PROJECT CASH FLOW FORECASTING WITH IMPRECISE ACTIVITIES SPECIFICATION

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Abstract: *The paper aims to present project cash flow projection in the presence of uncertainty in activity duration and cost. Data specification in the form of fuzzy logic allows combining distinct and imprecise data, and obtaining an optimistic and pessimistic cash flow scenario, as well as several intermediate scenarios. As a result, the project cash flow can be considered in terms of different risk levels. Each scenario can be assessed according to the criteria such as time, cost, and risk level. A presented cash flow generation methodology is based on fuzzy set theory, where data is specified in discretized α-cuts. The proposed approach tends to achieve a balance between complexity of methodology and an intuitive as well as effective tool that is realistic in modelling uncertainty.*

Keywords: *cash flow scenarios, integer programming, decision support system*

JEL Classification: *D81, M15, O22*

1. INTRODUCTION

Cash flow is crucial for the assessment of the difference between project expenditures and payments that determine the necessary capital reserves during project implementation. Furthermore, an accurate cash flow is required in conducting project cost-benefit analysis, the determination of project financing requirements and in performing earned value analysis [1]. Several researchers have applied different approaches to the assessment of project risk, e.g. [2-4], as well as fuzzy set theory or probability theory in project flow generation and analysis, e.g. [5-7]. However, the main focus in the research concerning fuzzy project scheduling is principally on the calculation of early/late start and finish times and the determination of activity and path criticality, whereas issues related to cash flows and uncertainty in cost have not yet been comprehensively addressed [1].

The traditional approach to project scheduling is the well-known CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique). The hypothesis made in CPM that activity durations are deterministic and known is rarely satisfied in real life where tasks are often uncertain and variable [8]. The inherent uncertainty and imprecision in project scheduling has motivated the proposal of several fuzzy set theory based extensions of activity network scheduling techniques. Among these extensions can be found, for instance, resource-constrained fuzzy project-scheduling problem [9], criticality analysis of activity networks with uncertainty in task duration [10], fuzzy repetitive scheduling method [11], fuzzy project prototyping with the application of constraint programming [12], and fuzzy dependency structure matrix for project scheduling [13].

The perception or estimation of uncertainty is encoded in the initial assignment of fuzzy activity duration and cost. Thereafter, in terms of project management, different α-cuts can be considered as separate risk levels [14]. Thus, a framework is provided for conducting risk analysis on the project cash flow with the appropriate α-cuts which limit the degree of fuzziness and essentially provide a measure of the prediction robustness. The risk levels can vary from "none", "low", "moderate" to "very high" as the α-cut moves from 1 towards 0. Moreover, at any given α-cut, besides a delay or cost escalation, there is also an opportunity to go ahead of schedule and reduce costs [1]. The difference between the proposed approach and PERT network diagrams concerns the number of scenarios and the use of integer numbers. PERT assumes only the absolute worst and best scenarios (everything goes worse or better than expected, respectively), whereas the proposed approach includes some possibility levels from 0 to 1.

The goal of this research is to present cash flow generation in project whose durations and costs are uncertain. The model of project planning is specified in terms of α-cuts, what enables the analysis of cash flow risk. The proposed methodology is relatively similar to what practitioners are using to forecast project cash flows and it is considerably more realistic in modelling uncertainty. The proposed approach for project planning allows a decision-maker to perform analysis of cash flow uncertainty at different α-levels, which appears to be more intuitive for forecasting cash flow in project management than alternative methodologies that employ other fuzzy techniques.

2. FUZZY CASH FLOW GENERATION

Given a project P consists of J activities: $P = \{A_1, ..., A_j, ..., A_J\}$, where the j-th activity of the project that is specified by the starting time of the activity $s_{j,1}$ (i.e. the time counted from the beginning of the time horizon), the completion time of the activity $s_{j,2}$, and the duration of the activity t_j. The project P is described as an activity-on-node network, where nodes represent the activities and the arcs determine the precedence constraints between activities. The constraints include, for instance, project deadline, available resources, including financial means. For the above decision variables and constraints, the problem formulation is reduced to a following standard routine query: what is the project cash flow and its uncertainty for the given constraints?

