadje: Sladkorna pesa je glavna kultura, ki se uporablja za proizvodnjo sladkorja v našem klimatskem pasu. Ukinitev Sistema kvot z letom 2016 odpira možnosti ponovne vzpostavitve proizvodnje v članicah EU, ki so se ji bile prisiljene odreči v letu 2006. V članku predstavljamo možnost uporabe modelov sistemske dinamike za potrebe podpore odločanju pri investicijah v sladkorno industrijo.
Metoda: Na nivoju vzročnega diagrama predstavljamo 2 modela sistemske dinamike. Prvi je holistični in predstavlja primer ocenejvanja efektov investicije v sladkorno insustrijo. Drugi model se pa ukvarja z delovanjem tovarne.

Rezultati: Holistični model predstavlja vse povratne zanke v ssitemu sladkorne industrije na regionalnem nivoju. Model proizvodnje pa se ukvarja z delovanjem tovarne.
Zaključki: Model omogoča iskanje odgovorov na strateška vprašanja in se bo uporabljal pri ocenejvanju scenarijev investicij v proizvodnjo sladkorja in njihovega vpliva ne proizvodno-ekonomske in okoljske parametre.

Ključne besede: sladkorna pesa, sistemska dinamika, simulacija, model

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Key Factors for Development of Export in Polish Food Sector

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Background: The accession of Poland to the European Union in 2004 facilitated increased exports of food products. It revealed a significant competitive advantage of Polish foreign trade in agri-food products compared to the countries of the »old EU«. After nearly 10 years of Polish membership in the EU, the food sector has still a considerable potential, fostering a further increase in exports.
Objectives: The purpose of the paper was an attempt to establish the current determinants for the possibility to increase the exports of the Polish food sector and to identify potential opportunities and potential threats in the future. It was also decided to give an answer to the question whether any of the group factors has a greater impact on the development of exports than the other, and which issues play only a minor role in the development of international exchange.
Method: The analysis used involved the review of the relevant literature and forming a group of experts to specify the key factors of success in the food sector export. Basing on the experts research the STEEPVL analysis was carried out.
Results: It turned out that apart from a number of organizational, financial and marketing factors the most important are: the level of the IT infrastructure and the fluctuation of the demand on the international markets for the goods offered by the sector.
Conclusion: Therefore, the focus on the new distribution channels, integrated company management IT systems and changes in the demand on the market is the key challenge for securing the current potential and for the further development of the sector.

Keywords: food sector, exports, key development factors, foresight, STEEPVL method

1 Introduction

The contemporary globalized economy, subject to constant changes in all areas of the enterprise surroundings, creates an extremely complex and turbulent business environment. Managers, those of traditional sectors included (ie. in the food sector), are forced to take up economic decisions in the conditions of high uncertainty and risk. Planning for the enterprise future, forecasting future events and needs is very difficult in these conditions. The same problems arise when trying to forecast the future and identify the key factors for the development of the food sector in Poland and its exports.

Using the experience of developed countries, the research on foresight has been conducted for several years in Poland to forecast future events and their effects. Since the 1970s, about 2000 studies of this type have been undertaken so far in the world, and in Poland nearly 40 such projects. The studies were conducted to monitor changes, to foresee and shape the future in relation to regions (regional foresight), industries (industry foresight) or technology (technological foresight), but also to individual companies,

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such as SMEs (the corporate foresight) or to countries (Miles and Keenan, 2002; Dreyer and Stang, 2013). These studies are used in strategic planning at each of these levels (Major and Cordey-Hayes, 2000). The growing interest in these issues is confirmed by topics published in reputed scientific journals, such as »Technological Forecasting and Social Change«, »Futures« ,«International Journal of Foresight and Innovation Policy«, »Foresight«, »Technology Analysis and Strategic Management«.

In the literature, the foresight has been defined as »the systematic, participatory process involving gathering intelligence and building visions for the medium-to-long-term future, and aimed at informing present-day decisions and mobilizing joint actions« (Miles and Keenan, 2002). This process is involved not only in foreseeing the future, but also in its creation. Studies of this type use different research instruments, such as the SWOT method, desk research, STEEPVL[1] method, brainstorming, building scenarios, the Delphi technique, in-depth interviews, questionnaire surveys and expert panels (Loveridge, 2002; Cairns et al. 2004; Ringland, 2007; Popper, 2008). The basis for all these research tools lies in the cooperation between the partners involved in the process of forecasting and shaping the future. These include representatives of various interest groups such as entrepreneurs, scientists, consumers, administrative staff, consultants and other experts. This makes the foresight a method both active and participatory.

2 The food sector as a subject of foresight study

The sector of food and human nutrition has been the subject of foresight studies since the 1990s. As a part of the American project »Food Foresight - Trends Intelligence for Agri-Food Chain« continued since 1993, analyses of trends in the international food trade have been carried out. Development scenarios are created, to be used in the agri-food enterprises and wholesale food distributors (Food Foresight 2011). In the European Union, the issue of the vision for the food industry, agriculture and food markets, in the national and global scale has been the subject of research foresight projects in the UK (Global Food and Farming Futures), the Czech Republic (National Research Programme), France (ie. the foresight for the future of agriculture or the current research on the possibilities for the development of the bio-economy conducted by the French National Institute for Agricultural Research). The results of the foresight projects funded by the EU Framework Programmes (Food, Agricultural and Fisheries 2009) and the work of experts of the European Technology Platform »Food for Life«, made it possible to create scenarios for the agri-food industry in Europe by 2025 (European Technology Platform in 2005; Downey, 2006).

In Poland, attempts to explore the complexity of the subject of food and nutrition were undertaken while working on the Pilot Foresight Project in the Health and Life research field and while implementing some regional projects, such as »Foresight - the prioritary technologies for the sustainable development of the Podkarpacki Region« or »LORIS Vision. Regional technological foresight« (Rogut and Piasecki, 2007; Woźniak ed. 2008). In these studies, the food industry was one of many sectors analyzed in terms of technology and development directions for the regions. These works, however, did not contribute to the creation of a vision for the development of the entire agri-food industry in the country. The research in this field was undertaken only upon the implementation of the project: »Food and nutrition in the twenty-first century - a vision of Polish food sector development« between 2008 and 2012. The food sector was recognized a very important segment of the Polish economy, with a significant share in the value of production sold, gross value added and international exchange.

The Delphi method (was attended by over 300 external experts, representing universities, businesses, institutions, as well as State and local governments) allowed to assess medium-and long-term changes in the market, as well as technological, demographic, social and economic conditions in the sector. The experts have also identified key technologies whose introduction will help to develop and enhance further the competitiveness of Polish industry (Michalczuk, 2011). This comprehensive research work inspired the authoresses to made the further analysis.

3 The food sector in Poland and its determinants

The food sector is one of the most important and fastest developing areas of the Polish economy. In 2011, its share in the total sales value of the industry amounted to 22.2%. This value exceeds the average for the European Union, which is 14.5%. Among the states belonging to the European Union, only Denmark and Greece have a higher share than Poland (European industry in a changing... 2009). The following industries have the highest share in the domestic production: meat (32.9%), dairy (18.5%), fruit and vegetable products (8.4%) (Statistical Yearbook of Agriculture 2012). The standing of the whole sector, as well as of its leading industries is the result of changes in the agri-food sector started in

1 The name of the research method used was formed from the first letters of the factor group names as follows: Social, Technological, Economic, Environmental, Political factors, those relating to the Value and Legal factors (see Chapter 4, Table 1).

the 1990s. They had the nature of capital and organizational concentration combined with a modernization of manufacturing processes (Gradziuk, 2009). Another important factor for the growth of the food sector performance in the last decade was the accession of Poland to the European Union on 1st May 2004. This event triggered further structural, modernization and investment changes.

These changes have led to the approximation of the structure and competitiveness of the Polish food industry to that of developed countries. This had a favourable effect on the international trade in this sector. The integration of Poland with the EU allowed to make clear the advantages of this country in the agri-food products foreign trade. It contributed to a rapid growth of the food industry exports and improved the balance of foreign trade (Rytko, 2005; Pawlak, 2007; Urban et al. 2010; Kowalski et al. 2012). The most competitive industries of the Polish food sector include: meat, dairy, fruit-and-vegetable, confectionery products, cereals secondary processing and tobacco products manufacturing.

Since the accession of Poland to the EU, the volume and value of agri-food products exports has been steadily increasing. The Polish food sector has un-uniform trade relations, ie the dominant partners in this exchange are the EU Member States (Production and trade in... 2013). The trade turnovers in agri-food products with these countries have kept increasing after the accession of Poland to the EU much faster than with third countries and contributed to the ever-growing positive trade exchange balance. In 2012, the value of food exports amounted to EUR 15.2 billion, which accounted for 10.6% of total exports. The turnover balance was positive and amounted to EUR 2.6 billion. As to the total balance of the Polish agri-food trade with non-EU members, it has been negative for years (Foreign Trade Statistical Yearbook 2013).

