Uncertainty Modeling in the Process of SMEs Financial Mechanism Using Intuitionistic Fuzzy Estimations

George L. Shahpazov, Lyubka A. Doukovska and Vassia K. Atanassova
Institute of Information and Communication Technologies, Bulgarian Academy of Sciences,
Acad. G. Bonchev str., bl. 2, 1113 Sofia, Bulgaria
atlhemus@abv.bg, doukovska@iit.bas.bg, vassia.atanassova@gmail.com

Keywords: SMEs Financial Mechanism, Credit Risk, Creditworthiness, Intuitionistic Fuzzy Sets, i-Fuzzification.

Abstract: In the present paper, we discuss 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 intuitionistic fuzzy sets 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.

1 INTRODUCTION

Supporting emerging and present legal entities as making a form of investment, such as financing 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. Results published in paper (Shahpazov, Doukovska, 2012), shows that the timing for financial support in Bulgarian SMEs from the manufacturing sector is perfect. The actual result lays on deep analysis of the sector, which forecasted a faster growth in the sector than local GDP growth during a 5-8 year period spread.

Over the same period, the share of service sector output in GDP is expected to raise from 61.5% - 63.4%.

Local agriculture sector is experiencing a boost in the last few years, and falls under the program of rehabilitation and modernization of value creating industries, as the main focus is to overturn present trade situation where the country imports more goods than it exports. The overall aim is to utilize the EU accession and its supportive instruments, local Government programs assistance, and financial institution involvement into accelerating growth processes and SMEs further development.

The above mentioned facts allow us to look for new techniques for intelligent analysis of the process of SMEs financial mechanism.

In paper (Shahpazov, Doukovska, 2013), an application of the apparatus of generalized nets is proposed for modeling of the mechanism of financial support of the SMEs.

The present work traces the most important steps of the process of evaluation of a business project proposal, applying for bank financing. It is a continuation of our previous research (Shahpazov, Doukovska, 2013). The research model is offered how the concept of intuitionistic fuzziness can be applied to the process of evaluating creditworthiness of the SMEs.

The evaluation follows a predefined hierarchy of the levels of the bank's decision makers, and sophisticated policies and procedures.

For the needs of our discussion, we 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. This model is schematically illustrated on Figure 1.

In this highly regulated process, for each level of the bank's decision making hierarchy, we are interested to estimate and interpret in terms of

Shahpazov G., Doukovska L. and Atanassova V.
Uncertainty Modeling in the Process of SMEs Financial Mechanism Using Intuitionistic Fuzzy Estimations.
DOI: 10.5220/0005427002710275
In *Proceedings of the Fourth International Symposium on Business Modeling and Software Design (BMSD 2014)*, pages 271-275
ISBN: 978-989-758-032-1

intuitionistic fuzzy sets the share of successfully approved applications, the share of rejected applications and the share of those applications, which for various reasons, may exhibit certain uncertainty (e.g. high risk / high return of investment) and thus get forwarded from lower to upper level of bank hierarchy, being a higher authority in the decision making process.

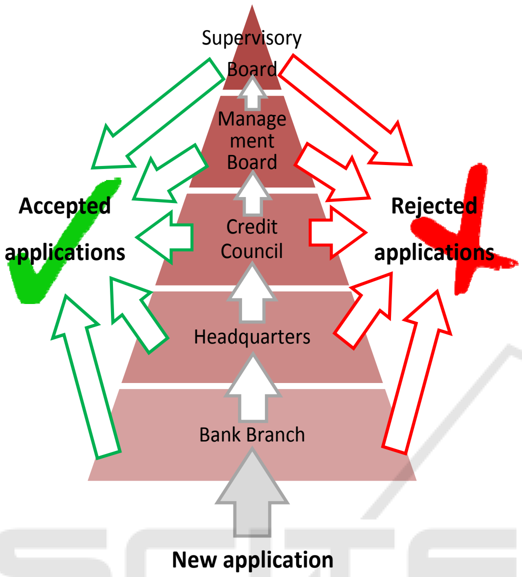

Figure 1: Diagram of the process of bank loan applictions review along the bank's decision making hierarchy.

2 SHORT REMARKS ON INTUITIONISTIC FUZZY SETS

Intuitionistic fuzzy sets (IFSs) were initially proposed by Atanassov in 1983 (Atanassov, 1983; Atanassov, 1986) as an extension of the concept of fuzzy sets, introduced by Zadeh in 1965 (Zadeh, 1965). The theory of IFSs has been extensively developed by the author in (Atanassov, 1991; Atanassov, 2012) and further developed by many other researchers worldwide.