It is assumed that the duration of the activity t_j is determined by convex membership function $\mu(s)$ (e.g. a triangular fuzzy number) and it can be specified as discretized α-cuts [15]. An example of a fuzzy number specified in terms of discretized three levels of α-cuts is illustrated in Figure 1. An α-cut is a crisp set consisting of elements belong to the fuzzy set at least to a degree of α (0 < α ≤ 1). An α-cut is a method of defuzzifying a fuzzy set to a crisp set at desired α-levels that correspond to the perceived risk (α=1 meaning no risk, α=0 meaning the highest risk). Additionally, the low (α=0–) and high (α=0+) values of every α-cut represent the optimistic and pessimistic outcomes of that risk level.

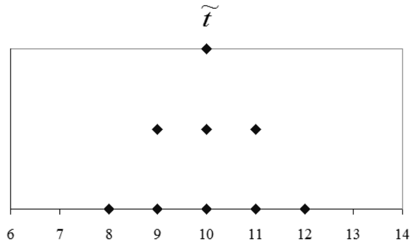

Figure 1 Fuzzy duration in terms of discretized α-cuts
Source: own study

In the project network, the starting time of the activity has distinct form, whereas the completion time of the activity is specified as a fuzzy number. The fuzzy completion time is the sum of the activity start with the fuzzy activity duration (see Figure 2). If in the fuzzy project scheduling algorithm, the start and completion times are in fuzzy form, then the level of uncertainty increases for subsequent activities according to the number of activities with fuzzy duration of activities. As a consequence, this leads to difficulties with the interpretation, as the fuzzy starting time of the activity can be greater than the fuzzy completion time. It is noteworthy that using the presented methodology, the intersection of starting and completion time is impossible and the interpretation is unambiguous.

In order to calculate the required cost per unit of time, the cost of every activity needs to be divided by its duration. However, the duration varies for different possibility measures and for optimistic and pessimistic scenarios. In the absolute best case (minD_α), the activity will start as early as possible and will last the minimum duration. In the absolute worst case (maxD_α), the activity will start as late as possible and will last the maximum duration. Hence, the financial means for all α-levels ($dp_{j,\alpha}$) is proportionately allocated to the activity.

Figure 3 shows an activity with a starting time of <3, 3, 3>, a duration of <8, 10, 12>, and a completion time of <11, 13, 15>. In this example, the duration intervals at α=0.5 are min$D_{0.5}$=[3, 12] and max$D_{0.5}$=[3, 14] and hence the activity cost is distributed in these intervals. In the best case, the activity begins as early as possible (in third time unit) and lasts the minimum duration (9 time units), whereas in the worst case, it lasts the maximum duration (11 time units). Equivalently, minimum and maximum duration intervals representing optimistic and pessimistic scenarios for different possibility measures can be created for all α-levels (between 0 and 1).

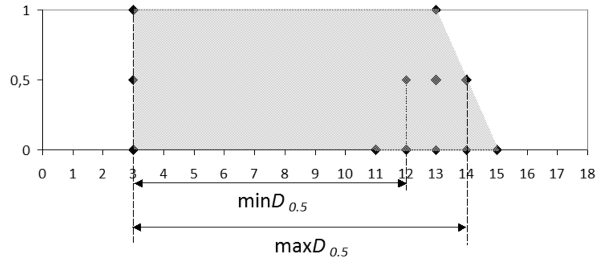

Figure 3 Fuzzy activity start and completion time
Source: own study

The uncertainties of the duration and cost of an activity are positively correlated, so the minimum (minD_0) and maximum (maxD_0) cost distribution per unit of time h of the j-th activity at the level α depict the best and the worst scenario respectively. The presented approach can be expanded for several α-cuts (e.g. 0.1, 0.2, …, 1) for minD_α and maxD_α, generating activity cost accordingly. In this case, a risk assessment of fuzzy cash flow for multiple optimistic and pessimistic scenarios is obtained. In order to illustrate the methodology application, a sample activity network is considered in the next section.

