

Allocation of logistic risk-investment in public-private-partnership – use of fuzzy TOPSIS method

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Abstract. Appropriate risk assessment related to the project, and then its distribution between partners is the core of cooperation in the framework of public-private partnership (PPP). Risk analysis for investment project in the PPP formula includes: preliminary identification of risks associated with the investment, preliminary assessment and forecast of probability of occurrence of risks in the recommended option of investment implementation, initial analysis of the distribution of risks between a public and private entity depending on the legal and organizational model adopted, including the determination of the appropriate separation between the parties to the contract. The article presents the possibility of using multicriteria methods, in particular fuzzy TOPSIS, for risk assessment and selection of the best contractor for a given project under PPP.

1 Introduction

In modern world, participation of infrastructure, financial investment in private-public partnership is still growing. More and more often investments for building logistic centers are realized in that way. As an experiences from Germany and Italy show, this model of investment realization was, strong support of the government and budget money is one of main features of success of their building. The most often in the basis of a decision about letting private capital to public. Money was an idea that this solution would positively influence not only for time of investment realization but also on savings of budget money and keeping deadlines with work. It should be mentioned that act about PPP in Poland doesn't put a duty of estimation and analysis of risk in enterprises [1]. Necessary condition to join common investment realization is only analysis of its effectiveness and potential dangers. According to art. 11 act. 1 from act about analysis of investment danger it should make it possible to identify risks, describe their optimal allocation and influence on level of public debt and public financial deficit. Optimal risk allocation in the context of projects under public-private partnership should be based on the transfer of particular types of risk. This risk should be transferred for this participant who has the greatest opportunities and opportunities to effectively reduce a given threat [2]. However, it should be remembered, that this is quite abstract concept. In practice, many types of risks are strongly correlated with each other. It is therefore difficult to separate them from each other and achieve a theoretical optimum by allocating to different participants. Nevertheless risk and rules of its share should be an every time point of a discussion [2, 3].

Creating logistic Centre is an expensive investment for many years with lots of risk, which can dishearten potential investors to participation in the project. Those risks are mostly visible in case when initiators want to realism an event in traditional way. Public Sector is worried about difficulties with gaining seers for created logistic infrastructure that contains many point elements. Private sector is afraid of big costs of investment, which should realism not only commercial goals but also social ones, that are not in a circle of private units' interest. Although banks are worried that public sector would not gain enough own money, which could make a guarantee of enterprises being real. In this context private-public-partnership looks to be perfect solution. Creating a partnership is equivalent to effort of allocation of financial benefits from enterprises and risk of its realization [4]. Although all risk is connected to social acceptance of investment realization through external units, is in public sector side. As a law says, responsibility for completing a task is on her. This make asymmetric share of risk. It's similar in case of curve effect experience: external contractor can use it without any constraints, public paymaster only on certain area and in reference to certain tasks [3]. Finding proper proportion between risk and expected benefits is one of key elements of success of public-private partnership. Having following under account in this article we will indicate to method of estimation of infrastructure investment risk realized for public-private-partnership with use of multi criteria method.

Taking the above into consideration in this study, the method of assessing the risk of infrastructural investments realized within public-private-partnership using multi-criteria methods will be indicated [5].

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2 Literature review – defining infrastructure risk

The extent of risk issues has exceeded all limits. The risk is connected with the most fundamental aspects of psychology, mathematics, statistics and history. Dice and a roulette wheel, as well as the stock market or the bond market are natural laboratories for risk research, because they are very easily quantifiable and their language is the language of numbers.

The word "risk" comes from the old Italian *risicare*, which means "dare". In this sense, the risk is a choice rather than an inevitable destiny. Risk is present in all areas of human activity when it is unable to control or accurately predict the future. The terms risk and uncertainty often co-exist or are even identified, but they do not mean the same [6, 7, 8].

Certainty is no doubt. One of the meanings of this term is "state no doubt", which may be a sufficient definition. Antonym of certainty there is uncertainty, which is defined as "doubting the ability to predict the effects of current activities". It is obvious that this term describes the state mind. We are dealing with uncertainty when we see that the effects of those present actions cannot be known with absolute certainty. Risk is the potential variability of events [9]. It is present almost in everything that people do. If this is the case, the result of the action cannot be precisely predicted and uncertainty is felt. Man is exposed to risk wherever activity generates potential benefits or losses that cannot be predicted. Risk is an objective concept and therefore it can be measured.

