RISK MANAGEMENT OF ENERGY EFFICIENCY PROJECTS IN THE INDUSTRY – SAMPLE PLANT FOR INJECTING PULVERIZED COAL INTO THE BLAST FURNACES

by

Filip P. JOVANOVIĆ, Ivana M. BERIĆ, Petar M. JOVANOVIĆ**, and Aca D. JOVANOVIĆ

Project Management College, Faculty of Project and Innovation Management, Belgrade, Serbia

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This paper analyses the applicability of well-known risk management methodologies in energy efficiency projects in the industry. The possibilities of application of the selected risk management methodology are demonstrated within the project of the plants for injecting pulverized coal into blast furnaces no. one and two, implemented by the company US Steel Serbia d.o.o. in Smederevo. The aim of the project was to increase energy efficiency through the reduction of the quantity of coke, whose production requires large amounts of energy, reduction of harmful exhaust emission, and increase productivity of blast furnaces through the reduction of production costs. The project was complex and had high costs, so that it was necessary to predict risk events and plan responses to identified risks at an early stage of implementation, in the course of the project design, in order to minimise losses and implement the project in accordance with the defined time and cost limitations.

Key words: *project, risk, management, efficiency, pulverized coal injection, methodology*

Introduction

The issue of ensuring energy and its rational use is a strategic objective of any country and any company. Therefore, energy efficiency projects are very important strategic projects, whose implementation leads to the fulfilment of the strategic objectives of a specific country, region or organisation. In this regard, the issue of the efficient selection and implementation of energy efficiency projects is extremely important and complex, needing special attention and the use of contemporary methods, techniques and methodologies with the purpose of achieving the desired results.

The majority of energy projects (hydroelectric power plants, thermal power plants, gas pipelines, oil pipelines, power lines, heating pipelines, *etc.*) are very complex and strategically important, standing for programmes that consist of a set of projects [1, 2]. The management of realization of such complex projects and programs requires the application of contemporary project management methodologies, as well as a number of methods and techniques for the evaluation, selection and control of strategic energy projects, and the risk management in these projects in particular. However, there is also a wide variety of smaller ener-

* Corresponding author; e-mail: drpetarj@gmail.com

gy projects (involving solar energy, boiler rooms, geothermal energy, improving energy efficiency in buildings, *etc.*), which also require project management and project risk management, just like the major energy projects.

In the course of implementation of energy projects and energy efficiency projects, attention should first be focused on the selection and choice of projects from a set of available ones, as well as on the preparation of the necessary studies and projects, and then on effective management of implementation of this projects. In this paper, we will deal primarily with the importance of the early identification of project risks and planning responses to them in order to minimise losses and ensure the more efficient implementation of energy projects and energy efficiency projects that require high investment. An example of the application of the risk management methodology will be presented through a project that was implemented by the company US Steel in Smederevo, aimed at reducing the consumption of coke and replacing it with cheaper types of coal. This increased the energy efficiency of the blast furnaces and resulted in achieving considerable savings. The increase in productivity, resulting from better thermal conditions, which was one of the objectives of this project, has been proven in numerous studies and can be measured using standard methods [3].

Project management is a specialised management discipline dealing with the management of various projects and ventures aimed at effective implementation. Today, the concept of project management is successfully used to denote managing the implementation of various construction, energy, traffic, military, business and other projects, and as a special management concept aimed at achieving the planned project objectives, reflected in the project implementation within the planned time and planned costs [2, 4-6].

Project risk management is one of the functional areas of project management, relating to the prevention, elimination or reduction of the harmful impact of risk events that may arise in the implementation of a specific project. Project implementation often takes several months or even years, and requires significant financial resources. Furthermore, project implementation must be in accordance with predefined quality standards. Potential risks could slow down the project implementation, increase costs, and affect the planned quality. For effective project management, it is necessary to constantly monitor progress at each stage of the project implementation, and monitor risks that could jeopardise the progress of the planned activities [7].

