The Impact of Risk Analysis in Project Cost Calculation

Konstantin NOVIKOV and Jana KLEINOVA
Department of Industrial Engineering, Faculty of Mechanical Engineering
University of West Bohemia
Pilsen, Czech Republic
novikov@kpv.zcu.cz, kleinova@kpv.zcu.cz

Abstract

Assuming costs have a major impact for decision making of any project, comparing the variety of cost calculation alternatives, this article emphasis the certainty of a risk degree. Risk is generally taken as part of business and working with affects the financial results of any company. So, it is considered as an uncertain event which leads to the possibility of losing. However, it can also be an opportunity. This research focuses on working with project-related risks, with a developed analyse on costs. In order to build a project budget, it is necessary not only to choose a suitable calculation method but above all is to identify all threats and opportunities and to analyse them thoroughly. Furthermore, it is important to define the procedure by which the risk will be quantified. The output of the study is the design of an appropriate project cost management model.

Keywords
Project, Risk, Costs, Budget, Reserve

1. Introduction

Investment decision making is one of the most important managerial functions at all, and therefore requires highly sophisticated approaches and methods that need to be followed to further develop the business. However, problems with investment decision-making are linked to inadequately suited assessment methods, and firms are making their investment decisions more intuitively. Underestimating this issue can lead to negative consequences. One of the most important factors in deciding on the implementation of the project is the budget. This must include not only all standard cost items but also risks associated with the project.

Risk is generally taken as part of the business, and work with it greatly affects the results of the business. Industrial businesses face a great deal of risks from strategic focus, make-or-buy decisions, quality of delivered products, compliance with negotiated terms to customer's payment risks. The risk is mostly related to the possibility of loss, damage or failure. It can be understood as an uncertain event that, if it occurs, leads to the possibility of losing, but it can also be an opportunity.

Expert literature dealing with project risk issues and their projection into the project budget deals with often rather complex methods and complicated mathematical apparatuses. Using complex procedures for simpler projects can not only be unnecessary and lead to a prolongation and expense of the project, but it can also have negative psychological impacts on the project team. On the other hand, large-scale and complex projects of major importance, important projects with publicly guarded dates or high costs require thorough preparation and detailed analysis. Even in such cases, however, it is advisable to choose the planning method as complex as is strictly necessary. Although this principle, which is actually the paraphrase of Occam's razor for project planning and management, seems to be quite obvious, unfortunately, in practice, it is often not respected. One extreme case is the effort to apply complicated procedures inappropriately to a small scale of the project, which may be motivated by the idea that using such practices will increase the prestige of the people responsible for the project. The second extreme is when an important and extensive project is conducted inappropriately simply without the necessary preparation and analysis of options. Both extremes usually lead to unnecessary prolongation of project duration and increase in project costs. In the latter case, the achievement of project objectives is also seriously threatened.

The aim of this study is to propose a concept for the calculation of project costs, including the methodology of quantification of individual risks and their projection into the budget of the project. The concept thus created should serve not only as a basis for decision-making but also as a tool for cost and risk management. This study is limited by the size of the project. It focuses on special and complex projects. For simple projects, it is possible to achieve a satisfactory result and an easier way. On the contrary, a huge project implies disintegration for better structuring subprojects.

2. Project

The project is seen as a unique set of activities leading to a targeted change of status. This is an unrepeatable sequence of steps that has a temporary nature and limited resources. It usually brings together professionals from different professions in order to achieve the greatest possible synergy effect. The project is always linked to a degree of uncertainty that can have a serious impact on business performance. Therefore, it is important to address the project's risks and to try to identify, limit or completely eliminate them.

2.1 Three-dimensional

Throughout the duration of the project, in all its sub-stages, are the basic and most important milestones of the project:

- Time- from start to finish
- Costs- funds spent on project activities
- Quality- properties, parameters and indicators by which the project goal is defined

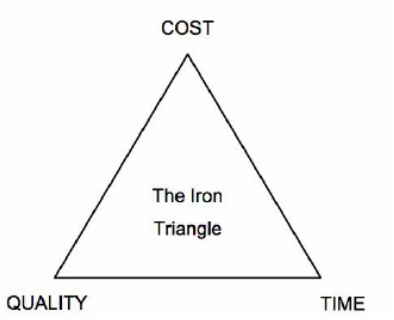

Fig 1. The iron triangle

These 3 project dimensions (as shown in Figure 1) are mutually dependent, and the change to one will cause a change to another or both.

