Fuzzy Uncertainty Modelling in Cost and Cash Flow Forecasting in Project

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Abstract. Numerous projects (e.g. more than 50% of IT projects) are not finished within budget and cause serious financial problems to the organisations implementing them. It is thus important to be able to predict the cost of projects and cash flows related to them early enough, in order to be able to assess with the necessary anticipation whether the necessary financial means will be available on time and if not, to take in time the necessary measures to solve the menacing problem. In the paper the sources of uncertainty with respect to project cost and cash flows will be identified and their modelling by means of fuzzy sets will be proposed. Such issues neglected in the project management literature as various taxes, duties and impositions, which belong to the area in which project managers are not experts and where they do not follow the detailed regulations, will be discussed too. They are of high importance, because legal changes in this area come often as a surprise for project managers and lead to serious liquidity problems. The approach will be illustrated with a real world case study, in which one of the authors was the member of the project team.

Keywords: Project cash flow · Project finance · Project budgetary risk

1 Introduction

It is well known that projects are often terminated at a much higher cost than their initial budget foresaw. In Chaos Report (2015) we find the information that over 55% of IT projects exceed their budgets. But the total project budget is only one side of the problem. Project managers have to face also another one, not quite independent of the budget problem but still of a different nature: that of project cash flows. During the whole project course cash payments have to made and the project manager needs to have enough cash inflows or resources for that. If the necessary payments are not made, the project may fall into serious problems. Various penalties and interests or even broken contracts may result in even higher project total cost or in the impossibility of achieving certain project outcomes. On the other hand, often project cash flows are not known exactly in advance.

That is why a lot of research has been made on project cash fuzzy modelling. However, the existing approaches have two basic drawbacks:

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- the modelling is performed on a high level of generality, i.e. the project cash flows are modelled on the level of compound magnitudes, without analyzing their individual components and relations among them;
- the modelling is performed only once, in the project planning phase. The fuzzy estimates of project cash flows are not updated later, which may result in their significant obsolescence and inadequacy.

Thus, the objective of this paper is to propose a method of project cash flow fuzzy modelling which would be a trial to make up for the above drawbacks. The method will be described and illustrated by means of a case study.

The outline of the paper is thus as follows: In Sect. 2 main sources of uncertainty in projects which may influence project cash flows are described. In Sect. 3 the existing research on fuzzy modelling of project cash flows is summarized and evaluated. In Sect. 4 we draw the reader's attention to certain aspects of fuzzy modelling which are not used in the existing literature on fuzzy modelling of project cash flows, but which might help to overcome its above mentioned shortcomings. In Sect. 5 we describe our proposal of the approach to fuzzy modelling of project cash flows. In Sect. 6 the proposal is illustrated with a real world project. The paper terminates with some conclusions.

2 Sources of Uncertainty in Project Finance

Project managers face many types of uncertainty at the planning stage of project. It causes difficulties in preparing an optimal plan. The sources of these uncertainties vary. Uncertainty related to financial categories present in the project plans or affecting the values expressed in these plans are of key importance. Below we present a proposal to divide the sources of uncertainty and extract from them some key financial factors.

There are many classifications of sources of uncertainty in the literature. It is worth quoting the classification from Atkinson et al. (2006), which was created on the basis of research carried out by the Rethinking Project Management Network. It is an organization of academics from fifteen UK universities and many senior practitioners from private, public and voluntary sector organizations. That is mostly why we consider it as worth mentioning.

Authors of the aforementioned paper divide uncertainties in projects into three basic groups:

1. Uncertainty in estimates.
2. Uncertainty associated with project parties.
3. Uncertainty associated with stages in the project life cycle.

Uncertainty in estimates – the most obvious field of uncertainty regarding cost, duration or quality forecasts. The sources of uncertainty in this case are e.g. lack of data, insufficient detail. There are also factors related to the interpretation of these data, such as lack of experience, lack of appropriate procedures or ignorance of the requirements. Uncertainty associated with project parties – this category contains sources as level of performance, quality, availability. It is possible that the parties will perceive the project's goals and their performance differently. Uncertainty associated with stages in the project life cycle – these are typical issues depending on the stage of project life cycle. They can vary according to project specification.