This paper presents project risk management methodologies that can be used for risk management in energy efficiency projects.

Review of literature

The literature sees project risk management [4, 5, 8-11] as an extremely important area of project management, which determines the success of a specific project. The references cited treat this area thoroughly, primarily by explaining the basic concepts, principles and methods used in the risk management of various projects. Very important for the effective implementation of various projects, including energy efficiency projects, is which methodologies have been developed and used for the successful risk management of energy efficiency projects. In this regard, a very wide range of capital energy projects and energy efficiency projects can be taken into consideration, such as various hydroelectric and thermal power plants, as well as smaller energy projects, such as energy efficiency projects, the use of solar panels and the like.

When we talk about risk management in energy efficiency projects, it should be noted that the literature [4-6, 8] usually presents risk as the possibility of unforeseen and unintended consequences in the implementation of a venture or work, and in some cases as an opportunity to achieve positive results. In this regard, the focus is most often on the definition of certain factors and elements that characterise the formation and impact of risk in the implementation of a specific project. The most frequently mentioned are: risk event, the probability of a risk event, and the extent of the impact, positive or negative, on the project. A risk event is an activity or event that can bring unforeseen and unintended consequences for the project. The probability refers to the likelihood of a risk event. The impact on the project refers to the extent of damage that the risk event can bring.

Kerzner [5] points to the connection between the probability of a risk event and the impact of the risk events on the project, through the equation:

$$\text{Risk} = \text{f (probability, impact)}$$

The realisation of complex energy efficiency projects involves a number of different risk factors and types of risk [12]. Jaafari [13] lists the following risk factors: market, political, technical, financial, operational, environmental, organisational, and other factors. The importance of energy efficiency projects and the large number of risk factors that can occur in their implementation, of which only some are listed above, shows that it is necessary to manage the risks that arise here in order to avoid or reduce the negative risk impact on the overall success of the project.

The theory and practice of project management elaborate and rely on different methodologies for managing project risks. Essentially, all methodologies are based on the same theoretical and methodological principles, and mainly propose the same or similar subprocesses or stages. Although a large number of methodologies have been analysed [2, 4-6, 9, 10, 14, 15], only methodologies proposed in famous guides and standards will be presented here in summary form. These are: Project Management Institute (PMI) methodology, German Project Management (GPM) methodology, and Serbian Project Management Association (YUPMA) methodology.

In guide to the project management body of knowledge (PMBoK) [4], PMI shows the area of knowledge of project risk management through si subprocesses. The methodology includes the subprocesses or stages:

– risk management plan,
– risk identification,
– qualitative risk analysis,
– quantitative risk analysis,
– risk response planning, and
– risk monitoring and control.

The risk management plan includes methods of defining, describing, monitoring and controlling risk. Risk identification includes research and finding possible risks, as well as their definition and classification into specific groups. Qualitative and quantitative analysis involve a procedure in which, by using methods and techniques of qualitative and quantitative analysis, identified risk events are considered and the impacts and consequences that certain risk events may have on the project objectives are determined. Risk response planning involves the definition of the activities and actions to be taken to avoid risks, to reduce the possibility of risk events, and to react to occurrence of risk events. The risk monitoring and control process involves the activation of responses to risk events when they occur, as well as the monitoring and control of risk events and reactions to risks.

Several authors [10] from the GPM association present a risk management process as consisting of this stages:
- risk identification,
- analysis and assessment,
- selection,
- monitoring, and
- planning risk response strategies.

The risk identification stage involves the initial phase of research and finding the risk. To carry out this phase, it is recommended to use specific checklists and organise workshops under the leadership of the project manager. Within the analysis and assessment stage, quantitative methods are used to assess the possible financial loss of the project, if certain risks materialise. It is also necessary to quantitatively assess the probability of the occurrence of a certain risk. In the selection phase, the categorisation of the risk into several groups occurs, in accordance with the assessed probability of occurrence and the potential loss, in order to focus on the risk group characterised by a higher probability and higher potential loss. The monitoring and control phase involves the assessment of risk factor impact, as well as the assessment of the effects of the applied risk response strategies during the project. In the course of planning the risk response strategy, the focus is on planning the response to a specific risk. In so doing, the choice is made between risk avoidance, risk reduction, risk mitigation, risk transfer and risk acceptance.