2.2 Project categories

According to book of Doležal (2009) projects can be divided according to their size, cost, scope or complexity. There is no exact boundary, yet each project can be grouped into one of the following four groups:

- Simple, small project with a simple goal, consisting of few activities, a short-term horizon, few people involved
- Special - Medium-sized project with several goals, contains many inter-linked activities, medium-term horizons, temporary assignment of staff to tasks
- A complex large project with many unique goals, many activities and sub-projects, a long term, many resources, the need for a project organizational structure, also requires high costs
- The program - a set of several unique projects, together make it possible to achieve a great and extraordinary goal

2.3 Project phases

The project usually starts with a conceptual design and continues through the definition of the project until its implementation. The period of exploitation follows until the end of the project and the results check. The project can be divided into 3 phases according to the amount of money invested in as mentioned by Rosenau and Milton (2007):

- Pre-investment - defining the main objectives, defining strategies, designing leaders, feasibility studies, evaluating the feasibility study, and admission decisions
- Investment - appointment of the main manager and project team, detailed project processing, tenders to the contractor, controlling, project implementation, start and trial operation, commissioning
- Operation and evaluation - use of project output, processing and submission of the final report, analysis of project progress data

2.4 Types of projects

The business is decisive for those activities that are directed to the direct achievement of the main business goal, i.e. profit. In order to achieve them, however, the enterprise must carry out a number of support activities. The starting point of the book by Šulák and Vacík (2005) is the division of project activities according to the relationship with the company and its surroundings:

- external activities, i.e. deliveries to customers, business activities for procurement and service activities,
- internal activities including bid preparation, research and development, investment and organizational activities.

In addition, activities can be divided into:

- activities generating profits,
- supporting activities.

For a better orientation between the different types, a basic breakdown of the company's activities was made, as shown in the following Figure 2.

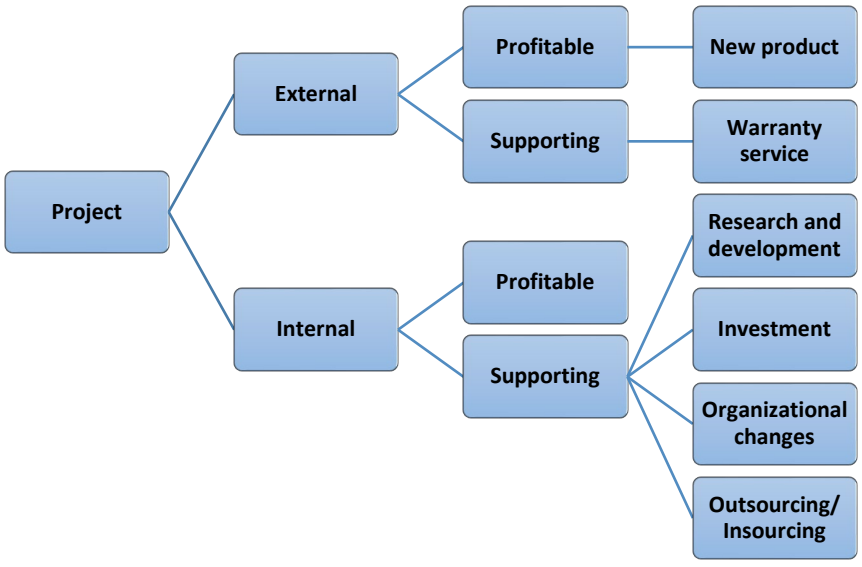

Fig 2. Types of projects

Activities that we consider to be appropriate for project management (managed as projects) include:

- from external activities:

    - delivery of the product, including development, purchase, production, testing, commissioning and delivery to the customer;
    - service in the form of so-called. complete service ("full service" = full service on a contractual basis, guaranteeing the customer defined operability of serviced products for contractual payment), the nature of the project has particular the development and implementation of a complete service

- from internal activities:

    - research and development projects;
    - investment (real estate, machinery and equipment, IT);
    - organizational changes;
    - outsourcing (outsourcing of selected activities, if possible in a more advantageous way), or insourcing.

