MAXIMIZING THE PROFITABILITY ON INVESTMENT BY OPTIMIZING THE PRODUCTION PROGRAM

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DOI: 10.17973/MMSJ.2021_10_2021035

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Investments in tangible fixed assets significantly affect the future production capacity of the company, they are a stimulator of the company's development. At the same time, they are associated with a degree of uncertainty that needs to be taken into account when making investment decisions. The article presents an approach to optimizing inhomogeneous production in order to maximize the economic efficiency of a particular business investment. The economic efficiency of the investment is assessed comprehensively in terms of profitability, liquidity and risk. The risk is addressed through Monte Carlo simulation and the production program is optimized using OptQuest. The result is a production program that maximizes the return on the assessed corporate investment.

KEYWORDS

Investment, investment decision-making, risk analysis, Net Present Value, production program

1 INTRODUCTION

The current business environment is highly competitive, subject to geopolitical influences and changes that are frequent, rapid and difficult to predict. The success of a company in such an environment is based on skills, right decisions and real performance. One of the ways to ensure the future success and prosperity of the company is to invest in the renewal of obsolete or development of new production technology. In this way, the production capacity of the company is increased, which the company can use and respond flexibly to market requirements and the associated degree of uncertainty. For this reason, production planning and the overall efficiency of corporate investments should be implemented with a stochastic approach and the application of simulation-optimization techniques. This issue is addressed by several authors who have focused their work on various areas of business. These include: [Gansterer et al. 2014], [Topal and Nakir, 2018], [Fedorko et al. 2018], [Strohmandl and Cujan 2019], [Digernes et al. 2018], [Zhang et al. 2021], [Şenyigit and Mutlu 2021], etc..

For example, investment decisions are made by authors [Haghighat and Zeng] based on scenarios. For this purpose, they developed a stochastic two-level optimization program. The authors [Smirnov et al. 2021] model this problem as a two-stage stochastic program with strategic decisions in the first phase and operational decisions in the second phase.

[Marques et al. 2017] represent production planning, which is based on a combination of an integer linear programming model and Monte Carlo simulation. The Monte Carlo simulation framework is designed as a two-step sampling procedure based on the Bernoulli and normal distribution function. The achieved results confirmed the significant impact of input risk variables on expected profitability. Subsequently, they presented measures that maximize expected profits, which provide a valuable knowledge framework to support a long-term decision-making process. [Dheskali et al. 2020] developed a probabilistic mathematical model for risk quantification. They use the Monte Carlo simulation to estimate the cumulative net present value distribution function, considering a large amount of uncertainty.

The authors [Janekova et al. 2018] compare the deterministic and stochastic approach to assessing the economic efficiency of development investment focused on mass production with an emphasis on maximizing Net present value (NPV). Even in this case, a stochastic approach based on simulation-optimization techniques is preferred. A detailed overview of simulation-optimization techniques used in solving problems with stochastic optimization was compiled by the authors [Ghasemi et al. 2021]. At the same time, they introduced a new simulation-optimization technique, Evolutionary Learning Based Simulation Optimization, inserted into Ordinal Optimization.

The aim of the research is to decide on the acceptability or unacceptability of the proposed investment. The decision-making is implemented and compared using a deterministic and stochastic approach to evaluation the economic efficiency of a proposed investment by dynamic financial criteria. In the case of acceptable investment, the effort is to optimize inhomogeneous production to achieve its maximum economic efficiency. The optimization of the production program is realized by the OptQuest tool through the financial criterion of NPV.

2 MATERIAL AND METHODS

The case study is focused on assessing the economic efficiency of development investment, focused on expanding the company's production program with three new products A, B, C. Product A consists of two components A1 and A2 and its production is supported by a closed long-term order of 3,500 pieces per year. The remaining free time capacity of the production facilities will be used for the production of products B and C so as to maximize the value of the financial criterion NPV. The annual production volume is determined by the annual effective time fund of production facilities and the selected production program. The solution procedure is implemented using a deterministic and stochastic approach.

2.1 Economic efficiency of investment - deterministic approach

In this case, the evaluation of the economic efficiency of the investment is carried out using a deterministic financial model, compiled for six years, including a one-month period of construction of the investment. Achieving the expected level of economic efficiency of the investment is influenced by time, cost and yield factors (see Tab. 1).

