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Research Article

ASSESSMENT OF THE ECONOMIC EFFICIENCY OF THE MODERNIZATION OF CRUSHED STONE MANUFACTURING PROCESS: CASE STUDY

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ABSTRACT

The aim of the paper is to evaluate the economic efficiency of the proposed modernization of the production process of crushed stone in the quarry and to decide whether to accept it or reject it. The project is assessed in a complex way. Profitability is evaluated using Net Present Value (NPV) and Profitability Index (PI), liquidity by means of Discounted Payback Period (DPP). The risk associated with the respective investment is assessed using a probabilistic method - Monte Carlo simulation.

Keywords: Modernization, economic efficiency, simulation.

INTRODUCTION

The issue of maintaining the competitiveness of an enterprise is always up to date. For each business, it is a challenge to look for ways to meet demand, customer requirements, and produce as efficient as possible. Modernization of technology and technological equipment is one of the ways of ensuring competitiveness; nevertheless it is associated with high investment costs and risk. Manufacturing companies are placing great emphasis on competitiveness and looking for ways to explore their resources more efficiently [1]. Levitin and Lisnianski addressed the multistage modernization problem for power systems. The procedure based on the universal generating function was used for evaluation of the availability of multistate series-parallel power systems [2]. Rusiński et al. presented investigation and modernization of buckets of surface mining machines taking into consideration the results of tests in real mining conditions [3]. The efficiency of the manufacturing process was researched also in [4, 5, 6].

Modernization is not only a way to increase productivity and efficiency. It interferes with other spheres such as safety, ecology or the social sphere. Without advancing development of machine building, it is impossible to solve problems of technological safety and other problems relating to social sphere [7]. In the case study, Orumbayev et al. [6] described significance and necessity of modernization and substitution an equipment with higher efficiency rates and improved ecological indexes.

Decisions to invest in manufacturing systems represent a strategic decision making process affecting long-term success, competitiveness and profitability of a company [8]. As investment projects consist of various uncertain jobs, only simulation technique can analyse the random characteristics of practical project model [9]. The paper by [10] established a nuclear power investment evaluation model by employing real options theory with Monte Carlo method. Makara et al. presented an evaluation of two production technology variants that were evaluated using Best Available Techniques Not Entailing Excessive Costs. The variants were assessed for the economic efficiency of investment projects using net present value and internal rate of return approaches [11]. Risk is a

Fig. 1. Production line

Fig. 2. Conveyors of the production line

necessary part of investment decisions. Hildebrandt and Knoke gave a comprehensive overview on techniques for financial decision-making under uncertainty [12]. Aven [13] looked for trends in perspectives and approaches and reflected on where further development of the risk field was needed and should be encouraged. Further approaches to assessing the investment projects and risk were introduced in [14, 15, 16]. Modernization and investing in a quarry was dealt in some case studies. The objective of the paper by Rukijkanpanich and Pasuk was to enhance the capability in managing the maintenance of transportation process from a quarry to a crushing plant, measured by the availability value and the process capability value [17]. Experimental research of the pipe conveyors was conducted by [18].

Research and modernization of production technology and conveyors is the subject of the present article. The efficiency of investment in the technology is assessed from the economic point of view using the Net Present Value (NPV), Profitability Index (PI) and Discounted Payback Period (DPP) indicators. Investment risk is analysed and assessed using the Monte Carlo simulation technique.

CASE STUDY AND DEFINITION OF THE PROBLEM

The subject of the study is an investment aimed at modernizing the production process of crushed stone in the BV quarry. This is the surface mining of the rock by blasting works in which the primary rock disintegration occurs. After checking the blast in terms of volume and size, then the secondary rock disconnection at the desired dimensions is followed by means of a hydraulic hammer.

In the current production process, the rock is transported to the production line (Figure 1). In a crusher with a hopper, the material is first crushed to obtain a fraction of 0/90. It is then conveyed to a two-sided grader. It divides the material into fraction 0/32, i.e. the final product and fraction 32/90, which is then conveyed by a conveyor belt to secondary grinding by means of a reflective crusher. Again, it is followed by sorting with a two-sided grader, which is designed to select fractions of desired size. Sorted fractions are moved to the trays. From the trays, an operator delivers them to lorries that transport them to the warehouse. In stock, the final products are up to shipping.

The bottleneck of this process is the production line (built in the 60's of the last century) because it has:

- insufficient production capacity in relation to market requirements (90 tonnes per hour),
- open conveyor belts (Figure 2) which, in adverse weather conditions and heavy weight of the material, lose traction and it accumulates

Fig. 3. Powerscreen Pegson XA 400S

Fig. 4. Powerscreen Pegson 1000SR Maxtrak

Fig. 5. Powerscreen Horizon 5163R

under the crusher, thereby sliding it stopped and the production line is inoperable.

