FUZZY PAYBACK PERIOD OF INVESTMENT INTO MODERNIZATION OF PRODUCTION NETWORK

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Abstract

The difference between the result of managerial calculations and reality can be largely attributed to uncertainty. In the case of discounted payback period (DPP), it concerns uncertain capital expenditures, positive cash flows, and discount rates. To resolve this problem the intervals of possible values instead of uncertain point values should be regarded. This idea is projected in defining the significant points of the input parameters for the DPP calculation from which the significant points of the fuzzy payback period (FPP) in the sense of triangular fuzzy numbers (TFN) are derived. For the TFN ranking, the weighted method is used. The FPP numerical formula thus becomes flexible in terms of the possibility of expressing faith in the incidence rate of the input data. The existing literature omits to regard negative weights for positive and/or negative cash flows in the FPP calculation. In the application, the relations are applied to the quantification of the FPP interval of possible values, by means of which the investment plan for the modernization of the lignite power plant is evaluated.

Keywords

Fuzzy payback period; Discounted payback period; Investment decision; Production network; Uncertainty.

Introduction

Management practice uses several methods to decide on investing in a long-term business plan. Some of them are based on a one-criterion evaluation of economic efficiency. The most significant representatives include net present value, internal rate of return, and discounted payback period. When it comes to the input components of these criteria, they are often associated with uncertainty, which usually has two main sources, the vagueness of the rules and external circumstances beyond the decision-maker. [1]

1 Research Subject

The aim of this article is to show how uncertainty stemming from uncontrollable circumstances can be dealt with, at least partially. For example, the discounted payback period (DPP) determined in a conventional manner e.g. in [2] will almost certainly differ from the actual payback period. This is because the calculation is based on a mathematical model of vague notions that the farther or riskier a project's cash flow (CF_i) is, the less significant value is today. [3] This is because today's money has a bigger value than the same amount expected in the future. However, most of the difference between the DPP calculation result and reality is due to uncertainty associated with ignorance of the exact future capital expenditure points (CF_0), CF_i and discount rate (r). There is a greater chance of estimating the intervals in which the respective point values of the indeterminate variables will be located than correctly estimating the point values themselves. It follows that we will be more successful in estimating the result of the criterion calculation if we use the intervals of possible values instead of indefinite point values. [4]

The article presented builds on this idea and further develops it, inspired by the works of Kahraman [5] and Banerjee and Roy [6]. For the purposes of calculating the discounted payback period (DPP), the "conventional" relationship valid for the point values CF_0, CF_i, and r is first reformulated to the relationship valid for the intervals of possible values $\boldsymbol{CF_0}$, $\boldsymbol{CF_i}$ and $\boldsymbol{r}$.

Within the calculus of intervals represented by their significant points $\boldsymbol{CF_0}$, $\boldsymbol{CF_i}$, and $\boldsymbol{r}$, the significant points of the fuzzy discounted return (FPP) interval are derived. This procedure is demonstrated in the evaluation of the perspective of the investment plan for the modernization of a conventional lignite power plant by the FPP criterion. The fuzzy return criterion is calculated for a specific implementation in the given regional conditions.

The contribution of the article is a new perspective of using the ranking function for ranking the triangular fuzzy numbers according to Chiu and Park [7], which is based on the weight parameter w, the value of which is determined by the evaluator. This allows him/her, based on currently available information, knowledge, and experience, to evaluate the input data flexibly and thus enter into an otherwise "mechanical" computational process. The method presented in this way is meaningful for practice and user-friendly.

2 Literature Review

The investment in the project is characterized by an initial capital expenditure with the subsequent assumption of its gradual return. Marić et al. [8] provide an overview of several static and dynamic methods designed for the economic evaluation of projects. Bhandari [9] and others in their work prove that static methods do not achieve as good results as dynamic methods. The basic dynamic methods of investment evaluation include payback period (DPP), net present value (NPV), and internal rate of return (IRR). There is a relationship between them [8]. Shinoda [10] encourages companies to select the evaluation methods that are most appropriate and accurate for determining the return on investment given the size of the project.

