Economic analysis of safety risks in construction

F. M. Almeida Santos[1], A. R. Costa[2] & A. Soeiro[3]
[1]*Tabique – Engenharia Lda, Braga, Portugal*
[2]*Ordem dos Engenheiros – Região Norte, Porto, Portugal*
[3]*Faculdade de Engenharia da Universidade do Porto, Portugal*

Abstract

The objective of this study revolves around the analysis of the safety risks involved within a large construction project, and the respective economic effects. This analysis is fundamental for the safety management and cost reduction of accidents.

The case study is the result of the safety coordination of systems, and of the harmonization between the project owner, the safety coordinator and the contractor. The result of this collaboration is and adequate strategy to prevent the risks during the construction of a large hydro-electric dam in the north of Portugal. The project is part of a governmental plan to invest in the energy obtained from hydraulic sources. The dam in the north of Portugal is located in a river and near the confluence with the river Douro. It will have a capacity of storage that will be strategic to the electricity generation in the country. It has two storage-pumped plants equipped with reversible units. The construction volume covers around 700000 m^3 of concrete, 600000 m^3 of excavation and an installed power of 170 MW. This dam presents a strategic value since it will increase the water supply reserves for domestic and industrial use. It will be the largest reserve of water in Portugal.

The safety risk evaluation on this construction project was carried out using simulation tools of the different phases of construction according to the tasks of the program plan. This overall analysis of the risks related with the planned tasks provides a sequence of risks over the duration of the project. The simulation allows the analysis to identify peaks and levels of high risks that are identified. The method proposes a scale to classify risks that is compatible with probability of occurrence and gravity of the consequences. There is also a systematic

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evaluation of risks to each type of the construction task. These conclusions allow the scheduling of additional proposals to prevent accidents and to reduce risks. These preventive measures will contribute to reduce the high risks and consequently, lead to a flattening effect of the project global risk chart. These measures consist in on-site measures and in an integrated implementation of working safety policies. Of course these measures contribute to the risk reduction and rarely to eliminate the risks. The implementation of these prevention systems and working safety policies implies additional costs but when costs are associated to the possible accidents it is concluded that safety has lower costs than a lack of prevention.
Keywords: construction, safety, risk analysis, risk management, accidents, risk prevention, prevention costs, safety plans.

1 Introduction

The Safety and Health Coordination Staff of the AHBS, in collaboration with the SST Department of EDP P, has decided to make an economic study of risks of labour accidents throughout the duration of the construction work (Figures 1 and 2). This analysis will be based on the detailed working construction plan that has been approved for execution.

This project started on July 2008 with an estimated completion date in the year 2014. It has approximately one year and a half in duration at the moment [1]. In each of the working programme activity there is an associated risk. This

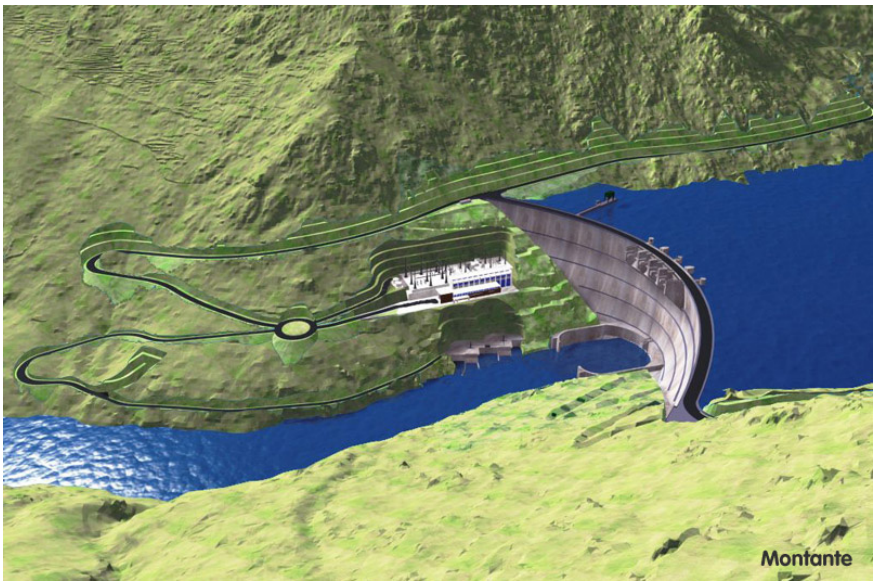

Figure 1: Upstream (preview).