A group of authors that work within the YUPMA association developed a general methodology for managing project risks, which includes subprocesses [6, 16]:
- risk identification,
- risk analysis and assessment,
- planning risk avoidance and risk responses, and
- control of the application of risk response.

Risk identification is the initial phase of the project risk management process, which involves the determination, classification, and ranking of all risk events that may occur in the project and that may have a certain detrimental effect on the observed project or venture.

The phase of analysis and assessment involves a detailed analysis of the impact of individual risk events on the results of the project, through the study of individual characteristics of risk events, analysis, and assessment of the likelihood of risk events, and quantifying the extent of the effects of certain risk events on the achievement of the project results. The stage of planning avoidance and the response to risk events involves the definition of strategies for managing project risks, which would avoid or minimise the possibility of risk events in the course of project implementation, and reduce potential losses.

The literature [4-6, 9] lists several possible strategies for planning the avoidance and response to risk: risk ignoring, risk bearing, risk reduction, risk transfer, risk division, and contingency planning. The last phase of the risk management process is the monitoring and control of the implementation of countermeasures and response to risks, in order to determine whether the planned responses are adequate and whether new ones should be introduced.

In the course of controlling the application of countermeasures and the response to risks, new strategies can be introduced, in accordance with the project implementation. In this way, the entire project risk management process turns into a continuous process, in which the previously mentioned project risk management stages recur, thus ensuring an efficient process.

Proposed methodology for the risk management of energy efficiency projects

The analysis of the advantages and disadvantages of the listed methodology for managing project risks and the possibility of their use is given in the literature [2, 4-6, 9, 10]. Based on these analyses, a significant similarity between the mentioned methodologies can be observed in terms of concept, phases of development and the content of individual phases. Certain adjustments of proposed methodologies are possible and depend of the specifics of the project. All the listed methodologies can be used in the process of project risk management for various projects, including energy efficiency projects.

Based on the listed analyses, we can draw certain conclusions from mentioned methodologies and use common basic steps:
– risk identification,
– risk analysis,
– planning the risk response, and
– risk monitoring and control.

Identification is the initial stage in the process of project risk management, which involves finding and determining risk events, *i. e.* risk factors, which occur in the life cycle of the energy efficiency projects, and the grouping and classification of risk factors according to certain criteria. Risk analysis is the phase in which the nature of certain risk factors is analysed, after which the analysis and assessment of the probability of the emergence of certain risk factors and the quantification of the impact of risk factors on the outcome of the project are carried out. In the course of the analysis, it is very important to identify high-risk events with a major impact on the result of the project.

Response planning is the stage in the process of project risk management where, based on previous analysis, strategies for the prevention or response to possible risk events are defined. Monitoring and control is the stage where it is determined whether the planned risk response strategies provide the desired results or whether there is a need to introduce new ones. All phases of the risk management of energy efficiency projects, are interrelated and represent a continuous process that lasts throughout the entire life cycle of the project. For larger energy projects, with a larger number of activities and probably a larger number of risk events, the described methodology should be somewhat expanded, or particular phases should be presented in more detail for the purpose of the easier coverage of the most significant risk events that arise in the implementation of a specific energy project. This detailed presentation should focus primarily on the use of certain methods and techniques that allow quantification of the probability of the occurrence of risk events and the extent of the impact on the result of the project. For larger energy projects, an initial phase called risk planning could be introduced, which would include the definition of a detailed plan for the execution of all the phases and activities in the risk management process and the observed energy projector energy efficiency projects.