From a theoretical point of view, Bhandari [9] dealt with the discounted payback method. This is the first period in which the accumulated value of net discounted cash flows equals or exceeds the capital investment. The DPP result is compared with the maximum allowable payback period or other criteria, such as the economic life of the project. Bhandari [9] compared this method with other investment evaluation methods. He then presented arguments about its advantages, which are the simplicity of the method, easy calculation, the ability to measure the profitability of the investment, liquidity determination of the investment, and risk reflection. The DPP criterion is widely used in many areas. For example, return on investment in photovoltaic power plants [11], return on investment in various ecological investment projects focused on building heating (insulation, low-energy buildings, biomass boilers, solar thermal systems, and heat pumps) [12], return on investment in agriculture in poultry farming and dairy production [13].

The use of multicriteria analyzes has been shown to be very effective in determining DPP investment [14]. Fuzzy arithmetic has a place in multicriteria evaluation [15]. Dick [16] introduces a comprehensive fuzzy approach as a new topic of computational intelligence. All research in the field of complex fuzzy systems has so far focused on conjunction, disjunction, and negation operators. In this approach, Pythagorean fuzzy sets are extended by the terms anti-membership and anti-non-membership to the already known terms membership and non-membership.

Fuzzy payback period (FPP) is an extension of the concept of the payback method for real cash flows [17]. The construction of the real cash flows generated by the project requires an estimate of future revenues and costs, which depends on many parameters such as the size of inflation, the interest rate, etc. [18]. These variables are uncertain in nature and, unless reliable information on their probability occurs, statistical methods are not appropriate to estimate them. If the source of uncertainty is incomplete information, it is possible to represent the values of variables using fuzzy numbers, which can be interpreted as fuzzy subsets of a set of real numbers satisfying some other conditions. Fuzzy numbers make it possible to model improbability phenomena in a simple way. [19]

Ratiu et al. [20] show that the fuzzy approach is able to capture uncertainty in the development of cash flow and interest rates. Its advantage is the ability to consider both financial and non-financial indicators; it allows, for example, to combine risk dimension, financial return, and non-financial factors [21]. In terms of determining the risk of an investment project, it is possible to use a fuzzy approach to evaluate quantitative and qualitative characteristics through the interpretation of input parameters by fuzzy sets. In this case, the fuzzy approach can function as a decision-making system that assesses whether the risk concern of a given project is justified or not. [22]

Vijayakumar et al. [23] compiled a ranking of evaluation criteria for investment projects. For the overall evaluation of the project, it is good to consider the NPV, DPP, investment size, cost and profitability, and time to make a profit. For the final evaluation of projects, they used a fuzzy approach, which processed the point results of the above criteria and quantities. Sergi et al. [24] propose fuzzy extensions for the most used capital budgeting techniques. It is an extension of NPV methods, equivalent uniform annual value, and benefit-cost ratio (B / C) to interval evaluation of investments using interval-valued Fermatean fuzzy sets and algebraic and aggregation operations.

Briozzo et al. [25] dealt with the modeling of missing data using a fuzzy approach and, for the purposes of applying traditional methods for project evaluation, including the DPP method, analyzed its use. They add that using the fuzzy approach has many advantages. The fuzzy method contributes additional information to the result obtained by the traditional method. The fuzzy method can be applied as a complex method for determining and estimating all input quantities and for individual evaluation of individual components separately, as shown by Ak et al. [26] when evaluating the investment in the wastewater treatment system.