In classical set theory, the membership of elements in a set is evaluated binary terms as either 'true' or 'false': an element either belongs or does not belong to the set. As an extension, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1].

The theory of intuitionistic fuzzy sets further extends both concepts by allowing the assessment of the elements by two functions, μ for the degree of membership and ν for the degree of non-membership, with which belong the element belongs to a set, where both these degrees and their sum are numbers in the [0, 1] - interval.

Speaking formally, if we have a fixed universe E and A is a subset of E, we can construct the intuitionistic fuzzy set A^*, so that:

$$A^* = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in E\},$$

where $0 \leq \mu_A(x), \nu_A(x), \mu_A(x) + \nu_A(x) \leq 1$. In the case of strict inequality to the right, i.e.:

$$0 \leq \mu_A(x) + \nu_A(x) < 1,$$

there is a non-negative complement of the sum of membership and non-membership to 1, and this complement is denoted by $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ and usually called degree of uncertainty or hesitancy margin.

IFSs represent a true generalization of fuzzy sets, since in the partial case when the non-membership function fully complements the membership function to 1, not leaving room for any degree of uncertainty, is practically the case of fuzzy sets.

IFSs have different graphic representations, for instance linear, which bears resemblance with the graphic representation of fuzzy sets, radar-chart, or triangular, which reflects the specifics of the IFS. The standard linear graphic representation has the form of Figure 2, where both functions μ and ν are visualized as is.

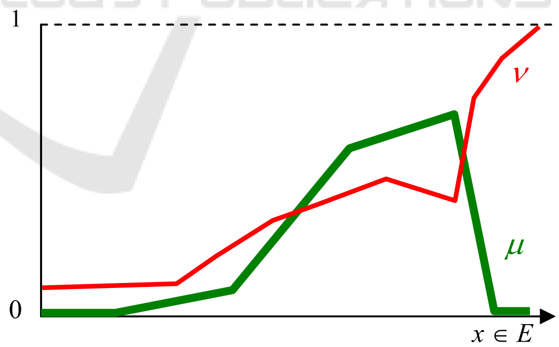

Figure 2: Standard graphical interpretation of IFSs.

However, together with the standard linear representation, a small modification of this graphics, as shown in Figure 3, was introduced (Atanassov, 1991) representing not the exact function ν, but the function $\nu^* = 1 - \nu$. It plots the non-membership function not in 'bottom-up' manner like the membership function μ, but in 'top-down' manner using its mirror image. Thus, we can very already well distinguish the formed in-between 'belt of uncertainty', which for every $x \in E$ complements the sum of $\mu_A(x)$ and $\nu_A(x)$ to 1. This modified linear representation of IFSs is probably the one most often used in practice.

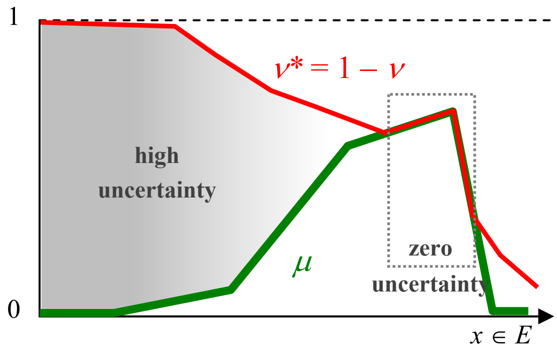

Figure 3: Modified graphical interpretation of IFSs.

3 MAIN RESULTS

As we mentioned above, 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.

Hence, it is of particular interest to trace the degrees of acceptance, rejection and uncertainty in taking the decisions on every bank hierarchy level, and for this purpose we can use a simple i-fuzzification procedure, analogous to the one given in (Atanassova, 2013), where from crisp data sets we can construct intuitionistic fuzzy data sets.

We can introduce intuitionistic fuzziness in these estimations, using two possible schemes, which are mathematically identical and can be used interchangeably, although visually they produce rather different results. In both cases, we will denote the levels of the bank's decision making hierarchy with the following denotations:

- Level 0 represents bank loan applicants,
- Level 1 is 'Branch' level,
- Level 2 is 'Headquarters' level,
- Level 3 is 'Credit Council' level,
- Level 4 is 'Management Board' level,
- Level 5 is 'Supervisory Board' level.