Figure 2: Downstream (preview).

list of risks associated with the construction tasks was evaluated by the Safety Coordination.

The analysis of the risks considered the risks and the planned preventive measures. The evaluation of risks and the decision about the choice of a preventive or of a non-preventive attitude lead to two different opposite situations: a good safety performance or the lack of safety during the construction work. For each of these extremes in terms of safety the risk is calculated for each task. This calculation is a combination of probability of occurrence and the level of damage, material and human, caused. Therefore for each task there is always two limits: optimistic and pessimistic situations. These two extreme values of risks represent the range of expected risk that is expected connected with each task. The planned tasks for each period of analysis have risks that are comprised in an interval. Finally, during the whole construction period two risk histograms represent the limits, superior and inferior, expected risks for each day.

2 Experimental work

With the detailed execution plan of AHBS as a basis for safety plan, it has been performed a study of the variation of risks associated with the different tasks along the construction [2]. Two simulations have been made taking into consideration the situation for each task with the maximum expected risk, characterised by the inexistence of any preventive measures, and the minimum expected risk, associated with the possible preventive measures. These situations

were defined using the information about previous accidents and combined the probability of occurrence and the gravity of the consequences provoked by the accidents.

The risks associated with the construction activities of the construction plan, that comprised about 1000 activities, were analysed for each of the tasks. This analysis was done considering the information included in the Safety and Health Plan that was adopted for implementation during construction [3]. The Safety and Health Plan contains inspection and prevention procedures adequate to the activities, related with the risks of each activity that should be implemented on site to minimise the corresponding risks of accidents.

To optimise the use of the data related with the risks the safety procedures became part of the construction plan. For each inspection and prevention procedure for each activity there are various risks that are associated. In the construction site referred in this study there were detected eighty two families of risks. These risks have varying probabilities of occurrence. To facilitate the analysis of the risks versus task plan a computer program was developed and used.

In order to organize the evaluation of the risks it was developed a table that combines the severity and the probability of occurrence. The risk scale that was used ranges from 1 to 5. The scale does not include 0 since there is not an absence of risk. Taking into consideration the lack of prevention a maximum value for each risk has been defined. For some cases it reaches 5, like the falls from height. The value of risk 1 was defined considering the use of all preventive measures.

After defining the evaluation tables for all tasks the calculation phase of the study was implemented. The analysis consisted in inserting in the "Primavera Project Planner", the adopted project management computer program, all related activities and respective risks. This data was obtained from the approved construction plan and from the risks values considered associated with each task. The risks were classified as activity resource data.

After that calculation the simulations were done for the two extreme situations. One corresponded to inexistence of preventive measures and the other to the use of all possible preventive measures [4]. The studies for the optimistic and pessimistic situations were presented using histograms for the whole project allowing the visual representation of the evolution of the risks along the period of construction of the dam.

3 Results of the analysis

According to the data inserted in the risk analysis program results are obtained simulated for the optimistic and pessimistic situations (Figure 3). In the first scenario, where risk forecast values are maximised assuming that there is no preventive measures there is a set of 356663 risk points from the addition of all risks related to the planned tasks. In the second situation, where it is assumed there are all preventive measures implemented, the number of risk points has a total of 92354. A simple conclusion obtained from these two numbers is that,

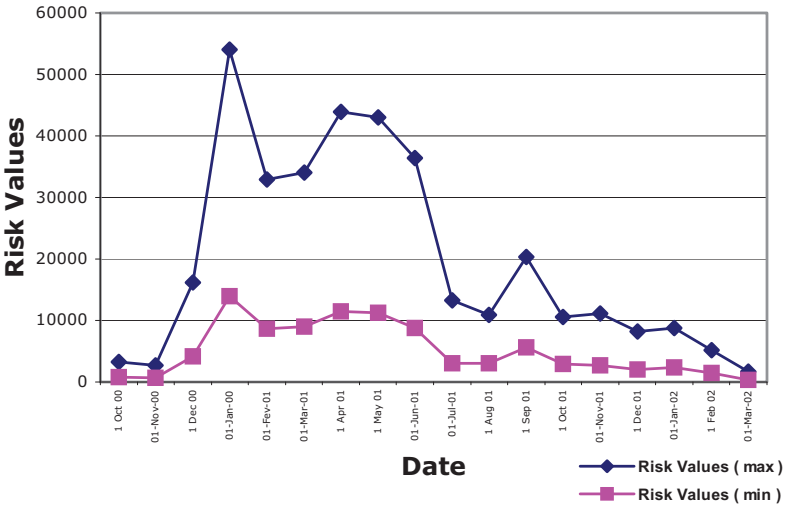

Figure 3: Evolution of risk values.

when prevention is not implemented, the number of situations with risk is about four times greater than when prevention is dully taken into account.

