BULGARIAN ACADEMY OF SCIENCES

INSTITUTE OF INFORMATION AND COMMUNICATION TECHNOLOGIES

INTELLIGENT TECHNIQUES FOR ANALYSING FINANCING PROCESSES OF SMALL AND MEDIUM ENTERPRISES

Thesis for awarding educational and scientific degree PhD

ABSTRACT

Scientific Field: **4. Natural sciences, mathematics and informatics**

Professional area: **4.6. Computer sciences**

Scientific Specialty: **01.01.12 Informatics**

Georgi Lazarov Shahpazov

Scientific Advisor: **Prof. Lyubka Atanasova Doukovska, DSc**

Sofia

2019

INTRODUCTION

The development of new, highly efficient, intelligent methods for the analysis of creditworthiness, and the processes of financing, especially for SME's, can be considered a scientific issue. The actuality of the problem is conditioned by the current trends in the introduction of technical and technological methods in financing, and in particular the increasing importance of internal automatization of the financing processes. These trends are reflected in many researchers desire to use the latest developments in the design of highly efficient, but sophisticated data processing algorithms from SME's behavior in local business environment. Modern smart methods require, processing of large data streams, using all available information for the observation of the biggest stake of legal entities in the country – Small and Medium size enterprises SME's.

These trends are reflected in the desire of researchers to use the latest developments in the design of highly efficient but sophisticated data processing algorithms derived from close monitoring of the financial sector. Present day intelligent methods require the processing of large data streams, using all the available information for the observed area.

Recent studies on the development of the country's economy, and in particular the progresses of SMEs over the past few years show a decline in development. The recovery and restructuring of the economy goes through the rebuilding and modernization of industries that create long-term value.

The continuous development of already established SMEs in some of the analyzed sectors of the economy is supported by the identified potential for above average growth. The initially appointed favorable sectors, subject of investment will be the main focus for future investments of each JEREMIE Fund, but will not limit the exploration of other options depending on market developments.

In recent years, wider application of intelligent methods in creditworthiness analysis and financing approach modeling are found being used, in order to extract the necessary data, to further optimize and improve potential lading processes. Each individual monitoring process is actually a collection of separate sub processes that are

ran in parallel over a spread of time. Utilization of financial modeling tools, including Generalized Nets, has been proven in practice as an adequate and correct method for improving and upgrading the complexity in overall landing processes.

This greatly complicates the detection of regularities in the functioning of the monitored system. Another approach, the subject of research in the dissertation work - InterCriteria Analysis, exploits two mathematical formalisms defined by Krassimir Atanassov: the algebraic apparatus of index matrices (IM), when it is necessary to apply algebraic operations on matrices of different dimensions and intuitions) as a mathematical tool for treating uncertainty.

The purpose is from a matrix that contains data on the measurements or estimates of “m” number of objects, evaluated by “n” number of evaluating criteria, as a result of binary comparisons by objects and by criteria it blurred the correlation pairs between each of the two criteria and gave the name, respectively, "InterCriteria Analysis - ICA". In the ICA approach, the raw data for processing are put within an index matrix M of m rows $\{O_1, \ldots, O_m\}$ and n columns $\{C_1, \ldots, C_n\}$, where for every p, q $(1 \leq p \leq m, 1 \leq q \leq n)$, O_p in an evaluated object, C_q is an evaluation criterion, and $e_{O_pC_q}$ is the evaluation of the p-th object against the q-th criterion, defined as a real number or another object that is comparable according to relation R with all the rest elements of the index matrix M.

A sufficiently high correlation between a decision maker (LA) indicated by an "unfavorable" criterion with a "favorable" criterion is obtained when the corresponding’s to these two criteria (in order and pillar) in the matrix is higher than a predefined threshold for intuitionist fuzzy affiliation and lower than a predefined threshold for intuitionist fuzzy incongruity (thresholds are numbers in the range [0, 1]).

IRMs are used for binary comparisons and assessments of the behavior of objects by criteria, as well as for determining the values of correlation thresholds between criteria and tolerance thresholds that are required in the decision-making process.

IRMs are an essential tool of the method, since they describe both input arrays with values of multiple objects against multiple criteria, and output arrays with calculated degrees of correlation between each pair of criteria. Research in the field of

IRM operations can also be reflected in the enhancement of the capabilities and performance of the algorithms incorporated in the InterCriteria Analysis method.

The proposed approach calculates the degrees of dependence between all possible pairs of criteria, which means that they can be distinguished as already known in the literature and other established dependencies, and to discover completely new, unknown so far dependencies, and hence a completely new scientific knowledge is generated and its usefulness is designed.

In this dissertation, original results related to the research of contemporary paradigms in the field of intelligent systems have been obtained, using analytical and experimental models. The main focus of dissertation work is the analysis of the considerable variety of research and existing methods that have to determine the approaches, methods and algorithms to be tested on particular classes of subjects. The main efforts to achieve the results sought are directed at different elements of the SME financing process in the spirit of global trends.

Current dissertation aims to develop, with the support of modern tools and intelligent systems, highly efficient intelligent methods in creditworthiness analysis, and further application of modern tolls, to better assist local small business entities, especially SME's in financing processes. To achieve this goal, the following tasks are formulated:

- to systematize the existing intelligent methods for the analysis of creditworthiness and financing processes through the JEREMIE initiative;
- to apply intelligent techniques to analyze the mechanism under which the first tier of a banking institution operates, for financing small and medium-sized businesses;
- to apply intelligent techniques to analyze the effectiveness of the internal financial structural units of different banks, such as levels of the decision-making hierarchy;
- to apply intelligent techniques for analyzing various types of hybrid credit products that are appropriate for the needs of small and medium-sized businesses;

- to apply intelligent data analysis techniques for micro, small, medium and large economic entities in the EU-27, evaluated by different economic indicators;
- to apply intelligent techniques to analyze the financing mechanism of the EU budget for small and medium-sized enterprises;

The dissertation work is structured in an introduction, three chapters and a conclusion, showing the actual results of the implementation of the methodology for the analysis of the Creditworthiness in SMEs financing.

Actual results of the optimization process have been published and presented in few international conferences. In the list of publications, used for the preparation of the dissertation, are included articles, which took place in *Notes on Intuitionistic Fuzzy Sets (NIFS), ISSN 1310-4926, e-ISSN 2367-8283*, *2th International Symposium on Business Modeling and Software Design – BMSD'12, Geneva, Switzerland, 3th International Symposium on Business Modeling and Software Design – BMSD'13, Noordwijkerhout, The Netherlands, 4th International Symposium on Business Modeling and Software Design – BMSD'14, Luxembourg, Grand Duchy of Luxembourg, 5th International Symposium on Business Modeling and Software Design – BMSD'15, Milan, Italy, 12th International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets – IWIFSGN'13, Warsaw, Poland*, *17th International Conference on Intuitionistic Fuzzy Sets*, *Notes on Intuitionistic Fuzzy Sets*, *Sofia, Bulgaria* and *International Workshop on Advanced Control and Optimisation: Step Ahead – ACOSA'14, Bankya, Bulgaria*.

All publications are referenced and indexed in world-renowned databases of scientific information, which comply with the requirements of the law for the development of academic staff in the Republic of Bulgaria.

CHAPTER 1

AN OVERVIEW OF THE INTELLIGENT METHODS FOR AN ANALYSIS OF COMPLEX PROCESSES

1.1. Computational intelligence.

In the last two decades there appeared gradually a new scientific field, which was termed “Computational intelligence”, one of the most popular definitions of computational intelligence in the respective academia is of the following type:

“Computational intelligence is a methodology, including calculations, showing possibilities for training and/or for coping with a new situation, so that the system is comprehended as having one or more attributes of judgements, such as summary, opening, association and abstraction.”, [3].

Finally, it can be concluded that **the applied methods of the classical artificial intelligence use human knowledge, whereas these of computational intelligence try to create the conditions for efficient interaction between man and computer, which leads to increasing human intelligence**.

1.3. Intelligent systems.

“**Intelligent systems**” is a term, having a wide scope and not accepted in a straightforward fashion. The magazine “Intelligent Systems” of the biggest professional organisation globally - Institute of Electrical and Electronics Engineers - IEEE is focused mainly on informatics, while in the numerous international scientific forums devoted to the intelligent systems, there is much wider understanding in the direction of interdisciplinary and multidisciplinary approach. There is special emphasis on the term “intelligent”, whose content corresponds to a great extent, in terms of sense and scope, to the terms and techniques, considered above. However, the term “systems” has a domineering importance. “System” means not only structural characteristics (elements, relationships, interactions), but also specific realization (including simulation). The examples of intelligent systems are exceptionally varied: intelligent systems for management, intelligent systems for decision taking, intelligent robotized systems, intelligent systems for training, intelligent bioinspired systems, intelligent virtual companies, etc., [53, 61, 62, 64, 65, 68, 69, 70, 82, 95, 97, 98].

1.4. Mathematical approaches for complex processes modelling.

The present dissertation will use a recently defined new approach for assisting the taking of decisions, called “InterCriteria Analysis - ICA”. With this approach from data sets, obtained via the measuring of many objects according to many criteria, the relations are calculated between them for each pair of criteria in the form of intuitionistic fuzzy pairs of values in the interval [0; 1]. The approach takes into consideration the effect of uncertainty, makes possible to work with sets with missing data, and works not only with numbers, but also with linguistic variables with entered profit. The InterCriteria Analysis has applications in tasks, where measuring according to some of the criteria are slower or more expensive, which in turn delays or makes expensive the whole process of taking decisions. With these problems we need a method to reasonable eliminate these criteria and in this way achieve economy and efficiency.

