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Procedia Engineering 57 (2013) 533 – 539

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Conference on Modern Building Materials, Structures and Techniques, MBMST 2013

Risk Management of Construction Works by Means of the Utility Theory: a Case Study

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Abstract

The construction works are implemented under conditions of risk. In this paper, a suggested method of risk analysis has been presented, based on the application of utility theory. This procedure embraces the following: data about conditions of construction, data about the economic situation, including a relationship between supply and demand, seasonality. Besides this approach includes variants of decisions, historical data, conditional probability, utility function. The method of defining the utility function can be briefly described as follows: the decision maker (for example, a contract engineer, building site manager) is faced with a choice between a certitude of a given result (a monetary value), and a lottery was to extreme results. The two contrasting (but practical) cases of function of utility, that is characteristic of a decision maker with an aversion to risk, and decision maker with a predilection to risk, are then analysed in detail. The economic effects of their decisions are then presented.

Keywords: risk analysis and assessment, risk management, attitudes to risk, construction management.

1. Introduction

The area of preparation and execution of construction works is a rewarding subject from the viewpoint of scientific research, and necessary from the viewpoint of economic effects of decisions being taken at different stages of the construction project. Such dilemmas as whether or not to invest, whether or not to order building materials, or manufacture ready-made products for warehouses while waiting the changes in market demand - those are only a few examples of decision making situations. It was the changes in demand, the competition in the market, seasonal character of the construction industry that make implementation of the investment process occur in unspecified conditions. If the demand for the developer's products or products of a manufacturer of building materials is low, which may be the result of a slow market, for example as a result of prolonged winter season or a lack of new building sites, losses can be substantial. The classic approach using the reliability theory and risk management is not enough, cf. [1–4].

What is needed is knowledge of the decision maker attitude towards risk taking. Is a decision maker (for example, a building site manager, a contract engineer) prone to taking risks, or is he averse to risk. It transpires that such an attitude is significant in view of economic effects of decisions taken. Therefore, the subject matter of this paper touches upon economic and psychological aspects of construction management.

The research into attitudes of decision-makers towards risk, and the influence of those attitudes and economic effects require a change of the criterion of risk assessment, namely replacement of the maximisation of expected values with the criterion of maximisation of expected utility. An attempt of formulating such a criterion was made by D. Bernoulli (1700–1782), but the first practical attempt at implementation of this criterion in construction management was to be noted only in the last decade cf., [5–9].

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doi:10.1016/j.proeng.2013.04.068

There are completely different applications of the utility theory. Let us list a few points:

- in quantitative evaluation of socio-economic systems [10, 11];
- building life cycle, cf. [9];
- modelling of construction and real estate crisis cf. [12];
- standardisation and integrative management [13];
- contractor's ranking [14];
- small business [15], economic history [16], consumer lending [17];
- offices of real estate agents and brokers [16];
- flexibility, method of scenarios, and risk transfer [18, 4];
- game theory & equilibrium (economics) [19, 5, 20].

The most common use of utilities is visible in the application of Multi-Attribute Decision Making Methods. In particular, in determining the weights and preferences of decision-makers, cf. [16, 7, 21, 22, 23].

The above-mentioned aspects of the utilities do not take into account the attitude of decision-makers, especially in the context of utility maximization [6].

An important factor in decision-making, in other words in preparation and execution of construction works, is aversion or predilection to risk taking. Therefore, attitude towards risk taking is important in assessment of options and, at the same time, indicates the need of taking personal traits of the decision maker into consideration.

2. The proposition of the procedure of analysing attitudes towards risk

The analysis of dilemmas listed in the previous section regarding decision-makers, as well as operational conditions, can be framed within a special procedure presented in Fig. 1. The mentioned dilemmas can be solved using dendrites cf. [24]. In construction industry, we most often deal with sequential decisions [25]. We are dealing with risk which stems from forecasting the above-mentioned market conditions. What becomes important is a number of random situations. Each of those situations is described using probability of its occurrence.

