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RISK MANAGEMENT AND MULTIPLE CRITERIA DECISION MAKING OF ENTERPRISE PRODUCTION PROGRAM

Abstract: *The paper reports investigation on the integration methods for risk management and multiple criteria decision making (MCDM) of production program for achieving better business results as well as mitigating business risks. Multiple criteria decision making was used to define the business strategy variant of production program. The starting point in defining the model of risk management integration for the choice of production program was to define the objective function and real constraints. It is found that the application of quantitative methods for risk assessment, i.e. Bayesian Network, for calculating total risk score more precisely describe a real state-of-art of the system compared to other risk assessment methods. Implementation of the integrated model for risk management and MCDM in manufacturing enterprises increases the quality of decision-making, because for all possible production program variant, profit and total risk are calculated and used to conclusively choose the variant with a highest revenue and lowest risk for production loss occurrence.*
Keywords:*Risk management, MCDM, Bayesian networks, production program.*

1. INTRODUCTION

In contemporary conditions of the operation of the business, the application of the concept of multiple criteria decision making of production program represents a very significant support for enterprise management. Multiple criteria decision making of production program means to determine such a program whose product range, volume and dynamic elaboration on a quarterly basis will bring in maximum revenue, i.e. rational utilization of material, human and machinery resources. Multiple criteria decision making of production program starts from optimality criteria: maximum profit, minimum cost, maximum capacity utilization level, maximum human resources utilization level, minimum material resources utilization level, etc.

Consequently, under contemporary conditions of operating a business it is needed to further develop models for production program management, with the requirement for maximum reduction of business losses. Risk, in general, is the product of the probability of a certain undesired event occurrence and consequences that can be generated by that event. In enterprise's operation of the business there are several categories of risk: safety risk, environmental risk, risk of equipment failure, risk of business losses, etc.

Risk management distinguishes between strategic risk, operational risk, financial risk and compliance risk. Strategic risk includes all aspects in regards to competition, position at the market, conditions of operating a business. Operational risk is related to everyday business operations, i.e. outcomes of everyday decision-making in the enterprise. Financial risks are affected by relationships with banks and shareholders and the like, whereas compliance risk refers to all regulations that one must meet, such as health and safety, environment protection and the like.

Investigation of an integrated model for risk management and multiple criteria decision making of production program is related to the risk of business losses and strategic risk, respectively, i.e. long-term decisions made in the enterprise.

The proposed investigation is highly topical since decision-making at the strategic level has far-reaching consequences, and currently there is no adequate support in the form of a mathematical model, because each enterprise is a unique system, while simulation of a real system in this domain has not been fully studied yet.

The investigation is important for the development of theoretical-cognitive process in defining production program, i.e. improvement of the risk management concept in strategic management of an enterprise, as a segment of the scientific area of industrial engineering and financial management. Also, the investigation is expected to contribute to extending the number of types of available models at disposal of strategic management in managing and decision-making in the enterprise.

2. PROBLEM STATEMENT

2.1. Basic assumptions

Basic hypothesis – the starting point:

An integrated model for risk management and multiple criteria decision making of enterprise production program can contribute to reducing risk of business losses and increasing enterprise management efficiency.

To test the hypotheses formulated in investigation, the designed model should be applied to a concrete example in a pilot factory and tested for the application of the model's impact on the reduction of operating costs, risk occurrence of business losses and increase of enterprise management efficiency.

3. MODEL OF INTEGRATION RISKS IN PRODUCTION PROGRAM OPTIMISATION

In this Section, the modeling procedure of introducing risk as criteria in MCDM of production program is described.

3.1 Modeling of Influence criteria and constrains

The aim of introducing the concept of risk in the production program optimization problem is to also include external factors (apart from internal) in the observed problem, which have significant impact on the enterprise's business results [1,2,3,4,10]. External and internal factors that significantly affect the enterprise's business results achieved by applying optimal production program are referred to as sources of production losses [, 5,6,7]. In real production conditions, production losses occur irrespective of whether the optimal production program has been applied or not. The purpose of employing risk management is to apply the program that is an optimal variant in both earning of maximum profit, maximum capacity utilization level, rationalization of production costs and maximum reduction of risk occurrence for production losses [7,8,9,11].

Influence criteria and constrains for new model for production planning is given on table 1.

***Table 1** – Influence criteria and constrains*

Criteria:	Formula
Maximum profit	$Z_1(X) = \sum_{j=1}^{n} d_j x_j$
Capacity maximum utilization level	$Z_2(X) = \sum_{i}^{m} \sum_{j=1}^{n} \frac{1}{a_{io}} a_{ij} x_j \;, (i = 1,2,...,m)$
Minimum costs	$Z_3(X) = \sum_{j=1}^{n} w_{ckj} x_j \qquad (j = 1,2,...,n)$
Minimum probability risk occurrence for production losses	$P(R_t) = min\{R_{var1}, R_{var2}, ... R_{varq}\}$ *(t=1,2...q)-different variants of production program*
Constrains:	
Limit the needs of the market	$0 \le x_j \le y_j, \qquad (j = 1,2,...,n)$