In the first years after the integration, Polish entrepreneurs exploited primarily competitive advantages based on lower labour and raw materials costs and lower margins of processing, but over the years, some of producers changed their competitive strategies. Leaders of industries include in the other sources of competitiveness: the quality and uniqueness of products, the ability to identify and meet the individual demands of customers, comprehensive promotional activities, as well as the creation of the company's image based on the confidence in the quality and the reliability of products and high quality customer service. The innovativeness, entrepreneurship, knowledge and intellectual capital are also considered important. New competitiveness strategies prepare companies to inevitable changes in the environment, the impact of current economic factors and the trend of globalization (Kowalski et al. 2012). Since 2011, a decreasing domestic demand has been observed together with escalating market restrictions, rising raw material prices, prices relations unfavourable for processors, high changeability and declining production dynamics, as well as an instability of financial results, slowing down processes of concentration and increasing external constraints. These conditions are forcing the sector enterprises to continue the process of business improvement and to enhance its efficiency.

The long-term planning of the company's development requires a monitoring of trends in the wider environment, not only in the nearest neighbourhood, but also in very distant countries. Entrepreneurs must be able to respond to the extent possible to changes in the demand for their products not only in the domestic market but also in the world. They are to notice export opportunities in the markets hitherto completely overlooked. The market opportunities create new products even such ones that formerly were treated as food products of little value. Yet, in other parts of the world they can be considered a delicacy. A very important factor to determine the presence of Polish products in the foreign markets is the reputation of Poland as a food producer. It depends on the observance of quality standards and food (veterinary, sanitary, commercial quality, et al.) safety.

4 Methodology

The most important research task of this study was to determine the key factors for the exports development of Polish food products, using the STEEPVL method. To implement the main purpose of the study, both primary and secondary materials were used. To evaluate the factors, influencing the development of the Polish food sector international exchange, an analysis of the literature dedicated to this topic was carried out. Based on the desk research and the secondary data (official statistics) the Polish food sector was presented and its hitherto conditions of development. Particularly highlighted were the achievements of the Polish food producers in the exports of agri-food products, mainly to the EU markets. The growing importance of the economic situation and the globalization for the possibility of development of the sector and its exports was pointed out. Then, the above analysis allowed to identify and determine the strength of the factors, influencing the development of the international trade (exports) of this sector, with the use of the STEEPVL method.

The analysis was made in the following stages:

- team of 11 experts was conducted. It consisted of scientists, entrepreneurs engaged in the production and trading in food products and consumers. The group of experts was chosen deliberately, according to the following criteria: knowledge of issues related to exports and imports of food products, direct or indirect participation in the international exchange processes of food products, their consent to participate in the study.
- according to literature (Mendonca et al. 2004; Ringland, 2007; Sutherland and Conwell, 2007) the 6 areas of the

main factors affecting the development of the test area were defined (i.e. Social, Technological, Economic, Environmental, Political Value and Legal),
- the group of experts were asked to write maximum number of factors within 6 areas, affecting the change in the volume of international trade in food products (by brainstorming),
- then, the factors of main 6 groups were reduced to 3 (display method - each of the expert participating in the study chose three factors which he/she considers the most

Table 1: The choice of the main factors in the different areas of STEEPVL analysis

Factors designation	**Type of STEEPVL factors**
Social (S)	
S1	Level of public confidence in food products (loss of confidence following such events as: salt scandal, horse meat scandal etc.)
S2	Human resources potential (a team of people to ensure smooth contacts with foreign partners)
S3	High quality assessment and tastiness of Polish food
Technological (T)	
T1	Technical and technological equipment, ensuring the standards of food quality and safety required abroad
T2	IT infrastructure development level (Access to novelties via the Internet, trade development – new distribution channels, integrated informative systems to manage the company)
T3	Level of technological advancement of enterprises while using new technologies (new lines, new technological solutions)
Economic (Ecn)	
Ecn1	Fluctuation in the demand for goods offered by industry in international markets
Ecn2	Price and cost competitiveness of Polish food products in foreign markets
Ecn3	Improvement in the management of production process
Enviromental (Env)	
Env1	Ecological and healthy food
Env2	Development barriers connected with environmental protection
Env3	Environmental organizations activities
Political (Pl)	
Pl1	Promotion of Polish brands in the world
Pl2	Support to exports of food products
Pl3	Introduction of restrictions on imports of food from defined states (because of threats or poor quality)
Value (V)	
V1	Level of readiness to co-operate
V2	Need of innovativeness
V3	Need of creativity
Legal (L)	
L1	Predictability of fiscal system
L2	Legal support to exports processes (transport, contracts, claims, warranties)
L3	Degree of red tape and regulations

important). In this phase, all 21 factors in separate 6 areas have the same importance for all experts (see table 1),

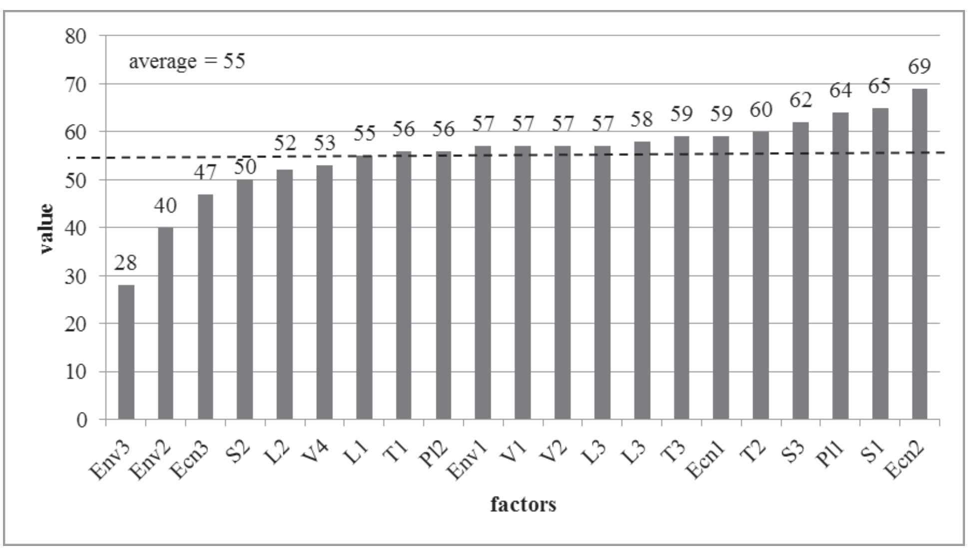
- then, the isolated groups of factors were evaluated in terms of the strength of the impact on the increased export. A 7-step Likert rating scale was used where »1« indicates factors of very little importance or unimportant, but »7« means very important factors for the achievement of the objective. The numbers between 1 and 7 described the increase in the importance of the particular factor. All the results obtained from the experts were summed up for the specific columns (using weights from 1 to 7). Afterwards, the sums of the answers (indications) were multiplied by the weights giving the ranking of the specific factors,
- in the next step was evaluation of uncertainty defined factors. The Likert 7-point scale rating was also applied. This time, however, rating »1« was assigned to the indicators labelled as very little predictable, while rating »7«- to very predictable. The experts taking part in the study were asked the question about the predictability of the factors, because according to Loveridge (2002) it appeared to be more relevant than the question on uncertainty. Then, the rating scale was converted as follows: (1 → 7) (2 → 6) (3 → 5) (4 → 4) (5 → 3) (6 → 2) (7 → 1).

Research was carried out from April to July 2013 amongst the experts, regarding the multi-faceted and multi-dimensional determinants for the development of the exports of Polish food products. When formulating the results, the quantitative and qualitative methods were applied. Based on Postma and Liebl (2005), Steinert (2009) and Godet et al. (2006) to analyze the collected material, the method of Key Success Factors was used. Owing thereto, the most important factors, the conditions to acquire the competitive advantages, were determined.

This allowed for the final inference to give the key factors, contributing to changes in the volumes of Polish food products exports.

5 Results and Discussion

The development and evolution of export destinations in enterprises belonging to the Polish food industry, as well as the determinants of these changes depend on many factors that are often in the surroundings of a given organization. In the opinion of the experts involved in the study, the value of the foreign turnover in the sector products does not depend so much upon the economic situation, or the rates



Example for calculation in factor Ecn 2-Price-and-cost competitiveness of food products in foreign markets:
(1*· 0**)+(2*·0**)+(3*·0**)+(4*·1**)+(5*·1**)+(6*·3**)+(7*·6**) = 69***
* the weights – from the least important to the most important
** the accumulated number of the answers given by the experts
*** the final ranking for the specific factor

Figure 1. Factors determining the development of international trade

of foreign exchange, but on public fear publicized by the mass media which concerns various aspects of unpleasant consequences of eating certain foods (bird flu, mad cow disease, foot and mouth disease, genetically modified food). During the discussion, the experts invited to participate in the study also raised numerous examples of activities in the so-called gray zone, and the failure to comply with the rules of good conduct in business (some companies never subject their marketed products to immunochemical testing so as to reduce costs). They also discussed the problems with financial liquidity and with the regularity of supplies of high quality raw materials for the production. Some speakers mentioned the recent activity of transnational corporations and progressive structural changes in the sector (vertical and horizontal concentration, consolidation, integration).

