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ADVANTAGES OF FUZZY APPROACH COMPARED TO PROBABILISTIC APPROACH IN PROJECT EVALUATION

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Abstract. Uncertainty is often encountered in relation to randomness or fuzziness. In the case of randomness, it can be described by means of a probability distribution; in the case of fuzziness, the fuzzy theory is applied. In the theoretical part, the authors deal with basic tools for describing both types of uncertainty. Probability and fuzzy method are interpreted in the context of their analogies and principal differences. Both techniques are applied in order to quantify the present expected value of a specific development project. The probabilistic solution leads to the point value E[PV], the fuzzy solution establishes the triangular fuzzy number with the subjective E[PV] not burdened with possible exaggerated expectations. The fuzzy approach proved to extend the probabilistic outcome by other additional information useful for decision-makers with different risk propensity.

Keywords: uncertainty; expected value; fuzzy number; risk propensity; evaluation

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1. Introduction

There is no doubt that in the last few years, there has been a massive development of artificial intelligence methods in the world and their implementation directly into practice (Horák et al, 2020). In connection with this, Vochozka (2016a) tried to find out whether the results obtained using neural networks are better than the results obtained using regression analysis. Horák and Machová (2019) compared both of these approaches on the example of the prediction of PRC exports to the USA. Vrbka et al. (2019) in turn used neural networks to predict the trade balance between the PRC and the USA with regard to seasonal fluctuations. Besides neural networks and genetic algorithms, this area includes approaches or systems that are based on fuzzy logic. A common feature of the above methods is the fact that they are inspired by nature and natural phenomena (Amari, 2013).

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The English term “fuzzy” (meaning blurred, vague, unclear) is referred to in Běhounek and Cintula (2006) as a mathematical discipline that works with a well-defined notion of inaccuracy. Kuchta (2000) adds that this refers mainly to the theory of fuzzy logic and fuzzy sets. Zadeh (1965) is the author of the formulation of fuzzy sets in the 1970s. This approach gained popularity at the turn of the 1980s and 1990s thanks to its fascinating applications implemented in Japan and subsequently in other countries. Since then, fuzzy approach has been considered a completely standard method. Dourra and Siy (2002) state that this approach can solve originally unsolvable problems in many areas, as it is simpler than other methods. Herrera et al (2009) consider the possibility of including inaccuracy and a relatively easy way of working with the meanings of natural language, which is one of the most important parts of human life, to be an essential source of success. Fuzzy approach is applied especially in regulation and control, and can be found more and more often in classification, decision-making, image recognition or in currently increasingly popular area of prediction (Ansari and Abu Bakar, 2014). Wang (2019) also used Fuzzy's approach to predict corporate financial distress. The applicability of this approach was proven and verified on a set of 180 companies, of which 50% were in financial distress and the other 50% were companies that were in no financial need. In contrast, Hašková (2016) used Fuzzy logic to assess the risk to which the investor is exposed. Models based on the correct use of fuzzy logic and a fuzzy set of devices to reveal the uncertainty of experts' reasoning, which ensure the authenticity of scientific results focused on the technology improving the security of crowdfunding platforms, are found in the work of researchers Polishchuk et al. (2019), etc.

Hašková (2019) states that one of the reasons for the inaccuracy of any prediction may be the lack of information needed to eliminate the uncertainty that can be encountered in any non-deterministic environment. If the uncertainty is based on insufficient knowledge of the relevant values of known factors entering the prediction model, it is the so-called external uncertainty (López-duarte and Vidal-Suárez, 2010). In contrast, according to Bloom (2009), the so-called internal uncertainty is based on the approximate nature of the formal description of the considered relationships between the prediction model´s inputs and outputs. In both cases, the uncertainty of two different types can be encountered. Within the research of the issue, we find the application work of researchers Kelemen et al. (2019), and Polishchuk et al. (2019), as fuzzy models, which are embedded in a generalized algorithm and tested in the example of risk assessment, and quantitative evaluation of projects aimed at initiating the environment in the aviation sector, and an innovative hybrid competency assessment model based on fuzzy logic and a network for neuro-fuzzy assessment as in Kelemen et al. (2021).