1.5. Introduction to the theory of the Generalized Nets.

1.5.1. Definition of transition and Generalized Nets.

During the years the definition of GN changed several times with the aim of improvement. The present definition dates back to 2007, [20]. The GN is made up of transitions. Graphically each transition is represented by two elements - ○ and ▽.

Each transition to GN should have at least one entry and one exit position (Figure 1.2) [1, 2, 4]. The graphical symbol of the position is (○).

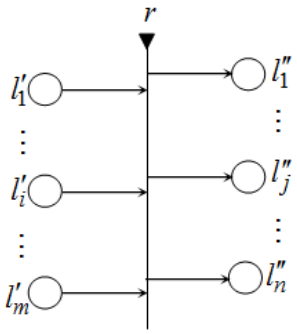

Figure. 1.2. Presentation of a transition in GN

In order to present the index matrix it is necessary first to define the sets I and R, whereas I is a fixed set of indices, and R is the set of the real numbers. Then, for

index matrix with index sets K and L ($K, L \subset I$ and $K = \{ k_1, k_2, \ldots, k_m \}$, $L = \{ l_1, l_2, \ldots, l_n \}$), the following is obtained:

$$\left[K, L, \left\{a_{k_i, l_j}\right\}\right] = \begin{array}{c|cccc} & l_1 & l_2 & \ldots & l_n \\ \hline k_1 & a_{k_1,l_1} & a_{k_1,l_2} & \ldots & a_{k_1,l_n} \\ k_2 & a_{k_2,l_1} & a_{k_2,l_2} & \ldots & a_{k_2,l_n} \\ : & \ldots & \ldots & \ldots & \ldots \\ k_m & a_{k_m,k_1} & a_{k_m,l_2} & \ldots & a_{k_m,l_n} \end{array}, \qquad (1)$$

where $a_{k_i,l_j} \in R$ for $i \in [1, m]$ and $j \in [1, n]$.

The transition of GN is defined via ordered set of seven of the type:

$Z = <L', L'', t_1, t_2, r, M, \square>$,

where:

- $L' = \{ l'_1, \ldots, l'_i, \ldots, l'_m \}$ – final not empty set of entry positions of the transition;

- $L'' = \{ l''_1, \ldots, l''_j, \ldots, l''_n \}$ – final not empty set of exit positions of the transition;

- t_1 – moment of activating the transition;

- t_2 – duration of the active state of the transition;

- r – a condition of the transition, which determines which token may pass from its entry positions to its exit positions.

It is formed via an index matrix of the type:

$$r = \begin{array}{c|cccccc} & l''_1 & \ldots & l''_j & \ldots & l''_n \\ \hline l'_1 & r_{1,1} & \ldots & r_{1,j} & \ldots & r_{1,n} \\ : & \ldots & \ldots & \ldots & \ldots & \ldots \\ l'_i & r_{i,1} & \ldots & r_{i,j} & \ldots & r_{i,n} \\ : & \ldots & \ldots & \ldots & \ldots & \ldots \\ l'_m & r_{m,1} & \ldots & r_{m,j} & \ldots & r_{m,n} \end{array}, \quad \text{for } i \in \{1,2,\ldots,m\},\ j \in \{1,2,\ldots,n\} \qquad (2)$$

$r_{i,j}$ is a predicate, which corresponds to i^{th} entry position of the transition and j^{th} exit position of the transition. If the predicate is true (has value "*true*") it is possible that the nucleus passes from i^{th} entry position to t^{th} exit position. The predicates may not depend on future events.

1.6. Intuitionistic Fuzzy Sets.

The theory of the Fuzzy Sets (FS) was defined by Lotfi Aliasker Zadeh in 1965 as a mathematical apparatus for an adequate description of the inaccuracy and uncertainty in nature [100, 101]. A proof of the increasing interest in these were the developments, defined subsequently: L-FS (L-Fuzzy Sets) of Goguen [66], FS with interval values (Interval Valued Fuzzy Sets) of Gorzalczany [67], "coarse" (rough) sets of Pawlak and intuitionistic fuzzy sets (IBS) of Krassimir Atanassov [10, 16, 17, 18, 19, 25, 27, 28, 40, 44].

A represents intuitionistic fuzzy sets (IFS), the description of which is of the following type [10]:

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in E \ \}, \tag{8}$$

where E is a fixed set, the function $\mu_A : E \to [0,1]$ specifies the respective degree of belonging, and the function $\nu_A : E \to [0,1]$ specifies the respective degree of not belonging of the element $x \in E$ to the set $A \subseteq E$ and for each $x \in E$ the following is complied with:

$$0 \le \mu_A(x) + \nu_A(x) \le 1. \tag{9}$$

The function π_A is described by the mathematical expression:

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x), \tag{10}$$

Which specifies the degree of uncertainty of the element's belonging $x \in E$ to the set *A*. Evidently, FS is a special case of IFS, where $\pi_A(x) = 0$ for each $x \in E$.

1.7. Index matrices.

The term Index Matrix (IM) was introduced in 1984 by Corresponding Member Krassimir Atanassov, doctor of technical sciences, doctor of mathematical sciences in [11, 14]. During the last 25 years some of their properties were studied, but were mainly used as an additional instrument for the description of the transitions of the Generalized Nets (GN), intuitionistic fuzzy relations and graphs with edges and as a whole in some algorithms for taking decisions [21, 22, 23, 24, 31, 33, 79]. During the last 30 years some of their properties were investigated and summarized in the book of Krassimir Atanassov "Towards an Augmented Matrix Calculus", [15]. The paper [31]

deploys and summarises the existing types of index matrices, the operations with them, and some of their properties, specifics and applications were studied.

Let I be the determined set of index and R be the set of real numbers. Via an index matrix with sets of indices K and L ($K, L \subset I$) we will note:

$$\left[K, L, \left\{a_{k_i,l_j}\right\}\right] \equiv \begin{array}{c|cccc} & l_1 & l_2 & ... & l_n \\ \hline k_1 & a_{k_1,l_1} & a_{k_1,l_2} & ... & a_{k_1,l_n} \\ k_2 & a_{k_2,l_1} & a_{k_2,l_2} & ... & a_{k_2,l_n} \\ : & ... & ... & ... & ... \\ k_m & a_{k_m,l_1} & a_{k_m,l_2} & ... & a_{k_m,l_n} \end{array} \quad (11)$$

where $K=\{k_1, k_2, ..., k_m\}$, $L=\{l_1, l_2, ..., l_n\}$, for $1 \le i \le m$, and $1 \le j \le n : a_{ki,lj} \in R$.

For the index matrices (IM) $A=[K, L, \{ a_{k_i,l_j} \}]$, $B=[P, Q, \{ b_{p_r,q_s} \}]$ the defined operations for summing and multiplication are analogous to the ordinary matrix operations, as well as to other specific operations.

1.8. Method of InterCriteria Analysis.

The method of InterCriteria Analysis was introduced in [30]. It is based on two mathematical formalisms – the apparatus of the index matrices for the processing of data batches with various sizes, and intuitionistic fuzzy sets as a mathematical instrument for the treatment of uncertainty.

Let M be an index matrix, built up in the following way:

$$M = \begin{array}{c|ccccccc} & O_1 & ... & O_k & ... & O_l & ... & O_n \\ \hline C_1 & a_{C_1,O_1} & ... & a_{C_1,O_k} & ... & a_{C_1,O_l} & ... & a_{C_1,O_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_i & a_{C_i,O_1} & ... & a_{C_i,O_k} & ... & a_{C_i,O_l} & ... & a_{C_i,O_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_j & a_{C_j,O_1} & ... & a_{Cj,O_k} & ... & a_{C_j,O_l} & ... & a_{C_j,O_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_m & a_{C_m,O_1} & ... & a_{Cm,O_k} & ... & a_{Cm,O_l} & ... & a_{Cm,O_n} \end{array} \quad (12)$$

where for each p, q ($1 \le p \le m$, $1 \le q \le n$):

- C_p is criterion;
- O_q is object;
- $a_{Cp,Oq}$ is the evaluation of the q-th object against the p-th criterion.

Each such evaluation is determined as a real number or another object, which is commensurate with regard to the relation R with the remaining a-objects, so that for each i, k, l is determined $R(a_{Ci,Ok}, a_{Ci,Ol})$. Let $\overline{R}$ be the dual relation of R in the sense that if R is satisfied, then $\overline{R}$ is not satisfied and vice versa. For example, if "R" is the relation "<", then $\overline{R}$ is the relation ">" and vice versa.

Let $S_{i,j}^{\mu}$ be the number of cases, in which $R(a_{Ci,Ok}, a_{Ci,Ol})$ and $R(a_{Cj,Ok}, a_{Cj,Ol})$ are satisfied at the same time. Let $S_{i,j}^{\nu}$ be the number of cases, in which $R(a_{Ci,Ok}, a_{Ci,Ol})$ and $\overline{R}(a_{Cj,Ok}, a_{Cj,Ol})$ are satisfied at the same time.