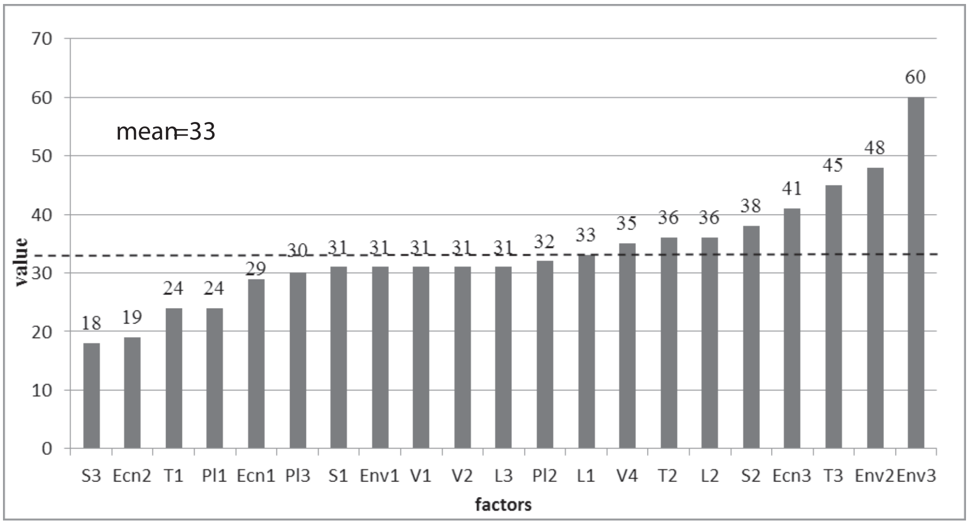
Hence, starting the main purpose, which was an attempt to select factors determining the development of food enterprises exports, in the first place, it was decided to isolate groups of the so-called Key Success Factors (see Table 1).

Then the strength of their impact on the increased export capacity of the food industry enterprises were evaluated, which is presented in Figure 1. It turned out that the most important factor for the development of enterprises exports is one from the economic group, marked as Ecn2 »Price and cost competitiveness of Polish food products in foreign markets« (Figure 1). Social issues were slightly less important, but located on the second place amongst the obtained results of analysis. At the same time, the S1 factor, »The level of public confidence in food products« was pointed out. On the third place, with only slightly fewer points, the Pl1 political factor, »Promotion of Polish brands in the world« was found. The Ecn3, »Improvement in the management of the production process« proved to be the least important in the economic group.

In the further part of the analysis, assessing the degree of predictability of the future state of the determinants which make the conditions for the growth of export were also ranked. A list of factors diversified in terms of uncertainties was obtained (Fig. 2).

Most concerns were raised by environmental issues, mainly by Env3 »Environmental organizations activities« and Env2 »Development barriers connected with environmental protection«. Slightly fewer points on a scale measuring the uncertainty factors were given to: Technological T3 »Level of technological advancement of enterprises while using new technologies (new lines, new technological solutions)«, and economic Ecn3 »Improvement in the management of production process«. In the case of the social factor labelled S3 »High quality assessment and tastiness of Polish food« the least risk for the development of export opportunities of Polish food producers was perceived. In this group, it received the least significant number of points.

The results of the analysis related to the uncertainty in combination with the assessment of the factors, affecting the opportunity to increase the exports of food industry enterprises were the basis for an initial separation of factors, making up the conditions for the task implementation (Fig. 3). Based on the data presented in Figure 3, the factors



Example for calculation in factor Env 3: Activity of environmental organizations (1 · 1) + (2 · 1) + (3 · 2) + (4 · 2) + (5 · 1) + (6 · 3) + (7 · 1) = 60

Figure 2. Evaluation of uncertainty factors associated with the development of international trade

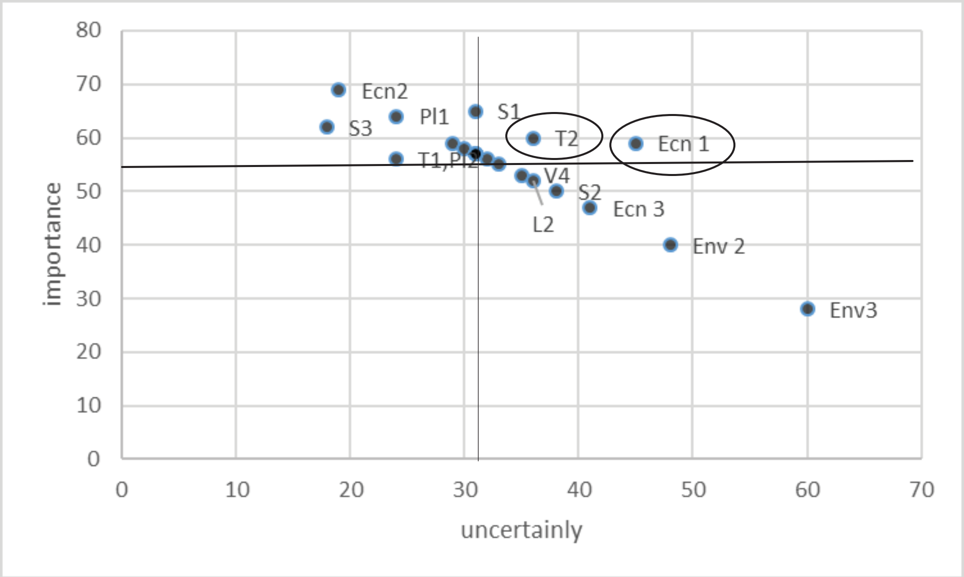


Figure 3. Factors crucial to the development of the international trade

included in the technological group T2 »IT infrastructure development level (Access to novelties via the Internet, trade development – new distribution channels, integrated informative systems to manage the company)« and economic Ecn1 »Fluctuation in the demand for the goods offered by industry in international markets« were considered as such.

At the same time, both of the above-mentioned factors were characterized by a higher assessment of uncertainty than the average for the entire group of 33 and a higher evaluation of validity than the average of 55 recorded there. It is surprising that the environmental issues concerns which give rise to worst fears (when measuring uncertainty) do not have key importance in the final chart.

The Ecn2 »Price and cost competitiveness of Polish food products in foreign markets« are similarly assessed just as the S1 issues of public confidence associated with a number of recent food scandals, which were pointed out as the most crucial for the prospects of the food sector exports in Poland. The analysis shows that in the future, it is necessary to focus not on technical and technological innovations, but rather on the knowledge and information, resulting from a continuous monitoring of changes in the sector surroundings and the level of customer satisfaction measured by the degree of meeting their demands.

6 Conclusions

The food sector as the one of the most important and the fastest developing areas of the Polish economy has been drawing attention of numerous experts for years. According to the previous analyses (e.g. Rytko, 2005; Pawlak, 2007; Urban et al. 2010; Kowalski et al. 2012) it has considerable export opportunities.

It has been shown that many of competitive advantages have become apparent after the accession of Poland to the EU. These included, among others: lower costs of labor and raw materials and processing margins. With the time, after a change in the market situation, the quality and uniqueness of products were focused on, together with the ability to identify and meet the individual needs of buyers, the comprehensive promotional activities and the creation of the company image based on the confidence in quality and reliability of products and in high quality of customer service.

Based on the STEEPVL analysis it was decided that:

- Most concerns were related to environmental issues, mainly to the activities of environmental organizations and the environmental protection.
- Experts were slightly less worried by the technological level of enterprises advancement in the use of new technologies, understood as the introduction of new lines and technological solutions and changes, regarding the need to improve the management of the production process.
- However, from all these elements, either supporting the development of the agri-food industry or threatening it, mainly two stand out in the foreground: the IT infrastructure development level (Access to novelties via the Internet, trade development – new distribution channels, integrated informative systems to manage the company) and the fluctuation in the demand for the goods offered by the industry in the international markets.

- The focus on these two areas should benefit both Polish enterprises and the entire sector concerned in trading in the food products in the international markets.
- It is necessary to deepen further the analyses of the factors, determining the possibilities to increase the exports of Polish food products.