Input variables (unit)	Value			
	A	B	C	D
Production (pcs/year)	3,500	3,500	-	-
Production with non-utilized T_{ef} (coeff.)	-	-	0.5	0.5
Production time (hour/pc)	0.25	0.30	0.18	0.10
Product price (EUR/pc)	18.80	20.20	12.20	6.50
Material consumption (EUR/pc)	5.00	6.00	3.40	2.10
Effective time fund of machine_2 machines (hour/year)	3,577			
Use of production capacity (coeff.)	0.8			
Energy consumption (hour/year)	3,000			
Personnel costs (hour/year)	36,000			
Repair and maintenance costs (hour/year)	4,200			
Other costs (hour/year)	7,000			
Depreciation (hour/year)	70,000			
Income tax (%)	21.0			
Discount rate (%)	3.0			
Lifetime of investment (years)	6			
Investment costs (EUR)	420,000			

Table 1. Input variables

The expected level of economic efficiency of an investment is assessed by dynamic financial criteria, such as net present value (NPV), profitability index (PI) and discounted payback period (DPP). In this work, only the financial criterion of NPV is considered, which is calculated according to relation (1), (2):

$$NPV = \sum_{n=1}^{N} \frac{CF_n}{(1+d_r)^n} - IC \qquad (1)$$

$$CF_n = EBITDA_n \times (1-t_n) + D_n \times d_r \qquad (2)$$

Where: *CF* is annual cash flow; d_r discount rate; *IC* amount of one-off investment costs; *N* economic lifetime of the investment; *n* number of years of economic lifetime of the investment; *EBITDA* earnings before interest, tax, depreciation and amortization; *D* yearly depreciation; *t* coefficient of income tax rate.

2.2 Economic efficiency of investment - stochastic approach

The evaluation of economic efficiency in this case is carried out through a stochastic financial model using Monte Carlo simulation and optimization of the production program through the OptQuest tool. In order to be able to use the Monte Carlo simulation, probability distributions and their statistical characteristics are defined for each risk input variable from the deterministic financial model (see Tab. 2). Subsequently, the mean NPV investment is determined.

Variables	Probability distribution	Min.	Likeliest	Max.
Revenues				
Price of product A1	Triangular	16.92	18.80	20.68
Price of product A2	Triangular	18.18	20.20	22.22
Price of product B	Triangular	11.50	12.20	13.50
Price of product C	Triangular	5.50	6.50	7.15
Costs				
Material consumption for A1	BetaPERT	4.50	5.00	5.50
Material consumption for A2	BetaPERT	5.40	6.00	6.60
Material consumption for B	BetaPERT	3.06	4.40	4.47
Material consumption for C	BetaPERT	1.89	2.10	2.31
Energy consumption	BetaPERT	2,700	3,000	3,300
Personnel costs	BetaPERT	32,400	36,000	39,600
Repair and maintenance costs	BetaPERT	3,780	4,200	4,620
Other costs	BetaPERT	6,300	7,000	7,700
Investment costs	Triangular	400,000	420,000	462,000
Times				
Production capacity utilization	BetaPERT	0.72	0.80	0.88
Production time A1	Triangular	0.24	0.25	0.26
Production time A2	Triangular	0.29	0.30	0.31
Production time B	Triangular	0.17	0.18	0.19
Production time C	Triangular	0.10	0.10	0.11

Table 2. Probability distributions of input variables and their statistical characteristics

The following constraints are considered when optimizing the production program with OptQuest:

– the minimum production volume of product A (A1 and A2) is 3,500 pieces per year,

– the maximum amount of the effective time fund (Tef) of the production facility is at the level of 2,861 hours per year, at the same time the following must be met:

$$T_{ef} = T_{A1} + T_{A2} + T_B + T_C \qquad (3)$$

Where: $T_{A,B,C}$ are production times.

– ensure that neither product B nor product C is excluded from production, therefore their share of the free time capacity of the production facility is minimum 0.1 and maximum 0.9. The free effective time fund of production facilities (Tef (free)) is calculated according to relation (4):

$$T_{ef(free)} = T_{ef} - \left(T_{A1} + T_{A2}\right) \quad (4)$$

3 RESULTS

The results of the evaluation of the economic efficiency of the investment by a deterministic approach are shown in Tab. 3.

Based on the calculated values of the financial criteria, it can be stated that the investment is acceptable.

Financial criteria	Unit	Acceptance of the investment according to	Value
NPV	EUR	NPV > 0	33,010
PI	coeff.	PI > 1	1.08
DPP	years	DPP < 6 years	5.49

Table 3. Values of financial criteria

The stochastic approach using the Monte Carlo simulation method takes risk into account when assessing the economic efficiency of an investment. The result is the mean NPV prognosis in graphical and numerical form (see Fig. 1).