The first concept of economic risk theory was published by A. H. Willett in 1901. A. H. Willett noticed the diversity of the meaning of the term commonly used in everyday life and made an attempt to unify it. According to him, the risk is the state of the environment, which should be related to the degree of uncertainty of occurrence, and not to the likelihood of materialization [10]. According to this theory, the risk understood as the state of the environment is objective and correlates with subjective uncertainty, and the impression whether the illusion of randomness is only an effect imperfections of human knowledge about objective laws that govern processes in the outside world [8, 11]. The second concept was presented by F. H. Knight in 1921. The main purpose of F. Knight's work was to quantify the uncertainty. In this concept, the risk is measurable uncertainty. Uncertainty which cannot be measured, it is the uncertainty *sensu stricto*, which Knight he called environment unmeasurable uncertainty. F. H. Knight "explicitly stated, that uncertainty was confused with risk, but only risk it is measurable, while uncertainty is unmeasurable [12].

The third basic concept was developed by the Commission for US Insurance Matters in 1966. According to her the risk is uncertainty about a specific event in the conditions two or more possibilities. In this sense, it is a measurable uncertainty, whether the intended objective of the action will be achieved [7, 13].

The extent of understanding risk and uncertainty means that they are not they are perceived in a homogeneous and

unambiguous manner. Their definitions evolving with the development of science are still used interchangeably. In order to distinguish the two concepts, one should pay attention to the objective one and the measurable nature of risk as well as subjective and irrational nature uncertainty [10]. Dependencies and differences between these two concepts illustrate table 1.

Table 1. Relationships and differences between the economic understanding of risk and uncertainty.

Risk	Uncertainty
Realized by business entities part of the uncertainty.	Accidentality resulting from the event from unforeseen behaviors or course of phenomena.
Rational, objective, empirical character	Immeasurable, subjective nature, subconscious.
A posteriori - it refers to cognition, resulting from experience, reasoning about something by way of induction	A priori - it refers to cognition pure, undistorted knowledge from other similar experiences.
An uncertain event, but it's known probability of occurrence	Unpredictable or unlikely happening.
An uncertain event whose effects materialization can be previously estimated.	An accidental event effects of materialization are not possible for an earlier estimate.
Measurable uncertainty of achievement assumed goals	Unpredictability of failure to achieve assumed goals.
Connects with the bonus for taking.	No bonus for acting in a state of uncertainty.

Idea of 'risk' in PPP context never gain one definition and its measure still gives some problems. In the literature concept of 'risk' has many meanings. Its connected to realization of plans to keep existing status quo. It's a consequence of making decision because every single one of them is connected to necessity of forecasting future midsection of surroundings .Because exact prediction of the future isn't possible, those action may not bring desired effects [11, 14]]. Oxford English Dictionary defines risk as "*chance or possibility of danger, loss, injury, etc.*". Although more of definitions concentrates on uncertainty and possibility of an event happening. In this context we can define risk as uncertainty connected to future midsections of surrounding or effects of decision. Moreover many people says that uncertainty and risk aren't identical, saying that risk is objectively co-dependent from uncertainty at it is subjective. In this point of view risk is objectified uncertainty of unwanted event happening [11]. In this context risk is defined by OECD: „*risk as the probability that the actual outcome (for example, sales, costs, and profits) will deviate from the expected outcome*” [15]. According to Furnell risk is “*the chance of an event occurring which would cause actual project circumstances to differ from those assumed when forecasting project benefit and costs*”[16]. According to

UK's Orange Book, risk is “*uncertainty of outcome, whether positive opportunity or negative threat, of actions and events*”[17]. This concept includes possibility of an event with its consequences. That's why “*The risk has to be assessed in respect of the combination of the likelihood of something happening, and the impact which arises if it does actually happen. Risk management includes identifying and assessing risks and then responding to them*” [17]. The definitions quoted above indicate that the risk in relation to investment projects is most often understood as the possibility or the danger of achieving real results that differ from the planned ones. And although these deviations can be both beneficial and unfavourable, in practice the term risk is used in a negative sense.