Proposed solution

To increase the efficiency of the crushed aggregate production, it is recommended to invest into the following group of equipment. It is a jaw crusher (Figure 3), a cone crusher (Figure 4) and a sorting unit (Figure 5). By purchasing and synergy of these devices and using already-owned machines, their operation can replace the current production line.

This solution causes a change in the production process of the crushed stones. As far as these are mobile devices that move on chains, they can be placed directly in the quarry and on any floor. In the manufacturing phase, these devices form a triangular formation which represents movement of the material from one device to another. Production began with the jaw crusher (Figure 3) which is filled by the digger. This crusher produces a fraction 0/125 which travels directly by the conveyor belt into the hopper of conic crusher (Figure 4). The conic crusher can produce three fractions of the required dimensions. The mixture it produces passes through the conveyor belt into the sorting unit (Figure 5). The result of this production process are three final fractions plus one extra that returns back to the LT200HP. This closure of the production process has resulted in minimal damage to material residues.

Benefits of the proposed solution:
- material handling is minimized (devices are mobile, placed on any part of the mining area),
- allows the production of a wide range of products (devices are easily adjustable to produce the required fraction),
- there is a reduction in production costs, including the number of employees,
- devices are able to produce their own electrical energy, which is especially helpful when repairing.

MATERIAL AND METHODOLOGY

The economic evaluation of the investment project is processed using the financial model created in MS Excel. The financial model is built on the economic life period of six years, since the purchased production equipment for the surface mining belong in accordance with the Slovak tax law into the 2nd depreciation group with a depreciation period of 6 years. Investment costs associated with the modernization of the production process are shown in Table 1.

The input parameters are determined by the incremental method, i.e. for each revenue and cost item, value of the item is considered that is calculated as the difference between the proposed

Table 1. Investment costs

Production equipment	Unit	Acquisition costs
PowerscreenPegson XA 400S	EUR/pcs	402,300
PowerscreenPegson 1000SR Maxtrak	EUR/pcs	547,700
Powerscreen Horizon 5163R	EUR/pcs	316,000
Investment costs total	EUR	1,266,000

Table 2. Input variables for case study

Input variables	Unit	1st year		
		Current condition	Proposed solution	Increase (+)/ Decrease (-)
Production capacity	t/hour	90	200	110
Utilization of production capacity	%	98	60	-
Production	t/year	140,000	190,080	50,080
Sales	EUR/year	1,120,000	1,520,640	400,640
Number of employees	person	11	7	-4
Average wage	EUR/year	145,200	92,400	-52,800
Fuel consumption, oil	EUR/year	79,000	114,048	35,048
Electricity consumption	EUR/year	27,800	5,702	-22,098
Spare parts consumption	EUR/year	32,000	10,000	-22,000
Transport services	EUR/year	20,700	19,008	-1,692
Drilling services, blasting	EUR/year	32,200	43,718	11,518
Maintenance and repair of machinery and equipment	EUR/year	25,000	15,000	-10,000
Maintenance and repair of commercial vehicles	EUR/year	6,200	6,200	0
Depreciation	EUR/year	0	211,000	211,000
Laboratory work and certification	EUR/year	5,900	5,900	0
Certification-related services	EUR/year	1,000	1,000	0
Geodetic and geological services	EUR/year	980	980	0
Security service	EUR/year	31,200	31,200	0

solution and the current situation (see Table 2, last column).

At the present state, the input variables in each year present the same values. The production capacity of the bottleneck of the production line is 90 tons per hour.

For the proposed solution, fixed costs (5 items - see Table 2) have the same value as the current solution. The production capacity is 200 tons per hour. Its utilization is planned at 60%, 70%, 80%, 80%, 85% and 85% in individual years of economic life of the investment.

At the same time, number of employees decreases by 4 employees in the first two years, in the following years by 3 employees. Variable costs (fuel consumption, oil, electricity consumption, transport services and drilling services, blasting) are increasing in individual years in line with rising production volumes.

Risk analysis of the investment project

The real development of the input variables of the project under consideration is likely to differ from their projected values. This is due to the inability to accurately estimate the values of the input variables. Significant risk factors are the nominal time fund and the utilization of production capacity. To a great extent they are influenced by the weather (rain, snow, frost etc.), particularly winter months are problematic when work activities are not possible to pursue for most of the time. For this reason, it is important to supplement the economic assessment with a risk analysis, specifically by using Monte Carlo simulation with software support. The output parameter is Net Present Value. In Table 3 are listed risk factors including expertly defined probability distributions.