According to Woju and Balu (2020), uncertainty is usually classified as random and fuzzy. Random uncertainty arises from the inherent randomness of the physical properties and environmental system, while fuzzy uncertainty stems from the lack of relevant knowledge and inaccurate information about the system (Li et al, 2016). Hašková (2019) adds that when talking about uncertainty in the sense of “randomness”, objectively identified basic characteristics are known, while uncertainty in the sense of “lack of knowledge - ignorance” is usually derived from vague terms - a little, approximately, little, simply, etc. The diverse types of uncertainties and ways to deal with them have been addressed in many studies. For example, Marano and Quaranta (2008) state that the problem of estimating random uncertainty is usually performed by probability theory requiring a large number of samples, while fuzzy uncertainty is usually modelled by possibility theories requiring a small sample.

The objective of this paper is to put fuzzy and probabilistic approach into context. The methodological part identifies the main principles, differences, and analogies of both approaches. In the application part, both approaches are compared on the basis of quantifying the internal value (PV) of a development project. The results are discussed and interpreted. The conclusion part summarizes key facts, principles, and benefits of the contribution from the theoretical and application point of view.

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2. Methodological approach

The most commonly used criterion in managerial decision-making is the expected present value (E[PV]) indicating the value of the expected annual cash flows E[CFi] in years i = 1, 2 to n that are transformed to the moment of decision – see formula (1).

$$\mathrm{E[PV]} = \sum_{i=1}^{n} \mathrm{E}[CF_i] / \prod_{j=1}^{i} (1 + r_j) \quad (1)$$

In (1) CFi, i > 0, symbols of net cash flows generated by the project in i-year of its implementation, rj is the annual discount rate valid in the j-year of the course of the project.

2.1 Public approach in PV evaluation

Probabilistic approach (see relation (1) is used if probability distribution of the frequency of possible cash flows outcomes is known. Otherwise, most decision-makers rely on the subjective opinion and expert knowledge when estimating the series of cash flows from the investment under consideration.
The analysis of probabilistic approach within investment evaluation in terms of E[PV] and its alternatives is addressed in professional literature by e. g. Zinn et al (1977), who analysed and justified the formulas of the expected net present value, variance, and semi-variance of net present values of various cash flow profiles at random time. Tufekci and Young (1987) present the method of the moments of the net present value in probabilistic investment alternatives. The publication of Benzion and Yagil (1987) compares discount methods for the evaluation of multi-time stochastic income flows that are identical and time-independent.

2.2 Fuzzy approach in PV evaluation

Fuzzy approach is based on the theory of fuzzy sets Zadeh (1983) and represents an alternative in the case of uncertain data, for which it is not possible to construct a probability distribution. In reality, a statistical description is seldom available for creating the probability structure of the CF_i values and the values of the discount rates r_j for long-term projects. The basis of the fuzzy set theory is described in detail in e.g. (Hašková, 2017).

In short, a fuzzy set is a class of ordered pairs in which the first element is an element of the universe in consideration, the second element is a part of the interval $\langle 0,1 \rangle$ that assigns each member a degree of membership in a subset of the universe (i.e., to the support of the fuzzy set). The degree of membership reflects the extent to which the element is compatible with the support of the fuzzy set. More specifically, as Hašková and Fiala (2019) state: the set U is a field of reasoning or discussion (a universe in consideration), μ_A: $U \rightarrow \langle 0,1 \rangle$ is a membership function, and A = $\{(y, \mu_A(y)): y \in U\}$ the set of all ordered pairs (y, $\mu_A(y)$), in which $0 \leq \mu_A(y) \leq 1$ indicates the membership degree of the pair (y, $\mu_A(y)$) to the set A on the given $y \in$ U. Thus, A is a fuzzy subset of the universe U. An important characteristic of the fuzzy subset A is its support $U_A = \{y: 0 < \mu_A(y) \leq 1, y \in U\} \subset U$. In terms of fuzzy logic, $\mu_A(y) = |y \in U_A|$; herein $|y \in U_A|$ designate the degree of veracity of the statement that y is the element of the support on the fuzzy set A. The element $y \in$ U with the degree of veracity $\mu_A(y) = 0.5$ is called crossover point in A. In the case of veracity degrees greater than 0.5, the element y rather belongs to UA, while in the case of smaller veracity degrees it rather does not belong to it.

The fuzzy subset A, whose support $U_A \subset U \subset$ R, where R is a set of real numbers and its function μA is given by normality and convexity, is called the fuzzy number. There are six different shapes of membership functions μA

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of fuzzy numbers: triangular, trapezoidal, bell-shaped, sinusoidal, cosinusoidal (Kahraman, 2008). The so defined fuzzy numbers can formally represent uncertain variables.