Noteworthy is the fact that the term uncertainty often appears when defining risk. In the literature on the subject, one can find a position that these concepts are identical [18, 19]. Most authors emphasize that despite the close relationship between these terms, they are not synonymous [6, 13]. Uncertainty it is a broader concept, but the risk is a derivative of uncertainty and is measurable. One of the first researchers in this issue was F.H. Knight, who announced the theory of uncertainty, measurable and unmeasurable.

The one we cannot measure is uncertainty of *sense stricte* [20], and basic criteria that differs uncertainty and risk is possibility to use theory of probability. Uncertainty we can meet when possibility of ginning wanted effects is unknown. Risk occurs when effect of decision we can describe according to mathematical, statistical or estimative possibility. In situation of uncertainty of we cannot predict the decision or describe it with help of any measures. In both cases there are deviations from predicted results [5]. Not to starting wide terminological discourse over risk and uncertainty we can accept that risk is connected to not completing expectations about certain event and it's described by a probability of an event by this formula:

$$\sum_{j=1}^n p_j = 1$$

It should be remembered that necessary condition of risk is existence of uncertainty, which means that every single risk situation is uncertain, although there can occur uncertainty without risk. From long-term investment realization projects point of view a prior meaning has correct management of risk. That's why government should concentrate on those risks that can bring big losses. From public sector point of view, about investment project success is connected to those features: social results, loss of reputation or image but also risk of breaking the partnership with private investor. Moreover there is a risk every time with lateness of realization of the project and unpredictable increase of costs, there than planned. That's why good allocation of risk and its control of level of constructing conditions of agreement with private investor is important. Concentration of public sector mainly on those risk that determine share of roles and obligations of partners is necessary. We should we

conscious that in All time of project investors (private and public) are coping with uncertainty, which makes a catalogue of risk actually unlimited and even the most detailed descriptions may not be able to include them. Nevertheless thank to long duration of agreement and its big content, risk should be underestimated [2, 21]. The risk assessment is the key, being a process used to identify and determine the probability of destructive factors and their consequences. Kaplan and Garrick (1981) presented the risk assessment as a set of three questions to be answered [22]:

- (1) What can go wrong ?,
- (2) What is the likelihood?
- (3) What are the consequences?

Usually in estimation of infrastructure risk investment we can use numerical and quality methods [23, 7]. Among most used numerical methods we should pay attention of ranking method, that uses probability of occur of event and its consequences in a scale from 1 to 5 [1, 4], sensitivity analysis and Monte Carlo simulation [24, 25]. Usually is estimation of risk in projects realized for PPP, its method TOPSIS finds its use , mainly because projects realized because of multi-level partnerships and every single one of them has their own risk features and sources of success. TOPSIS method allows to overall and synthetic analysis of estimation of risk from perspective of all life of the project.

3 TOPSIS method

In recent years, it can be find a wide range of applications of the TOPSIS method. TOPSIS was extended by Chen in 2000 to fuzzy environments, which used a fuzzy linguistic value as a substitute for the directly given crisp value in the grade assessment. This method is used, among others, for the choice of supplier [16, 26, 27], selection of projects and risk assessment [28], evaluation of websites [28], selection of the object [29], etc. It is also possible to find hybrid approaches. In [30], it's proposed an integration of the Fuzzy TOPSIS method of linear programming for credit risk assessment. Sun and others [31] propose creating decision models and rankings based on integration of Fuzzy AHP and Fuzzy TOPSIS methods.

The TOPSIS method (Technique for Order Preference using Similarity to Ideal Solution) is a useful tool that is used to rank variants (alternatives, criteria) during the decision making process. The factor that distinguishes this method is the use of a measure of relative distance to the best solution, which is a model (ideal) and the worst solution, which is anti-ideal [29].

In decision-making analysis it could be found two problems:

1. imprecise defining the decision issue
2. imprecise defining the decision-maker preference.

The reason of this situation can be the lack of precise determination of criteria's level of realization by analyzed variants and uncertainty of consequence of some variants of choice [24].

The main difference between classical TOPSIS and Fuzzy TOPSIS is concerned to definition of decision matrix. In fuzzy TOPSIS method this matrix is defined by triangular

fuzzy numbers. The fuzzy decision matrix choose the appropriate linguistic variables for the alternatives with respect to criteria. Decision matrix is made by fuzzy assessment of decision variants due to further criteria's. These assessments are given by formula [28]:

$$\tilde{f}_k(a^j) = (l_{jk}; m_{jk}; u_{jk}) \quad (1)$$

and this are triangular positive fuzzy numbers where: l_{jk} - pessimistic assessment of j-th variant based on the k-th criterion; m_{jk} – most expected assessment of j-th variant based on the k-th criterion; u_{jk} – optimistic assessment of j-th variant based on the k-th criterion; $l_{jk} \geq 0$; $m_{jk} \geq 0$; $u_{jk} \geq 0$.