The determinants for the development of foreign trade in Polish food products, determined in the desk research, were confirmed by the list of key factors, influencing the export sector, established by the experts and other participants in the STEEPVL study. The studies lead to the conclusion that the Polish food industry operators should take advantage of price and cost competitiveness of Polish products in the foreign markets and the high assessment of the quality and flavor of these products combined with the public confidence in Polish products. However, let us not forget of price-cost competitive advantages being reduced and the need for Polish producers to search new opportunities to increase exports with the use of, inter alia, innovative products (that better meet the needs of buyers), to improve production efficiency, to try to achieve the highest possible quality and food safety. This will allow maintaining a favorable opinion on the Polish food products domestically and abroad. It is also necessary to search for new markets (outside Western Europe), which will ensure the decrease in the dependence of Polish food sector on the EU market and the consequent vulnerability to the economic situation, fluctuations in currency and demand in the European and Polish food markets. To achieve this goal, not only the activity of the Polish food producers seems necessary to acquire new customers in the global market and to compete with transnational corporations, but also the involvement of the State in assisting to promote Polish products and brands in foreign markets. Another factor to help to increase the opportunities for the international exchange sector development should be better endeavors of the State to ensure that the principles of fair competition and integrity in business and while food producing are met by Polish producers, in accordance with the requirements for food products quality and safety.

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Ključni dejavniki za razvoj izvoza prehrambnega sektorja na Poljskem

Ozadje: Vstop Poljske v EU leta 2004 je omogočil večji izvoz prehrambnih izdelkov na tržišče EU. Pokazalo se je, da ima Poljska pomembne konkurenčne prednosti pri izvozu hrane v primerjavi s »starimi« državami članicami EU. Po 10 letih članstva v EU ima poljski prehrambni sektor še vedno velik potencial za nadaljnje povečanje izvoza.
Cilji: Namen članka je ugotoviti ključne dejavnike za nadaljnje povečanje izvoza prehrambnega sektorja in identificirati potencialne priložnosti in grožnje. Namen članka je tudi odgovoriti na vprašanje katera skupina dejavnikov ima večji vpliv na razvoj izvoza prehrambnega sektorja, in kateri dejavniki imajo manjšo vlogo pri razvoju mednarodne menjave.
Metoda: Analiza vključuje pregled relevantne literature in oblikovanje skupine ekspertov, da bi lahko opredelili ključne dejavnike uspeha v prehrambnem sektorju . Na osnovi zbranih mnenj ekspertov je bila izvedena STEPVL analiza.
Rezultati: Poleg vrste organizacijskih, tržnih in finančnih dejavnikov sta med najbolj pomembnimi dejavniki tudi raven informacijske infrastrukture in fluktuacija v povpraševanju po artiklih, ki jih nudi prehrambni sektor na mednarodnih tržiščih.
Zaključek: Zato je ključnega pomena, da se poljski prehrambni sektor usmeri na nove distribucijske kanale, integrirane poslovne informacijske sisteme in fluktuacije v povpraševanju, da bi lahko zagotovili sedanji in bodoči razvoj tega sektorja.

Ključne besede: prehrambni sektor, izvoz, ključni dejavniki razvoja, predvidevanje, STEEPVL metoda

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Extended Technology Acceptance Model for SPSS Acceptance among Slovenian Students of Social Sciences

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Background and Purpose – IBM SPSS Statistics is among the most widely used programs for statistical analysis in social sciences. Due to many practical values it is frequently used as a tool for teaching statistical concepts in many social science university programs. In our opinion, motivation to learn and to use SPSS during the studying process plays a significant role in building a positive attitude towards SPSS which influences its usage at the professional level after finishing study.
Design/Methodology/Approach – The aim of this paper is the development of the model for analysing the acceptance of the SPSS among university students of social sciences. The model is based on the widely known Technology Acceptance Model (TAM). In addition to the traditional components of the TAM, six external variables were included. The model is tested using the web survey on the university students of social sciences from seven faculties at three Slovenian universities.
Results – The evaluation of the questionnaire was performed. Descriptive statistics were calculated. The dependencies among the model components were studied and the significant dependencies were pointed out.
Conclusion – The results of the empirical study prove that all external variables considered in the model are relevant, and directly influence both key components of the traditional TAM, »Perceived Usefulness« and »Perceived Ease of Use«. Therefore, our model is useful to study the adoption and continuous utilization of SPSS among the students of social sciences. The obtained results are useful for educators, and can help them to improve the learning process.

Keywords: university education, statistics, statistics anxiety, SPSS, acceptance, TAM model

1 Introduction

Courses in statistics are important to all business majors because they represent the formal exposure to statistical analyses and research methods which many students may find useful in their careers. Analytical skills enhance students' ability to read, interpret, synthesize and use reported results. On the other hand, research production skills enable students to design and initiate original research (Ravid and Leon, 1995). However, students' personal experiences toward statistics are often a source of anxiety producing negative perceptions. Many researchers have indicated that courses in statistics are among those that cause the most anxiety, especially for students in non-mathematics-oriented disciplines (e.g. Zeidner, 1991; Baloğlu, 2003; Onwuegbuzie, 2004; Pan and Tang, 2004, DeVaney, 2010). Statistics anxiety is experienced by as many as 80% of graduate students in the social and behavioural sciences and is at least partly responsible for the procrastination of stu-

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dents enrolling in required statistics courses (Onwuegbuzie and Wilson, 2003). Our several years teaching experiences at higher education courses prove that the situation at the Slovenian universities seems to be quite similar. We think that students' motivation for learning statistics and using statistical software is not at a desirable level.

The development and psychometric properties of statistics anxiety scales and the factors affecting statistics anxiety have been extensively studied for more than twenty years, but few studies focused on how to reduce the statistics anxiety for graduate students in the social sciences. A comprehensive summary of the literature on statistics anxiety is provided by Onwuegbuzie and Wilson (2003).

The results of some previous studies indicate that using computers in a statistics class has been generally successful in lowering the statistical anxiety (Stickels and Dobbs, 2007). Among the most widely used programs for statistical analysis in social science is IBM SPSS Statistics. Integration of SPSS into higher education courses in statistics can have many positive effects such as (IBM, 2010):

- Focuses students' attention on learning concepts rather than on formula manipulation.
- Enables teaching of real-life problems, engaging students more actively in the learning process.
- Increases students' confidence in being able to learn and understand what they initially anticipated as being a complicated and difficult subject.

Due to many practical values SPSS is frequently used as a tool for teaching statistical concepts in a majority of social science programs at Slovenian universities.

In our opinion, the motivation to learn and the use of SPSS during the studying process plays a significant role in building a positive attitude towards SPSS and to statistics itself which influences the usage of SPSS at the professional level after finishing the study. The aim of this research is to

1. identify the external factors which may influence the adoption and continuous utilization of the statistical package SPSS among the university students of social sciences;
2. examine the direct and indirect influences of selected external variables on students' behavioural intention which directly affect their actual use of SPSS in the future.

For this purpose a research model, based on Technology Acceptance Model (TAM) will be developed. The model will be tested on university students of social sciences from seven different faculties at three Slovenian universities.

2 Technology Acceptance Model – TAM

Technology Acceptance Model (TAM) is one of the most widely used conceptual models in explaining and predicting the adoption behaviour of information technology (Hsu et al., 2009). TAM is widely known and it has received strong theoretical and empirical support in literature, having been cited more than 700 times (Padilla-Meléndez et al. 2013). It was developed by Davis (1986, 1989) to explain the nature and determinants of computer usage. The principal scheme of the original TAM is shown in Figure 1.

The original TAM postulates that »Perceived Usefulness« and »Perceived Ease of Use« are key constructs in determining users' acceptance of technology. As articulated by Davis et al. (1989) these constructs are defined in the following way:

- »Perceived Usefulness« is referred to as »the degree to which a person believes that using a particular system would enhance his/her job performance«.
- »Perceived Ease of Use« is referred to »the degree to which a person believes that using a particular system would be free of effort«.

Both, »Perceived Usefulness« and »Perceived Ease of Use« have influence on »Behavioural Intention to Use«. The user of IS/IT intends to use technology if the user feels the technology will be useful for them and they feel it is easy to use. Despite that, »Perceived Ease of Use« also influences

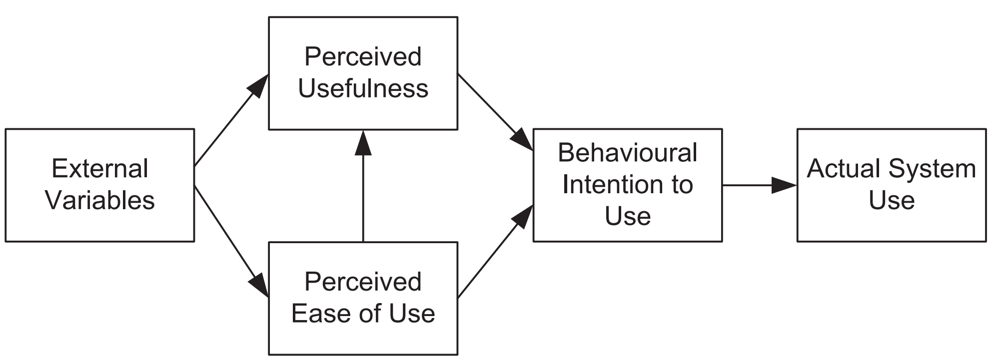


Figure 1: The principal scheme of the original TAM

»Perceived Usefulness« but not vice versa. Therefore, in TAM applications three conventional relationships are usually formulated in the following research hypothesis (Lee and Letho, 2013):

- »Perceived Usefulness« positively affects »Behavioural Intention to Use«.
- »Perceived Ease of Use« positively affects »Behavioural Intention to Use«.
- »Perceived Ease of Use« positively affects »Perceived Usefulness«.