3. Risk management

Risk management should be an ever-improving, continuous process that is integrated into the organization's strategy and its enforcement. It should carefully deal with all the risks that relate to the past, the presence and, in particular, the future of the organization and its activities. Risk management must be involved in the culture of the organization along with an effective policy and plan adopted by a majority of senior management of the organization. It has to transform the strategy into tactical and operational goals and share responsibility in the organization so that risk management is a part of the work of each manager and employee. It also promotes responsibility, measurement, and performance rewards, thereby contributing to greater efficiency.

It is important for the project team to keep in mind that there are a number of dangers in the course of the project which may be a causal threat to the success of the project. Therefore, the people who form the project team must carefully observe the possible adverse effects on the project and must take measures to reduce the threat to the project and thus increase the probability of successful completion of the project. The project team must work with risks throughout the project.

The risk is mostly related to the possibility of loss, damage or failure. It can be understood as an uncertain event that, if it occurs, leads to the possibility of losing, but it can also be an opportunity.

3.1 Types of risks

In order to ascertain as simply as possible the potential risks of external projects, a table of possible risks for certain areas, with a description of the type of risk and the measures to eliminate it, contained in the book by Merna (2007) follows.

- Political and territorial
- Financial
- Exchange rates
- Technical
- Guarantee
- Range
- Timetable
- Workers (capabilities)
- Purchase
- Legal
- Managerial

3.2 Risk models

In order to work more closely with risks during planning and project management, you need to choose a suitable model to assess the size of the risk and the likelihood of its occurrence.

- Probability- expressed as 0 to 1
- Impact- effect on the project if the risk arises

The significance of the risks is determined by multiplying the probability x the impact. It is possible to sort the risks according to their dangers.
Literature from Korecký (2011) offers 4 basic models of work with risks:

- Simple
- Standard
- Cascade
- Ishikawa

The most suitable for use is a standard model that divides the risk into a risk event, the impact, and the total possible loss. This model suits due to its relative simplicity and risk-sharing to event and impact.

3.3 Degree of risk

According to the standard model, the risk is assessed as:

Expected risk = probability x impact magnitude

It is therefore possible that the expected risk may be the same for high and low probability risks. For this reason, risks are plotted in a curve diagram that defines the risk acceptability limit. The graphical distribution of risks helps to make decisions about access to risks. By approaching removal or mitigation, we can divide the risks into a simple matrix of 4 basic groups (Figure 3).

	High Frequency	Low Frequency
High Severity	Avoid Reduce	Transfer
Low Severity	Retain Reduce	Retain

Fig 3. Risk strategies

The individual risk classification into quadrants demonstrates the methods to handle them according to Hnilica and Fotr (2009). It is possible to avoid, reduce, transfer (insurance) or accept the risk.

3.4 Reserve for risks

In any project, it is necessary to take into account the possibility of occurrence of risks in the reserve. Determining the amount of the reserve is very difficult, yet it is important to set the reserve as accurately as possible. A low reserve may reduce the project margin, on the other hand too high a reserve will cause the bid to be unacceptable against competition.

According to the book by Fotr and Souček (2011) reserves can be distinguished from the point of view of costs:

- Expected costs - will not be exceeded with a probability of 50-60%
- Binding costs - will not be exceeded with a probability of 80-90%
  - Expected costs
  - Reserves
- Target costs – motivating, should not be exceeded with a probability of 20%

3.5 Risk analysis

Qualitative and quantitative analysis can be included in the risk analysis. Qualitative analysis assesses the probability of risk and its consequences. The evaluation is done using word terms, where terms can be assigned a certain numerical limit (e.g. medium = cost growth by 5-10%). In this section, the probability / impact matrix, event trees, source-response diagram are also used. The next step is to determine the risk holder.