Banda [27] applied a fuzzy payback period to evaluate investment in mining projects and to evaluate mining methods. The financial and technological aspects of individual project variants were evaluated. Kahraman et al. [28] dealt with the implementation of fuzzy logic into other methods used to evaluate investment projects, including FPP. In [29], Kahraman focused on software development, which includes, among other things, a function for evaluating an investment project using FPP. Computational software capable of synthesizing the results of dynamic methods NPV, IRR, cost-benefit ratio and DPP was designed and developed by Samartkit and Pullteap [30]. Fuzzy approach was subsequently used to evaluate the level of probability of the rate of return and the payback period of the investment project.

3 Methodology

The discounted payback period method (DPP) considers the time needed to cover the initial investment costs of the project. The calculation of the DPP considers the time value of money, and thus makes it possible to provide a more objective result with regard to the time and risk factor than the calculation of the undiscounted return. In the following, let us denote C_0 as the investment expense, CF_i as the net return generated by the investment for the period i and r as the discount rate of the project. If $CF_i > 0$ then:

$$\sum_{i=1}^{m} CF_i(1+r)^{-1} \geq CF_0, \tag{1}$$

where m represents the return horizon considering the time value of money. According to the DPP criterion, the investment is realized when discounted payback period is shorter than its economic lifetime.

In the case of uncertain values CF_0, CF_i and r, we substitute into (1) for CF_0, CF_i and r the symbols of the triples of real numbers $CF_0 = (CF_{0l}, CF_0, CF_{0r})$, $CF_i = (CF_{il}, CF_i, CF_{ir})$ and $r = (r_l, r, r_r)$, composed of significant points of intervals of possible uncertain values. Left index l, respectively the right index r in the respective trio indicates the smallest, respectively the largest element of the set of values. The middle number indicates the value of the most common or unexpected element - it is a number whose value we estimate under the standard approach in risk conditions.

For the Triangular Fuzzy Number (TFN) generally represented by the three parameters $\boldsymbol{A} = (a_l, a, a_r)$, for which $a_l \leq a \leq a_r$ applies, and defining the payback period it holds (2):

$$\left(\sum_{i=1}^{m}\left(\frac{CF_i^{l(y)}}{(1+r^{r(y)})^i}\right), \sum_{i=1}^{m}\left(\frac{CF_i^{r(y)}}{(1+r^{l(y)})^i}\right)\right) \geq \left(\left(CF_{2(0)} - CF_{1(0)}\right)y + CF_{1(0)}, \left(CF_{2(0)} - CF_{3(0)}\right)y + CF_{3(0)}\right), \tag{2}$$

where $CF_{k(0)}$ represents the k-th parameter of the triangular fuzzy number CF_0, $CF_i^{l(y)}$ is the left representation of the triangular fuzzy CF_i, $CF_i^{r(y)}$ is the right representation of the triangular fuzzy CF_i, $r^{r(y)}$ is the right representation of the discount rate, $r^{l(y)}$ is the left representation of the discount rate.

If the discount rate varies across periods, then for $(1+r^{r(y)})^i$ and $(1+r^{l(y)})^i$ it holds (3):

$$\prod_{i'=1}^{i}\left(1+r_{i'}^{r(y)}\right), \prod_{i'=1}^{i}\left(1+r_{i'}^{l(y)}\right) \tag{3}$$

There are a few methods for ranking Triangular Fuzzy Numbers (TFNs), for example, Jain [31], Chiu and Park [7], Kaufmann & Gupta [32], and others.

Methods can take different ranking results and most of them require complex mathematical calculations. Chiu and Park [7] present a weighted method for ranking Triangular Fuzzy Numbers with parameters (a_l, a, a_r) as follows (4):

$$\left(\frac{a_l+a+a_r}{3}\right) + wa, \tag{4}$$

where $w \in \langle 0,1 \rangle$ is the value determined by the nature and size of the value a. Another ranking method that does not require complex mathematical calculations is the graded means method (5):

$$\left(\frac{a_l+4a+a_r}{6}\right) \tag{5}$$

which Shanmugasundari & Ganesan [33] used to solve the fuzzy transportation problem.