There, the apparent analogy shall be noticed between the function *f(x)* (the probability density of a random variable x) and the function $\mu_A(x)$ (the degree of the element x membership to the support of the uncertain variable – a fuzzy number A). For instance, a similar meaning that in the case of a random variable x achieves an average or expected value *E[x]*, which corresponds to the horizontal coordinate of the gravity centre of the area under the function *f(x)* on its definition field, is represented by the horizontal coordinate of the centre of gravity under the course of the function $\mu_A(x)$ above the interval defined by fuzzy support A in the case of the uncertain variable.

This analogy can be useful when solving problems with variables that are beyond descriptive statistics. In such a case, a reliable point estimation can be carried out using the corresponding coordinate of the position of gravity centre of an appropriate fuzzy number with the support matching to the set of all possible results. In practice, this approach is often applied to measure an issue that is difficult to quantify and it is thus changed for a more easily measurable issue (e. g. the value of the quality of life for measuring GDP – see (Ackoff, 1989).

Let us assume that $A = (A_L, A, A_R)$ and $B = (B_L, B, B_R)$ are triangular fuzzy numbers, where the indexes $_L$ and $_R$ indicate the left and right limits of their supports. Let the middle numbers be the subjectively expected values for which it can be assumed that $\mu_A(A) = \mu_B(B) = 1$ (the subjectively expected values are placed at the centre of the fuzzy number supports; in the case of symmetrical probability density, they coincide with the statistically expected values).

Application of the algebraic operations (+), (–), (⋆) and (/) of the calculus of triangular fuzzy numbers stated in Zadeh (1965), from which we mention $A (+) B = (A_L+B_L, A+B, A_R+B_R)$, $A (–) B = (A_L–B_R, A–B, A_R–B_L)$, $k (\star) A = (k\star A_L, k\star A, k\star A_R)$ and $A (/) B = (A_L/B_R, A/B, A_R/B_L)$, enables the formulation of the fuzzy number PV = (PVL, PV, PVR) in order to describe a model of uncertain cash flows (the fuzzy numbers CF_i) and uncertain discount rates (the fuzzy numbers r_j), as shown in Hašková (2017):

$$PV_L = \sum_{i=1}^{n} \left[\max\{CF_{iL}, 0\} / \prod_{j=1}^{i} (1 + r_{jR}) + \min\{CF_{iL}, 0\} / \prod_{j=1}^{i} (1 + r_{jL}) \right],$$

$$PV = \sum_{i=1}^{n} CF_i / \prod_{j=1}^{i} (1 + r_j), \qquad (2)$$

$$PV_R = \sum_{i=1}^{n} \left[\max\{CF_{iR}, 0\} / \prod_{j=1}^{i} (1 + r_{jL}) + \min\{CF_{iR}, 0\} / \prod_{j=1}^{i} (1 + r_{jR}) \right].$$

3. Practical application

In order to show the differences, both approaches will be applied and analysed within a hypothetical but a realistic decision-making managerial task. Table 1 below shows the basic input parameters of the task and the focus.

Table 1. The imput data of the task

Object of investment	Investment in the construction of a residential building on the outskirts of the capital.
Timetable for completion and possible scenarios	Completion of the construction completion including the inspection of apartments is planned after two years from the start. If there is a one-year delay in the plan, the company decides either to complete the project with annual one-year delay or to sell the project in the third year at an estimated price of EUR 30 million. The possibilities of completing the construction without any delay or with a one-year delay are equal.
Estimate of demand for apartments	In the case of the completion of the construction, the apartments will be sold in the following year. The amount of budgeted revenue from the sale of the apartments (net revenue refers to the difference between the revenues from the sale of the apartments and the operating costs, paid fixed costs associated with the investment and income tax) depends on the development of uncertain demand for apartments. In the case of selling the apartments in the third year, strong demand is estimated with an 80% probability and weak demand with a 20% probability; in the case of postponing the sale, strong demand is estimated with a 60% probability of 60 % and weak demand with a 40% probability.
Project´s discount rate	The discount rate of the project r is equal to the average project capital costs of 15 %. As the company does not intend to change the structure of its long-term funding sources, it is considered a constant.
Net revenues scenarios	The prediction of net revenues in the third year N31 and N32, and the fourth year N41 and N42 from the sale of the apartments are shown in the decision tree in Figure 1.
The managers´ goal	a) To assess the project within its expected value E[PV]. b) To specify the maximum investment if the project is loss-making concerning an adequate project risk rate.