RESULTS

The project is assessed using three financial criteria (Table 4). Based on their values, it can be stated that the project is acceptable to the enterprise, i.e., effective. The value of NPV is EUR 2,805,041 and the return on investment is approximately 2 years and 5 months.

Due to the high investment costs and the long life of the equipment, the risk assessment is an important aspect of a comprehensive assessment of the investment project. The most important input variables, whose future development is only estimated for six years, are defined by distribution functions (Table 4). The risk of the invest-

Table 3. Probability distribution of risk factors of the project

Risk factors	Unit	Statistical characteristics	Distribution function
Investment costs	EUR	Min. 1,200,000; Likeliest 1,266,000; Max. 1,400,000	Triangular
Utilization of production capacity	%	5% 56.27; Likeliest 60.00; 95% 63.73	Triangular
Nominal time fund	day/year	Min. 195.00; Likeliest 210.00; Max. 220.00	BetaPERT
Average price per unit	EUR/t	Min. 7.20; Likeliest 8.00; Max. 9.50	BetaPERT
Fuel consumption, oil	EUR/t	Min. 0.55; Likeliest 0.60; Max. 0.65	Triangular
Electricity consumption	EUR/t	Min. 0.03; Likeliest 0.03; Max. 0.03	Triangular
Transport services	EUR/t	Min. 0.09; Likeliest 0.10; Max. 0.11	Triangular
Drilling services, blasting	EUR/t	Min. 0.21; Likeliest 0.23; Max. 0.25	Triangular
Average wage	EUR/ month	Min. 990.00; Likeliest 1,100.00; Max. 1,210.00	Triangular

Table 4. Financial indicator of the project

Financial indicator	Abbreviation	Unit	Acceptance of the project according to	Value
Net Present Value	NPV	EUR	NPV > 0	2,805,041
Profitability Index	PI	coeff.	PI > 1	3.22
Discounted Payback Period	DPP	years	DPP < 6 years	2.41

ment project is assessed by Monte Carlo simulation of the NPV financial indicator. Simulation was run for 10,000 trials, which ensured sufficient reliability of the outcome. The histogram of the NPV simulation is presented in Figure 6. The simulation confirmed the high economic efficiency of the investment. However, the results point to the overly optimistic expectations. Based on simulations, the mean NPV (EUR 2,517,969) is significantly lower than NPV calculated (EUR 2,805,041). Nevertheless, this value is relatively accurate within the interval "mean+1standard deviation". According to the simulation, the probability of achieving NPV higher than EUR 2,805,041 is only 19.24%.

Other simulation outputs are in the form of the tornado chart (Figure 7). The tornado chart points out the risk factors; e.g. input variables whose individual change has most affected the output. Figure 7 shows the variables hierarchically arranged according to their strength and the impact of their change in range of 10%. In this