4 Data

The data of the investment plan for the modernization of a conventional lignite power plant consisting of the implementation of PtG technology were obtained from the article by Straka [34]. Based on the knowledge of technological parameters and production possibilities of the future installation of PtG technology (Power to gas), the author estimates the annual cash flow (CF), which is captured in Table 1.

To carry out the process of so-called methanation (splitting into methane) of emitted CO_2 Straka in [34] estimates electricity consumption for one year at 56,134 MWh, while the current price of 1MWh on the market is around 131 € (at the time of the investment calculation in 2021). The author estimates the water consumption for the methanation process due to the supply of hydrogen at 4,806.5 m^3 at an average price of 3.5 € / m^3. The fixed operating costs of the entire facility are estimated at € 430,500. The total annual expenditure is calculated at € 7,800,877.

The author calculates annual revenues from the operation of the facility as follows: sales of produced oxygen due to the production possibilities of the technology are estimated at € 12,819,384, sales of methane at € 1,551,184, sales of waste heat the author estimates at € 645,227. Recycling of waste CO_2 reduces its emissions into the atmosphere, which results in a reduction in the cost of obtaining emission allowances. The price of the emission allowance per 1 ton of CO_2 emitted was at the level of € 25 at the time of the investment calculation. Due to the amount of recycled CO_2, this represents a saving of € 146,905. The budgeted value of the annual cash flow is € 7,361,823.

Tab. 1: *Estimation of cash flows*

Item	**Amount**	**€ / unit**	**€ / year**
Electricity consumption	56,134 MWh	131 € / MWh	7,353,554.00 €
Water consumption	4,806.5 m^3	3.5 € / m^3	16,823.00 €
Fixed operating costs	430,500	€	430,500.00 €
Total expenditure			7,800,877.00 €
Oxygen sales	8,546,256 kg	1.5 € / kg	12,819,384.00 €
Sales of methane	1,666,625 kg = 23,152 MWh CH4	67 € / MWh NG	1,551,184.00 €
Sales of waste heat	11,731 MWh	55 € / MWh	645,227.00 €
Saving CO2 emission allowances	5,876,208 kg	25 € / ton of CO_2	146,905.00 €
Total revenue			15,162,700.00 €
Annual cash flow			**7,361,823.00 €**

Source: Own processing based on Straka [34]

Capital expenditures for the implementation of PtG technology are estimated at € 21,525,000. A detailed breakdown of investment items is given in Table 2.

Tab. 2: *Breakdown of capital expenditures*

Investment item	**Price (€)**	**Note**
3 alkaline electrolyzers of 3.56 MW, a total of 10.68 MW	12,390,000.00	1,180 € / kW
2 medium pressure gas tanks (O_2 and H_2)	2,940,000.00	490 € / kg
Methanation reactor	2,478,000.00	20 % ALE*
CO_2 capture unit	2,478,000.00	20 % ALE*
Other and unforeseen expenses	1,239,000.00	10 % ALE*
Total investment costs	**21,525,000.00 €**	

*Purchase price of alkaline electrolyzer

Source: Own processing based on Straka [34]

Straka [34] used the conventional approach to calculate the discounted payback period of 3.8 years at a discount rate of 8% and 5.1 years at a discount rate of 15%. Given the estimated lifetime of the project since its commissioning, the results of the return show a promising investment.

As part of the evaluation of the project, Straka [34] admitted the occurrence of risk and projected it into two different values of discount rates. Further on, we will deviate from the author's conventional approach and consider the occurrence of factors that are inherently uncertain, and their impact on the return result may be significant. Uncertainty in the fossil fuel market (N1), uncertainty on the part of the EU towards conventional power plants (emission allowance prices, fines, taxes) (N2), uncertainty about energy market prices (N3), uncertainty in product gas prices (N4) and/or uncertainty in technology acquisition prices (N5). These uncertain factors are reflected in the uncertain values of CF, capital expenditures, and project discount rate.