In the process of risk assessment of logistic investments, the following stages of calculation can be distinguished on the Fuzzy TOPSIS method [26, 28, 29, 31]:

normalization of the fuzzy decision matrix $\tilde{N} = [\tilde{z}_{jk}]$ where:

$$\tilde{z}_{jk} = \left(\frac{l_{jk}}{\max u_{ik}}, \frac{m_{jk}}{\max u_{ik}}, \frac{u_{jk}}{\max u_{ik}} \right) \quad (2)$$

- benefit criteria;

$$\tilde{z}_{jk} = \left(\frac{\min u_{ik}}{u_{jk}}, \frac{\min u_{ik}}{m_{jk}}, \frac{\min u_{ik}}{l_{jk}} \right) \quad (3)$$

- cost criteria.

1. Calculate the weighted normalized fuzzy decision matrix:

$$\tilde{V} = [\tilde{r}_{jk}] \quad (4)$$

where:

$$\tilde{r}_{jk} = w_j \tilde{z}_{ij} \quad (5)$$

for $i=1, \dots, m$ and $j=1, \dots, m$.

2. Identify the fuzzy positive ideal solution (FPIS)

$$(f_k(\tilde{a}^+)) = \tilde{v}_k^+ = \max \tilde{r}_{ik} \quad (6)$$

and fuzzy negative ideal solution (FNIS)

$$(f_k(\tilde{a}^-)) = \tilde{v}_k^- = \min \tilde{r}_{ik} \quad (7)$$

for $i=1, \dots, m$ and $k=1, \dots, n$.

3. Calculate the distance of each alternative from ideal and negative ideal:

$$d_j^+ = \sum_{k=1}^n d(\tilde{r}_{jk}, \tilde{v}_k^+) \quad (8)$$

and

$$d_j^- = \sum_{k=1}^n d(\tilde{r}_{jk}, \tilde{v}_k^-) \quad (9)$$

for $j=1, \dots, m$.

4. The closeness coefficient S_j represents the distances to fuzzy positive ideal solution and the fuzzy negative ideal solution:

$$S_j = \frac{d_j^-}{d_j^+ + d_j^-} \quad (10)$$

for $j=1, \dots, m$.

5. The alternative with highest closeness coefficient represents the best alternative and is closest to the Fuzzy Positive Ideal Solution and farthest from Fuzzy Negative Ideal Solution.

4 Application of fuzzy TOPSIS method to assessment of risk of logistics investment in PPP projects

We are considering a discrete problem of multi-criteria decision making. The decision problem is: how to choose a contractor who will be realize logistic project PPP. We consider three criteria which represents the possibility of risk: f_1 -the risk of delay in completing construction works, f_2 -the risk associated with a change in the technology of providing services, f_3 -the risk of inability to deliver the contracted number of services. Six of contractor will be assessed due to these criteria.

Table 2. Fuzzy decision matrix

		Offer of a logistics operator						
		a1	a2	a3	a4	a5	a6	
criteria	f1	1	1	3	8	1	1	5
	f1	m	5	5	9	2	2	9
	f1	u	7	6	12	7	5	10
	f2	1	3	2	1	4	3	3
	f2	m	8	3	2	8	5	6
	f2	u	10	5	4	9	5	6
	f3	1	5	4	4	3	7	1
	f3	m	7	7	5	5	9	3
	f3	u	9	10	12	10	12	4

The profitable criteria will be considered, and each of them will be defined by a triangular fuzzy number. Assessment of decision variants against the criteria forming the decision making matrix is provided by the table 2.

The next stage involves steps as outlined in Section 3. Construct a normalized fuzzy decision matrix as shown in Table 3. The step of data normalization is necessary to overcome differences between the units. Normalization also enables valuation measure in the same range of values which is usually between zero and one. In the range

system, 1 represents the highest value in upward movement where 0 represents the lowest value.