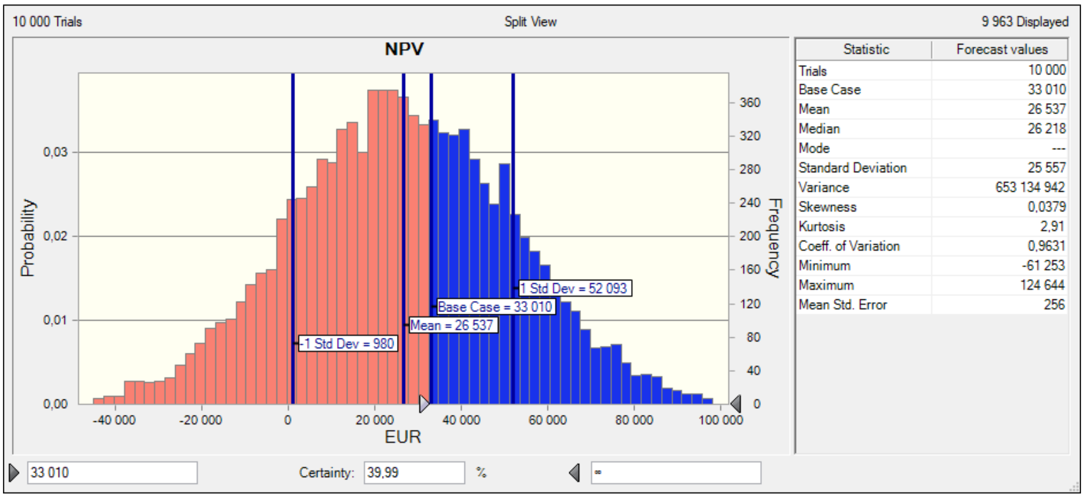

Figure 1 Probability distribution of NPV and statistical characteristics before optimization

The goal of optimization is to increase the return on investment, i.e. determine the volumes of products A1, A2, B and C in such a way as to achieve a maximum NPV in compliance with the defined production conditions. Decision variables are defined as shown in Tab. 4.

Decision variables	Lower bound	Base case	Upper bound	Type	Step
Production A1	3,500	3,500	3,600	Discrete	1
B_share in Tef(free)	0.1	0.5	0.9	Conti-nuous	-
C_share in Tef(free)	0.1	0.5	0.9	Conti-nuous	-

Table 4. Parameters for decision variables

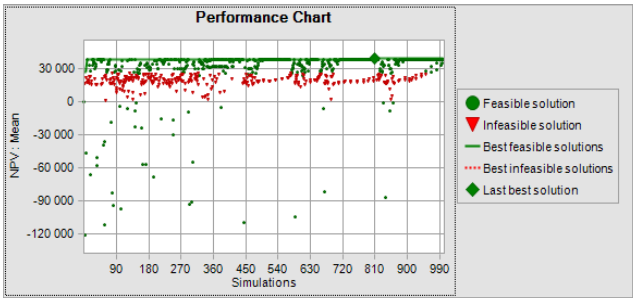

Figure 2. OptQuest results - graphic output

The number of selected optimization repetitions is 1,000 and the results obtained from the OptQuest optimization are shown in Tab. 5 and Fig. 2.

Objective	Value	
Maximize the mean of NPV (EUR)		39,208
Constraints	**Left side**	**Right side**
$T_{A1}+T_{A2}+T_B+T_C$ <= 2,861	2,859	2,861
B+C share in Tef(free) <= 1	1.00	1.00
Decision variables	**Value**	
Production A1		3,600
B_share in Tef(free)		0.90
C_share in Tef(free)		0.10

Table 5. OptQuest results – best solution

By optimizing production to 3,600 pieces per year of products A1 and A2 and redistributing the acquired free production capacity in a ratio of 0.9 in favor of product B with a production volume of 4,405 pieces and 0.1 for product C with a production of 881 pieces, a maximum mean NPVopt value of EUR 39,208 is achieved. The probability that the NPV will be at least as calculated deterministically is 60.58 % for the optimized variant. Further statistical characteristics of the optimized variant are recorded in Fig. 3.

The investment risk analysis is supplemented by a sensitivity analysis of the effects of the uncertainties of the input risk variables to the uncertainty of the output. From the graph (Fig. 4) it is clear that the uncertainty of the mean NPVopt forecast is mostly influenced by the following input variables:

– positive uncertainty of the price of product A2, the price of product A1 and the price of product B,

– negative uncertainty of investment costs and personnel costs.