4 Discussion of results

From the analysis of the histograms representing the range of risks, throughout the construction, the ratio average between maximum and minimum values is 3.86. It can be concluded that in the different phases of construction the action of the safety coordinator should pay more attention, in terms of risks, to the periods when the maximum peak risks occur. A parallel analysis can also be done to evaluate the costs associated with the evolution of the risks. Lower values of risks represent higher costs of preventive measures and maximum vales represent higher values of costs caused by possible accidents. This may lead to a costs representation of relation between costs and the level of safety adopted.

Taking into consideration recent studies that show that prevention costs for similar projects in Portugal are about 2% of the construction cost, it is possible to say that this percentage may correspond to cost associated with the minimization of risks through implementation of all preventive measures. According to some research in construction works the ratio of costs between prevention and possible accidents is 1 to 2.1 [4].

In this analysis of costs of accidents the values considered are composed by quantifiable values (fines, employees' salaries, lawyers, damaged equipment material, etc.) and by indirect costs (work interruption, productivity decrease, time wasted by technical and legal staff, damage of company image, insurance,

etc.). Using this ratio the possible costs due to the lack of prevention should be 4.2% of the construction costs. Therefore the decision of the safety management is to combine the level of risk assumed with the affordable investment in prevention of accidents.

An example of these considerations was made in the application of these numerical assumptions in the execution of the "Escola de Ciências da Saúde da Universidade do Minho" (Health Science School of the University of Minho). The value of the construction is an estimated 15 millions of Euros and the values to be analyzed by the owner and by the safety manager were:

a) Costs of implementation of prevention measures
   (2%) ~ 0,30 MEuros
b) Potential costs of non-safety
   (4,2%) ~ 0,63 MEuros
c) Possible savings due to existence of prevention
   (2,2%) ~ 0,33 MEuros

5 Conclusion

This study indicates that it is beneficial to invest in prevention of accidents if costs and risks should be decreased. This example of the analysis the ranges of risks along the construction phase and the possible costs incurred, according to the different levels of prevention, allows the safety manager to make decisions with justified background. It may become a tool that can help the safety managers to dedicate the prevention efforts so the gap between the extreme situations is reduced and the investment in prevention is adequately made. This type of analysis, connected with the plan of the construction schedule, may become a powerful tool to handle the fact that the safety managers and technicians cannot be prevent all risks and cannot be present in all construction tasks. The use of time and resources can be more rational in the prevention of accidents in construction.

In the future other studies can be performed to improve the technique of Risk Management in construction. Analysis of costs created by the indirect consequences in accidents in construction should be developed to allow a more accurate evaluation of the costs. In fact the costs considered in this study were related with direct costs. Another area to be researched and analyzed is the effect, in terms of effective prevention of accidents, is the inclusion of safety measures like coordination and information meetings with the stakeholders, safety committee actions and meetings, safety training, workers counselling and discussing the safety plan with the participants. These developments, addressing the costs and the effects of indirect safety actions, will contribute to a better and efficient safety management. The risk management approach should be implemented to address the most dangerous situations that are expected to occur with adequate investment. It is also appropriate to state the aphorism "Decreasing risks means decreasing total construction costs".

References

[1] Alves Dias, J., *Plano de Segurança e Saúde*, IDICT, Portugal, 1997.
[2] Reis C., *Análise Económica de Segurança na Construção*, Universidade do Porto, Mestrado em Construção de Edifícios, Portugal, 1998.
[3] Santos J. M, Rodrigues M. F., Baptista M. A., Santos Reis S., Maduro Roxo M., *Coordenação de Segurança na Construção*, IDICT, Portugal, 1999.
[4] Alves Dias J., Safety and Health on Construction Sites, CIB W099 Netherlands, 2000.
[5] Soeiro A., Almeida Santos F. M., Reis C., *Economic Overview of* Construction *Safety*, Singh A., Hinze J., Coble R.J., ed., USA, 1999.