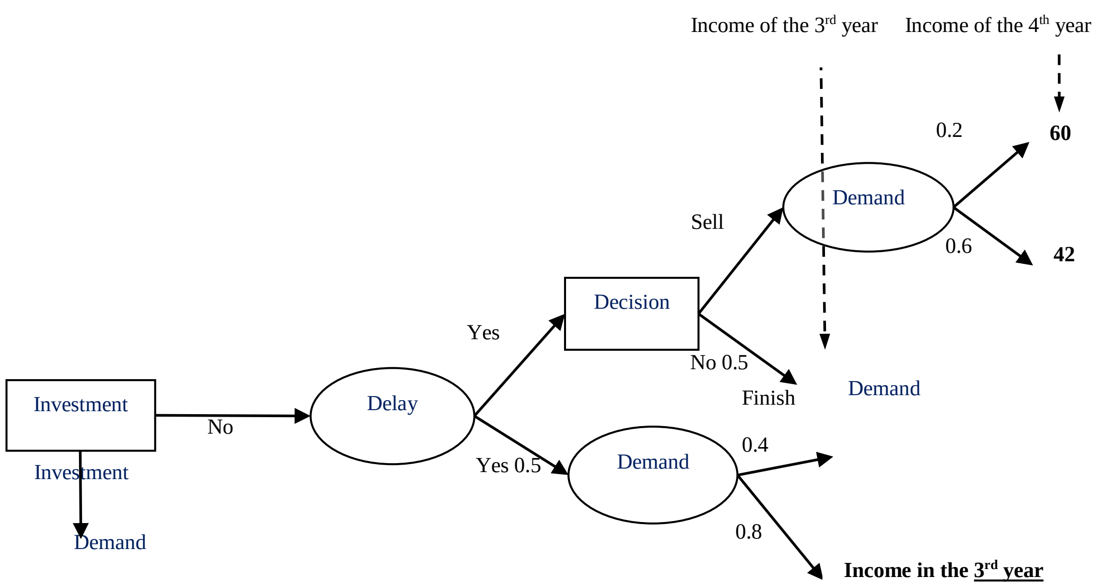

Figure 1. Project decision tree at current prices of the 3rd and 4th year in millions of EUR

Source: Own processing.

Additional analyses r performed enable assessing whether the probability criterion E[PV] plays a decisive role in the manager decision-making.

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3.1 Probabilistic evaluation of task based on *E [PV]*

The model of the decision tree (see Fig. 1) shows the probabilistic solution to the task. The input parameters are the point estimations of the net revenue random variable. Completion time and estimate of demands are also random variables described by the probabilistic distribution. The positive values of the revenue estimates suggest that E[PV] > 0 (see the goal a)). The goal b) focuses on answering the question of "How much to invest (I = ?)" – the first decision node.

In the second decision node (Decision), two values are compared: the amount of EUR 30 million from the sale of the project outcome in the 3rd year and the statistically calculated amount of net revenue $(0.6 \cdot 42 + 0.4 \cdot 28) / 1.15 = 31.65$. This amount is higher than 30 million; therefore, the "Decision" node can be cancelled. This enables the simplification of the tree structure in Fig. 1 into the form shown in Fig. 2. Each of the four scenarios is evaluated by its current value $PV_{ij} = N_{ij} / (1 + r)^i$ to the time t = 0 (I = ?), where Nij represent the net revenue in the 3rd and 4th year of the project implementation. It applies that $E[PV] = 0.3 \cdot PV_{41} + 0.2 \cdot PV_{42} + 0.4 \cdot PV_{31} + 0.1 \cdot PV_{32} = 0.5 \cdot (0.6 \cdot PV_{41} + 0.4 \cdot PV_{42}) + 0.5 \cdot (0.8 \cdot PV_{31} + 0.2 \cdot PV_{32}) = 0.5 \cdot (E[PV_4] + E[PV_3])$. The last derived equality enables further reduction of scenarios, as shown in Fig. 2 below, in which $E[PV_4] = 36.4 / 1.15^4$ and $E[PV_3] = 53.8 / 1.15^3$ have the same probability of occurrence.