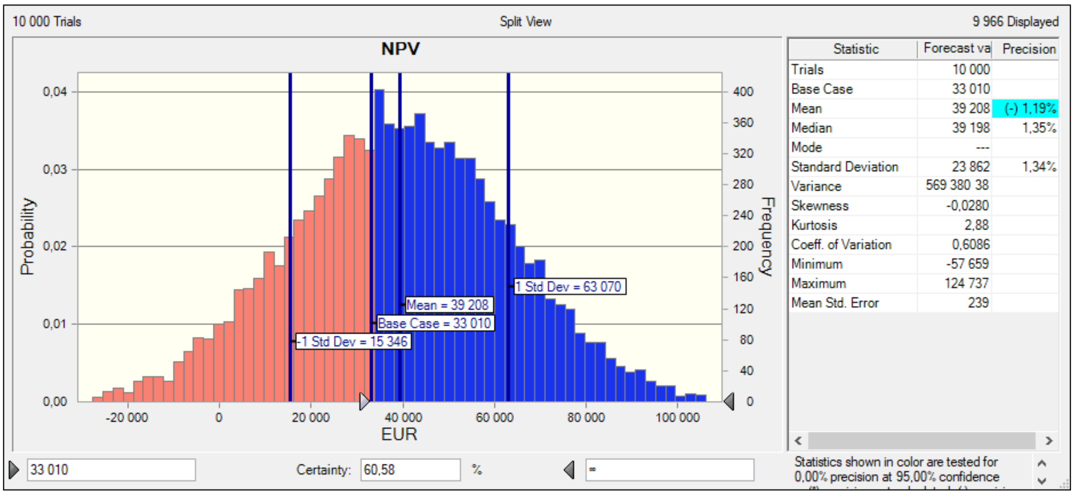

Figure 3 Probability distribution of NPV and statistical characteristics after optimization

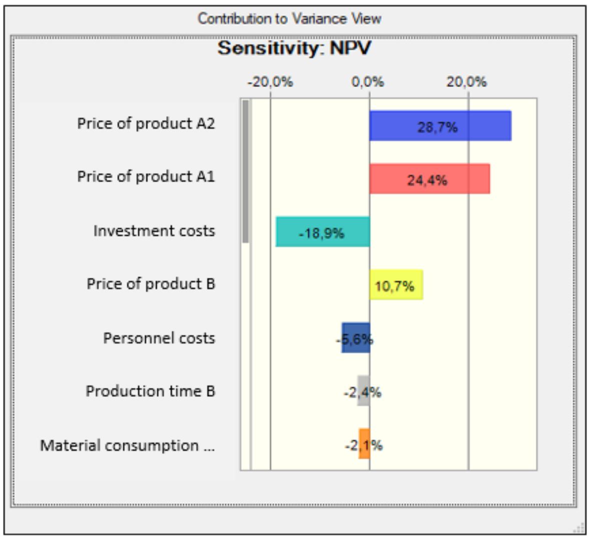

Figure 4. Graph of sensitivity of input risk variables to NPV after optimization

Identifying the most serious risk factors is important from a risk management perspective, as it allows to choose measures that increase the likelihood of achieving the expected result or reduce the negative effects of their changes.

4 CONCLUSIONS

It can be stated that the presented approaches to assessing the economic efficiency of the investment led to the same conclusion when deciding on the acceptance of the investment. The difference between the applied approaches lies in the way of including risk in investment decision-making and the subsequent possibility of analysis and management of risk. Risk considerations can be applied not only when deciding on investments, production planning, logistics but also other decision-making tasks.

The deterministic approach to investment assessment is currently the most commonly used. Dynamic financial criteria are preferred, which consider the time value of money, thus partially involving risk in the form of a discount rate. This approach does not make it possible to assess the impact of individual risk factors on the monitored financial criterion, nor at the same time to assess the impact of the uncertainty of several input variables. This means that this approach simplifies reality, which can lead to wrong decisions.

The stochastic approach in the assessment of investments uses simulations that allow multiple repetitive calculations of the observed financial criterion with the values of risk input variables according to their probability distributions. Thus, the simulations consider the impact of risk input variables on the observed financial criterion. At the same time, the outputs of the simulation provide a picture of the reliability of the forecast of the monitored financial criterion through statistical characteristics and the possibility to examine the impact of individual risk input variables on the monitored financial criterion.