The logic of reflecting the effects of uncertainty on the evaluation criterion is directly offered at the time of the ongoing "energy revolution". Let us consider the rapid development of energy market prices, caused by societal pressure to increase the carbon neutrality of EU Member States and the transition to fully renewable energy sources [35], which is currently stimulated by the Russian-Ukrainian war [36], the turbulent development of prices in the market for technologies, energy, building materials or services, driven by pandemic restrictions and the slowdown in efforts to curb mining earlier. [37]

Uncertainty factors N1-N5 have an impact on the uncertainty of the project input data, which can in fact be projected in the intervals of possible values of the input investment CF_0, annual cash flow CF_i generated for the lifetime of the project and discount rate r as $CF_0 = (CF_{0l}, CF_0, CF_{0r})$, $CF_i = (CF_{il}, CF_i, CF_{ir})$ and $\boldsymbol{r} = (r_l, r, r_r)$, where index 0, respectively *I*, indicates the period of capital expenditures in year 0, respectively, the period of positive cash flows. Left index *l*, respectively the right index *r*, indicates the smallest, respectively, the largest element of the set. The middle number indicates the value of the most common or most expected element (the value we estimate under the standard risk approach).

Table 3 shows the intervals of possible CF_0 values, annual CF_i and $\boldsymbol{r}$ identical for the expected lifetime of the investment.

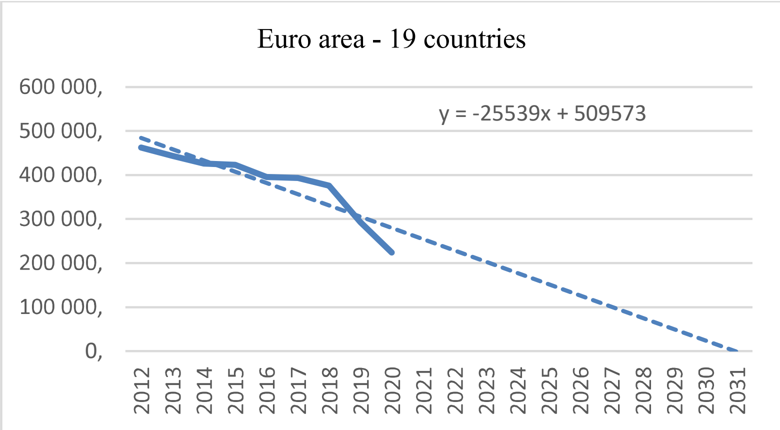
Tab. 3: *Intervals of limit values of uncertain variables*

Uncertain variable	CF_0 in thousands €	Annual CF_i in thousands €	Annual $\boldsymbol{r}$ in %
Range of possible values	(-25,502; -21,252; -17,001)	(5,889, 7,361, 8,833)	(8; 11.5; 15)

Source: Own

The range of possible values of the interval CF_0 and CF_i was determined by a deviation of +/- 20% from the budgeted value, see Tables 1 and 2, the range of possible values of the interval ***r*** is defined by the minimum and maximum rate *r* reflected in the standard DPP calculation.

The minimum lifetime of the investment, resulting from the forecast for coal mining in the Eurozone, is estimated at 9 years if the investment is put into operation in 2022. [38] The estimate was made based on data representing the development of fuel coal production in thousands of tons in the period 2012-2020 in the Euro area region of 19 countries. The trend of this development and its future approximation is shown in Figure 1.



Source: Own processing based on [38]

Fig. 1: *Development of mining in the Euro region of 19 countries*

5 Results

In accordance with the methodology in part 2 and according to (4), we use the classification method to sort the Triangular Fuzzy Numbers (TFN) according to Chiu & Park [7].