Uncertainty in estimates are key to this paper, from which we extract financial sources of uncertainty. We propose a division of these factors into macroeconomic and microeconomic ones:

1. On a macroeconomic scale there are:
   1.1. Inflation,
   1.2. interest rates,
   1.3. taxes.
2. On a microeconomic scale:
   2.1. costs/expenditures amounts,
   2.2. terms of expenses and receipts,
   2.3. conditions of financing.

The first group are factors that are not considered directly when planning a project but will affect the quantities located in a project plan. It is worth bearing in mind their impact on budgeted numbers.

Inflation is the first example of such factors. Inflation has an impact on all figures in the project budget and thus on revenues and costs. Interest rates can affect the cost of financing. If the project budget involves a loan with variable interest rates, its costs may vary. This may have both positive and negative effects. Taxes are a category that is usually not characterized by short-term volatility. At least when it comes to the scale of taxation which can basically be described as certain data. However, there are some situations that can be an exception, in case of changes in the law.

The second group are the financial factors on a microeconomic scale. Their possible volatility should be referred directly to the shape of the budget. These factors partly result from the previously described group of macroeconomic factors. The first factor is costs – or to be more precise – expenditures. We propose to consider a category of expenditures rather than costs as costs refer more to an accounting point of view. This approach allows to broaden it for example by payment terms. It is obvious that the prices of certain goods and services may change over time. This results either from inflation, as previously described, or from changes in prices on the markets. Therefore, possible changes in prices should be considered at the planning stage. The prices volatility can be minimized by negotiating contracts for services possibly early. Another factor connected with expenditures is payment terms for goods and services. The liquidity of the entity running the project will depend on the payment deadlines and their timing. In the case of earlier payments, there may be a need to finance them with a loan, which will generate additional costs.

The above issues lead to the last category mentioned – the conditions for loans or, more broadly, for obtaining financing. The exact terms of obtaining a loan may not be known at the planning stage, when managers have not yet entered negotiations with financial institutions. In the case of projects organized with the participation of grants from public funds, which can often take place in the example considered here, uncertainty to the amount of funding received may exist.

3 Project Cash Flows and Modelling of Their Uncertainty – State of Art

In the previous section it was shown how many uncertainty factors influence project finance. It is thus clear that if we want to analyse project cash flows, we have to identify all the most important factors. But the papers in the scientific literature which refer to modelling of uncertainty of project cash flows by means of fuzzy numbers (Cheng et al. 2010; Djatmiko et al. 2019; Etgar et al. 1997; Fathallahi and Najafi 2016; Maravas and Pantouvakis 2019; Maravas and Pantouvakis 2012; Mohagheghi et al. 2017; Shavandi et al. 2012; Tabei et al. 2019; Yu et al. 2017) use an expert base approach to express cash flows by means of fuzzy numbers, asking the expert to give fuzzy estimates for total cash flow planned for a certain moment or linked to a project activity. No types of cash flow are distinguished and no factors influencing them. But if the factors influencing cash flows are so numerous and diversified (on the microeconomic and macroeconomic scale, referring to various project parties and to various project phases – which we explained in the previous section), it cannot be possible for an expert, even a very experienced one, to grasp all of them in his or her fuzzy estimation. Thus, in our opinion the only way to model uncertainty in project cash flows in an efficient way is to try to identify their types, their components and all the factors influencing them.

The other reproach we have to formulate with respect to the existing literature on cash flows modeling in projects, is a complete disregard of dynamism. Fuzzy models of cash flows are done once and for all and the fact that projects are element of a dynamic world, where things do change almost continuously, is fully ignored. And the basic rules of project risk management and project control (Project Management Institute 2008) require that risk and uncertainty have to be identified, quantified and then managed and controlled throughout the whole project. In our opinion ignoring this rule may seriously distort the whole cash flow modelling.

A typology of project cash flows is found e.g. in Gatti (2018). The most important categories are: (a) costs of fuel and other consumables, (c) costs of obtaining any other materials, supplies, utilities or services for the project, (d) franchise, licensing, property, real estate franchise, licensing, property, real estate, sales and excise taxes (e) employee salaries, wages and other employment-related costs (f) insurance cost and (g) capital expenditure. Each type of project cash flow is subject to different rules, behaves in a different way and is influenced by other factor. Thus, in our opinion they cannot be treated as one total. An additional problem is that, within each category, we have to adjust individual cash flows, subtracting the quantities unpaid in the given moment (with delayed payment, e.g. in case of materials purchased on credit) and adding the debts relating to the given category and paid in the given moment (e.g. payment of an invoice for materials purchased some time ago).