»Perceived Usefulness« and »Perceived Ease of Use« could be influenced by several external variables which may affect attitudes toward using the system (e.g., documentation, system feature, training, user support, etc.). There are many external variables which are used with practical applications of TAM. Yousafzai et al. (2007) divided them into four categories of organizational, system, users' personal characteristics, and other variables.

The TAM has been validated over a wide range of systems and has been identified as a useful model in a relatively large number of applications over the past two decades. A comprehensive overview of the TAM can be found in Legris et al. (2003) and Chuttur (2009). Some interesting applications in system dynamics can be found in Kljajić et al. (2012) and Wang and Liu (2005).

In recent years several papers have been published on the context of application of TAM in higher education (e.g. Teo, 2009, 2010, 2011a, 2011b). A number of studies have used TAM to examine learners' willingness to accept e-learning systems (e.g., Al-Adwan et al., 2013; Shah et al., 2013; Sharma and Chandel, 2013; Shroff et al., 2011; Tabak and Nguyen, 2013) or to predict learners' intentions to use an online learning community (Liu et al., 2010). Some papers are focused to validate TAM on some specific software which is applied in higher education. For example, Escobar-Rodriguez and Monge-Lozano (2012) use TAM for explaining or predicting university students' acceptance of Moodle platform, while Hsu et al. (2009) performed an empirical study to analyze the adoption of statistical software among online MBA students in Taiwan.

3 Research model and hypothesis

The main goal of the paper is to identify the influential factors (the TAM external variables) that may facilitate or hamper the adoption of the commercial statistical package SPSS among the university students of social sciences. The basis for our study represents the empirical study of Hsu et al. (2009). The authors developed an extended TAM including three external variables which are considered also in our model. These variables are:

- »**SPSS Self Efficacy**« – it can be defined as the belief that one has the capability to perform a statistical analysis using SPSS. Individuals who have high SPSS self efficacy are more likely to use SPSS and would feel a higher level of mastery over SPSS applications.
- »**Computer Attitude**« – it can be defined as an index of the degree to which a person likes or dislikes about computers. A number of empirical studies have found significant relationships between attitudes about computers and usage of them (Hsu et.al, 2009). It is postulated in our model that computer attitude affects the perceived usefulness and the perceived ease of use of SPSS, which in turn, affects the intention of using SPSS in the future.
- »**Statistics Anxiety**« – it refers to the feeling of anxiety experienced by those taking a statistics course or undertaken statistical analyses. It consists of six dimensions: worth of statistics, interpretation anxiety, test and call anxiety, computational self-concept, fear of asking for help, and fear of statistics teacher. Worth of statistics refers to students' perceptions of relevance and usefulness of statistics, and is a key source of statistics anxiety (Hsu et.al., 2009). It is hypothesized that lower level of statistics anxiety increases the level of perceived usefulness as well as the level of perceived ease of use. Therefore, such students are likely to be more comfortable using SPSS in class and later in their daily jobs.

The model of Hsu et al. (2009) was tested on online MBA students, where many of them are full time employees. However, the results were not compared to students who completed a traditional in class course. Since the online MBA students appear to be more capable, savvy and demanding than traditional students (Bisoux, 2002), it is our opinion that the model for traditional students needs some adjustment. Therefore, we supplemented the model of Hsu et al. (2009) by involving the following additional external variables:

- »**Statistics Learning Self Efficacy**« – Similar to SPSS self efficacy, this variable can be defined as the students' belief in their own ability to perform well in statistics learning tasks. It is hypothesized that higher level of self efficacy increases the level of perceived usefulness as well as the level of perceived ease of use of SPSS.
- »**Statistics Learning Value**« – The value of statistics learning is to let the students acquire problem-solving competency, experience the inquiry activity, stimulate their own thinking, and find the relevance of statistics within daily life. If they can perceive these important values, they will be motivated to learn statistics. In our opinion the increase of statistics learning value decreases the level of statistics anxiety and increases the level of statistics learning self efficacy. Higher statistic learning value also increases the level of the perceived usefulness and the perceived ease of use of SPSS.
- »**Satisfaction with Achievements**« – As students increase their competence and achievement during

learning statistics they feel satisfaction. This results in a higher level of the perceived usefulness and the perceived ease of use of SPSS.

The components of our TAM-based extended model are presented in Figure 2. Arrows in Figure 2 represent the dependencies between the model components, where signs »+« and »-« indicate the positive or the negative dependence, respectively. Regarding the model description, the following hypotheses are postulated:

- H1a: »SPSS Self Efficacy« has positive effect on »Perceived Usefulness«.
- H1b: »SPSS Self Efficacy« has positive effect on »Perceived Ease of Use«.
- H2a: »Computer Attitude« has positive effect on »Perceived Usefulness«.
- H2b: »Computer Attitude« has positive effect on »Perceived Ease of Use«.
- H3a: »Statistics Anxiety« has negative effect on »Perceived Usefulness«.
- H3b: »Statistics Anxiety« has negative effect on »Perceived Ease of Use«.
- H4a: »Statistics Learning Self Efficacy« has positive effect on »Perceived Usefulness«.
- H4b: »Statistics Learning Self Efficacy« has positive effect on »Perceived Ease of Use«.
- H5a: »Statistics Learning Value« has positive effect on »Perceived Usefulness«.
- H5b: »Statistics Learning Value« has positive effect on »Perceived Ease of Use«.
- H5c: »Statistics Learning Value« has positive effect on »Statistics Learning Self Efficacy«.
- H5d: »Statistics Learning Value« has negative effect on »Statistics Anxiety«.
- H6a: »Satisfaction with Achievements« has positive effect on »Perceived Usefulness«.
- H6b: »Satisfaction with Achievements« has positive effect on »Perceived Ease of Use«.
- H7: »Perceived Ease of Use« has positive effect on »Perceived Usefulness«.
- H8: »Perceived Usefulness« has positive effect on »Behavioural Intentions to Use«.