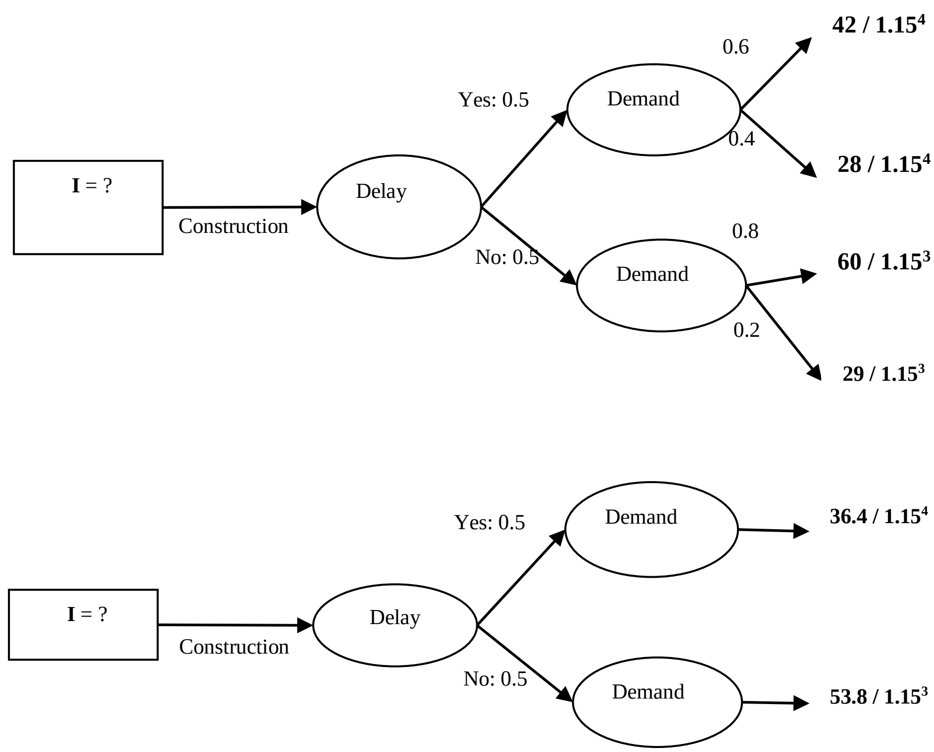

Figure 2. Simplifications of tree structure shown in Fig. 1 based on results of managerial calculations

Source: Own processing.

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The sought solution of E[PV] = 0.5 · (E[PV4] + E[PV3]) = 0.5 · (36.4 / 1.154 + 53.8 / 1.153) ≈ 28.1 million EUR. This also provides information about the maximum possible investment in a project that is not loss-making

3.2 Fuzzy evaluation of task based on interval values

The fuzzy approach deals with uncertainty by replacing the point estimates with triangular fuzzy numbers in the form of (L, S, P); the left edge of the interval (L) indicates the smallest considered value, the right edge (P) indicates the largest estimated value, and the centre (S) represents the middle of the interval. The S value is formed in accordance with the principle of indifference (Pettigrew, 2014). It results from its nature that when multiple alternative outcomes occur with no relevant reason to prefer one over another, they will be assigned the same probability. Therefore, S is the subjectively expected value, which does not converge to any of the interval limits (based on the observation, the statistically expected value is objective). The task in question contains uncertain data on future demand, which makes the resulting net revenue value uncertain as well.
The subjectively expected value of the fuzzy procedure is 35 / 1.15 ≈ 30.4, which is compared with the expected amount for the sale of the project outcome - EUR 30 (see Fig. 1, the upper "Decision" node). As the subjective value is higher than 30, the upper "Decision" node can be ignored and the model can be constructed in a reduced way in analogy to Fig. 2 to get Fig. 3, where the second subjective value is 44.5 (see the "Demand" node in Fig. 1 and Fig. 2, above).
The application of the tools of interval calculus leads to the following solution:

$$E[PV]_L, E[\mathit{PV}], E[PV]_R) = (0.5 \cdot 28 / 1.15^4 + 0.5 \cdot 29 / 1.15^3; 0.5 \cdot \mathit{30.4} / 1.15^4 + 0.5 \cdot \mathit{44.5} / 1.15^3; 0.5 \cdot 42 / 1.15^4 + 0.5 \cdot 60 / 1.15^3) = \mathbf{(16.3; \mathit{23.3}; 31.7)}, \quad (3)$$

Where the subjective E[PV] of potential net revenue from the sale of the apartments is written in italics.

The fuzzy E[PV] number (16.3; 23.3; 31.7) can be viewed as an interval of possible present values generated by the project, in which the left number represents a pessimistic scenario, while the right number can be perceived as a result of an optimistic scenario, and the middle number represents the subjectively expected value. It shall be noticed that the interval range also provides information on the maximum investment costs for a project that is not loss making.