In conclusion, we have to state that due to the complexity of components of project cash flows and factors influencing them, among which the time is a very important factor, it is in our opinion necessary to subject them to a much more thorough analysis than it has been done in the literature so far. An approach to such an analysis is proposed in the Sect. 5. In Sect. 4 we will draw the readers attention to the fact that certain elements of fuzzy modelling should be used in the proposed approach, in order to widen its possibilities of real world reflection. These useful fuzzy modelling theory elements are not taken into account in the existing literature on project cash flow fuzzy modelling.

4 Non-classical Fuzzy Theory Elements to Be Used in the Proposed Approach

In any modelling based on fuzzy notions, the known elements of the fuzzy modeling theory should be used. Fuzzy modelling is a vast area with a lot of findings (see e.g. (Bector and Chandra 2005); (Novák et al. 2016); (Bezdek et al. 1999)), but in most applications of fuzzy sets to project cash flow modelling only its basic elements are used, which makes fuzzy modelling much less powerful. Here we will mention two example elements of fuzzy modelling, which go beyond the fuzzy sets theory used in the existing literature on modelling project cash flows.

The first problem are arithmetic operations of fuzzy sets. In all the existing applications of fuzzy modelling to project cash flow modelling all arithmetic operations * are defined for λ-cuts of fuzzy numbers $\tilde{A}$ and $\tilde{B}$ ($A^{\lambda} = \left[a_l^{\lambda}, a_u^{\lambda}\right]$, $\lambda = [0, 1]$, B^{λ} analogously) as leading to a fuzzy number defined through the λ-cuts (1).

$$\left[min\left\{a_l^{\lambda} * b_l^{\lambda}, a_l^{\lambda} * b_u^{\lambda}, a_u^{\lambda} * b, a_u^{\lambda} * b_u^{\lambda}\right\}, max\left\{a_l^{\lambda} * b_l^{\lambda}, a_l^{\lambda} * b_u^{\lambda}, a_u^{\lambda} * b, a_u^{\lambda} * b_u^{\lambda}\right\}\right] \tag{1}$$

It is thus assumed that all the couples

$$\left\{x * y,\ x \in A^{\lambda} \text{ and } x \in B^{\lambda}\right\} \tag{2}$$

belong to the λ-cut of the result. But sometimes non-classical fuzzy operations should be used, because in fact not all the couples (2) are possible. This is the case for example when we are dealing with a situation which can be informally described as (big with big, small with small): a_l^{λ} and b_u^{λ} occurring together is impossible – because the fuzzy numbers $\tilde{A}$ and $\tilde{B}$ refer to two correlated magnitudes, where in both the pessimistic or in both the optimistic scenario can occur. In such a case another fuzzy subtraction should be used, defined in Gani and Assarudeen (2012), in order to render properly the fuzzy result of the subtraction.

Another issue which should be taken into account are so called linguistic modifiers (Bouchon-Meunier and Jia 1992). If we have a fuzzy number expressing e.g. the notion "big", we can use linguistic modifiers to transform this fuzzy number into one expressing the notion "vey big", "averagely big" etc. Similarly, if we have a fuzzy number expressing the notion "around 10", we can transform the membership function to render e.g. the idea "still around 10 but bigger values should have a higher possibility". Such transformations allow us to modify the existing fuzzy evaluation on the basis of new information.

In the next section we will show how the wide possibilities of fuzzy modelling can be used in modelling project cash flows. The method will require a lot of effort, so – according to the philosophy of project risk and uncertainty management – it should be applied only to relatively high cash flows, which may have a considerable influence on project liquidity, and thus its ultimate success.