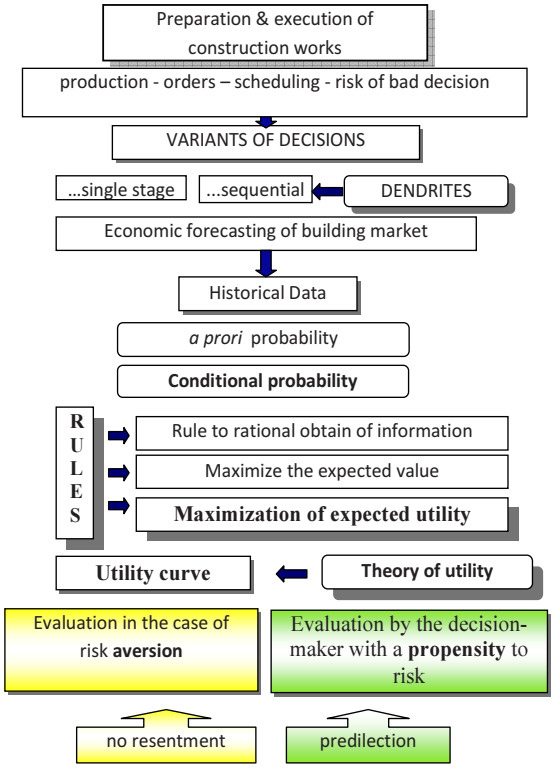

Fig. 1. The proposed method of analysis

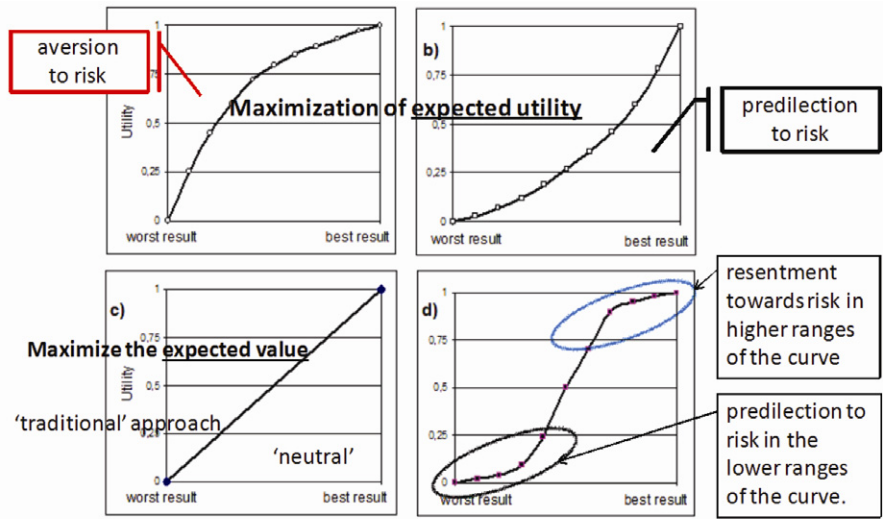

Fig. 2. Four typical cases of the utility function

Then, we use historical data regarding temperature and the so-called "dead season" in construction industry. The decision making process at this stage is enriched by new items of information. Most of the time, this is subjective data, called a priori probabilities. After we have defined a priori probabilities and conditional probabilities for a specific case, we will arrive at a set of expected results. We continue using the foundation of the utility theory [26, 27]. Utility, in other words – worth is a relative value of possible results of decisions taking into consideration the decision maker preferences. The utility curve (function) is an expression of a decision-maker's attitude. Fig. 2 presents a comparison of basic utility functions presenting themselves in construction industry.

In practical terms, a utility curve can consist elements of all curves presented in Fig. 2. Quite often management staff shows resentment towards risk in higher ranges of the curve and, simultaneously, an predilection to risk in the lower ranges of the curve. Then, the utility curve takes the shape resembling the letter ***S.***

3. The method of defining utility function

The analysis of the shape of utility function has been carried out for data presented in Fig. 3. The survey was anonymous. Finding a relationship between creativity and attitude towards risk was the main purpose of this research. A complete initial data of the analysis and the dendrites were presented in the paper: [6, 25]. Within the framework of the analysed problem, according to the data presented in Fig. 3, the decision maker arrived at six possible financial results: –430 000; –250 000; 0; 20 000; 150 000; 300 000 (PLN). Due to the fact that the utility scale is discretional, it can be assumed that utilities (U) of extreme results are: $U(300\,000) = 1$ and $U(-430\,000) = 0$.