These approaches have also their limitations associated with their application. Although the deterministic approach considers risk to a small extent and only with dynamic financial criteria, it is more independent in terms of the subjective influence of the evaluator. On the contrary, the stochastic approach uses software simulations, but the result is strongly dependent on the expertise of the evaluator. This means that incorrect selection of risk factors, incorrect definition of their probability distributions or unprofessional evaluation of simulation outputs can also lead to incorrect decisions in the company.

The limitation of the study is the fact that the uncertainty of demand was not considered in the stochastic approach of the solution. In order to increase the reliability of the forecast, it is appropriate that, where historical data exist, uncertainties be defined using quantitative forecasting methods. For this reason, further research in this area will focus on the use of simulations and quantitative forecasting methods in solving optimization problems in the field of investment decision-making.

ACKNOWLEDGMENTS

This work has been supported by the Slovak Grant Agency KEGA 009TUKE-4/2020, VEGA 1/0438/20 and VEGA 1/0340/21.

REFERENCES

[Dheskali 2020] Dheskali, E., et al. Risk Assessment Modeling of Bio-Based Chemicals Economics Based on Monte-Carlo Simulations. Chemical Engineering Research and Design, vol.

163, Institution of Chemical Engineers, Nov. 2020, pp. 273–80, ISSN 0263-8762
[Digernes 2018] Digernes, M. N., et al. Global Optimisation of Multi-Plant Manganese Alloy Production. Computers & Chemical Engineering, vol. 110, Pergamon, Feb. 2018, pp. 78–92, ISSN 0098-1354
[Fedorko 2018] Fedorko, G., et al. The Application of Simulation Model of a Milk Run to Identify the Occurrence of Failures. International Journal of Simulation Modelling, vol. 17, no. 3, DAAAM International Vienna, Sept. 2018, pp. 444–57, ISSN 1726-4529
[Gansterer 2014] Gansterer, M., et al. Simulation-Based Optimization Methods for Setting Production Planning Parameters. International Journal of Production Economics, vol. 151, Elsevier, May 2014, pp. 206–13, ISSN 0925-5273
[Ghasemi 2021] Ghasemi, A., et al. Evolutionary Learning Based Simulation Optimization for Stochastic Job Shop Scheduling Problems. Applied Soft Computing, vol. 106, Elsevier Ltd, July 2021, pp. 1–19, ISSN 1568-4946
[Haghighat 2021] Haghighat, H., and Zeng, B. Stochastic Network Investment in Integrated Gas-Electric Systems. Electric Power Systems Research, vol. 197, Elsevier Ltd, Aug. 2021, pp. 1–8, ISSN 0378-7796
[Janekova 2018] Janekova, J., et al. Product Mix Optimization Based on Monte Carlo Simulation: A Case Study. International Journal of Simulation Modelling, vol. 17, no. 2, 2018, ISSN 1726-4529
[Marques 2017] Marques, C. M., et al. A Simulation-Optimization Approach to Integrate Process Design and Planning Decisions under Technical and Market Uncertainties: A Case from the Chemical-Pharmaceutical Industry. Computers and Chemical Engineering, vol. 106, Elsevier Ltd, Nov. 2017, pp. 796–813, ISSN 0098-1354
[Şenyigit 2021] Şenyigit, E., and Multu, S. New Two Level Robust Models for Transmission Expansion Planning Problem under Uncertainty. Journal of the Faculty of Engineering and Architecture of Gazi University, vol. 36, no. 2, Gazi Universitesi, 2021, pp. 897–911, ISSN 1300-1884
[Smirnov 2021] Smirnov, D., et al. Long-Term Resource Planning in the High-Tech Industry: Capacity or Inventory? European Journal of Operational Research, vol. 293, no. 3, Elsevier B.V., Sept. 2021, pp. 926–40, ISSN 0377-2217
[Strohmandl 2019] Strohmandl, J., and Cujan, Z. Risk Minimisation in Integrated Supply Chains. Open Engineering, vol. 9, no. 1, De Gruyter, Jan. 2019, pp. 593–99, ISSN 2391-5439
[Topal 2018] Topal, O., and Nakir, I. Total Cost of Ownership Based Economic Analysis of Diesel, CNG and Electric Bus Concepts for the Public Transport in Istanbul City. Energies, vol. 11, 2018, p. 2369, ISSN 1996-1073
[Zhang 2021] Zhang, Ch., et al. Balancing Irrigation Planning and Risk Preference for Sustainable Irrigated Agriculture: A Fuzzy Credibility-Based Optimization Model with the Hurwicz Criterion under Uncertainty. Agricultural Water Management, vol. 254, Elsevier B.V., Aug. 2021, pp. 1–14, ISSN 0378-3774

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