Research in this field has shown that the factors with an impact on the occurrence of risk events should be included in the investment decision process, as they would improve the calculations relating to energy investments, although, according to some authors, energy investments have a lower level of risk than production investments [17]. Another recommendation could be to expand the risk analysis phase and divide it into several subphases, which would encompass quantitative and quantified analysis of identified risk events, and then the evaluation and selection, for the purpose of ranking the risk events according to their impact on the success of the project. This would provide a better basis for defining the response strategies to possible risk events, especially regarding proactive strategies, which could possibly prevent the occurrence of certain risk events or reduce their impact.

Project description

The construction of the new plant for blowing pulverized coal (PCI – pulverized coal injection) in blast furnaces was realised with the main purpose of performing coal pulverization and its pneumatic transport and blowing through the injection nozzles in the blast furnace no. one and no. two (BF1 and BF2), thus achieving a reduction in the consumption of coke. Although there have been cases of using the techniques of PCI trough injection nozzles in blast furnace in Belgium and France in 1850, in the amount of 10% of the total fuel of the furnace, these experiments were sporadic and lasted a couple of years due to the problems that emerged with the current level of technology. The first mass use of pulverized coal began in the last decade of the 19th century in the cement industry for heating the dry column [18].

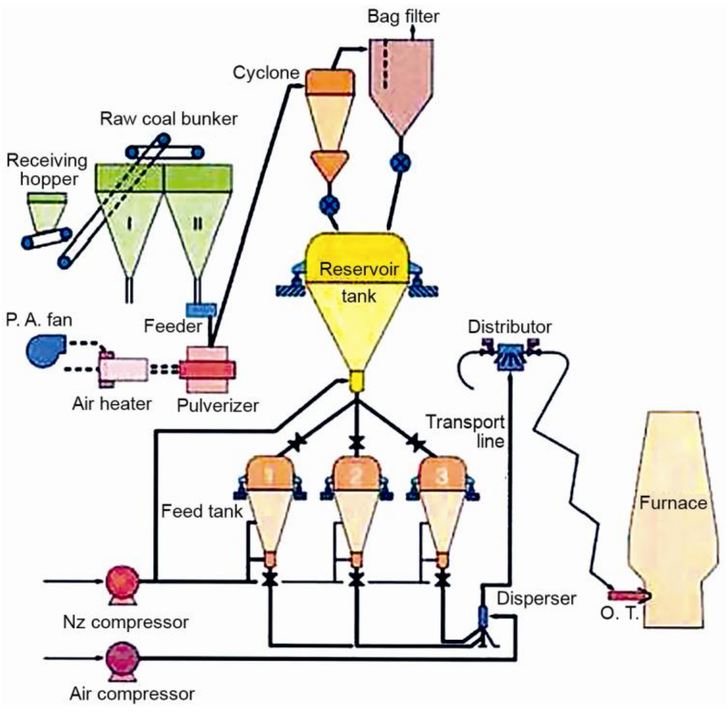

Figure 1. Schematic representation of the PCI plant

Schematic representation of the PCI plant is given in fig. 1 [19].

Most of integrated plants for the production of iron and steel plant has built in PCI. Insufflation (injection) of milled coal into the blast furnace reduces the amount of coke and therefore the consumption of large amounts of energy in the plant for the coke production – coke ovens and reduces the emission of gases from coke oven [20]. The injection rate of such coal ranges from 100-200 kg/t of molten steel [21]. The latest practice records attempts to form a mixture of different coal. Therefore, not only pulverized coal is used, but an optimal mixture is sought that will burn well and that will at the same time be economical enough for preparation and use. Figure 2 shows the intensity of reduction of coke consumption with the increase of intensity of the use of pulverized coal.

Energy savings [19, 20] in blast furnaces due to blowing pulverized coal instead of coke is estimated to be 3.76 GJ per tone of blowing coal, and 0.77 GJ per tone of raw iron. The reduction in production costs is estimated to be 10 €/t of raw iron. The expected period of return of funds is about two years.