In case that of $w = 0.2$ for positive and negative *CF* (Table 3) we get (in thousands €):

$$X_0 = (-(25{,}502 + 21{,}252 + 17{,}001)/3) + 0.2(-21{,}252) = -25{,}500$$

$$\text{TFN}_1 = \frac{1{,}472y + 5{,}889}{1.15 - 0.035}, \frac{-1{,}472y + 8{,}833}{1.08 + 0.035} = (5{,}281;\ 6{,}602;\ 7{,}923)$$

$$X_1 = 7{,}922$$

Due to the identical interval of annual *CF*´s across the project lifetime, the interval of possible values of TFN_i, hence the fuzzy value X_i, where $i = 1\dots m$, and m represents the year of the project in which the investment is repaid, is the same. In this case, $m = 3.21$

The result of the method is a dependent variable of the subjective choice of weight w. Given that investment flows tend to have a different nature of "certainty" than the income flows generated by the investment, this is considered in the following such that $w_0 > w_{CF}$, where index 0, respectively, *CF*, is the weight of capital expenditure, respectively of a positive cash flow. We base on the findings of proven practice that projected capital expenditures are a safer flow than projected revenue flows. In the case where $w_0 = w_{CF}$, respectively, $w_0 < w_{CF}$, expresses the evaluator neutral attitude to the occurrence of CF_0 and CF_i, respectively, the evaluator tends to believe in a higher value of the occurrence of future positive flows compared to negative flows.

Consider the turbulent period 2021/2022, within which the uncertainties N1-N5 can be identified. As a result, the evaluator chooses $w_0 = 0.5$ and $w_{CF} = 0$. Then

$$X_0 = (-(25{,}502 + 21{,}252 + 17{,}001)/3) + 0.5(-21{,}252) = -31{,}878,$$

$$TFN_1 = \frac{1{,}472y+5{,}889}{1.15-0.035}, \frac{-1{,}472y+8{,}833}{1.08+0.035} = (5{,}281;\ 6{,}602;\ 7{,}923),$$

$$X_1 = 6{,}602.$$

In this case $m = 4.82$.

Table 4 presents the results of m when $w_0 = 0.5$ for $X_0 = -31{,}878$ and $w_{CFi} = 0, 0.1, 0.2, 0.3, 0.4$ and 0.5 to calculate X_i from the range of possible TFN_i values.

Tab. 4: *Fuzzy discounted payback period of the project in the number of years m depending on the weight w for the calculation of X_i from the range of possible values TFN_i*

w_{CFi}	X_i	m
0.0	6,602	4.82
0.1	7,262	4.39
0.2	7,922	4.02
0.3	8,582	3.71
0.4	9,244	3.45
0.5	9,903	3.22

Source: Own

6 Discussion

The contribution at the theoretical and practical level shows how it is possible to, at least partially, cope with circumstances that cannot be described in a conventional way. Under certain circumstances, the DPP determined by the deterministic relation (1) may differ significantly from the actual payback period. Therefore, relation (1) valid for point values CF_0, CF_i and r was reformulated to relation valid for intervals of possible values CF_0, CF_i and $\boldsymbol{r}$ and defined by TFN relation (2). The weighted method according to Chiu & Park [7] was used for TFN ranking. The reason for choosing the Chiu & Park´s method is the possibility of choosing the weight w, which allows the evaluator to express his / her subjective opinion about the occurrence of the middle cash flow “*a*” of the interval.

The result of the FPP investment is a dependent of a weight change w. With the evaluator's equivalent expectation of positive and negative flows (for $w = 0.2$ and 0.5), the payback period is 3.2 years (the same fuzzy return is calculated according to (5)). In comparison with the results according to Straka [34] it is a return of 7 months, respectively almost 2 years shorter (depending on the choice of the minimum or maximum discounted rate considered by the author).

The approach of equal access to investment and income flows is contradicted by Kothari et al. [39]. Based on empirical data, about 50,000 observations for the period 1972-1997 they analyzed the relative contributions of current R&D investments and long-term, tangible assets investments to future revenue variability. The conclusions showed that both types of investment generate future benefits that are more uncertain compared to investment expenditures, with the benefits of R&D investment being less certain than the benefits of investing in long-term, tangible assets.