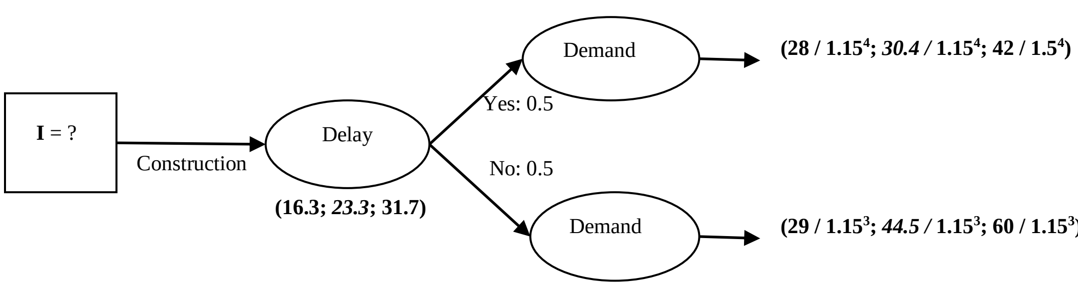

Figure 3. Reduced model of task - fuzzy approach perspective

Source: Own processing.

4. What do the analyses indicate?

Fuzzy analysis extends the standard probabilistic result by other information. These particularly follow from the nature of the fuzzy number $\underline{E[PV]}$ = ($E[PV]_L$, E[*PV*], $E[PV]_R$), whose limit values indicate the smallest and highest possible present values of the project with the middle value representing the *subjectively* expected one. The range ($E[PV]_L$, $E[PV]_R$) provides an idea about the span between the pessimistic and optimistic development of the project in terms of its expected outcomes.

The fact that the *subjective* E[*PV*] = *23.3* is lower than the *probabilistic* E[PV] = 28.1 confirms the finding (e. g. in Kahneman (1993) that managers tend to exaggerate positive flows and reduce negative flows. This tendency corresponds with the probability distribution of the demand for the sale of the apartments both in the 3rd and the 4th year of the project in question. This tendency can result in late completion of projects and exceeding the planned budget; consequently, in some of them, the expectations of the investors may even never be fulfilled (Vochozka, 2016b).

A manager assuming on the basis of E[PV] = 28.1 that the investment of EUR 27 million will provide him with, for instance, a minimal required profit of EUR 0.8 million, is wrong. The fuzzy analysis says that the achievement of this objective is most likely if the initial investment does not exceed EUR 15.5 million (i.e., 0.8 less than the value of pessimistic scenario PV_L). Thus, a question arises whether the project would be feasible under these circumstances. The answer depends, among other things, on the investor's willingness to take risks.

From the above, it is clear that knowing the limits of the possible interval values $\underline{E[PV]}$ provided by the fuzzy approach can be useful; it provides the decision-makers with extra information in terms of possible development project scenarios.

5. Conclusions

In the area of management, uncertainty of different types is encountered. The basic distinction sees uncertainty in the sense of randomness and uncertainty in the sense of fuzziness. The first type mentioned could be described, for instance, by a probability distribution, while in the latter case, the technique of fuzzy approach has been successfully proved.

The most commonly used probability criterion in financial management is the expected present value E[PV]. In the fuzzy approach, the decision criterion is performed by the fuzzy number $\underline{E[PV]}$ = ($E[PV]_L$, E*[PV], $E[PV]_R$) of uncertain cash flows ($\underline{CF_i}$ fuzzy numbers) and uncertain discount rates ($\underline{r_j}$ fuzzy numbers). L and R stand for the left and right limits of the support of the fuzzy number.

The analogies and differences of the approaches were described in order to determine the value of the project of constructing and selling apartments by means of E[PV] and $\underline{E[PV]}$. The comparison revealed that the fuzzy approach extends the standard E[PV] result by additional information. More specifically, E[PV] is a weighted average, whose calculation erases all limits given by the project´s extreme scenarios. The fuzzy number $\underline{E[PV]}$ = ($E[PV]_L$, E*[PV], $E[PV]_R$) provides decision-makers with an interval of possible values where the centre value is a subjectively expected value not burdened with excessive optimism or scepticism. Taking these limits into consideration provides useful information to decision-makers with a different propensity to risk.

The above stated advantages of fuzzy approach compared to the probability approach are the original benefits of the application. The theoretical superstructure identifies the analogy between the probabilistic and fuzzy approach.

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