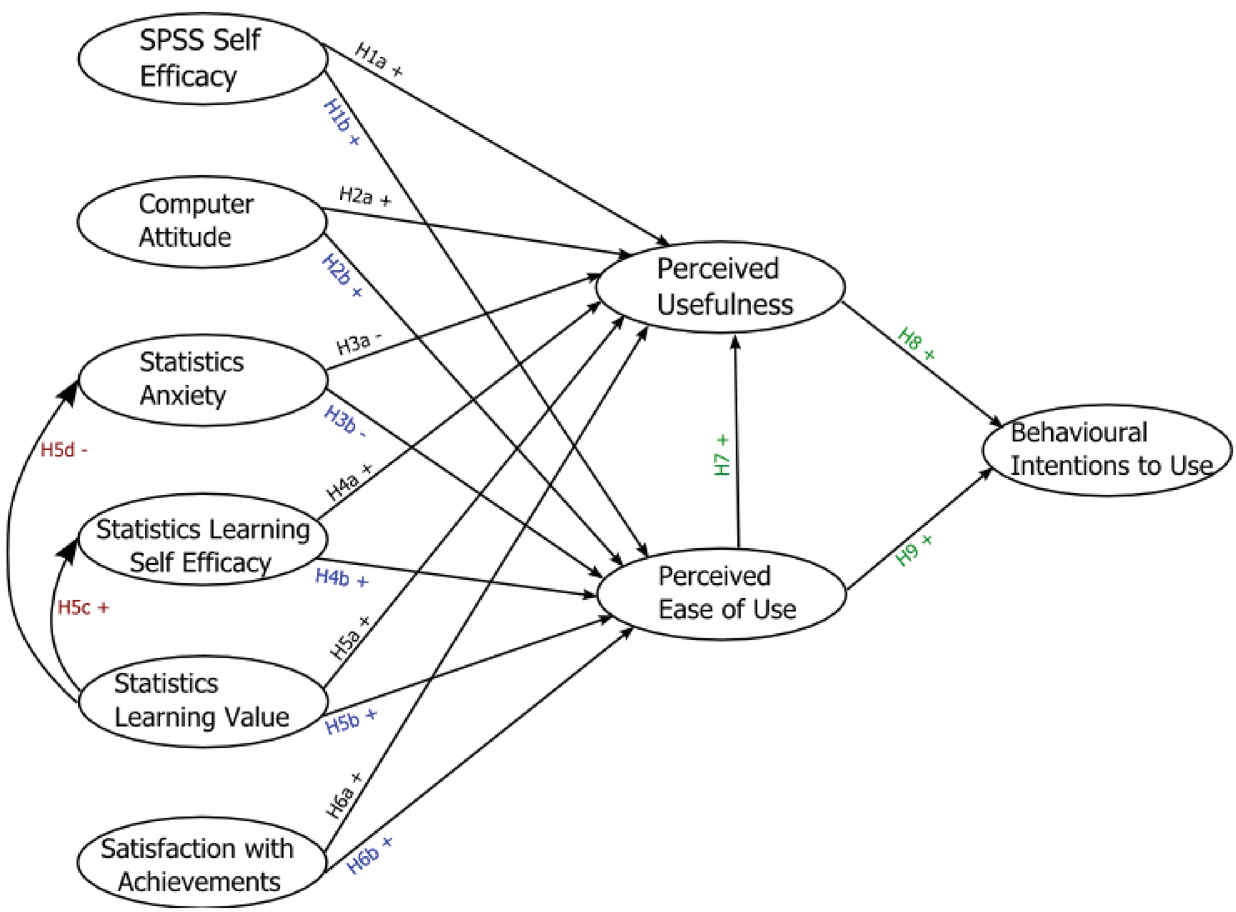


Figure 2: The extended TAM for analysing the acceptance of SPSS among the students of social sciences

- H9: »Perceived Ease of Use« has positive effect on »Behavioural Intentions to Use«.

4 Methodology

4.1 Instrumentation

Our TAM-based extended model was tested on the university students of social sciences in Slovenia. For this purpose we prepared a questionnaire where every model component is described with a particular construct which is represented by several variables. In addition to the questionnaire given by Hsu et al. (2009) we considered also the questionnaire published in Tuan et al. (2005). The number of variables within a particular construct of our questionnaire is as follows (see Table 1):

- »Statistics Learning Self Efficacy« - 3 variables,
- »Behavioural Intentions to Use« and »Perceived Ease of Use« - 4 variables,
- »Perceived Usefulness«, »SPSS Self Efficacy«, »Computer Attitude«, »Statistics Learning Value« and »Satisfaction with Achievements« - 5 variables,
- »Statistics Anxiety« - 7 variables.

All construct variables are measured on the 5-point Likert type scale of agreement, where 1 means »strongly disagree«, and 5 means »strongly agree«.

4.2 Population, sample and data collection method

The web survey was performed from June 2013 till February 2014. Seven faculties of three Slovenian universities collaborated:

- University of Ljubljana (Faculty of Administration, Faculty of Education, Faculty of Arts),
- University of Maribor (Faculty of Organizational Sciences, Faculty of Criminal Justice and Security, Faculty of Arts),
- University of Primorska (Faculty of Tourism Studies).

The total number of completed questionnaires is 329.

4.3 Data analysis

Data gathered from the survey were analysed in two stages. In the first stage the questionnaire used in the survey was evaluated. The reliability of the instrument was checked with Chrombach's α measure which was calculated for each questionnaire construct (i.e. model component). The sampling adequacy of the analysis was checked with the Kaiser-Meyer-Olkin measure and Bartlett's test of sphericity. Since our sample (N=329) is big enough (Field, 2013), a confirmatory factor analysis for each construct was conducted. Furthermore, descriptive statistics of each construct were calculated.

In the second stage of data analysis the dependencies among the model components were studied using the regression analyses.

Before the analyses, we reversed scales of all three variables of the construct »Statistics Learning Self Efficacy« (which were negatively keyed in the original questionnaire).

5 Results

5.1 Questionnaire evaluation and descriptive statistics

The results of the first stage data analysis are presented in Table 1. In the first two columns the names of the constructs and the corresponding variables are listed. The third column of the table represents the number N of respondents that answered all the questions within the particular construct. In the fourth column Chrombach's α is shown. The fifth column combines the first two eigenvalues together with the percentage of explained variance (EV), while in the sixth column the values of KMO and Bartlett's test are given. In the seventh column factor loadings are shown, and finally in the last column the average mean $\bar{x}$ and the average standard deviation (SD) for each construct are presented.

We can conclude from the results in Table 1 (columns from four up to seven) that our data reveals the same factors as proposed in our questionnaire.

It is evident from the last column of Table 1 that the highest rated construct is »Computer Attitude« with the highest av. mean 4,00 and the lowest av. standard deviation 0,63. This shows that students are accustomed to working on computers, and are aware of computer usefulness and its importance nowadays.

Taking into account that all the questions of the construct »Statistics Anxiety« were reverse phrased, it follows that the lowest rated construct is »Behavioural Intentions to Use«, with av. mean slightly above three ($\bar{x}$ = 3,05 and SD = 0,99). On the other hand, the estimates of the construct »Perceived Usefulness« were much higher ($\bar{x}$ = 3,66 and SD = 0,85). Results for these two constructs suggest that students actually are aware of the importance of SPSS and they find it quite useful for their job in the future, but at the moment they obviously have a lot of other priorities, and SPSS does not seem to be one of them.

Furthermore, the construct »Perceived Ease of Use« has the av. mean slightly above the intermediate value three ($\bar{x}$ = 3,21 and SD = 0,89), which indicates that students are not very skilful at using SPSS. But on the other hand, from the values obtained for the construct »SPSS Self Efficacy« ($\bar{x}$ = 3,75 and SD = 0,67), it is evident that students believe that they could complete a statistical analysis using SPSS, if

Table 1: Results of the first stage data analysis

Factor / Construct	Questions - Variables	*N*	Chr. α	Eigenvalues, Explained Var. (EV)	KMO, Bartlett's test	Factor Loadings	Average Mean, SD
Behavioural Intentions to Use	I always try SPSS to conduct a task whenever it has a feature to help me perform it.	289	0,73	λ_1 = 2,62 λ_2 = 0,79 EV=65,36%	0,74 p<0,0001	0,88	$\bar{x}$ = 3,05 SD=0,99
	I always try SPSS in as many cases/ occasions as possible.					0,91	
	SPSS has lots of exciting functions that I intend to use.					0,84	
	I intend to increase my use of SPSS in the future.					0,55	
Perceived Usefulness	SPSS use can improve my job performance.	287	0,90	λ_1 = 3,62 λ_2 = 0,56 EV=72,36%	0,87 p<0,0001	0,89	$\bar{x}$ = 3,66 SD=0,85
	SPSS use can make it easier to do my job.					0,91	
	SPSS use in my job can increase my productivity.					0,88	
	I find SPSS useful in my job.					0,82	
	SPSS use would enable me to accomplish statistical analysis more quickly.					0,74	
Perceived Ease of Use	I find it easy to get SPSS to do what I want it to do.	290	0,90	λ_1 = 3,06 λ_2 = 0,37 EV=76,56%	0,84 p<0,0001	0,85	$\bar{x}$ = 3,21 SD=0,89
	My interaction with SPSS is understandable and clear.					0,91	
	I find SPSS to be flexible to interact with.					0,88	
	It is easy for me to become skilful at using SPSS.					0,86	
SPSS Self Efficacy	*I could complete a statistical analysis using SPSS ...*	291	0,81	λ_1 = 2,99 λ_2 = 0,80 EV=59,78%	0,80 p<0,0001		$\bar{x}$ = 3,79 SD=0,67
	... if I had seen someone else using SPSS before trying it myself.					0,67	
	... if someone else had helped me get started.					0,87	
	...if someone showed me how to do it first.					0,86	
	... if I could call someone for help if I got stuck.					0,83	
	... if I had used similar software before this one to do the same job.					0,59	

Table 1: Results of the first stage data analysis (continued)

Factor / Construct	Questions - Variables	*N*	Chr. α	Eigenvalues, Explained Var. (EV)	KMO, Bartlett's test	Factor Loadings	Average Mean, SD
Computer Attitude	Computers are bringing us into a bright new era.	298	0,83	λ_1 = 3,00 λ_2 = 0,69 EV=59,91%	0,83 p<0,0001	0,81	$\bar{x}$ = 4,00 SD=0,63
	The use of computers is enhancing our standard of living.					0,82	
	There are unlimited possibilities of computer applications that haven't even been thought of yet.					0,73	
	Computers are responsible for many of the good things we enjoy.					0,77	
	Working with computers is an enjoyable experience.					0,73	
Statistics Anxiety	I wonder why I have to do all these things in statistics when in actual life I'll never use them.	299	0,92	λ_1 = 4,76 λ_2 = 0,64 EV=68,01%	0,92 p<0,0001	0,82	$\bar{x}$ = 2,27 SD=0,82
	Statistics is worthless to me since it's empirical and my area of specialization is philosophical.					0,82	
	I feel statistics is a waste of time.					0,87	
	I don't want to learn to like statistics.					0,73	
	I wish the statistics requirement would be removed from my academic program.					0,84	
	I don't understand why somebody in my field needs statistics.					0,83	
	I don't see why I have to clutter up my head with statistics. It has no significance to my life work.					0,87	
Learning Statistics Self Efficacy	No matter how much effort I put in, I cannot learn statistics. (R)	307	0,69	λ_1 = 2,18 λ_2 = 0,50 EV=72,56%	0,69 p<0,0001	0,81	$\bar{x}$ = 3,69 SD=0,86
	When statistics activities are too difficult, I give up or only do the easy parts. (R)					0,89	
	When I find the statistics content difficult, I do not try to learn it. (R)					0,86	