5 Proposal of an Approach to Project Cash Flow Fuzzy Modelling

We propose to use the following approach to the modelling of project cash flows:

Step I. Choose a moment "zero" before project start;
Step II: Identify all the types of cash flow, separating them both with respect to the foreseen moment of occurrence (i.e. cash flows which are not connected formally (e.g. by one single invoice) should be treated separately) and with respect to their types (thus if two cash flows are expected to be linked by a single invoice, but are of a different type – see Sect. 3 – they should also be separated).
Step III: For each individual cash flow *CF* defined in Step II identify all its components which cannot be divided any more. For example, a cash flow "payment for materials purchase" (*PMP*) expected to take place in a certain moment of time should be expressed e.g. as formula (3) shows (no fuzziness is introduced yet):

$$PMP = np \cdot p - npl \cdot p + npe \cdot pe \tag{3}$$

where *np*: number of units purchased in the considered moment, *p*: purchase price, *npl*: number of units purchased in the given moment which will be payed later, *npe*: number of units purchased earlier which will be paid in the considered moment, *pe* – earlier purchase price.

Let denote the formula defining *CF* as $CF\left(c_1^{CF}, \ldots, c_{n_{CF}}^{CF}\right)$, where $c_1^{CF}, \ldots, c_{n_{CF}}^{CF}$ are individual components of the formula (e.g. in case of (3) we have components np, p, npl, npe, pe).

Step IV: For each *CF* define factors that influence the individual components $c_1^{CF}, \ldots, c_{n_{CF}}^{CF}$. The set of factors for each component will be denoted as $F\left(c_i^{CF}\right), i = 1, \ldots, n_{CF}$ and will contain factors $\left\{f_j^{CF,i}\right\}, j = 1, \ldots, m$. These factors should be identified using risk identification methods from the project risk management area (Kerzner 2017; PMI 2009), with focus on financial factors, and will comprise such factors as inflation, current general economic situation, current situation of the suppliers etc.
Step V: For each *CF*, taking into account $F\left(c_i^{CF}\right), i = 1, \ldots, n_{CF}$ and experts opinions, define the best (according to the knowledge of the present moment) fuzzy estimates of $c_1^{CF}, \ldots, c_{n_{CF}}^{CF}$ and the best arithmetic operations to be used in $CF\left(c_1^{CF}, \ldots, c_{n_{CF}}^{CF}\right)$. Use the results of $CF\left(c_1^{CF}, \ldots, c_{n_{CF}}^{CF}\right)$ to make managerial decisions in the project.
Step VI: If the project is still in a phase where there is risk and uncertainty with respect to its final outcome, choose a control moment *t* and go to Step VII. Otherwise STOP.

Step VII: Take all the cash flows *CF* which in moment *t* are still uncertain. For each of them reidentify $F\left(c_i^{CF}\right), i = 1, \ldots, n_{CF}$ and recalculate $CF\left(c_1^{CF}, \ldots, c_{n_{CF}}^{CF}\right)$. Make respective decisions. Go to Step VI.

Such an approach, to be used for large project cash flows, allows to have control over their fuzzy estimates – in the sense that they will be generated:

- using expert opinions not with respect to complex, compound magnitudes, where it is doubtful if the expert can take into account all the complexity of factors influencing the magnitudes, but with respect to individual components of cash flows and arithmetic operations on them;
- not only in one moment before the project start, but on an ongoing basic, in regular control moments, which is in line with the basic philosophy of project management, and additionally, takes into account the uncertainty linked to the project life cycle (see Sect. 3)

The proposed approach will be now illustrated with a real-world case study.

6 Case Study

The example project will be a 3 days long scientific conference, due to take place in June 2020 in an European large city, organized jointly by two universities, for a number of participants equal roughly to 40–50. The conference is a cyclical one – it takes part every two years in another European city. In such a project there may occur all the sources of uncertainty enumerated in Sect. 3. Uncertainty due to various parties taking part in the project may result from a potential divergence between goals of organizational committee and scientific committee. The organizational committee may focus mainly on performance described in financial terms when the scientific committee may put emphasis on scientific level of the conference. As far as project phases are concerned, uncertainty may be linked to: determining the number of potential participants in the planning phase, effective communication between organizers in preparation phase, effective control in implementation phase (during the conference), capturing knowledge and experience in the summary phase after the conference. Inflation may affect planning accuracy in some ways. A conference is usually planned at least several months in advance. During this period, even in conditions of standard inflation, consumer goods prices may increase which will entail an increase in the prices of goods and services. In the conditions of higher inflation these problems will obviously be widened. On the other hand, price uncertainty will cause a problem with determining the amount of revenues understood as contributions from participants. The registration fee set at the planning stage will have to cover the costs of organizing the conference. Attention has to be paid to taxes. There was a case when a change in tax regulations resulted in a change in VAT rates paid by the organization carrying out the project. A university organizing a conference, that had not previously been a VAT payer, was assigned to pay VAT by change in national law. That situation caused significant discrepancies between previously budgeted numbers and real expenses and led to serious problems with accounting for the conference. Thus, there are important uncertainties and risks linked to a conference project which may seriously affect the formal closure of the conference, especially considering that conference organisers are usually not experts in finance.