3. EXAMPLE

The network diagram of the project activities is shown in Figure 4. The duration of some activities (A_4, A_7, A_8, A_{10}) is specified in the imprecise form. The sequence of activity duration for the considered project can be described as follows: T = (2, 1, 1, "about 6", 2, 2, "about 6", "about 6", 1, "about 4"). For instance, the duration of the activity A_4 is "about 6", i.e. the activity can be executed within the time period of 4 to 8 units of time.

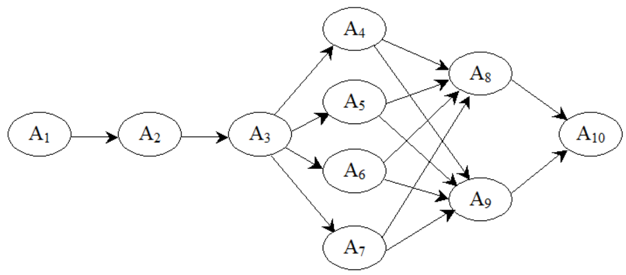

Figure 4 Project activity diagram
Source: own study

Figure 5 presents the project schedule (for α=1), in which the time of project equals "about 20", and sequences of activity starting and completion time are as follows: $S_{j,1}$ = (0, 2, 3, 4, 4, 4, 4, 10, 10, 16), $S_{j,2}$ = (2, 3, 4, "about 10", 6, 6, "about 10", "about 16", 11, "about 20").

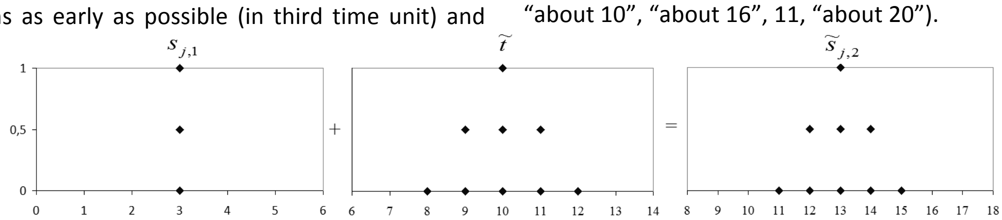

Figure 2 Determination of fuzzy completion time of activity
Source: own study

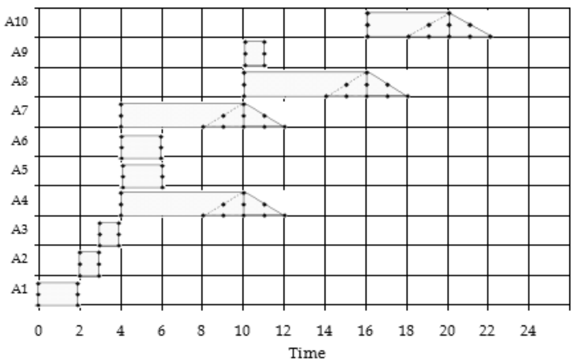

Figure 5 Project schedule
Source: own study

Figure 6 presents five different cash flow scenarios for the project. At α=1, the cash flow (dotted line) is equivalent to that generated from deterministic analysis. At α=0.5, there is an optimistic scenario below and a pessimistic one above (dashed line). In turn at α=0, the optimistic and pessimistic cash flows (solid line) have a wider spread indicating a higher degree of uncertainty. In the best case (minD_0), the project will be completed in 14 months with the total cost of 190 m.u., whereas in the worst (maxD_0) in 26 months with the total cost of 310 m.u.