Reflecting the greater uncertainty about future revenues compared to capital expenditures and considering several specific uncertainties N related to the task, the weight of the average investment expenditure “*a*” was further set at 0.5. The positive mean flow “*a*” in line with the expectations associated with the greater uncertainty was evaluated with a weight less than 0.5 ($w_{CFi} = 0, 0.1, 0.2, 0.3, 0.4$). Under these conditions, the fuzzy payback period **FPP** = (3.45, 4.14, 4.82) years, where the middle number can be interpreted as the subjectively most expected value of the payback period. Given the estimated lifespan of the investment of 9 years, this is a very promising project.

At w_{CFi} = 0, fuzzy X_i is equal to the arithmetic mean of the *CF* limits. A weight $w > 0$ indicates a higher expectation of the occurrence of the mean value "*a*" with an impact on the fuzzy intake X_i towards the right limit value or exceeding it. The same applies to the behavior of fuzzy expenditures X_0 - with the increased *w* the expenditures grow in the direction to the left of the mean value "*a*".

Using the weighted ranking method assumes a positive *w*. Negative value of *w* would have the opposite effect on X_0 and X_i, but not on the FPP result. The strategy of "weighing" negative and positive flows in the same direction (with a "+" or "-" sign) is unsustainable from a practical point of view. The nature of the sign *w* for a given type of flow and its magnitude has to be primarily given by the evaluator's reasonable belief in the occurrence of the most promising value "*a*".

In our case, when $w_0 = 0.5$ and w_{CFi} = 0, 0.1, 0.2, 0.3, 0.4 and 0.5, the choice of the positive sign type for both flows can be justified as follows: due to the identified uncertainties, both investment costs, especially technology acquisition prices, and income flows, mainly due to rising electricity and heat prices, may increase.

The ranking method with weighs determining the most promising middle value of the *CF* of the project allows the decision maker to flexibly evaluate the input data according to currently available information, according to his/her knowledge and experience under identified uncertainties related to a particular task.

The current literature considers only positive $w \in \langle 0, 1 \rangle$ for positive and negative flows for the purposes of FPP calculation, thus not considering the possibility of negative weights for flows for which a decrease compared to the mean value "*a*" can be expected.

Conclusion

In the world of economics and management, most decision-making problems are characterized as a complex process for which complete information is often not available. The result is usually the difference between the results of the numerical criteria on which the decision-makers rely and the reality. This is largely due to the uncertainty associated with not knowing the exact point input values of the managerial or financial criterion. This fact is circumvented in the article by the fact that instead of uncertain point values we start from the intervals of possible input values. Methodologically, this idea is solved by defining significant points of intervals CF_0, CF_i and *r* and significant points of discounted payback interval (DPP) derived from them. Triangular Fuzzy number for calculating fuzzy discounted payback period (FPP) is defined, which is a parameter for evaluating an investment plan of lignite power plant modernization.

For the TFN ranking, a weighted method was used, based on the weight *w*, which evaluates the mean value of the interval. This allows the evaluator to reflect its own subjective opinion about the occurrence of the middle value of flows. The numerical formula for FPP thus becomes flexible in terms of the possibility of expressing faith in the incidence rate of input data, depending on the currently available information, knowledge, and experience of the evaluator within identified uncertainties related to a particular task. The current literature does not consider negative weights for the subjective evaluation of the mean values of positive and/or negative cash flows, which can cause significant inaccuracies in the outcome in confrontation with reality.

The results of the calculation answer the question of whether the payback period of the project with respect to the expected lifetime of the investment is a promising project. Given the FPP = (3.45, 4.14, 4.82) years, where the middle number is interpreted as the subjectively most expected value of return and the estimated lifespan of the investment is 9 years, it is possible to judge so.