This is followed by a quantitative analysis that aims to give the most accurate expression of the likelihood and magnitude of the impacts. To do this, methods are often used:

- Sensitivity analysis
- Decision trees
- Monte Carlo

PERT is used to investigate the variability of project time duration, where it is necessary to identify an optimistic, pessimistic and probable estimate. From this, the expected and standard deviation time will come out.
The layout for application in projects should be simple, so a triangular layout is chosen (Expected value = (O + N + P) / 3).

For clarity and retention of information, it is necessary to choose the appropriate format for recording and working with potential risks. An example may be a table showing the type of risk, status, description, impact, measure, owner, date, probability of a risk event, probability of impact, resulting probability, total impact (finance, time) costs, total costs incurred by the risk.

4. Proposal of calculation methodology

For projects in general, it is not possible to set one calculation method that would suit in all cases. Each type of project is specific and needs to be approached individually (Král 2002). It is important to focus on how detailed and trustworthy information we have in the pre-investment phase and what we want to use the results of the calculation for as shown in Figure 4.

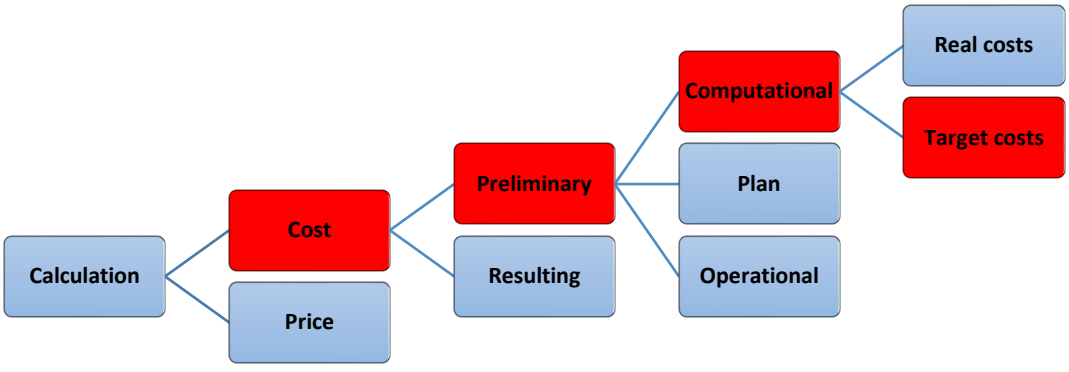

Fig 4. Calculation method

From the nature of the projects (Temporary efforts to create a unique product, service, or result), we can assume that costing will have a major impact on decision-making on project implementation or on benchmarking. It is therefore a preliminary calculation, which will include a certain degree of risk.

It is therefore advisable to select the calculation method according to the type of project. We can divide projects by profitability into gaining and supporting. We also divide the projects into internal and external. The goal of external projects is to achieve the highest gross margin. These projects are a source of profit, resources for further business development, and customer references. Internal projects focus on achieving competitive advantage, streamlining business activities. Measuring the success of an internal project is to achieve a return on investment.

Table 1 divides the projects according to their basic characteristics and purpose. The risk analysis method is selected according to the size and complexity of the project. The basic division would look as follows:

Table 1: Risk analysis methods

Complicasy / Budget	***Simple***		***Special***		***A complex***		***Program***	
	Small	Medium	Small	Medium	Medium	Large	Medium	Large
Guesstimate	✔		✔					
Qualitative analysis	✔	✔	✔	✔	✔			
Semi-quantitative analysis		✔	✔	✔	✔	✔	✔	
Quantitative analysis		✔	✔	✔	✔	✔	✔	
Simulation methods						✔	✔	✔

4.1 Risk assessment

Risk assessments are sometimes difficult to grasp, so we will divide the individual risks into three basic groups, according to how we will continue to work with them. It is also different to include them in project costs. We will rely on the risk register for the risk assessment.