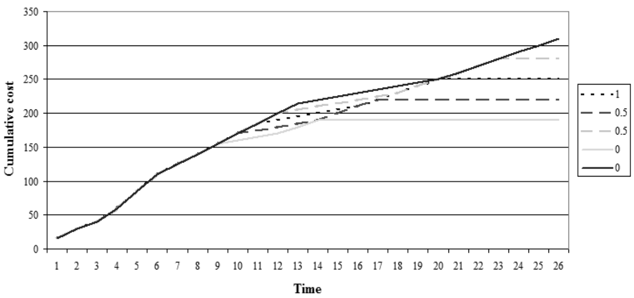

Figure 6 Cash flow scenarios
Source: own study

The presented in Figure 6 S-curves concern the cumulative cost for the project and they are the basis for the detailed cash flow analysis. This analysis can include the required cost allocation in the horizon of the project that is illustrated in Figure 7.

The presented approach allows the decision-maker to consider a wide range of further analyses. For instance, a risk level for cash flow can be treated as an additional criterion choosing a possible variant of a project completion.

4. CONCLUSIONS

Present environment full of turbulent changes concerning technology, economics, and society, influenced e.g. by globalisation and world economic crisis, creates completely new conditions for activities of enterprises [16]. Most projects are executed in the presence of uncertainty and are difficult to manage, due to comprising of many activities linked in a complex way. Hence, there is an increase in demand for new knowledge that enables the solution of problems encountered during complex project execution (e.g. in the development of new products in the automotive industry).

In the project implementation environment, a pure deterministic approach for the study of project cash flow seems to be inadequate. The proposed approach takes into account the elements such as fuzzy activity cost and duration estimations, project S-curves, and cost distribution. Data specification in the form of α-cuts enables the generation of a set of scenarios concerning the project scheduling and cash flows that can be assessed according to criteria such as time, cost, and risk level. Moreover, the use of discrete α-cuts facilitates the combination of distinct and imprecise data.

The limitations of existing commercially available tools (e.g. lack of possibility for data specification in an imprecise form) was the motivation to develop a design methodology for forecasting of fuzzy project cash flow. The output of the proposed approach can easily be communicated to financial managers with limited technical ability who are responsible for securing sufficient project capital reserves and/or monitoring of project execution. Moreover, the presented approach assumes the distinct form of the activity starting time. Consequently, it avoids the intersection of the fuzzy starting and completion time of an activity, and the interpretation is unambiguous. In that context, the presented approach can be considered as a new contribution alternative to project management.

The proposed methodology can be easily incorporated into available fuzzy project scheduling software to provide a better perception of risk which is usually obscured in the conventional approach. The number of α-levels can be modified according to the decision-maker's requirements. As a result, it can assist project managers to gain deeper insight into the sources and extents of uncertainty, which may in turn lead to the avoidance of troubles during project implementation. Moreover, it tends to achieve a balance between complexity of methodology and an intuitive, effective tool that is realistic in modelling uncertainty. Finally, its application in performing earned value analysis during project monitoring may also prove useful.

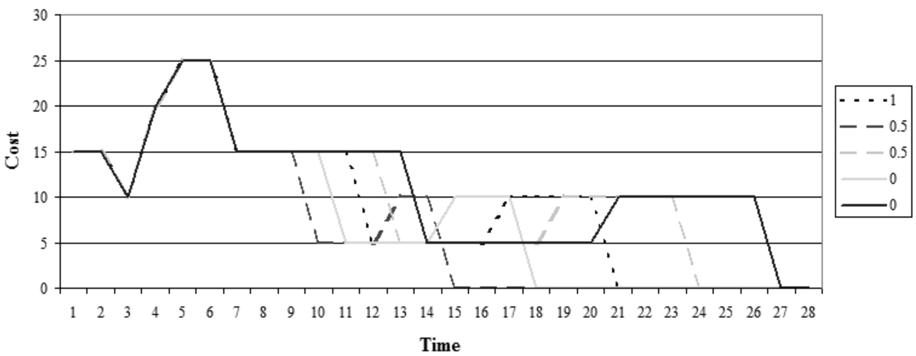

Figure 7 Cost distribution for different cash flow scenarios
Source: own study

Further research focuses on the extension of the proposed approach towards the multi-project environment. Moreover, further research can be aimed at developing a decision support system towards real life verification. The subject of future research also includes an influence the numbers of α-levels on the obtained results.

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