There are a number of ways of defining the utilities of intermediate results. In the survey, only one of those ways of defining utility has been assumed, namely: A decision maker is placed before a choice between certainty of a given result and a lottery involving two extreme results. In the present problem, there are, in descending order, six possible results: from +300 000 to –430 000 (PLN). A decision maker (company owner) is asked to make a choice between the first option, signifying a sure result (in the following order: 150 000; 20 000; 0; –250 000), and the second option, which is a lottery, were the figure of +300.000 may occur with probability p or the second option, that is a lottery were the figure of +300 000 may occur with probability p or –430 000 was probability $1 - p$.

Firstly, there was a survey for the result of 150 000 (PLN) - compare Fig. 3. With $p = 0$, the decision maker in will certainly choose 150 000. It could happen was the probability of 0.9 of winning and 0.1 of loss –430 000; or 0.8 of winning and probability of 0.2 of loss –430 000; or 0.7 of winning and probability of 0.3 of loss –430 000; 0.6 of winning and 0.4 of loss –430 000. Increasing the probability of winning 300 000 PLN to a maximum, we are going to reach such a distribution of probabilities were both possibilities will be equal for the decision maker. And this is what depends on the decision-maker's attitude.

Determine the operating conditions

Data entry into the dendrite I

Historical data on economic trends and seasonality

Events	A long break in construction work Z1	A short break in construction work Z2	
Cold autumn W1	75	25	100
Warm autumn W2	10	90	100

Data entry into the dendrite II

Conditional probability

$$P(Z_1 / W_1) = \frac{P(Z_1 \cap W_1)}{P(W_1)} = \frac{\frac{75}{200}}{0.5} = 0.75$$

Testing

150 thousand (sure)	300 thousand p
	– 430 thousand $1 - p$

Construction of the utility function

The influence of attitude towards risk taking on the choice of an option

Fig. 3. Application of the procedure in practice

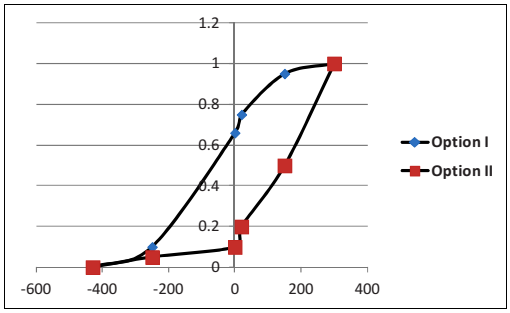

Fig. 4. Two chosen options of the decision-makers attitudes towards risk-taking

The results of tests of two different attitudes towards risk taking the shape of two utility functions were presented in Fig. 4. Those two attitudes will be the subject of further analysis.

4. An example: the effects of individual preferences of managers

The shape of utility function is usually ignored. It is taken for granted that it would not have any significance. Using the suggested procedure of analysis of preferences we are going to prove that individual preferences can not be ignored.

The result of the different attitudes towards risk which were mentioned earlier is placed onto a dendrite thanks to which we have arrived at six results which are, at the same time, decision-making variants. The final results of the analysis were presented in Fig. 5. Those results should be interpreted as follows. In the first case (option **I**), we come across the decision maker was a clear aversion to risk taking, who will not prefer the choice of x_B option (purchasing only half of the necessary material, that is 1000 pieces), whereas in the second case (option **II**) we come across a decision maker with a stronger

tendency to risk-taking. Such a decision maker will choose options x_F and Z_2, that is, he is going to wait for an appropriate situation and will buy twice as many pieces in a single action. Moreover, this decision maker assumes a shorter break in works on the building site, thanks to which he will be able to make a profit of 300 000 PLN. Both behaviour options have been written onto Fig. 5 using a bold line.

The result of this analysis is as follows. A cautious (fearful) decision maker is aiming at a profit of about 150 000 PLN, while a decision maker with a tendency to risk taking (option **II**) is aiming at a profit of about 300 000 PLN.