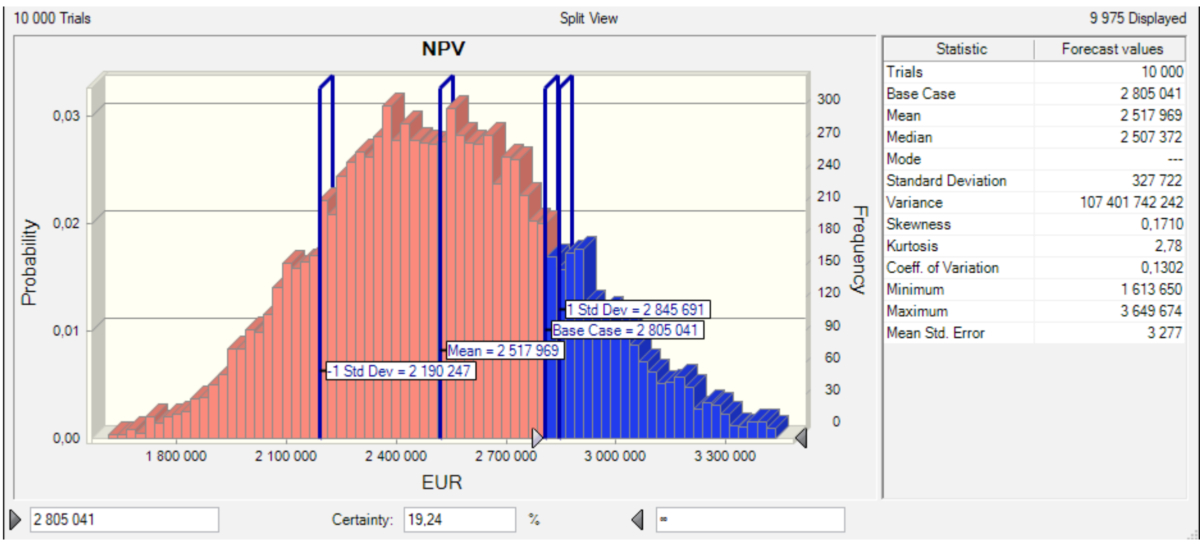

Fig. 6. Histogram of NPV

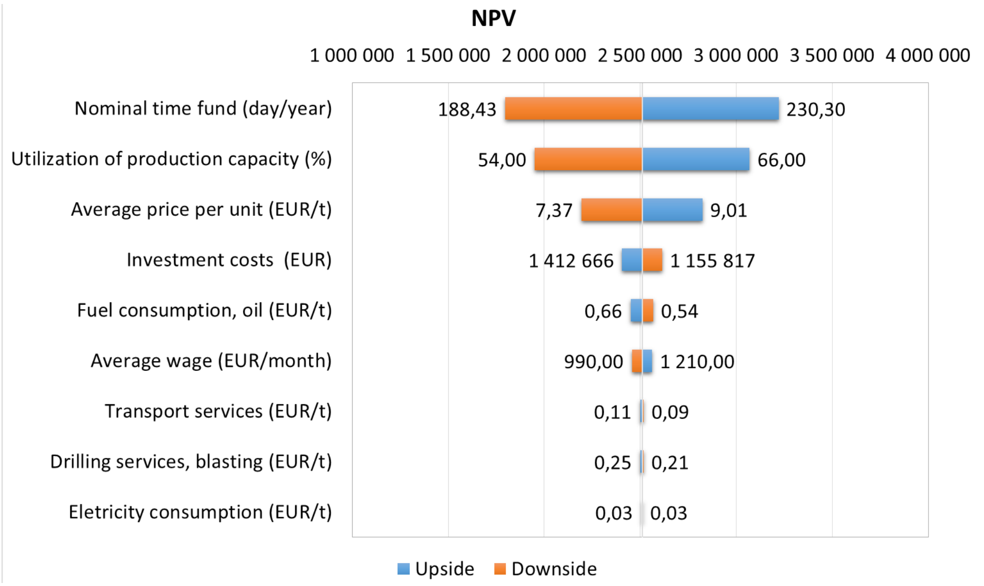

Fig. 7. Tornado chart of NPV

respect, the most important variable is nominal time fund, which is mainly influenced by climatic conditions. Sensitivity chart (Figure 8) presents the contribution of individual factors to output variance. In this respect, the most critical factor is the utilization of production capacity. Uncertainty in the utilization of production capacity is mainly a reflection of demand uncertainty.

CONCLUSION

Modernization of technology and technological equipment is one of the ways of ensuring competitiveness. The increase in production capacity and productivity represents an important competitive advantage for the enterprise. However, this process is associated with high investment costs and investment risk. The goal of the paper was to present modernization of the production process and risk assessment of the investment. The economic efficiency of the modernization was assessed by indicators NPV, PI and DPP. By computing the financial indicators, the investment was assessed as highly efficient with a payback period of 2.4 years and NPV of EUR 2,805,041. Subsequently, the investment risk was assessed by Monte Carlo simulation. Based on the simulation, the mean NPV was significantly lower than the calculated one. In terms of the expected economic efficiency, the greatest risk factor was utilization of production capacity and nominal time fund.

The presented way of assessing an investment project of modernization is a comprehensive approach to investment decision making, which also implements investment risk. However, the reliable use of simulations assumes very good orientation in the market environment, market variables and ability to accurately estimate other impacts such as weather or human factor. These are prerequisites for proper use of simulation tools in risk assessment.

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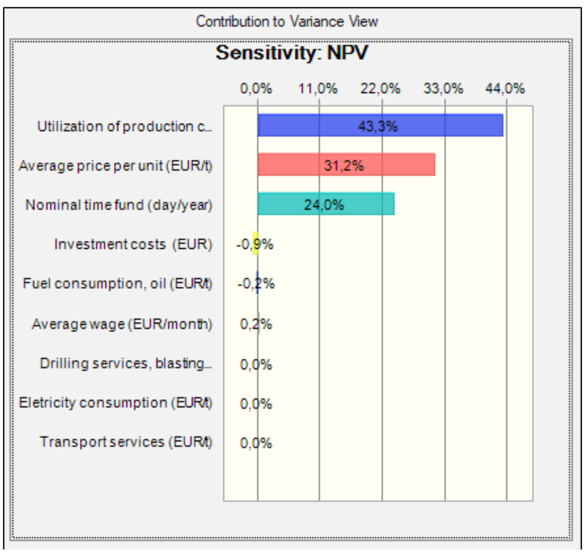

Fig. 8. Sensitivity chart of NPV

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