- Scale + Numeric (SN) - projects with a large number of risks where it is necessary to quantify the impact on costs, timetable and project contribution
- Scale (S) - for small and medium-risk projects where there is no need to quantify the impact on costs, timetable and project contribution
- Numerically (N) - uses gross risk quantification, suitable for projects with fewer risks, where it is necessary to quantify the impact on costs, timetable and measurable benefit of the project

4.2 Risk quantification

In connection with uncertainty, we are talking about the probability of event occurrence. The event itself can take various forms. Discrete risks will be quoted differently than continuous (Fig. 5). Of course, their combination is also possible.

- Discrete - gets the final number of values (coin toss, yes x no)
  - Probability x Impact
- Continuous - takes an infinite number of values (height of persons, shutdown of the machine, measured noise)
  - For simplicity - triangular distribution
  - Optimistic, most probable, pessimistic estimate
  - (O + N + P) / 3

- Multi-discrete
- Multi-triangle
- Multi-combi

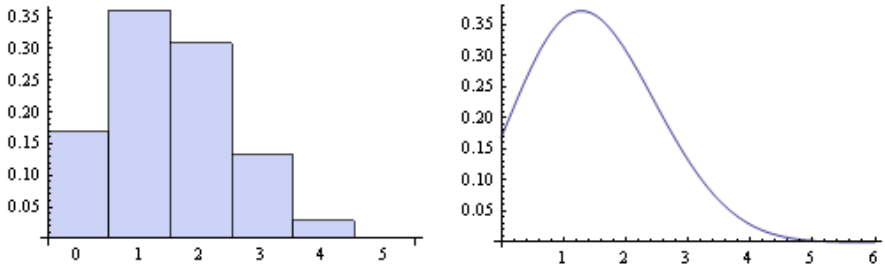

Fig 5. Discrete and continuous distribution

4.3 How to create reserve for a risk

The following diagram in Figure 6 was created to determine the risk assessment procedure. Evaluations are done numerically, using scales or combinations. First, we get a rough overview of possible risk costs. We will further analyse the risks in order to express the overall risk of the project.

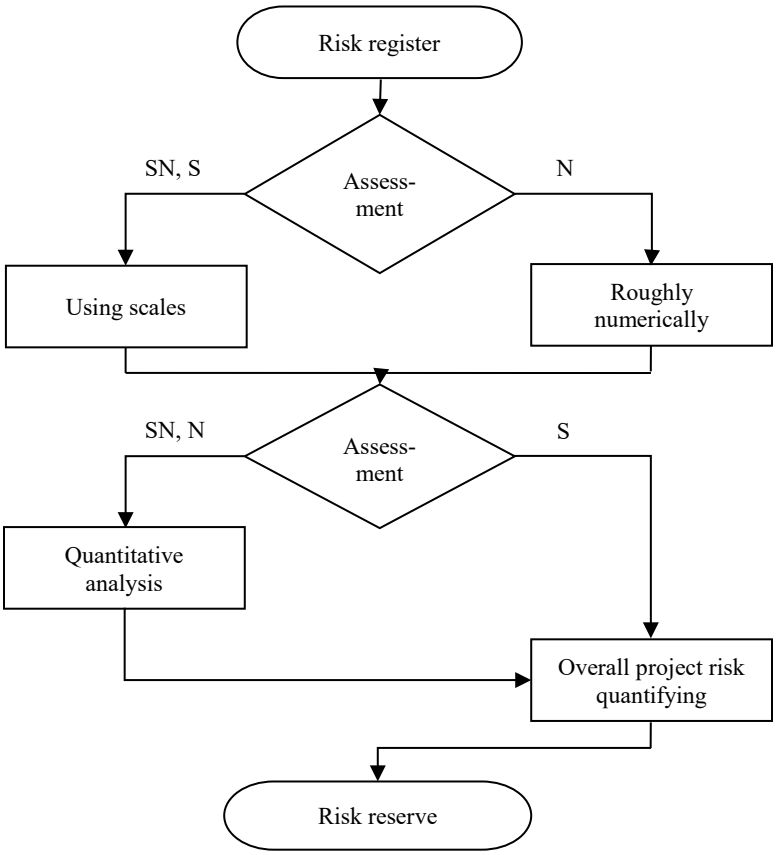

Fig 6. Risk reserve determination

After the total risk is calculated, we also create risk reserves. This item is not part of the cost, but it is a side-by-side insight for executives. Incorporating risks directly into project costs could have a negative psychological effect.