Since the total number of comparison in pairs between the objects is $\frac{n(n-1)}{2}$, it is evident that:

$$S_{i,j}^{\mu} + S_{i,j}^{\nu} \leq \frac{n(n-1)}{2} \tag{13}$$

For each i,j, such that $1 \leq i < j \leq m$, and for $n \geq 2$ we determine:

$$\mu_{C_i,C_j} = 2\frac{S_{i,j}^{\mu}}{n(n-1)}, \quad \nu_{C_i,C_j} = 2\frac{S_{i,j}^{\nu}}{n(n-1)} \tag{14}$$

For each two criteria C_i and C_j these two values may be used to build up intuitionistic fuzzy pair $\langle \mu_{C_i,C_j}, \nu_{C_i,C_j} \rangle$. This pair plays the role of intuitionistic fuzzy evaluation of the relation between the two criteria.

The matrix M may be transformed into another index matrix M^*, which shows the relationships between all criteria:

$$M^* = \begin{array}{c|ccc} & C_1 & \ldots & C_q \\ \hline C_1 & \langle \mu_{C_1,C_1}, \nu_{C_1,C_1} \rangle & \ldots & \langle \mu_{C_1,C_q}, \nu_{C_1,C_q} \rangle \\ \ldots & \ldots & \ldots & \ldots \\ C_q & \langle \mu_{C_q,C_1}, \nu_{C_q,C_1} \rangle & \ldots & \langle \mu_{C_q,C_q}, \nu_{C_q,C_q} \rangle \end{array} \tag{15}$$

The last step of the algorithm is to determine between the criteria pairs.

Let $\alpha, \beta \in [0; 1]$ be such numbers that $\alpha + \beta \leq 1$. Regarding the two criteria C_k and C_l it is assumed that they are in:

- (α, β)-positive consonance, if $\mu_{C_i,C_j} > \alpha$ and $\nu_{C_i,C_j} < \beta$:

- (α, β)-negative consonance, if $\mu_{C_i,C_j} < \beta$ and $\nu_{C_i,C_j} > \alpha$:
- (α, β)-dissonance, otherwise.

In detail, according to the table presented below the relations between the criteria are termed “strong positive consonance”, “positive consonance”, “weak positive consonance”, “weak dissonance”, “dissonance”, “strong dissonance”, “weak negative consonance”, “negative consonance” or “strongly negative consonance”. If each evaluation a_{CpOq} is intuitionistic fuzzy pair of the form $\langle \alpha_{C_p,O_q}, \beta_{C_p,O_q} \rangle$, then the method of InterCriteria Analysis may be applied in a similar way.

Table 1.1. Relation between the criteria

Degree of relation	***Type of consonance***
[0; 0,05]	Strongly negative consonance (SNC)
[0,05; 0,15)	Negative consonance (NC)
[0,15; 0,25)	Weak negative consonance (WNC)
[0,25; 0,33)	Weak dissonance (WD)
[0,33; 0,43)	Dissonance (D)
[0,43; 0,57)	Strong dissonance (SD)
[0,57; 0,67)	Dissonance (D)
[0,67; 0,75)	Weak dissonance (WD)
[0,75; 0,85)	Weak positive consonance (WPC)
[0,85; 0,95)	Positive consonance (PC)
[0,95; 1]	Strongly positive consonance (SPC)

Let $\langle a,b \rangle$ and $\langle c,d \rangle$ be two intuitionistic fuzzy pairs. The following relations may be determined between them:

$\langle a,b \rangle \leq \langle c,d \rangle$ if $a \leq c$ and $b \geq d$,

$\langle a,b \rangle \geq \langle c,d \rangle$ if $a \geq c$ and $b \leq d$,

$\langle a,b \rangle < \langle c,d \rangle$ if $a \leq c$ and $b > d$ or $a < c$ and $b \geq d$ or $a < c$ and $b > d$,

$\langle a,b \rangle > \langle c,d \rangle$ if $a \geq c$ and $b < d$ or $a > c$ and $b \leq d$ or $a > c$ and $b < d$,

$\langle a,b \rangle = \langle c,d \rangle$ if $a = c$ and $b = d$.

CHAPTER 2

ANALISING FINANCING PROCESSES OF SMALL AND MEDIUM ENTERPISES

2.1. Statistical data analysis.

Most recent statistics of the Eurostat on SMEs (2012) report that the EU of 28 states (EU28) has more than 22.3 SMEs which are a staggering 99.8% of all companies. Taken together, SMEs generate 67.1% of all jobs and make a 57.5% contribution towards the creation of wealth. Other additional factors that could be taken into account when segmenting the SME clients are the legal form of the company, accounting practice (single and double entry), audited financial statements, which are important factors, when comes down to potential financing.

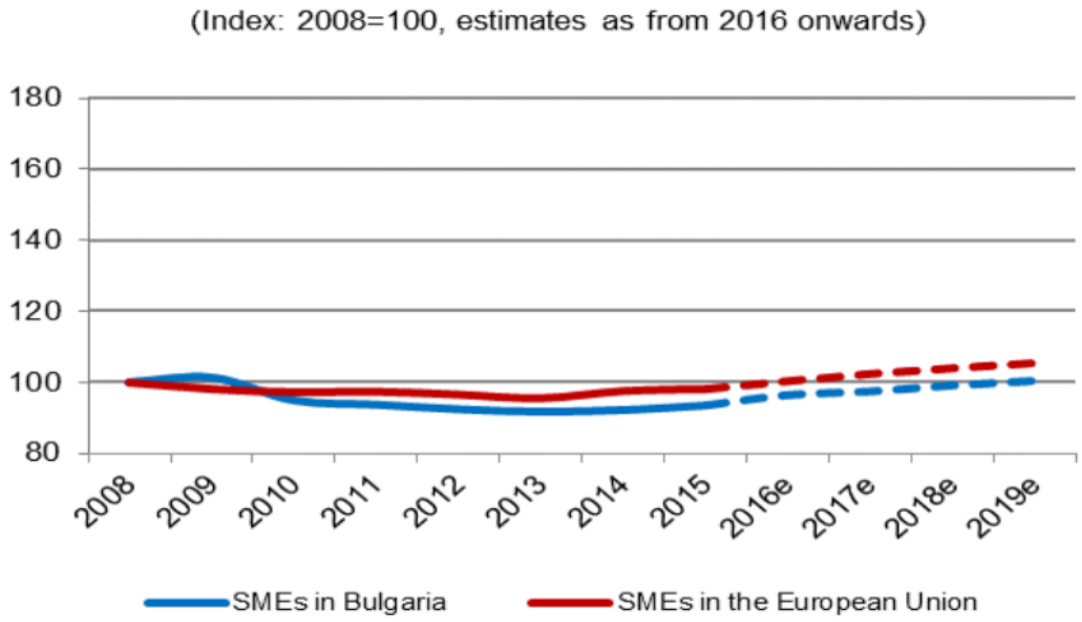

Figure 2.1. Number of persons employed in SMEs

As all throughout Europe, likewise in Bulgaria, SMEs are the backbone of non-financial business economy. Local SMEs represent 65.2 % of all value added businesses, and 75.4 % of employment providers, which is well above the EU average of 56.8 % and 66.4 %, respectively. Bulgarian SMEs employ approximately 4 and a

half people, against 3.9 in the EU as a whole. During the spread of 2011-2017, local SMEs generated sharp value added growth of 60.5 %. The increase was notably strong in micro firms, with value added rising by 83.9 % within the same period. After a prolonged downturn starting with the 2009 crisis, SME employment bottomed out in 2013, gradually rising afterwards, contributing to moderate overall growth of 4.1 % in 2011-2017. Most recently, in 2016-2017, SME employment increased slightly, by 1.1 %, and SME value added rose, by 3.6 %. In 2017-2019, SME value added is forecast to increase by 15.1 %. Likewise, SME employment is predicted to increase, by 3.1 % within the same period, corresponding to around 46 500 new jobs.

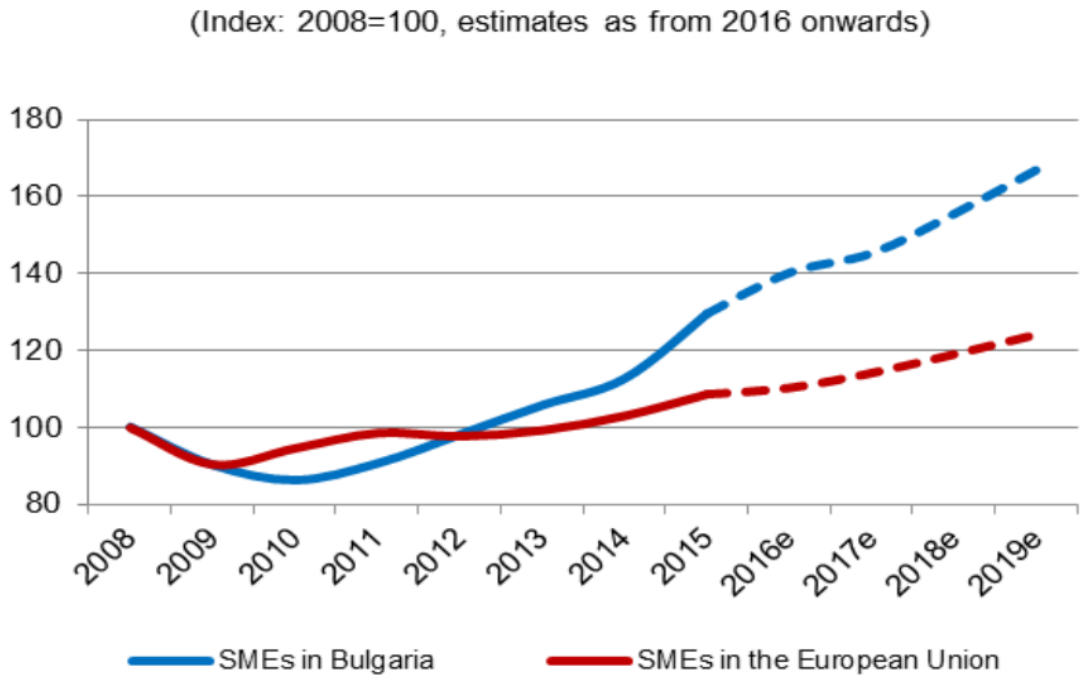

Figure 2.2. Value added of SMEs

During the transition of 2011-2017, as with the overall non-financial business economy, in terms of value added, in wholesale and retail trade, SME's input grew up to 58.7 %. In contrast, SME employment declined by 2.7 %. Bigger companies significantly outperformed SMEs, with their value added and employment growth, increasing by 75.5 % and 17.0 % respectively. The large gains in value added in the sector as a whole are primarily thanks to the generally positive economic climate in