Table 1: Results of the first stage data analysis (continued)

Factor / Construct	Questions - Variables	*N*	Chr. *α*	Eigenvalues, Explained Var. (EV)	KMO, Bartlett's test	Factor Loadings	Average Mean, SD
Statistics Learning Value	I think that learning statistics is important because I can use it in my daily life.	311	0,77	λ_1 = 2,63 λ_2 = 0,71 EV=52,68%	0,82 p<0,0001	0,734	$\bar{x}$ = 3,20 SD=0,71
	I think that learning statistics is important because it stimulates my thinking.					0,746	
	In statistics, I think that it is important to learn to solve problems.					0,730	
	In statistics, I think it is important to participate in inquiry activities.					0,665	
	It is important to have the opportunity to satisfy my own curiosity when learning statistics.					0,751	
Satisfaction with Achievements	During a statistics course, I feel most fulfilled when I attain a good score in a test.	308	0,77	λ_1 = 2,73 λ_2 = 0,97 EV=54,55%	0,72 p<0,0001	0,643	$\bar{x}$ = 3,94 SD=0,66
	I feel most fulfilled when I feel confident about the content in a statistics course.					0,763	
	During a statistics course, I feel most fulfilled when I am able to solve a difficult problem.					0,725	
	During a statistics course, I feel most fulfilled when the teacher accepts my ideas.					0,788	
	During a statistics course, I feel most fulfilled when other students accept my ideas.					0,764	

they had appropriate support and enough experiences. This holds true especially for the second degree students ($\bar{x}$ = 3,94 and SD = 0,65).

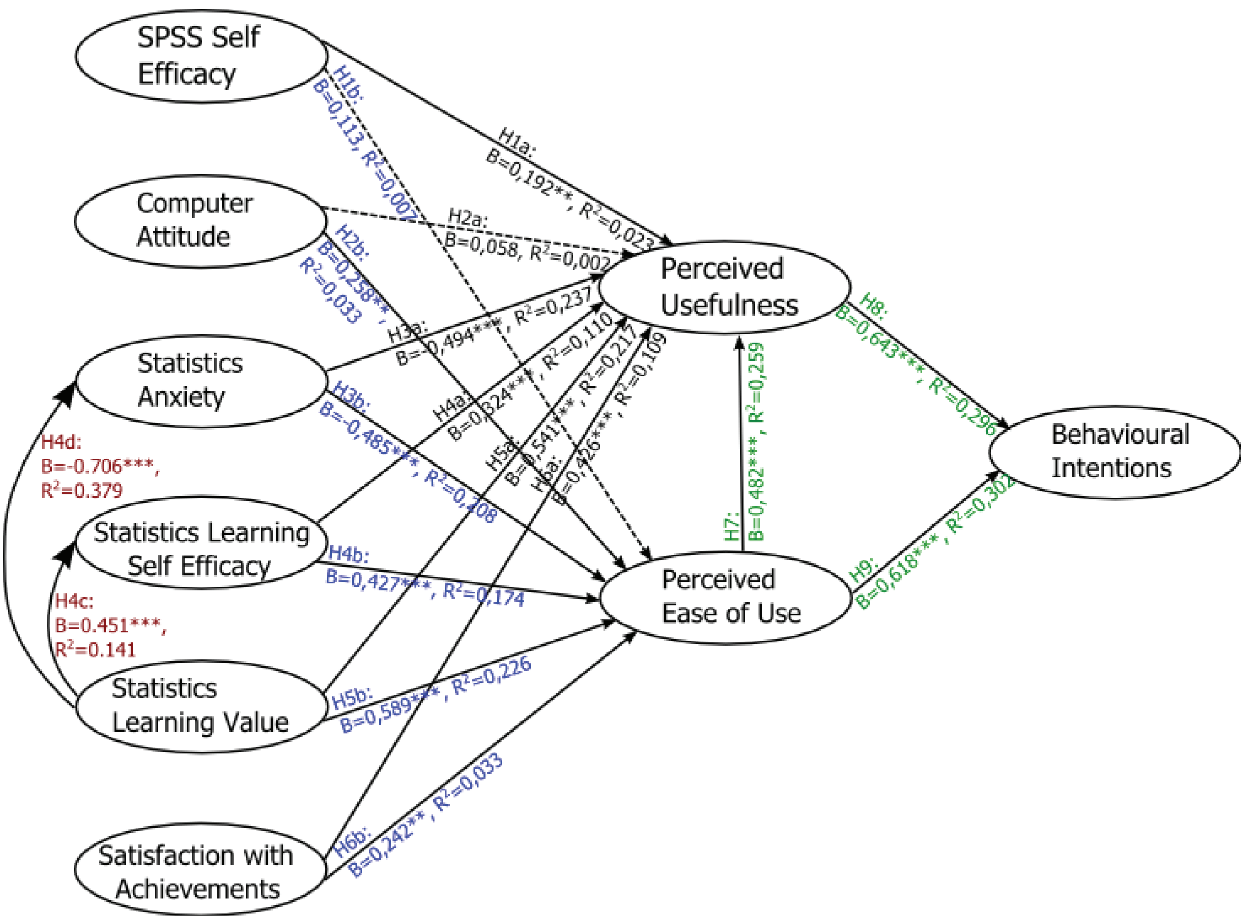
For the construct »Statistics Anxiety« we obtained $\bar{x}$ = 2,27 and SD = 0,82. These values mean that students are not too anxious about statistics, although we would like the values to be even lower. Similarly, the construct »Statistics Learning Value« has the av. mean slightly above the intermediate value three ($\bar{x}$ = 3,20 and SD = 0,71), indicating that an average student is not aware in what way statistics can contribute to his everyday activities and critical thinking.

The results for the construct »Satisfaction with Achievements« ($\bar{x}$ = 3,94 and SD = 0,66) mean that students are quite satisfied when they achieve some good results regarding statistics.

For the last construct »Statistics Learning Self Efficacy« we obtained $\bar{x}$ = 3,69 and SD = 0,86. Taking into account that we analyzed the recoded variables of this construct, these values indicate that learning statistics is not very easy for students, but it does not cause an insurmountable obstacle for them either.

5.2 Regression analysis

In the second stage of data analysis the regression analysis was performed. The unstandardized regression coefficients indicating dependencies among the model components are presented in Figure 3.



Statistical significance of unstandardized regression coefficients:
* denotes 5% statistical significance level
** denotes 1% statistical significance level
*** denotes 0,1% statistical significance level

Figure 3: Unstandardized regression coefficients of model components

We can see from Figure 3 that all predicted dependencies between nine model components are statistically significant at 5% significance level, except the dependence of »Perceived Ease of Use« on »SPSS Self Efficacy« (B=0,113, R^2=0,007) and »Perceived Usefulness« on »Computer Attitude« (B=0,058, R^2=0,002), where the percentages of explained variances in both regressions are low and the unstandardized regression coefficients are not statistically different from zero at 5% significance level. Therefore, the hypotheses H1b and H2a could not be confirmed.

The »SPSS Self Efficacy« has a positive effect on »Perceived Usefulness« (B=0,192, R^2=0,023) at 5% significance level which confirms our first hypothesis H1a. The »Computer Attitude« has positive effect on »Perceived Ease of Use« (B=0,258, R^2=0,033) at 1% significance level which confirms the hypothesis H2b.

In the questionnaire the negatively stated items for »Statistics Anxiety« were used which means that higher scores represent higher level of statistics anxiety. Therefore, we assumed that there exists a negative effect on both »Perceived Usefulness« (H3a) and »Perceived Ease of Use« (H3b). The results confirmed our expectations since both unstandardized regression coefficients are negative and statistically significant at 0.1% significant level, while B=-0,494 (R^2=0,237) for the »Perceived Usefulness« and B=-0,485 (R^2=0,208) for the »Perceived Ease of Use«.

The »Statistics Learning Self Efficacy« has a positive effect on the »Perceived Usefulness« (B=0,324, R^2=0,110) and the »Perceived Ease of Use« (B=0,427, R^2=0,174) at 0.1% significance level. Therefore, our hypotheses H4a and H4b could be confirmed.