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FUZZY DOBA NÁVRATNOSTI INVESTICE DO MODERNIZACE PRODUKČNÍ SÍTĚ

Rozdíl mezi výsledkem manažerského propočtu a skutečností lze do velké míry přičíst na vrub neurčitosti. V případě diskontované doby návratnosti (DPP) může jít o nejisté vstupy na úrovni investičních výdajů, cash flow a diskontní sazby. S tímto se lze částečně vyrovnat tím, že místo neurčitých bodových hodnot se vychází z intervalů možných hodnot. Metodologicky je toto řešeno definováním významných bodů vstupních parametrů pro výpočet DPP a z nich odvozených významných bodů intervalu fuzzy doby návratnosti (FPP) ve smyslu trojúhelníkových fuzzy čísel (TFN). Pro klasifikaci TFN je použita vážená metoda. Početní formule FPP se tím stává flexibilní z hlediska vyjádření víry v míru incidence vstupních dat v závislosti na aktuálně dostupných informacích, znalostech a zkušenostech hodnotitele. Dosavadní literatura tento aspekt pomíjí. Prakticky jsou dané vztahy aplikovány na vyčíslení intervalového odhadu FPP, který je parametrem pro zhodnocení investičního záměru modernizace hnědouhelné elektrárny.

UNSCHARFE AMORTISATIONSZEIT DER INVESTITION IN DIE MODERNISIERUNG DES PRODUKTIONSNETZWERKS

Der Unterschied zwischen dem Ergebnis einer Managementkalkulation und der Realität ist größtenteils auf Unsicherheit zurückzuführen. Im Fall von diskontierten Amortisationszeiten (DPPs) können dies unsichere Investitionsausgaben, Cashflows und Abzinsungssätze sein. Dies kann teilweise kompensiert werden, indem anstelle von unbestimmten Punktwerten Intervalle möglicher Werte ausgedrückt werden. Methodisch wird dies gelöst, indem die signifikanten Punkte der Eingangswerte für die DPP-Berechnung und die signifikanten Punkte des daraus abgeleiteten Fuzzy-Return-Intervalls (FPP) im Sinne von dreieckigen Fuzzy-Zahlen (TFN) definiert werden. Zur Klassifizierung von TFN wird ein bewährtes Verfahren verwendet. Die FPP-Berechnung wird somit flexibel dank der Möglichkeit, die Rate im Auftreten von Eingabedaten auszudrücken. Die vorhandene Literatur vernachlässigt diesen Aspekt. In der Praxis werden diese Beziehungen zur Quantifizierung der FPP-Intervallschätzung verwendet, die den Investitionsplan für die Modernisierung des Braunkohlekraftwerks bewertet.

ROZMYTA STOPU ZWROTU INWESTYCJI W MODERNIZACJĘ SIECI PRODUKCYJNEJ

Różnica między wynikiem obliczeń menedżerskich a rzeczywistością wynika w dużej mierze z niepewności. W przypadku zdyskontowanego okresu zwrotu (DPP) mogą to być niepewne dane wejściowe dotyczące nakładów inwestycyjnych, przepływów pieniężnych i stopy dyskontowej. Można to częściowo skompensować, bazując na przedziałach możliwych wartości zamiast na niepewnych wartościach punktowych. Metodologicznie jest to rozwiązywane poprzez zdefiniowanie ważnych punktów wartości wejściowych do obliczenia DPP oraz wyprowadzonych z nich ważnych punktów przedziału rozmytej stopy zwrotu (FPP) w sensie trójkątnych liczb rozmytych (TFN). Do klasyfikacji TFN stosuje się metodę ważoną. Formuła obliczeniowa FPP staje się w ten sposób elastyczna pod względem możliwości wyrażenia wiary w częstość występowania danych wejściowych zależnie od aktualnie dostępnych informacji, wiedzy i doświadczeń oceniającego. Istniejąca literatura pomija ten aspekt. W praktyce zależności te są stosowane do ilościowego oszacowania okresu FPP, który jest parametrem służącym do oceny przedsięwzięcia inwestycyjnego modernizacji elektrowni na węgiel brunatny.