Bulgaria, typified by rising incomes and consumer spending. As for example, in 2017 per capita, income in Bulgaria was 8.1 %, which is a figure, higher than the one result from 2016. Nevertheless, the subdued development of employment in this sector, especially in SMEs, is largely related to the transformations, currently taking place in the retail trade. Online retail sales, are becoming more and more prevalent, although Bulgaria is still lagging behind the rest of Europe in terms of online shopping. However, new technologies have also affected traditional in-store shopping: retail traders face consumer pressure to provide cashless and contactless payment options, as well as mobile device payment systems, all of which require access to modern and risk-free payment networks. The operational and training costs of adopting this technology are more of a barrier for small and micro firms than for large retail companies. Nonetheless, these technological trends have the potential to pave the way for cost reductions and productivity gains for SMEs. However, they are likely to result in reduced demand for labor.

Table 2.1. Eurostat statistics sourses

Class size	**Number of enterprises**			**Number of persons employed**			**Value added**		
	Bulgaria		***EU-28***	**Bulgaria**		***EU-28***	**Bulgaria**		***EU-28***
	Number	**Share**	***Share***	**Number**	**Share**	***Share***	**Billion €**	**Share**	***Share***
Micro	309 050	91.5 %	93.1 %	586 140	29.7 %	29.4 %	5.5	21.3 %	20.7 %
Small	23 734	7.0 %	5.8 %	474 078	24.0 %	20.0 %	5.8	22.4 %	17.8 %
Medium-sized	4 316	1.3 %	0.9 %	427 087	21.6 %	17.0 %	5.5	21.5 %	18.3 %
SMEs	**337 100**	**99.8 %**	**99.8 %**	**1 487 305**	**75.4 %**	**66.4 %**	**16.8**	**65.2 %**	**56.8 %**
Large	649	0.2 %	0.2 %	485 486	24.6 %	33.6 %	9.0	34.8 %	43.2 %
Total	**337 749**	**100.0 %**	**100.0 %**	**1 972 791**	**100.0 %**	**100.0 %**	**25.7**	**100.0 %**	**100.0 %**

The numbers in the table above are estimates for the period 2017-2019, and are based entirely on figures from the database statistics of Eurostat. The structural business statistic covers the spread between the years 2008-2015. The data summarizes directions in business economy, which includes industries such as construction, trade, and the services sector. Not included in the analysis are enterprises in agriculture, forestry and fisheries and the largely non-market service sectors such as education and health. Utilization of Eurostat statistics is an advantage to the point that provides harmonized and comparable data across EU-28.

2.2. Ways of financing, strategies, tools.

JEREMIE is a joint initiative set up in 2007 by the European Commission (Directorate-General for Regional and Urban Policy) in co-operation with the European Investment Bank Group and other financial institutions to enhance cohesion across the EU. The JEREMIE instrument was set up to deploy part of the EU Structural Funds allocated to the regional and national Managing Authorities through new risk finance initiatives for SMEs. In this regard, JEREMIE is a predecessor to the current ESIF-backed programmes managed by EIF under the new 2014-2020 programming period.

JEREMIE offered EU Member States, through their national or regional Managing Authorities, the opportunity to use part of their EU Structural Funds to finance SMEs in a more efficient and sustainable way. JEREMIE's financial resources have been deployed through selected financial intermediaries across the EU, which have provided loans, equity and guarantees to SMEs.

At the end of 2015, EIF managed 13 JEREMIE holding funds for a total of EUR 1.1bn, involving 50 financial intermediaries and resulting in 84 transactions. In the course of 2015, additional commitments were made to the holding funds in Romania (EUR 75m) and Slovakia (EUR 40m) with the implementation period of the financial instruments being extended into 2016. Furthermore, given the revolving nature of financial instruments, several Member States and regions have entrusted the management of reflows from initial JEREMIE investments to EIF. Accordingly, EIF will redeploy these legacy funds in the respective markets through existing and new financial instruments targeting the support of SME access to finance.

The entrepreneurs below benefited from JEREMIE support which allowed EIF financial intermediaries to give them the necessary kick-start to launch or expand their businesses and carry out their ambitions.

In Bulgaria, the JEREMIE Holding Fund (JHF) is financed by the European Regional Development Fund (ERDF) and co-financed by 15% by the State Budget within the framework of the Operational Programme (OP) “Development of the Competitiveness of the Bulgarian Economy 2007 – 2013”. Under this OP, the Ministry of Economy, Energy and Tourism (MEET), has allocated contributions under the

Priority Axis 3, including a national contribution, equal to EUR 349 million for the implementation of the JEREMIE Initiative aiming to improve the access to finance for Small and Medium-sized Enterprises (SMEs) through various financial engineering instruments.

2.3. Fund focus, including stage and sector (investment criteria).

The individual investments in the fund's portfolio will be selected based on the combination between the mandatory and at least on of the optional criteria:

Mandatory Criteria

- Management team and human resources' potential;
- Profound market and industry knowledge;
- Business model scalability;
- Distinctive competitive advantages;
- Double digit growth potential of the companies revenues;
- Clear Exit Route.

Optional Criteria

- Value-adding opportunities through process optimization, strategy fine-tuning;
- Market scalability of the products (export);
- Potential for horizontal or vertical integration.

The majority of SME companies in Bulgaria experience difficulties in maintaining a normal life cycle and tend to suffer from early maturity and decline without being able to materialize its full potential. There are many reasons for this, with the most common being – poor management and lack of financing. The Fund will aim in this cases at eliminating these factors with different optimization strategies, so the company converges to its natural development path and then seek expansion opportunities. Companies that have already accomplished this stage of their life cycle will be prepared for the next level.

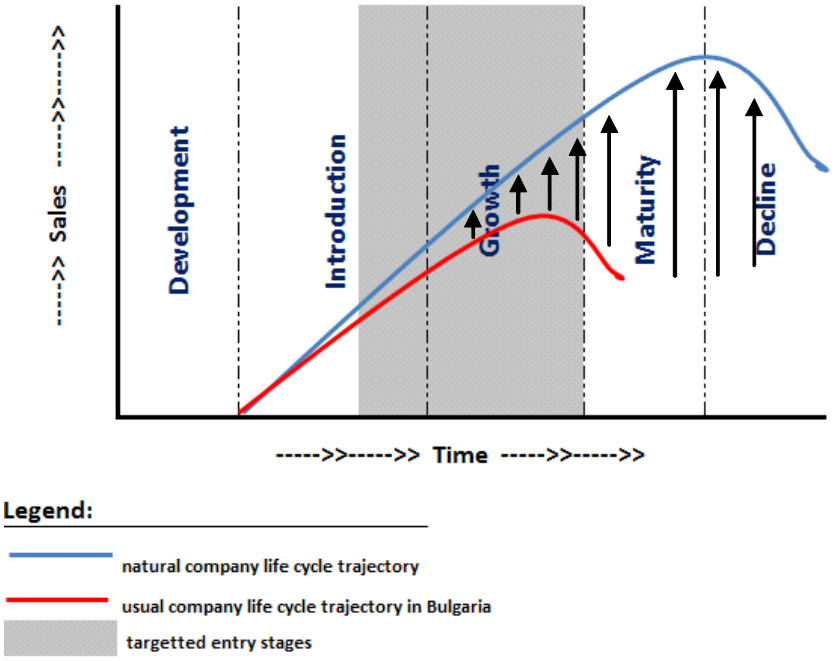

Figure 2.6. Life cycle of SME companies

2.4. Expected number of investee companies, planned investment rate including follow-on policy and envisaged strategy for risk diversification of Fund's capital.

Investing in growth capital in the SME sector involves substantial risk in general and particularly in emerging markets like Bulgaria. A significant portion of this risks results from the lack of business ethics in the market and a legislation, which doesn't support in particular this kind of investments. Several cases from the experience of international PE players in Bulgaria have shown that even a complete loss of the investments is possible due to fraud and weak legal execution. We believe that the combination between the accumulated experience in each fund's team, combined with previous successful financial deals in the local business environment and the necessary understanding of the peculiarities of the execution of financial deals in Bulgaria will be crucial for mitigating the legislative and fraud risk.