When the enrichment of air is taken into consideration, there are two techniques for that. One is the enrichment by oxygen in the stream of air (direct enrichment), and the other is the use of a coaxial nozzle. In the case of another technique, the tube for injecting oxygen is placed within the nozzle. Studies have shown that this second technique is better, because the cold air that is injected through the outer nozzle tube prevents the turbulent mixing of pure oxygen and pulverized coal, which are injected through the inner tube. Coal is injected into the system with air heated to 1100-1200 °C.

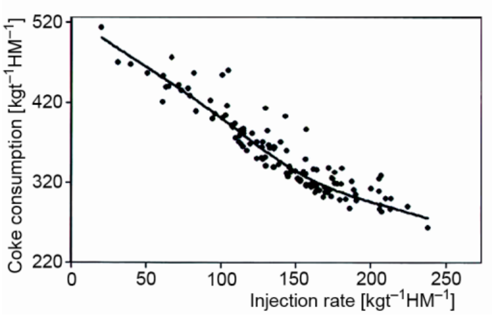

Figure 2. Consumption of coke *vs.* pulverized coal consumption [18] *(HM stands for hot metal or pig iron which presents the product of blast furnace)*

The project implementation was aimed at:
- increased productivity of the blast furnace, *i. e.* the amount of metal that is produced daily,
- reduced consumption of expensive coal, by replacing coke with cheaper coals,
- easier maintenance of the stability of the furnace, and
- improved consistency of the metal quality and reduced silicon content in pig iron.

The purpose of the plant is the pulverizing of the raw coal to a particle size of 90 μm in size (80%), and their injection into blast furnaces (BF1 and BF2) through nozzles. The plant consists of this subsystems:
- coal storage,
- receiving station of raw coal,
- tower – supporting steel structure plant for grinding coal,
- pump station,
- electrical hall,
- plato (the foundation of the water tank and the tank foundation for nitrogen), and
- platform distributor of coal dust,

In this project, it was necessary to manage risk due to the complexity of the project, the numerous analyses that were necessary in the initial stages and high investment value of the project. The investment value of the project was 52 million dollars and it was necessary, even in the design phase, to predict possible risk events in order to minimise the possibility of adverse events and potential project delays or increased costs. Any unexpected or adverse event could lead to an overrun of the cost and time required for implementation, but also to a decrease in the predefined desired quality of the project results.

The application of the methodology for risk management in the construction of plants for injecting pulverized coal into blast furnaces

In order to illustrate the possibilities of application of the above methodology, the example of risk management in this real energy efficiency project is given. For the purposes of this study, the example was a bit shortened to fit the scope of work, but the shortening did not impair the clarity of the presentation of real examples of risk management of the energy project.

A quantification of the total risk, as a combination of the degree of the impact on the project objectives and the estimated probability of occurrence, was made on the basis of tabs. 1 and 2.

The list of basic risk events, with the quantified degree of impact and the perceived probability of occurrence, is given in tab. 3. In addition, the planned strategies for responding to the risk event are given. As for the probability of occurrence of risk events – they are subjectively determined based on experience of the project managers and project team members. In doing so, authors used data from a large number of project reports submitted in the process of international certification of project managers in YUPMA and the lessons learned from project managers and project team members.

Table 1. Quantification of risk events [18]

Project objectives	Impact on the project objectives				
	Very low – VL	Low – L	Moderate – M	High – H	Very high – VH
Budget	Insignificant increase	Increase <5%	Increase 5-10%	Increase 10-20%	Increase >20 %
Time of implementation	Insignificant overrun	Overrun <5%	Overrun 5-10%	Overrun 10-20%	Overrun >20 %
Contracted scope	Barely noticeable decrease	Noticeable in smaller units	Noticeable in major units	Decreased and unacceptable for the client	Unusable
Quality	Barely noticeable decrease	Noticeable decrease in the most demanding applications	Decreased to the extent that it requires the approval of the client	Decreased to an extent that is unacceptable for the client	Unusable

Table 2. Total risk quantification [18]