We will also agree to denote with μ_i, ν_i and π_i respectively, the number of applications, which on the i-th level are accepted, rejected or forwarded for decision to the level $(i + 1)$, and with t – the total number of applications submitted for evaluation.

Obviously, in the top level of the Supervisory Board, $\pi_5 = 0$, as all applications that have reached this level must there get final resolution.

The whole process, interpreted in terms of IF estimations can be graphically illustrated in the following Figure 4.

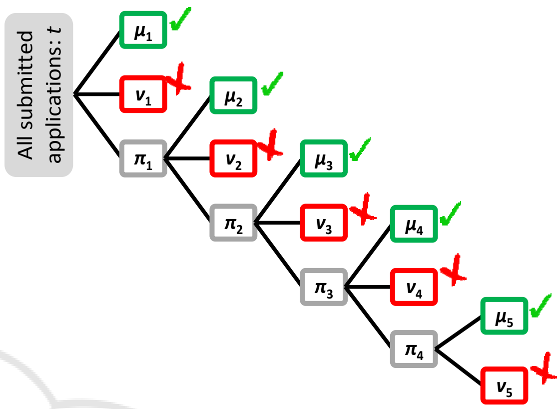

Figure 4: IF estimations of the performance of the different levels of decision making hierarchy during the bank loan applications review process.

First Scheme of i-Fuzzification. In the first scheme of i-fuzzification, on every level of the bank's decision making hierarchy, at a given moment of time, we estimate what percentage of the total number of submitted applications for evaluation have been approved, and, respectively, hitherto rejected. Let us denote these by M_i^1, N_i^1, $i = 1, \ldots, 5$, hence:

$$M_i = \frac{\sum_{k=1}^{i} \mu_k}{t}, \quad N_i = \frac{\sum_{k=1}^{i} \nu_k}{t}.$$

Second Scheme of i-Fuzzification. In the second scheme of i-fuzzification, on every level of the bank's decision making hierarchy, at a given moment of time, we estimate what percentage of the applications for evaluation, received from the lower level are approved, and, respectively, rejected, on that level. Let us denote these by M_i^2, N_i^2, $i = 1, \ldots,$ 5, hence:

$$M_i^2 = \frac{\mu_i}{\pi_{i-1}}, \quad N_i^2 = \frac{\nu_i}{\pi_{i-1}}.$$

Numerical Example. Graphical Interpretation of the Two Proposed i-Fuzzification Schemes. Let us give the following numerical example, which will make the differences between both proposed schemes easy to follow.

In given moment of time, let the following exemplary distribution of project applications along the levels in the bank's decision making hierarchy be observed, as shown on Figure 5.

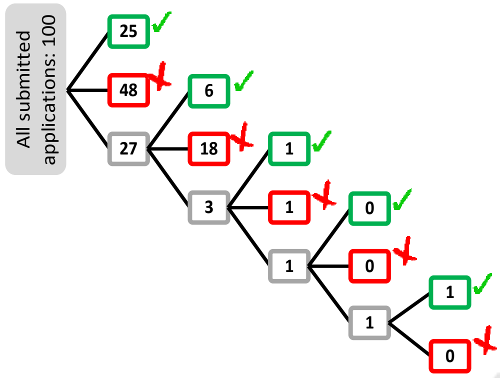

Figure 5: IF estimations for the numerical example.

Applying the first scheme of i-fuzzification over these data, will give the results in the following Table 1, as illustrated in Figure 6.

Table 1: Application of the first i-fuzzification scheme over the data from Figure 5.

	μ_i	ν_i	π_i
Level 1	25/100 = 0.25	48/100 = 0.48	27/100 = 0.27
Level 2	(25 + 6)/100 = 0.31	(48 + 18)/100 = 0.66	3/100 = 0.3
Level 3	(31 + 1)/100 = 0.32	(66 + 1)/100 = 0.67	1/100 = 0.01
Level 4	(32 + 0)/100 = 0.32	(67 + 0)/100 = 0.67	1/100 = 0.01
Level 5	(32 + 1)/100 = 0.33	(67 + 0)/100 = 0.67	0/100 = 0.00

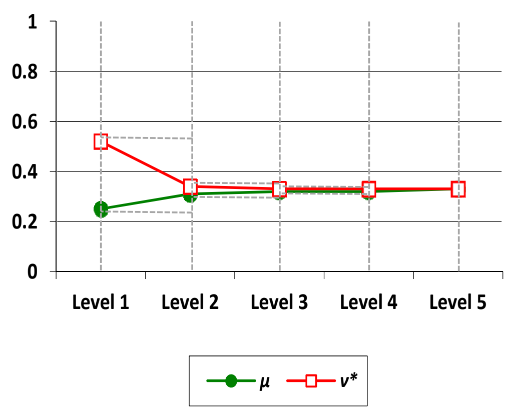

Figure 6: Interpretation of the first i-fuzzification scheme.