Generally the management processes of the companies will be reviewed and if needed adjusted. Preferable to invest in companies that have already existing or are willing to implement modern business and management processes, which are detached

and independent from individual talent skills and single persons authority. The latter is unfortunately still the business standard for the majority of SMEs in Bulgaria, and bares a high potential business risk in the cases of disloyalty of this key people.

As funds will be investing in growth, the equity investments as a general rule should be done as a capital increase and not as a partial or full shareholders exit. Exceptions to this rule can be evaluated if one or some of the shareholders hinder the development of the company.

Considering the required experience of each developed structure and the targeted industries, the ideal investment sizes should be between EUR 1.5 million (smaller investments) and EUR 8 million (large). This numbers show the initial investment size. For follow-up capital increases funds are advised to keep special reserves of 10% to 15% of the total fund capital. Ideally, capital injections should be scheduled in tranches tied to performance and/or investment cornerstones.

2.5. Strategy for generation of deal flow, adding-value to investee companies post-investment and exit strategy.

Deal Origination

Funds must utilize a two-pronged approach for deal flow generation. The origination will benefit from the commitment of local commercial banks specialized in SME financing, and partners' extensive network and experience in Bulgaria's financial market. Combined network covers majority of Bulgarian SMEs in the targeted size and industries.

Investment Process

Structured Funds under the JEREMIE initiative must follow an organized and well documented investment process. The investment process will be aimed at providing exhaustive research on the investment opportunity, thorough due diligence and efficient deal closing corresponding to the strategy and criteria of each Fund. Investment processes are expected to last up to 9 months. The following sections are summarizing the key steps and cornerstones of the deal making points.

Post-Investment Policies

Funds will strive to maximize value creation by following policies providing in-direct and direct support to capital beneficiaries. Taking into consideration the

business environment in the country and the usual practices of SMEs, structured funds management is convinced that the potential for value-creation is immense and should be addressed adequately. As already several times described in this document even well-run Bulgarian companies often suffer from inefficient management, un-timely access to performance metrics, no monitoring procedures, and lack of access (or unwillingness to rely) to third-party advisory/consulting services. Post-investment strategies for value creation should also be designed as to address the mentioned risks of fraudulent behaviour, and to handle resistance for cooperation.

Investment Exit Strategy

Fund's management has to have significant expertise in M&A and capital markets transactions in Bulgaria and they will employ a broad range of investment exit strategies that have been identified to provide viable exit options. In order to maximize investment return, each Fund will follow predetermined time horizon and exit strategies for each investment. The exit strategies will be stated in the investment agreements signed from both parties (the fund and the beneficiaries) at the time an investment is made.

2.6. Financial instruments used and expected returns.

We believe that given the development stage and nature of the SMEs in Bulgaria the most suitable instruments created by Funds management have to be as plain and simple as possible. Sophisticated financial products generally create mistrust on the local market. Thus each Fund must intend to use for its investment needs primarily direct participation in the companies via investing in common stock and in certain cases through a combination with investments in preferred stock of the company.

Structured Funds under JEREMIE most likely will aim at purchasing a significant portion of a particular company in order to be able to have a larger influence in its governing and to speed up its growth via the experience and know-how of its investment team. Typically Funds will seek to participate via a capital increase aiming at further strengthening the shareholder's equity, and support the continued growth through acquisitions as well as organic growth.

CHAPTER 3

EXPERIMENTAL RESULTS OF THE SIMULATION ANALYSIS

3.1. Structuring of growth funds with the purpose of SME's evolution under the JEREMIE initiative.

Structured Funds under JEREMIE most likely will aim at purchasing a significant portion of a particular company in order to be able to have a larger influence in its governing and to speed up its growth via the experience and know-how of its investment team. Typically Funds will seek to participate via a capital increase aiming at further strengthening the shareholder's equity, and support the continued growth through acquisitions as well as organic growth.

Each structured Fund must target an investment with a clear potential to generate above 30% internal rate of return (IRR). As some of them could be expected to not realize their full potential and reach all financial targets at the predefined time horizon, managers should expect that the overall performance that one Fund will be able to achieve will be equivalent to IRR of 18%, [1*].

3.2. Generalized Net model of the methodology for analysis of the creditworthiness and evaluation of credit risk in SMEs financing.

A Generalized Net (GN) model is described in [2*] used GN shown on Figure 3.1. Five types of tokens move in this GN. The tokens from the first type are α_1 and α_2, and they represent bank-administrators. The tokens have the initial and current characteristics: *"Credit specialist at branch level"* in place l_8 and *"Experts at Headquarters level"* in place l_{15}.

The tokens from the second type are the φ-tokens that permanently enter place l_1 with initial characteristic *"Potential SME Borrower"*.

The tokens from the third type are χ_1, χ_2 and χ_3, representing Bank management. They have the initial and current characteristics: *"Credit Council"* in place l_{18}, *"Management Board"* in place l_{21} and *"Supervisory Board"* in place l_{24}.

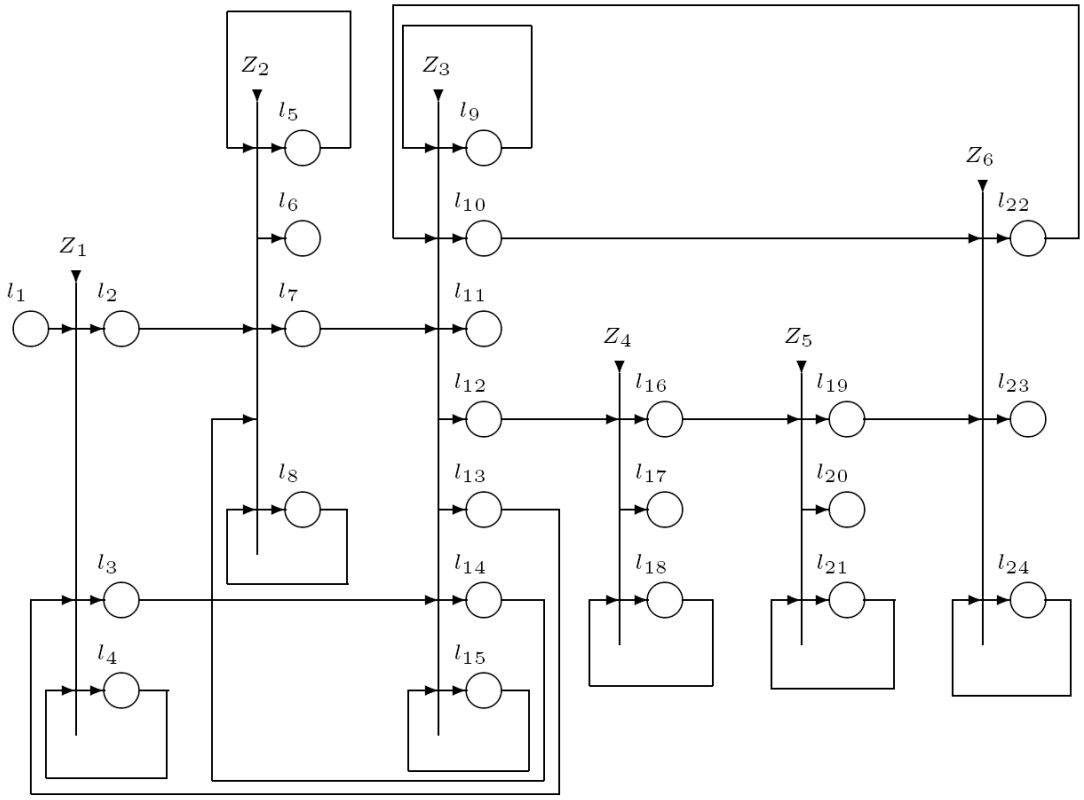

Figure 3.1. Generalized Net model of the methodology for analysis of the creditworthiness and evaluation of credit risk in SMEs financing

The so constructed Generalized Net (GN) model describes the most important steps of the process of evaluation of a business project proposal intended for financing**.**

3.3. Generalized Net model of internal financial structural unit's functionality with intuitionistic fuzzy estimations.

The GN model, discussed in [3*], is shown on Figure 3.2 and contains five transitions, that represent sub-transitions of the transitions Z_2, …, Z_6 respectively. The sub-transitions' input/output places here are subsets of the input/output places, and for the sake of simplicity the indexes are kept as given in [2*]. For each of these transitions, construct intuitionistic fuzzy estimations representing the number of all projects, qualified to reach the respective *i*-th stage of the process of evaluation of loan applications (let us mark it by *i*, where $i = 2, \ldots, 6$, to correspond to the ordering of the generalized net transitions).