We will illustrate the approach from Sect. 5, above all with respect to one of the most important cash flows of the conference: participation fees cash inflows (*PF*).

In January 2020 the following evident formula was formulated:

$$PF = n_p * pf \tag{4}$$

where n_p stands for the participants number and pf for the participation fee. In the same moment triangular fuzzy numbers for both n_p and pf were delivered by experts, on the basis of the numbers known from the previous conferences. It was set: $n_p = (30, 40, 50)$ and $pf = (1200, 1400, 1600)$ (in local currency). The difference between the two fuzzy sets was that the concrete realisation of n_p was dependent on both exterior and interior factors (on the publicity, but also on the situation at other universities or on the offer of other conferences), but the concrete realisation of pf was the independent decision of the organisers, which had to be taken on the basis of the relation between (4) and the outflows, which we modelled using the same procedure. We will not enter here into the modelling of the outflows. Let us only mention that their two big components were preparation of the conference materials and the organisation of the conference sessions, breaks and social events. While choosing the subtraction operator for the inflows and outflows, the subtraction from (Gani and Assarudeen 2012) had to be chosen, as more participants mean higher outflows for coffee breaks and social events.

In February 2020 the organizers had access to more information about the possible number of participants, as they had been sent positive signals from the participants from previous conferences. So it was possible to apply a modifier "still about forty, but more than it was thought before" and update n_p to the trapezoidal fuzzy number $(35, 40, 45, 55)$. At the same time, in the fuzzy numbers representing cash outflows the supports were narrowed, as the uncertainty linked to them became lower (after some negotiations with the future suppliers).

In March 2020 it became clear that the coronavirus pandemic had started. The whole concept of the conference had to be changed. The organizers were forced to change the conference into an on-line event. The number of participants became less certain than it was in February, both in the negative and positive direction (the new conference form could be more attractive for some potential participants, because it would be cheaper, but for other potential participants, who like personal exchange, it might be less attractive). Thus n_p was updated to the trapezoidal fuzzy number $(30, 40, 45, 60)$. Of course, the conference fee had to be updated. It was clear it was to be lower, but on the other hand its uncertainty degree (the width of the fuzzy number support) became bigger, as prices of the conference proceedings became more uncertain – due to new circumstances – and a tool for remote conferences was still to be sought for among different offers (the prices of such tool were bound to increase, because of an increased demand). Thus, pf was updated to $(800, 1000, 1300)$.

In the moment when this paper was finished, the story was still going on. But its previous course shows clearly that estimating the highest cash flows in projects cannot be performed on a high level of generality and once for all in a fixed moment. This process has to be detailed and repetitive. Only than the risk of running out of cash in the project can be properly managed.

7 Conclusions

In the paper we propose a new approach to fuzzy modelling of project cash flows, much more detailed and much more attentive to changes in the project and its context than the existing approaches. Its application is linked to much effort, that is why it is dedicated to important cash flows, on which the project fate may depend. For such cash flows the application of the proposed procedure may be of primordial importance, because lack of cash in any project implementation moment may be among the causes of project failure – or at least serious problems.

The proposal is still in its initial stage. It needs real world case studies, where project managers and experts would cooperate on its practical verification. Ideally, it should undergo a development similar to that of project risk management systems: where the process of risk identification, evaluation, analysis, management and constant updating is systematically embedded into (in case of project mature (Souza and Gomes 2015) organizations) the organizational project management system.

The proposal needs also intensive cooperation with fuzzy modelling experts. Fuzzy modelling, including various forms of fuzzy sets, operations on them and relations between them has today a huge potential, which is little used in project financial management. Making use of this potential, in cooperation with experts, might lead to the creation of an efficient project finance management system.

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