4.4 Threat x Opportunity

The diagram in Figure 7 shows the risk-based work based on the likelihood of occurrence.

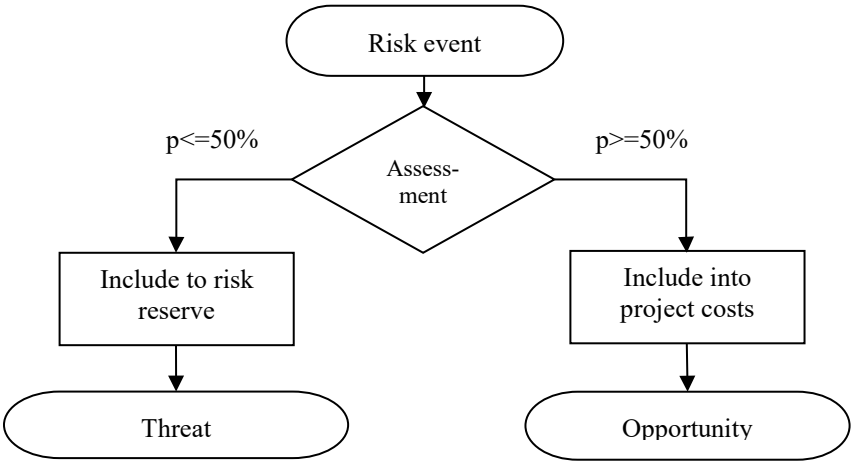

Fig 7. Threat and Opportunity distinction

If the risk probability exceeds 50%, we include the possible costs directly between the expected costs of the project. With this risk, we continue to work as an opportunity. If the probability of occurrence is less than 50%, we are talking about a possible threat that is not included in the cost but in the risk reserve.

4.5 Designing a model for project cost management using PKR

When selecting the appropriate calculation method, it is necessary to take into account whether it is a bidding calculation or whether we already know the necessary selling price, according to which the project will be conceived (Novikov 2018). It is also important to consider whether it is a project-driven organization. Also, overheads and the way they are should be incorporated into the calculation are also important (Dhillon 2010).