Table 3. Fuzzy normalized decision matrix for the selection

criteria		Offer of a logistics operator						
		a ₁	a ₂	a ₃	a ₄	a ₅	a ₆	
criteria	f ₁	1	0,0 8	0,2 5	0,6 7	0,0 8	0,0 8	0,4 2
		m	0,4 2	0,4 2	0,7 5	0,1 7	0,1 7	0,7 5
		u	0,5 8	0,5	1	0,5 8	0,4 2	0,8 3
	f ₂	1	0,3	0,2	0,1	0,4	0,3	0,3
		m	0,8	0,3	0,2	0,8	0,5	0,6
		u	1	0,5	0,4	0,9	0,5	0,6
	f ₃	1	0,4 2	0,3 3	0,3 3	0,2 5	0,5 8	0,0 8
		m	0,5 8	0,5 8	0,4 2	0,4 2	0,7 5	0,2 5
		u	0,7 5	0,8 3	1	0,8 3	1	0,3 3

The next step is constructing a weighted normalized fuzzy decision matrix. For this purpose, the weight vector was as follow (0,35; 0,25; 0,4). To get multi criteria index, data from each of the criteria need to be aggregated. A lot of various methods can be implemented to do this. In this paper weighted mean was used, which can be calculated in two ways: by using arithmetic and geometric mean. Index based on arithmetic mean is generally more popular because of easily understood and implemented.

The next step is to get the fuzzy positive ideal solutions (FPIS) and fuzzy negative ideal solutions (FNIS). After getting the ideal solutions, the next step is to calculate the distance of the alternatives from (FPIS) and (FNIS) using equation (8) and (9), respectively (tab. 6). The last step is to find the closeness coefficient of each alternative, which is calculated according to formula (10): a₁=0,57; a₂=0,42; a₃=0,63; a₄=0,47; a₅=0,49; a₆=0,40.

Based on table 6, it can be seen that the coefficients of the third alternative is the highest value followed by first and the fifth. Based on the coefficients, an alternative to selecting the firms listed on third should be the first choice, followed by selecting the firms listed first and the last one is to select a firm on the sixth.

Table 4. Weighted normalized fuzzy decision matrix

criteria	f ₁	Offer of a logistics operator						
		a ₁	a ₂	a ₃	a ₄	a ₅	a ₆	
criteria	f ₁	1	0,0 3	0,0 9	0,2 3	0,0 3	0,0 3	0,1 5
		m	0,1 5	0,1 5	0,2 6	0,0 6	0,0 6	0,2 6

	u	0,2	0,1 8	0,3 5	0,2	0,1 5	0,2 9
f ₂	1	0,0 8	0,0 5	0,0 3	0,1	0,0 8	0,0 8
	m	0,2	0,0 8	0,0 5	0,2	0,1 3	0,1 5
	u	0,2 5	0,1 3	0,1	0,2 3	0,1 3	0,1 5
f ₃	1	0,1 7	0,1 3	0,1 3	0,1	0,2 3	0,0 3
	m	0,2 3	0,2 3	0,1 7	0,1 7	0,3	0,1
	u	0,3 3	0,3 3	0,4	0,3 3	0,4	0,1 3

In essence, the greater the value of the coefficient indicates the priorities of the decision to be made. This method not only allows the decision maker to provide the rank of each alternative, but also shows the degree of likelihood of alternative selection.

Table 5. Fuzzy positive ideal solutions (FPIS) and fuzzy negative ideal solutions (FNIS)

	Criteria								
	f ₁			f ₂			f ₃		
	1	m	u	1	m	u	1	m	u
FPS	0,23	0,26	0,35	0,10	0,20	0,25	0,23	0,30	0,40
FNS	0,03	0,06	0,15	0,03	0,05	0,10	0,03	0,10	0,13

5 Conclusion

Ensuring the highest quality of logistic services provided is an important element of establishing cooperation in the field of private-public-partnership. Choosing the best logistics service provider can be a choice in the field of multicriteria methods. Many decisions are burdened with risk; the aim is to minimize it.

The article presents a risk assessment procedure for the implementation of PPP projects. The subject of the analysis was potential offers of logistic operators evaluated in terms of the occurrence of risk in the implementation of projects. These offers were evaluated on the basis of three criteria: the risk of the completion of contracted works, the risk of a delay in the delivery of the services. The paper presents the application of Fuzzy TOPSIS method. The main advantage of this method is the ability to quantify the hierarchy of decision variants and the quantitative risk assessment

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