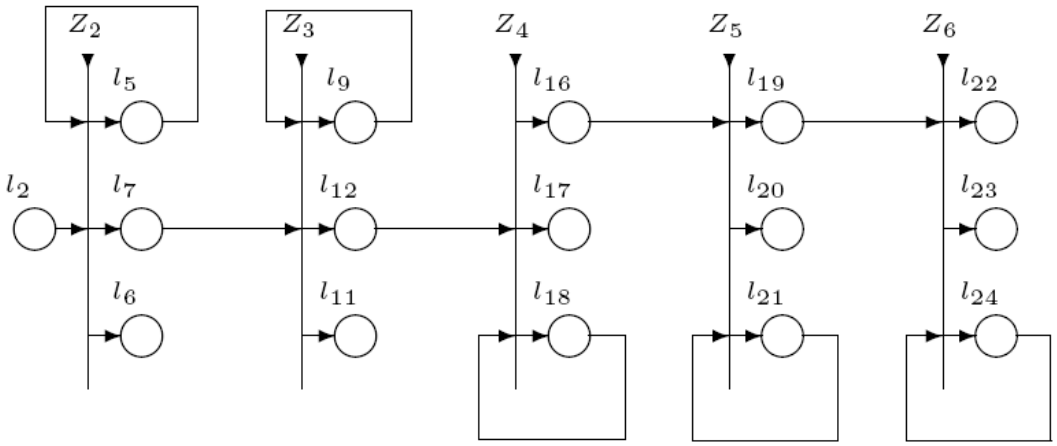

Figure 3.2. Generalized Net model of internal financial structural unit's functionality

Intuitionistic fuzziness is introduced in these estimations, using the following scheme:

$$\mu_i = \frac{\text{number of accepted by the moment projects}}{\text{number of all received by the moment projects}},$$

$$\nu_i = \frac{\text{number of rejected by the moment projects}}{\text{number of all received by the moment projects}},$$

$$\pi_i = 1 - \mu_i - \nu_i,$$

where π_i is the index of uncertainty and it corresponds to the number of projects that are under discussion in the respective bank administration, as described by the transition Z_i. The model can be implemented in the internal banking scoring system, as it would aim to reach the optimal period of evaluation process.

3.4. Uncertainty modeling in the process of SMEs financial mechanism using intuitionistic fuzzy estimations.

For the needs in paper [4*], is make a relatively simple model, which takes into account which levels of the bank hierarchy receive and process the business applications for bank loans, which levels make funding decisions, and in case of uncertainty, which upper levels of the hierarchy are these applications directed to, for taking a decision at the higher level, illustrated on Figure 3.3.

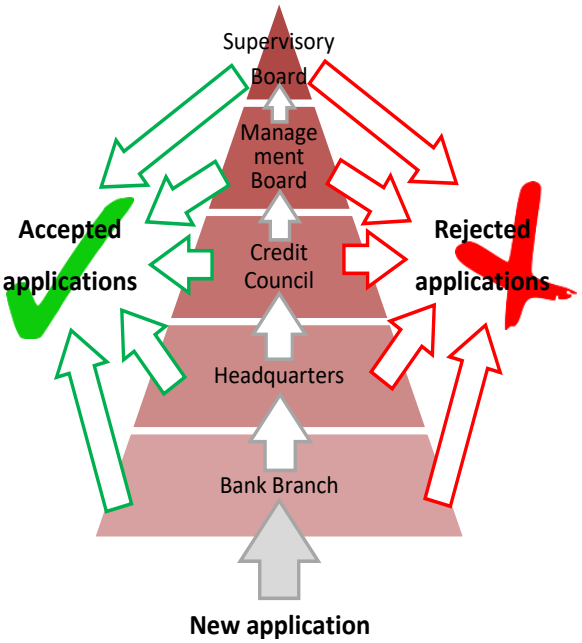

Figure 3.3. Diagram of the process of bank loan applictions review along the bank's decision making hierarchy

The process of evaluation of every bank loan application passes through one or more (rarely more than three) levels of the bank's decision making hierarchy. Usually the decision about the approval or rejection of the applications is taken on the Branch level or the Headquarters level, however in certain cases when lower levels cannot take a categorical decision, the application is sent to the upper level.

3.5. Generalized Net model of internal structural unit functionality focused on SME financing.

In [5*] is proposed an original GN model of internal structural bank unit functionality. The advantage of this approach is in modelling the inherent aspects of parallelism and concurrency between agents in a situation of competition.

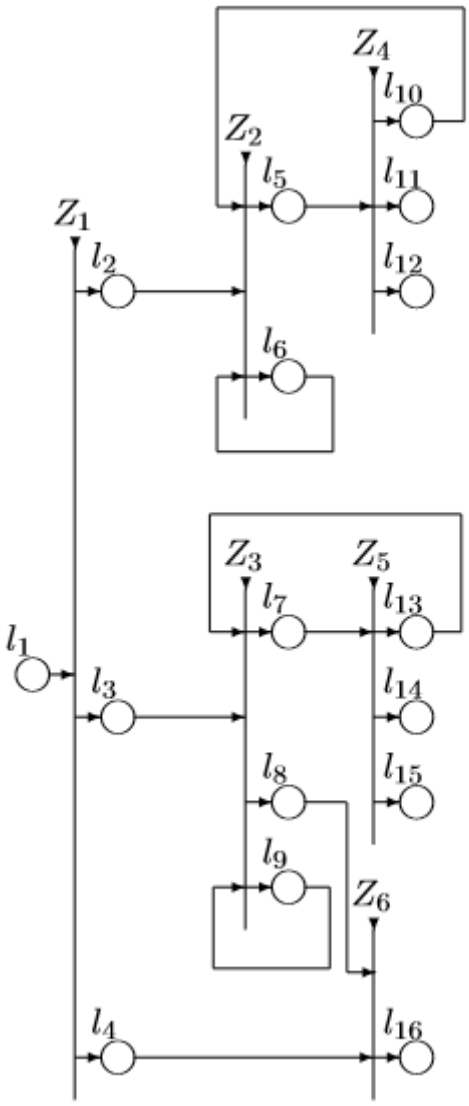

Figure 3.8. The constructed Generalized Net model

The results, obtained in this research, can be successfully applied to analyze the work of any structural unit of a financial institution.

3.6. Assessment finance approach from the glance of a Generalized Net model implemented in a structural unit of a financial institution.

The paper [6*] traces the most important steps of the process of evaluation of a business project proposal, applying for bank financing. The research model is offered how the concept of the generalized nets (GN) can be applied to the process of evaluating creditworthiness of the SMEs.

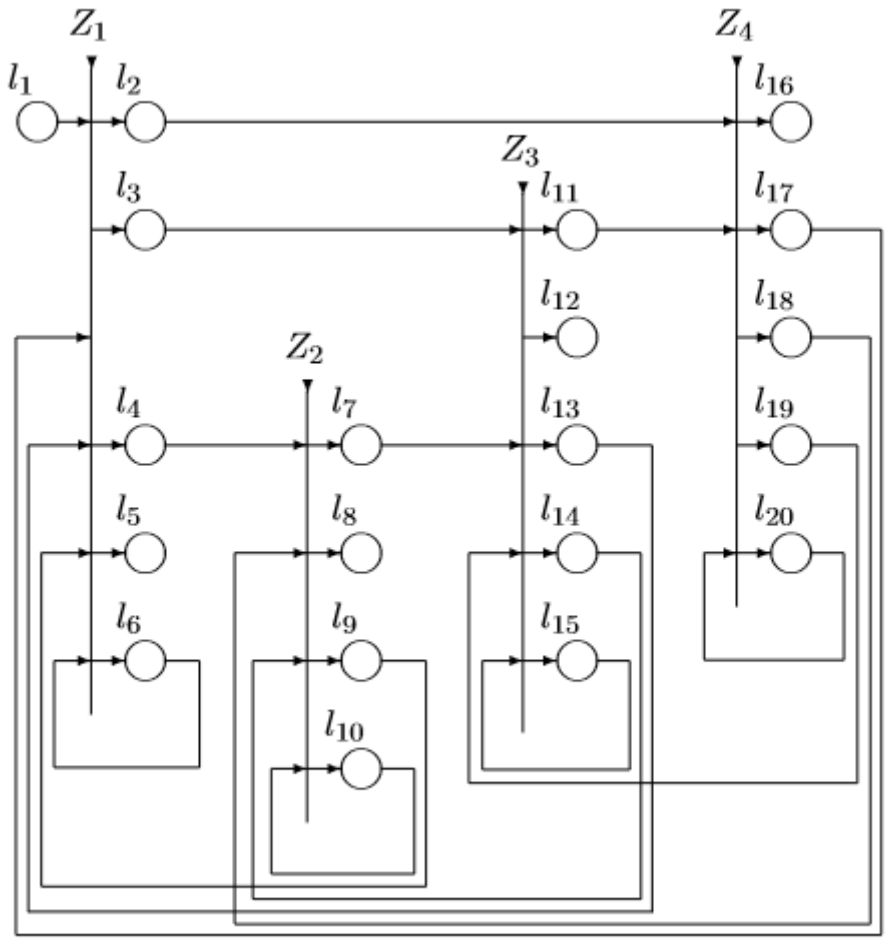

Figure 3.9. The constructed Generalized Net model

The obtained in this research results can be successfully applied for analysis of the work of one structural unit of a financial institution. In a next step of research, estimations of the effectiveness of the described process will be made, taking consideration of the aspects of uncertainty. Uncertainty is an inherent part of the processes of evaluation of applications for bank support and evaluation of the process itself. For this sake the apparatus of intuitionistic fuzzy sets will be used.

3.7. Optimisation procedures in SMEs financial mechanism.

In the paper [7*] is discussed the mechanism of bank support of small and medium-sized enterprises (SMEs). Analysis is made of the effectiveness of the bank's internal financial structural unit and hierarchy, and it is shown how the concept of Multi-Criteria Decision Analysis (MCDA) can be applied to the process of evaluating

creditworthiness of the SMEs applications for bank loans, from the bank's perspective. The presented approach aims to yield estimations of the effectiveness of the process, taking consideration of the aspects of uncertainty, which is an inherent part of the processes of evaluation of applications for bank support and evaluation of the process itself.