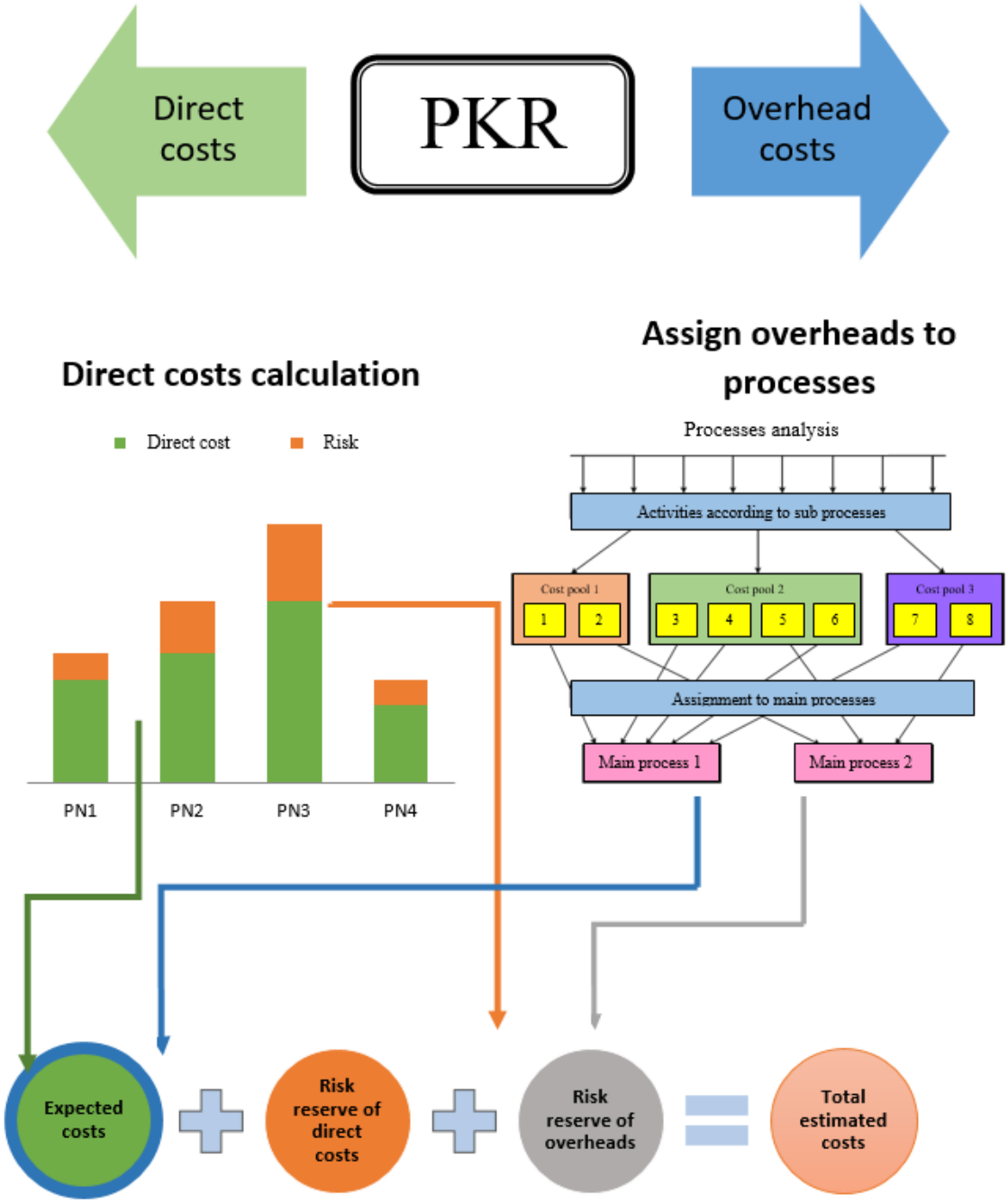

Fig 8. Project costs calculation model

The proposed model shown in Figure 8 is based on the German Prozesskostenrechnung (PKR) method. This is a cost-per-process calculation similar to ABC (Ofert 2006). The difference, however, is that it considers costs in the areas of indirect performance as the basis of the calculation. Processes and their assigned costs are broken down into performance-induced and power-neutral. It is based on cost points. Individual activities merge into main processes through partial processes (Ehrlenspiel et al. 2007).

For direct and indirect costs, we define all the risks that could threaten or cost the project. Each component of direct costs is assigned a risk that is quantified and included in the risk reserve. Risks of overhead costs will be included in the budget after the calculation using the PKR method. Overhead costs (including risk premiums) together with direct

costs are included in the expected costs. The sum of these costs with the risk margin will indicate the total estimated costs of the project.

5. Conclusion

The aim of the study was to create a concept for calculating project costs, including the methodology of quantification of individual risks and their projection into the project budget. Firstly, basic information was provided on projects where not only the course of the project is but also the types of projects based on important criteria. The next part contains an overview of the used calculation methods, with examples of their application in projects. There is a considerable amount of risk and uncertainty about projects, so it is necessary to find out what models, degrees and types of risk exist and also, how to work with the risks and the possibility of their projection into the project reserve.

The final chapter deals with the proposal of a suitable method of calculating project costs. The starting point is that the calculation will be made in the pre-investment phase of the project. This is a preliminary calculation method. Projects were divided into several groups according to their complexity and purpose. The risks were divided into continuous and discrete. Their evaluation will be done in one of 3 selected ways. Part of this work is also a table for selecting an appropriate method of risk quantification depending on selected criteria. A model for working with a threat or opportunity has also been created. This is followed by the risk creation process.