Applying the second scheme of i-fuzzification over these data, will give the results in the following Table 2, as illustrated in Figure 7.

Table 2: Application of the second i-fuzzification scheme over the data from Figure 5.

	μ_i	ν_i	π_i
Level 1	25/100 = 0.25	48/100 = 0.48	27/100 = 0.27
Level 2	6/27 = 0.22	18/27 = 0.67	3/27 = 0.11
Level 3	1/3 = 0.33	1/3 = 0.33	1/3 = 0.33
Level 4	0/1 = 0.00	0/1 = 0.00	0/1 = 0.00
Level 5	1/1 = 1.00	0/1 = 0.00	0/1 = 0.00

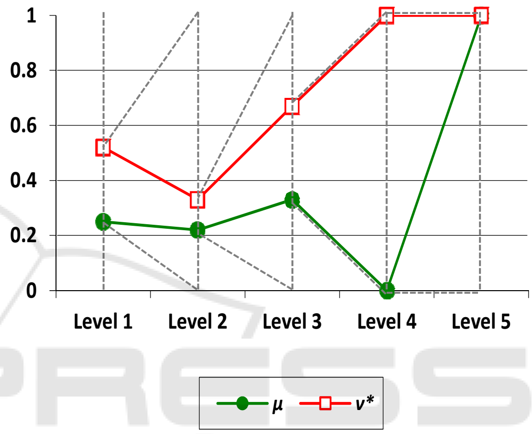

Figure 7: Interpretation of the second i-fuzzification scheme.

4 CONCLUSION

The comparison between both i-fuzzification schemes shows well that in the first scheme, at every level i, the [0, 1] - interval corresponds to the initial number of t submitted bank loan applications, and M_i^1, N_i^1, $i = 1, \ldots, 5$, are cumulative. In comparison, in the second scheme, on every upper level i we only operate with the IF evaluations for that level, and every time the degree of uncertainty from the lower $(i-1)^{\text{-th}}$ level is again re-normed to match the [0, 1] - interval (see the grey dotted lines).

Both approaches can be used interchangeably, and may prove useful in different situations, when it is necessary to evaluate the effectiveness of the different bank's internal financial structural unit as levels of the bank's decision making hierarchy.

ACKNOWLEDGEMENTS

The research work reported in the paper is partly supported by the project AComIn "Advanced Computing for Innovation", grant 316087, funded by the FP7 Capacity Programme (Research Potential of Convergence Regions) and partially supported by the European Social Fund and Republic of Bulgaria, Operational Programme "Development of Human Resources" 2007-2013, Grant № BG051PO001-3.3.06-0048.

REFERENCES

Atanassov K. (1983) Intuitionistic fuzzy sets, VII ITKR's Session, Sofia, June 1983 (in Bulgarian).

Atanassov K. (1986) Intuitionistic fuzzy sets. Fuzzy Sets and Systems. Vol. 20 (1), pp. 87-96.

Atanassov K. (1999) Intuitionistic Fuzzy Sets: Theory and Applications. Physica-Verlag, Heidelberg.

Atanassov K. (2012) On Intuitionistic Fuzzy Sets Theory. Springer, Berlin.

Atanassova, V. (2013) From fuzzy to intuitionistic fuzzy: Easy and lazy. Notes on Intuitionistic Fuzzy Sets, Vol. 19, 2013, № 3, 51-55.

Shahpazov G., L. Doukovska (2012) 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, Geneva, Switzerland, ISBN 978-989-8565-26-6, pp. 159-164.

Shahpazov G., L. Doukovska, K. Atanassov (2013) 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, pp. 292-297.

Shahpazov, G., L. Doukovska (2013) Generalized net model of internal financial structural unit's functionality with intuitionistic fuzzy estimations. Notes on Intuitionistic Fuzzy Sets, Vol. 19(3), 111-117.

Zadeh L.A. (1965) Fuzzy Sets. Information and Control Vol. 8, pp. 333-353.