Multi-Criteria Decision Analysis (MCDA) [109] is a valuable tool that can apply to many complex decisions. It is most applicable to solving problems that are characterized as a choice among alternatives. It has all the characteristics of a useful decision support tool. It helps us focus on what is important, is logical and consistent, and is easy to use.

In limited number of cases each Fund have to aim at lending different types of hybrid loan products, suited to best fit the business needs of each company. A common type of debt product that Funds will be looking at will be the convertible debt, where the loan is secured via the right to convert it to common stocks at certain predetermined conditions. This will reduce both the risk to each Fund and the requirement to the company to provide collateral, which as have mentioned before proves to be a major obstacle for the SMEs on their way to receiving a proper financing.

3.8. InterCriteria Analysis applied to various EU enterprises.

The present research, published in [8*], aims to detect certain correlations between four economic indicators, against which have been evaluated the economic entities of the European Union with 27 Member States, as split into four categories: micro, small, medium and large enterprises. The mathematical formalism employed for revealing these dependencies, particularly termed here 'positive' and 'negative consonances', is a novel decision support approach, called InterCriteria Analysis, which is based on the theoretical foundations of the intuitionistic fuzzy sets and the augmented matrix calculus of index matrices. The proposed approach can be useful in processes of decision making and policy making, and it can be seamlessly integrated and further extended to other related application areas and problems, where it is reasonable to seek correlations between a variety of economic and other indicators.

Here can note for the interested reader, that the intuitionistic fuzzy interpretation triangle, shown on Figure 3.10, is the IFS-specific graphical interpretation of IFSs. The triangle is part of the Euclidean plane, with vertices the points (0, 0), (1, 0) and (0, 1), staying respectively for the complete uncertainty, complete truth and complete falsity as the boundary values with which elements of an IFS can be evaluated. The hypotenuse corresponds to the graphical interpretation of the [0, 1] interval, and points belonging to it are elements of a classical fuzzy set.

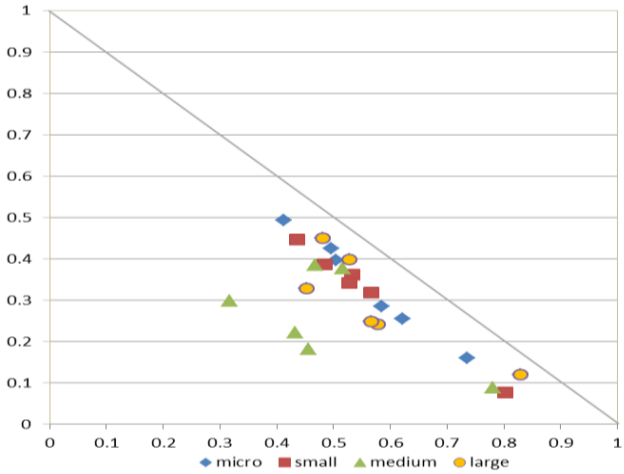

Figure 3.10. ICA results with respect to the type of enterprise

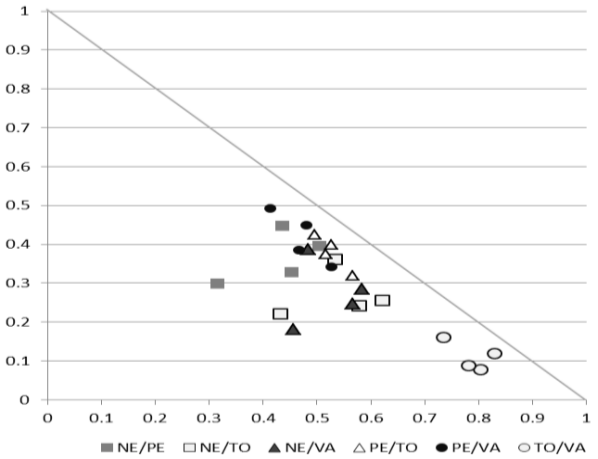

Figure 3.11. ICA results with respect to correlations between economic indicators

The present research analysed data about the micro, small, medium and large economic entities in the EU27, as evaluated against four economic indicators (criteria). The utilized method for analysis of the datasets was the novel decision support

approach, called InterCriteria Analysis. The results are two-fold: they outline correlations between economic indicators on these four levels of economic enterprise, new thus potentially brining new knowledge and understanding, and also contribute to elaboration of certain aspects of the methodology of ICA.

3.9. InterCriteria Analysis of the creditworthiness of SMEs.

The paper [9*] further employ the InterCriteria Analysis, as an approach for detection and identification of dependencies between these objective and subjective characteristics of SMEs. Here input the above dataset into the InterCriteria Analysis software, developed by Mavrov, [77], and as a result obtain two tables (Tables 3.14 and 3.15) staying for the resultant table of intuitionistic fuzzy pairs, giving the positive consonance, negative consonance or dissonance, relating each pair of evaluation criteria. Here are interested in the pairs of highest positive consonance, defined as definite correlation between a pair of criteria, while negative consonance represents definite lack of correlation, and dissonance – uncertainty. Obviously, along the main diagonal all consonance values are ⟨1.00, 0.00⟩, i.e. in Table 3.14 are 1.00 and in Table 3.15 are 0.00, since each criterion correlates with itself perfectly.

Table 3.14. The membership parts of the IFS InterCriteria pair

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**
(1)	1.00	0.76	0.73	0.53	0.67	0.53	0.38	0.33	0.29	0.58	0.42	0.53	0.20	0.29	0.36
(2)	0.76	1.00	0.98	0.56	0.56	0.44	0.31	0.27	0.29	0.64	0.47	0.56	0.16	0.24	0.20
(3)	0.73	0.98	1.00	0.53	0.53	0.44	0.33	0.27	0.29	0.67	0.49	0.58	0.18	0.27	0.22
(4)	0.53	0.56	0.53	1.00	0.73	0.51	0.29	0.36	0.31	0.49	0.42	0.42	0.13	0.22	0.33
(5)	0.67	0.56	0.53	0.73	1.00	0.44	0.31	0.38	0.31	0.42	0.40	0.36	0.22	0.27	0.40
(6)	0.53	0.44	0.44	0.51	0.44	1.00	0.62	0.67	0.62	0.53	0.44	0.40	0.27	0.33	0.42
(7)	0.38	0.31	0.33	0.29	0.31	0.62	1.00	0.53	0.51	0.53	0.51	0.51	0.56	0.49	0.71
(8)	0.33	0.27	0.27	0.36	0.38	0.67	0.53	1.00	0.56	0.42	0.51	0.36	0.36	0.33	0.44
(9)	0.29	0.29	0.29	0.31	0.31	0.62	0.51	0.56	1.00	0.38	0.40	0.27	0.24	0.24	0.38
(10)	0.58	0.64	0.67	0.49	0.42	0.53	0.53	0.42	0.38	1.00	0.69	0.80	0.42	0.44	0.42
(11)	0.42	0.47	0.49	0.42	0.40	0.44	0.51	0.51	0.40	0.69	1.00	0.69	0.47	0.42	0.49
(12)	0.53	0.56	0.58	0.42	0.36	0.40	0.51	0.36	0.27	0.80	0.69	1.00	0.49	0.47	0.49
(13)	0.20	0.16	0.18	0.13	0.22	0.27	0.56	0.36	0.24	0.42	0.47	0.49	1.00	0.87	0.67
(14)	0.29	0.24	0.27	0.22	0.27	0.33	0.49	0.33	0.24	0.44	0.42	0.47	0.87	1.00	0.58
(15)	0.36	0.20	0.22	0.33	0.40	0.42	0.71	0.44	0.38	0.42	0.49	0.49	0.67	0.58	1.00

Table 3.15. The non-membership parts of the IFS InterCriteria pairs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)	0.00	0.24	0.27	0.42	0.31	0.33	0.40	0.29	0.49	0.27	0.36	0.24	0.31	0.36	0.38
(2)	0.24	0.00	0.02	0.40	0.42	0.42	0.47	0.36	0.49	0.20	0.31	0.22	0.36	0.40	0.53
(3)	0.27	0.02	0.00	0.42	0.44	0.42	0.44	0.36	0.49	0.18	0.29	0.20	0.33	0.38	0.51
(4)	0.42	0.40	0.42	0.00	0.20	0.31	0.44	0.27	0.42	0.36	0.36	0.36	0.38	0.42	0.36
(5)	0.31	0.42	0.44	0.20	0.00	0.40	0.49	0.22	0.44	0.40	0.36	0.40	0.31	0.36	0.36
(6)	0.33	0.42	0.42	0.31	0.40	0.00	0.16	0.09	0.16	0.18	0.20	0.24	0.24	0.31	0.18
(7)	0.40	0.47	0.44	0.44	0.49	0.16	0.00	0.04	0.13	0.18	0.13	0.18	0.09	0.16	0.07
(8)	0.29	0.36	0.36	0.27	0.22	0.09	0.04	0.00	0.02	0.13	0.02	0.18	0.09	0.20	0.04
(9)	0.49	0.49	0.49	0.42	0.44	0.16	0.13	0.02	0.00	0.29	0.20	0.38	0.18	0.27	0.27
(10)	0.27	0.20	0.18	0.36	0.40	0.18	0.18	0.13	0.29	0.00	0.07	0.04	0.20	0.22	0.24
(11)	0.36	0.31	0.29	0.36	0.36	0.20	0.13	0.02	0.20	0.07	0.00	0.04	0.09	0.18	0.16
(12)	0.24	0.22	0.20	0.36	0.40	0.24	0.18	0.18	0.38	0.04	0.04	0.00	0.11	0.13	0.20
(13)	0.31	0.36	0.33	0.38	0.31	0.24	0.09	0.09	0.18	0.20	0.09	0.11	0.00	0.00	0.02
(14)	0.36	0.40	0.38	0.42	0.36	0.31	0.16	0.20	0.27	0.22	0.18	0.13	0.00	0.00	0.07
(15)	0.38	0.53	0.51	0.36	0.36	0.18	0.07	0.04	0.27	0.24	0.16	0.20	0.02	0.07	0.00