The output of the article is a proposal for a project cost management model based on the PKR method. This method makes it possible to calculate the costs that are usually included in the manufacturing process in a procedural manner, thus making them transparent. While some cost items will continue to fall between overheads, we will be able to quantify and identify most of the related items specifically and identify the relevant measurement quantities for them.

The next step will be to verify the usability of the proposed solution in practice. The model will be progressively upgraded and refined so that we can better integrate not only the costs but also the risks associated with the projects.

6. Ackowledgments

This article was created with the support of the internal grant of the University of West Bohemia, SGS-2018-031 entitled Optimizing sustainable production system parameters.

7. References

Dhillon, B.S. (2010). *Life Cycle Costing for Engineers*, CRC Press, ISBN 978-1-4398-1688-2.
Doležal, J. (2009) *Projektový management podle IPMA*, Praha, Grada.ISBN 978-80-247-2848-3.
Ehrlenspiel,K., Kiewert,A., Lindemann,U. (2007). *Kosten günstig Entwickeln und Konstruieren*, Springer, ISBN 978-3-540-74222-7.
Fotr, J. & Souček, I. (2011) *Investiční rozhodování a řízení projektů: jak připravovat, financovat a hodnotit projekty, řídit jejich riziko a vytvářet portfolio projektů.* Praha, Grada. ISBN 978-80-247-3293-0.
Hnilica, J. & Fotr, J. (2009) *Aplikovaná analýza rizika: ve finančním managementu a investičním rozhodování*, Praha, Grada, ISBN 978-80-247-2560-4.
Korecký, M. & Trkovský, V. (2011) *Management rizik projektů: se zaměřením na projekty v průmyslových podnicích*, Praha, Grada Publishing, ISBN 978-80-247-3221-3.
Král, B. (2002) *Manažerské účetnictví*, Praha, Management Press, ISBN 80-7261-062-7
Merna, T. & Al-Thani, F. F. (2007) *Risk management: řízení rizika ve firmě*, Brno, Computer Press, ISBN 978-80-251-1547-3
Novikov, K. & Kleinova, J. (2018). *The Impact of Personnel Costs on the Competitiveness of Automated Manufacturing Systems*, Proceedings of the 29th DAAAM International Symposium, pp.0916-0921, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-20-4, ISSN 1726-9679, Vienna, Austria, DOI: 10.2507/29th.daaam.proceedings.132
Ofert, K. (2006). *Kostenrechnung*, Kiehl, ISBN 3-470-51-102-0.
Rosenau, M. D. (2007) *Successful Project Management*, Brno, Computer Press, ISBN 978-80-251-1506-0.
Šulák, M. & Vacík, E. (2005) *Strategické řízení v podnicích a projektech*, Praha, Vysoká škola finanční a správní, ISBN 80-86754-35-9.

Biographies

Konstantin Novikov is a PhD student in the Department of Industrial Engineering and Management at the University of West Bohemia, Pilsen, Czech Republic. He earned bachelor degree at the Faculty of Mechanical Engineering and during that time was studying one semester at Cukurova University in Turkey. He spent one semester at the Chienkuo University in Taiwan during the master program. He was working about 4 months in the company Arbonia AG in Switzerland on completing of diploma thesis. He has published conference papers. Ing. Novikov was working as an industrial engineer in Kermi and now is a coordinator of projects specialized in lean industry and logistics. His research interests include manufacturing, cost calculation, optimization, risk management and lean.

Jana Kleinova is an Associate Professor in the Department of Industrial Engineering and Management at the University of West Bohemia, Pilsen, Czech Republic. She is a guarantor of many courses such as: Economic evaluation of production processes, Engineering economics, Cost calculations in engineering, Corporate Finance etc. Mrs. Kleinova has been participating on many educational projects. She has published journal and conference papers. Doc. Ing. Kleinova, CSc. earned her master degree at the Faculty of Mechanical Engineering. Her habilitation thesis topic was Cost view of production issues. Her research interests include calculation of production and product costs and financial management of engineering companies.