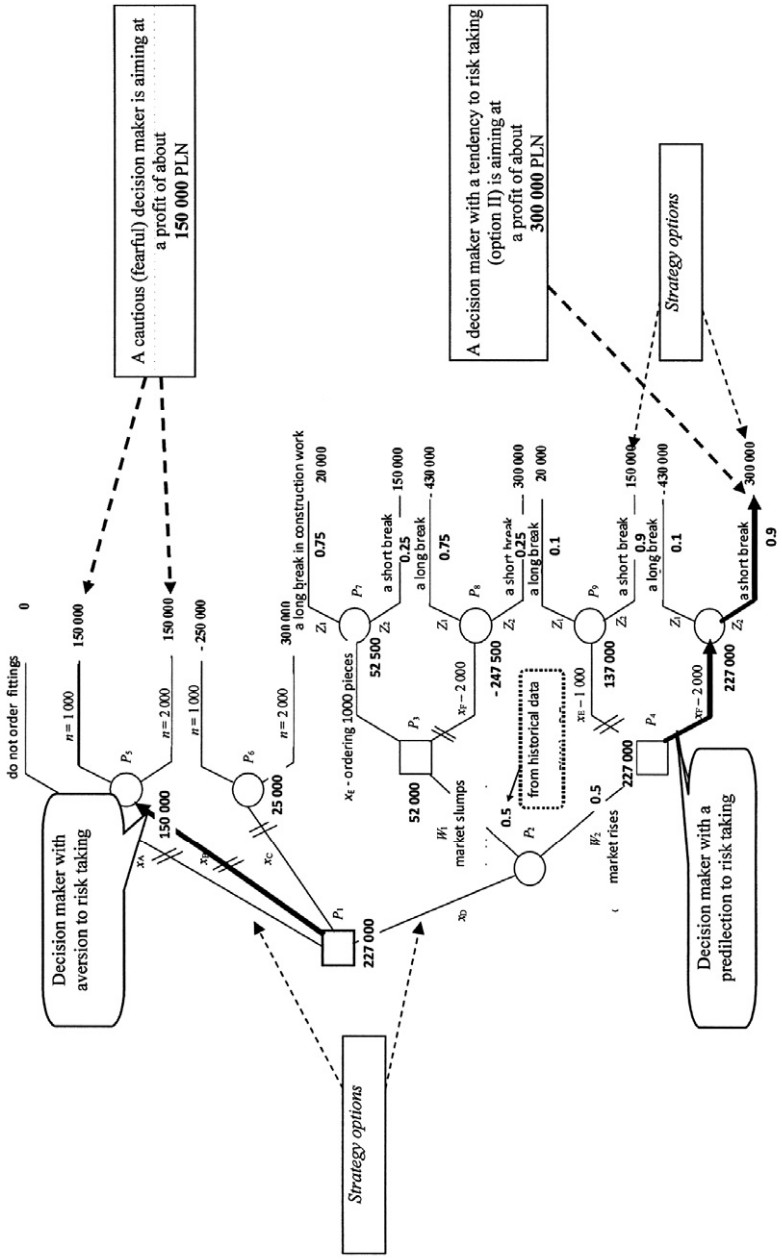

Fig. 5. The result of the analysis

5. Conclusions

Tests have been carried out confirm the main thesis of this paper regarding significant influence of attitudes towards risk while managing construction projects. The attitude towards risk influences operational strategy. At the same time, the above indicates the need of taking into account the personal features of the decision maker. Why recruiting management staff it would be advisable to use the procedure suggested in the paper and define the utility function for a future manager.

Simultaneously, studying attitudes towards risk brings interesting viewpoints on the problem of operational strategy. It explains the mechanism of decision-making, connecting economic and psychological aspects.

The suggested procedure of analysing and identifying attitudes towards risk is based on the new criterion of maximisation, namely the criterion of maximisation of the expected result which has been replaced by the criterion of maximisation of expected utility. It significantly changes the approach to analysing risk, especially in construction industry.

Acknowledgements

This paper is the result of an international cooperation in the triangle Lithuania - Germany - Poland since 1986, under the topics construction management and operational research.

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