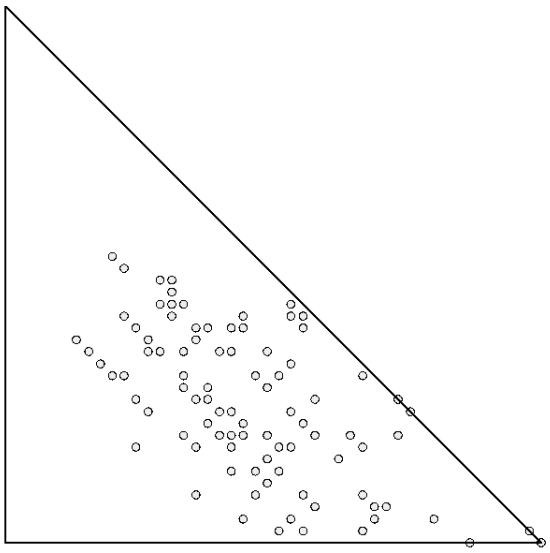

Figure 3.12. Graphics of the points, staying for the intuitionistic fuzzy pairs of InterCriteria consonances

In addition, following the recent researches in the theory of InterCriteria Analysis, the obtained results can be plotted onto the intuitionistic fuzzy interpretational triangle, shown on Figure 3.12.

Finally, the lack of positive consonance between the subjective criteria (seen from Tables 3.14 and 3.15) is also result of the limited evaluation frame, excepted at present time. Additionally increasing the evaluation range, e.g. by refining the decimal division will provide finer discrimination among the objects, as evaluated against the criteria, and can be formulated as one of the recommendations for the future.

CONCLUSION

The dissertation is dedicated to the application of innovative, intelligent techniques for analyzing the processes of financing small and medium-sized businesses. The latest developments in the design of highly efficient data processing algorithms are applied. The intelligent techniques used require the processing of large data streams, relying on all available information about the processes being monitored.

In the dissertation, mathematical modeling tools were used for the purposes of the analysis, being selected as the most appropriate apparatus of Generalized Networks (OM). Another approach used in the dissertation work is InterCriteria Analysis, which is based on two mathematical formalisms: the algebraic index matrix (IM) apparatus, when it is necessary to apply algebraic operations on matrices of different sizes and intuitionistic fuzzy sets (IRM), as a mathematical tool for treating uncertainty.

The methodology of applied research in the dissertation, involves the use of a numerical and experimental approach. The numerical approach was used in the implementation of the algorithms by computer-based calculation of intelligent methods for analyzing the processes of financing small and medium-sized businesses.

The experimental approach is used to collect data from observations of indicators characterizing the financing processes of small and medium-sized businesses.

The list of publications used in the dissertation are included nine articles, of which two book chapters in the series:

- In: Modern Developments in Fuzzy Sets, Intuitionistic Fuzzy Sets, Generalized Nets and Related Topics, with editors K. Atanassov, M. Baczynski, J. Drewniak, J. Kacprzyk, M. Krawczak, E. Szmidt, M. Wygralak, S. Zadrozny (Eds.), two articles in magazine Notes on Intuitionistic Fuzzy Sets, and five articles in International conferences works.

SUMMARY OF OBTAINED RESULTS

As a result of the research presented in this dissertation, the following scientific, applied and applied results have been achieved:

1. The existing instrument for financing small and medium-sized businesses has been systematized through the JEREMIE initiative.

2. The results of the analysis of the processes of financing small and medium-sized businesses were obtained by applying intelligent techniques for analysis of the mechanism according to which the first level of a bank institution for financing small and medium-sized businesses operates.

3. The results of the analysis of the processes of financing small and medium-sized businesses were obtained by applying intelligent techniques for analyzing the effectiveness of the internal financial structural units of different banks, such as the levels of the hierarchy for decision-making.

4. The results of the analysis of the processes of financing small and medium-sized businesses were obtained by applying intelligent techniques for the analysis of different types of hybrid credit products.

5. The results of the analysis of SME financing processes were obtained by applying intelligent data analysis techniques for micro, small, medium and large economic entities in the EU-27, estimated by different economic indicators.

6. The results of the analysis of the SME financing processes were obtained by applying intelligent techniques for analyzing the financing mechanism of the EU budget for small and medium-sized enterprises.

GUIDELINES FOR FUTURE RESEARCH

The results obtained in the dissertation are applicable to solving a broader range of tasks related to the analysis of SME financing processes. This could be a guide for future research that will enrich the research area.

PUBLICATIONS ON THE TOPIC OF THE THESIS

1*. Shahpazov G., L. Doukovska - Structuring of Growth Funds with the Purpose of SME's Evolution under the JEREMIE Initiative, Proc. of the Second International Symposium on Business Modeling and Software Design – BMSD'12, 4-6 July 2012, Geneva, Switzerland, ISBN 978-989-8565-26-6, DOI 10.5220/0004462301590164, pp. 159-164, 2012.

2*. Shahpazov G., L. Doukovska, K. Atanassov - Generalized Net Model of the Methodology for Analysis of the Creditworthiness and Evaluation of Credit Risk in SMEs Financing, Proc. of the International Symposium on Business Modeling and Software Design – BMSD'13, Noordwijkerhout, The Netherlands, ISBN 978-989-8565-56-3, DOI 10.5220/0004776702920297, pp. 292-297, 2013.

3*. Shahpazov G., L. Doukovska - Generalized net model of internal financial structural unit's functionality with intuitionistic fuzzy estimations, Proc. of the 17th International Conference on Intuitionistic Fuzzy Sets, Notes on Intuitionistic Fuzzy Sets (NIFS), vol. 19, №3, ISSN 1310-4926, e-ISSN 2367-8283, pp. 111-117, Sofia, 2013.

4*. Shahpazov G., L. Doukovska, V. Atanassova - Uncertainty Modeling in the Process of SMEs Financial Mechanism Using Intuitionistic Fuzzy Estimations, Proc. of the International Symposium on Business Modeling and Software Design – BMSD'14, 24-26 June 2014, Luxembourg, Grand Duchy of Luxembourg, ISBN 978-989-758-032-1, DOI 10.5220/0005427002710275, pp. 271-275, 2014.

5*. Shahpazov G., L. Doukovska, K. Atanassov - Generalized Net Model of Internal Structural Unit Functionality Focused on SME Financing, Proc. of the 12th International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets – IWIFSGN'13, Warsaw, Poland, In: Modern Developments in Fuzzy Sets, Intuitionistic Fuzzy Sets, Generalized Nets and Related Topics, K. Atanassov, M. Baczynski, J. Drewniak, J. Kacprzyk, M. Krawczak, E. Szmidt, M. Wygralak, S. Zadrozny (Eds.), Warsaw, Poland, ISBN 83-894-7554-5, pp. 83-92, 2014.

6*. Shahpazov G., L. Doukovska, V. Atanassova - Assessment Finance Approach from the Glance of a Generalized Net Model Implemented in a Structural Unit of a Financial Institution, Proc. of the 12th International Workshop on

Intuitionistic Fuzzy Sets and Generalized Nets – IWIFSGN'13, Warsaw, Poland, In: Modern Developments in Fuzzy Sets, Intuitionistic Fuzzy Sets, Generalized Nets and Related Topics, K. Atanassov, M. Baczynski, J. Drewniak, J. Kacprzyk, M. Krawczak, E. Szmidt, M. Wygralak, S. Zadrozny (Eds.), Warsaw, Poland, ISBN 83-894-7554-5, pp. 93-102, 2014.

7*. Shahpazov G., L. Doukovska - Optimisation procedures in SMEs financial mechanism, Proc. of the International Workshop on Advanced Control and Optimisation: Step Ahead – ACOSA'14, 8-10 May, 2014, Bankya, Bulgaria, ISSN 1314-4634, pp. 57-62, 2014.

8*. Doukovska L., V. Atanassova, G. Shahpazov, F. Čapkovič - InterCriteria Analysis Applied to Various EU Enterprises, Proc. of the International Symposium on Business Modeling and Software Design – BMSD'15, Milan, Italy, ISBN 979-989-758-111-3, pp. 284-291, 2015.

9*. Doukovska L., G. Shahpazov, V. Atanassova - Intercriteria analysis of the creditworthiness of SMEs. A case study, Notes on Intuitionistic Fuzzy Sets (NIFS), ISSN 1310-4926, e-ISSN 2367-8283, vol. 22, № 2, pp. 108-118, 2016.

DECLARATION OF ORIGINALITY

Hereby, I declare that I have composed the presented thesis independently on my own and without any other resources than the ones indicated.

All thoughts taken directly or indirectly from external sources are properly denoted as such.

This work has neither been previously submitted to another authority nor has it been published yet.

Sofia, 19.09.2019 Signature:

(G. Shahpazov)