About »Statistics Learning Value« four hypotheses were postulated (see Figure 2). All of them can be confirmed. Namely, the »Statistics Learning Value« has a positive effect on the »Perceived Usefulness« (B=0,541, R^2=0,217), the »Perceived Ease of Use« (B=0,589, R^2=0,226), and the »Statistics Learning Self Efficacy« (B=0,451, R^2=0,141), and a negative effect on the »Statistics Anxiety« (B=-0,706, R^2=0,379). Therefore, all four hypotheses H5a, H5b, H5c, and H5d can be confirmed at 0,1% significance level.

The hypotheses H6a and H6b explore the effects of the »Satisfaction with Achievements« on both the »Perceived Usefulness« and the »Perceived Ease of Use«. Both regressions reveal positive effects of the »Satisfaction with Achievements« on two dependent variables. More precisely, the unstandardized regression coefficient for the »Perceived Usefulness« is equal to B=0,426 (R^2=0,109), and the unstandardized regression coefficient for the »Perceived Ease of Use« is equal to B=0,242 (R^2=0,033). Since both reported regression coefficients are positive and statistically significantly different from zero at 1% significant level, both hypotheses H6a and H6b can be confirmed.

The hypothesis H7 stated that »Perceived Ease of Use« has a positive effect on »Perceived Usefulness« can also be confirmed while the unstandardized regression coefficients is positive (B=0,482, R^2=0,259) and statistically significantly different from zero at 0,1% significance level.

Two of the highest three proportions of explained variance were obtained in two linear regression models with the »Behavioural Intentions to Use« as a dependent variable. To be precise, »Perceived Usefulness« (B=0,643) can explain 29,6% of variance of the »Behavioural Intentions to Use«, while the »Perceived Ease of Use« (B=0,618) can explain 30,2% variance of the »Behavioural Intentions to Use«. According to positive unstandardized regression coefficients in both regressions, hypotheses H8 and H9 can be confirmed.

6 Discussion

The first objective of our paper was to identify the external factors which may influence the adoption and continuous utilization of the SPSS among the university students of social sciences. We defined six potential factors (»SPSS Self Efficacy«, »Computer Attitude«, »Statistics Anxiety«, »Statistics Learning Self Efficacy«, »Statistics Learning Value« and »Satisfaction with Achievements«) which represent the external variables of our extended TAM. Since all these variables are found to have a direct influence on the »Perceived Usefulness« and/or »Perceived Ease of Use«, we can assert that they also affect the behavioural intentions to use SPSS. Therefore, all these variables are relevant to be involved in analysing the adoption of SPSS among the students of social sciences.

The second objective was to examine the relationships among the model components. The results of our empirical study show that all three conventional relationships, usually formulated in TAM applications, can be confirmed. Namely, our results prove that both key components of the TAM, »Perceived Usefulness« and »Perceived Ease of Use« positively influence students' behavioural intentions to use SPSS, while »Perceived Usefulness« is also positively affected by »Perceived Ease of Use«. In our opinion these results prove the applicability of TAM to our topic.

Since four of six external variables of our model are the same as the external variables considered by Hsu et al. (2009) it is interesting to compare the results of both studies.

In our study we found out that »SPSS Self Efficacy« has a positive effect only on »Perceived Usefulness«, while the effect of this model component on »Perceived Ease of Use« is not significant. These statements agree with the findings of Hsu et al. (2009).

However, our results show that »Computer Attitude« has a positive influence on »Perceived Ease of Use«, while the effect of this model component on »Perceived Usefulness« is not significant. It is interesting that the results of Hsu et al. (2009) are just the opposite.

As we expected, it was found that »Statistics Anxiety« has a direct negative impact on both, »Perceived Usefulness« and »Perceived Ease of Use«. This reflects in a negative influence on students' behavioural intentions to use SPSS. The results of Hsu et al. (2009) are similar. We agree with the authors that educators should try to eliminate students' anxiety toward using SPSS by introducing a few carefully designed activities and by presenting real-world examples. In order to effectively reduce students' anxiety in learning statistics, Pan and Tang (2004) recommended the combination of application oriented teaching methods and instructors' attentiveness to students' anxiety. The results of our study also indicate that statistics anxiety can be mitigated by increasing the value of statistics learning.

There are some limitations that should be taken into consideration in the future research. For example, future research may examine whether demographic variables such as gender, age, educational level, etc. could potentially confound the observed relationships. As previous researches suggest that the TAM and the end-user technology usage may differ across the cultural borders (Hsu et al., 2009), a reasonable next step would be to extent this research to other countries.

7 Conclusion

In the paper, an extended Technology Acceptance Model (TAM) for analysing the acceptance of IBM SPSS Statistics among the university students of social sciences was developed. On top of the traditional components of the TAM, the following six external variables were included: »SPSS Self Efficacy«, »Computer Attitude«, »Statistics Anxiety«, »Statistics Learning Self Efficacy«, »Statistics Learning Value« and »Satisfaction with Achievements«. The model was tested using the web survey involving the university students of social sciences from seven different faculties at three Slovenian universities.

The questionnaire used in the survey was evaluated with a confirmatory factor analysis. The reliability of the scale with Chrombach's α was examined. The sampling adequacy for the analysis with the Kaiser-Meyer-Olkin measure and Bartlett's test of sphericity was checked. Descriptive statistics of the model components were calculated, and dependencies between the model components were studied using the regression analyses.

The empirical results prove that all external variables considered in our model are relevant, and directly influence the »Perceived Usefulness« and »Perceived Ease of Use« which are the key components of the traditional TAM. Both, »Perceived Usefulness« and »Perceived Ease of Use« have direct impact on the students' behavioural intention which affects their actual use of SPSS in the future. Therefore, we can assert that all external variables included in our model represent the potential areas where activities to reduce the students' anxiety and to strengthen the positive attitudes towards statistics and SPSS can be planned.

Therefore, we can conclude that the aim of the paper has been achieved. Our TAM-based extended model is found to be useful in studying the adoption and continuous utilization of SPSS among the students of social sciences. Findings obtained with the model application are of great value for educators, and can help them to improve the learning process.

In the next stage of our research we are going to continue the validation of our model by expanding the survey to some faculties from other East European countries covering the social science studying programs. In addition to regression analyses we intend to employ other applicable statistical methods. For example, structural equation modelling which could enable us to investigate all causal connections among the model components simultaneously, or hierarchical clustering combined with K-means clustering which may reveal clusters of students with similar attitudes toward statistics and SPSS.

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Razširjeni model TAM za analizo sprejetosti statističnega paketa SPSS med slovenskimi študenti družboslovja

Ozadje in namen – IBM SPSS Statistics je eden izmed najpogosteje uporabljanih programov za izvajanje statističnih analiz v družboslovnih vedah. Zaradi številnih prednosti se SPSS pogosto uporablja tudi kot pripomoček pri učenju statistike na mnogih družboslovnih študijskih programih. Po našem mnenju igra motivacija za učenje in uporabo SPSS-a med samim študijem odločilno vlogo pri oblikovanju pozitivnega odnosa do tega statističnega paketa, kar vpliva na njegovo uporabo na profesionalnem nivoju po zaključku študija.
Zasnova/metodologija/pristop – V prispevku smo razvili model, ki omogoča analizo sprejetosti SPSS-a med študenti družboslovnih študijskih programov. Model je zasnovan na znanem modelu TAM (Technology Acceptance Model), ki se v strokovni literaturi pogosto uporablja za proučevanje sprejetosti IT tehnologije med uporabniki. S pomočjo spletne ankete smo model preskusili na študentih družboslovja iz sedmih fakultet treh slovenskih univerz.
Rezultati – Opravili smo evalvacijo vprašalnika in za komponente modela izračunali opisne statistike. S pomočjo regresijske analize smo proučili odvisnosti med komponentami modela in izpostavili tiste povezave, ki so se izkazale za statistično značilne.
Zaključki – Rezultati empirične raziskave dokazujejo, da ima vseh šest zunanjih spremenljivk, ki smo jih v model vključili, posreden vpliv na obe temeljni komponenti modela TAM. To potrjuje, da izbrane zunanje spremenljivke predstavljajo relevantne dejavnike, ki učinkujejo na uporabo SPSS-a na profesionalnem nivoju. S tega stališča je njihova vključitev v model upravičena. Zaključimo lahko, da je predstavljeni model primeren za analizo sprejetosti SPSS-a med študenti družboslovja. Rezultati, ki jih s tako študijo dobimo, so uporabni predvsem za pedagoge, saj so v pomoč pri izboljševanju študijskega procesa.

Ključne besede: visokošolsko izobraževanje, statistika, anksioznost zaradi statistike, SPSS, sprejetost, model TAM