Probability	Impact on the project objectives				
	Very low – VL	Low – L	Moderate – M	High – H	Very high – VH
VH (0.9)	VH-VL	VH-L	VH-M	VH-H	VH-VH
H (0.7)	H-VL	H-L	H-M	H-H	H-VH
M (0.5)	M-VL	M-L	M-M	M-H	M-VH
L (0.3)	L-VL	L-L	L-M	L-H	L-VH
VL (0.1)	VL-VL	VL-L	VL-M	VL-H	VL-VH

Table 3. shows the predicted risk events that might affect the successful implementation of the project in terms of the time schedule, cost and availability of necessary parts of the project. For high-risk events, preventive and reactive actions are planned, while risks where the probability of occurrence is low, as well as the consequences of their possible occurrence, are just taken note of and do not require any special planned measures to mitigate the effects of their occurrence.

The early identification of risk events was very important for the successful implementation of the project presented in this paper. The project was implemented on time, in accordance with the projected costs and resources, and within the required scope. All delays and changes in the scope of the project, as well as errors in the elaboration of the project design were avoided due to the adequate implementation of the presented methodology.

Table 3. List of risk events and response plan

RM* No	Description of the risk event	Type of risk	Probability of occurrence	Impact on the project objectives	Overall risk extent	Response plan
RM-1	Changes in the investor's requirements	External	0.3	0.9	0.27	Define the terms of reference. Terms of reference must be signed by the investor
RM-2	Change of the input parameters by the technology provider	External	0.3	0.9	0.27	Define the terms of reference. Terms of reference must be signed by the technology provider
RM-3	Errors in the project elaboration	Internal	0.5	0.7	0.35	Include internal control from the beginning of the project
RM-4	Problem and changes during the technical control	Internal	0.5	0.5	0.25	Agree *Ongoing technical control* with the investor
RM-5	Lack of human resources	Internal	0.5	0.7	0.35	Subcontract parts of the project. Engage associates based on temporary service agreements
RM-6	Delay in the delivery of items	External	0.3	0.5	0.15	Early identification of the necessary parts
RM-7	Obtaining permits	External	0.7	0.3	0.21	The timely preparation of project designs and applications for permit at the competent Ministry
RM-8	Collection of payment for realised work	External	0.3	0.3	0.09	Response is not planned

*RM (abbreviation of risk management) used to label risk events

Conclusion

Project risk management is a special field of project management aimed at eliminating or reducing damage caused by the occurrence of possible risk events during the course of a particular project implementation, and it is necessary for the effective implementation of energy efficiency projects and achieving the planned project results. In order to properly manage the project risks, it is necessary to use a specific methodology for project risk management, which is recommended in the literature or in specific guides and standards. In this paper, several well-known methodologies have been analysed and basic principles of the PMI, GPM, and YUPMA methodologies have been presented. It was noted that all are based on the same principles and that they contain the same or similar phases or subprocesses and propose the use of the same, well-known methods and techniques. These analyses and presentations were used to define a general risk management methodology for energy efficiency projects, for which it can be concluded that the risk is high.

The possibilities of application of the previous methodology are validated and shown using a real project of energy efficiency-plant for injecting pulverized coal into blast furnaces. At the present time, pulverized coal is widely used in thermal power plants in the production of electricity, and is also extensively used in metallurgy in the process of metal refining. As regards the production of iron, coke (product of high-temperature pyrolysis of coal) conventionally serves as the primary reactant in the reduction of iron ore to pig iron in a blast furnace. However, due to the high energy consumption required to produce coke, which simultaneously determines its high cost, as well as due to environmental problems associated with this production, the technique of ground coal injection (PCI) through injection nozzles furnace is expanding and partly replaces the use of coke. In this project, it was necessary to manage risk due to the complexity of the project, numerous analyses that were necessary in the initial stages of the project, and high investment value of the project. Any unexpected or adverse event could lead to an overrun of the cost and time required for implementation, but also to a decrease in the predefined desired quality of the project results. Project management methodologies assume that the actions taken that result from the risk management process contribute to the success of the project, which was confirmed during the implementation of this complex venture.

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