Limitation of material resources	$\sum_{j=1}^{n} s_{\nu j} x_j \le s_{\nu o}\ , \quad (\nu = 1,2,...,g)$
Limitation of human resources	$\sum_{j=1}^{n} b_{lj} x_j \le b_{lo}\ , \quad (l = 1,2,...,h)$
Limit funds for the work	$\sum_{j=1}^{n} a_{ij} x_j \le a_{io}\ , \quad (i = 1,2,...,m)$
n – Different products which can be produced (j=1 2 ….. n) m – Various machines (i=1, 2….. m), h – Different categories of workers (l=1, 2 …..h) g – Different types of raw materials (ν=1, 2 …..g)	

x_j –	amount of j^th product that enters the production program
y_j –	amount of j^th product that can be sold on the market
$s_{\nu j}$ –	amount of the ν- raw materials needed for production j- unit of product
$s_{\nu o}$ –	amount of the ν- raw materials, materials in stock
b_{lj} –	the time it takes worker of that l-category (profession, specialty, qualifications) to produce the j^th unit of product
b_{lo} –	available fund of working time worker of that l-category
a_{ij} –	time needed for producing j- unit of product on i-machine
a_{io} –	capacity of i-machine, (time unit)
w_{ckj} –	cost per unit for j- unit of product
w_{cpj} –	selling price per unit for j- unit of product
d_j –	profit per unit for j- unit of product

Considerations of the production program optimization problem require the involvement of probability of the occurrence of production losses sources, i.e. the risk of production losses occurrence for different variants of production losses. As there are a number of causes of production losses, and probabilities of their occurrence are mostly conditioned, it is convenient to use Bayesian theorem for a series of input variables. Table 2 displays risk sources that we try to identify that occur in the different phases of the production program such as planning, design, realization and implementation process.

Table 2 *– Risk sources in production program optimization*

No.	Source of risk
R1	Wrong perception of the environment
R2	Wrong assessment of competition
R3	Lack of ecological aspect perception
R4	Policy/market stability
R5	Wrong goal-setting
R6	Wrong SWOT matrix setting
R7	Mistakes in success assessment of previously applied strategy
R8	Mistakes in success assessment of future business operating strategy
R9	Accurate assessment of the environment but mistake in anticipating future trends
R10	Possibility of error in data collection
R11	Possibility of error in the choice of method for optimal production program design
R12	Possibility of error in the choice of model abstractive level, i.e. detailing degree in real model mapping to mathematical model
R13	Possibility of error in determining the criteria, i.e. defining the objective function
R14	Possibility of error in determining constrains
R15	Sales plan
R16	Production plan
R17	Investment plan

R18	Personnel plan
R19	Supply plan
R20	Distribution plan
R21	Depreciation plan
R22	Creation of project documentation
R23	Changes and corrections of project documentation
R24	Technology
R25	Production documentation
R26	Supervision of production processes
R27	ISO standards, procedures and records
R28	EU directives, ecology and the like
R29	Real constraints, stoppages due to environmental impacts
R30	Stoppages in production process due to poor organization
R31	Stoppages due to lack of energy carriers, raw materials, tools, material, etc.
R32	Stoppages due to human factor
R33	Waste occurrence
R34	Possibility of stoppage in the supply chain process
R35	Logistic problems, routes, optimization, means of transport, etc.
R36	Delay due to breach of contract with a contractor/retail and wholesale trade
R37	Transport documentation
R38	Export regime
R39	Payment of financial means from realization of sales for further reproduction

4. EXPERIMENTAL INVESTIGATION

Experimental investigation was conducted at the Factory of Cylinder Assemblies (FCA), Limited Liability Company.. Production program includes pistons, cylinder liners and pins primarily for diesel engines in commercial vehicles, tractors, buses and passenger cars. Cylinder operating space is 50 – 200 mm in diameter. In a large-lot production of a small number of diverse products, the installed capacity could manufacture annually approx. 700,000 pistons and 200,000 cylinder liners. Due to a large number of diverse products and a long setup time, it is possible to manufacture at most 400,000 pistons and 100,000 liners for engines. Currently, pistons and liners are manufactured for the biggest home and world engine manufacturers.

4.1 Calculating risk for FCA for different variants of production program

The analysis of risk source for FCA for current situation identified the following risk sources R = (R1, R4, R14, R15, R16, R17, R19, R29, R30, R31, R33, R34, R35, R38, R39). Figure 3 represents dependencies between risk sources for FCA.

Total risk for variant expressed through Bayes formula for conditional dependencies:

$$P(R)=P(R_1)\cdot P(R_4)\cdot P(R_{14}|R_1)\cdot P(R_{14}|R_2)\cdot$$

$$\cdot \prod_{i=15}^{17} P(R_i|R_{14})\cdot P(R_{19}|R_{14})\cdot$$

$$\cdot \prod_{i=29}^{31} P(R_i)\cdot \prod_{i=33}^{51} P(R_i)\cdot \cdot \prod_{i=38}^{39} P(R_i)$$

Expert assessments were used to estimate the probability of identified risk sources for business variant 1 – work in unchanged conditions of operating a business, generated network, and results for risk sources is given on table 3, (In table 3 is given origin risk source value, calculated as independency events and used for comparison analysis).

***Table 3** – Risk sources assessment for business strategy of the production program – Variant 1*

No	No.	Probability of occurrence (%)
1	R1	10
2	R4	8
3	R14	7.64
4	R15	5.38
5	R16	5.38
6	R17	7.61
7	R19	7.23
8	R29	8
9	R30	11
10	R31	16
11	R33	10
12	R34	8
13	R35	10
14	R38	6
15	R39	10

For the displayed production program variant, total risk amounts to:

$$P(R)=P(R_1)\cdot P(R_4)\cdot P(R_{14}|R_1)\cdot P(R_{14}|R_2)\cdot$$

$$\cdot \prod_{i=15}^{17} P(R_i|R_{14})\cdot P(R_{19}|R_{14})\cdot$$

$$\cdot \prod_{i=29}^{31} P(R_i) \cdot \prod_{i=33}^{51} P(R_i) \cdot \cdot \prod_{i=38}^{39} P(R_i) = 6.58 \cdot 10^{13}$$

Let us denote the products, piston assemblies and cylinder liners, with X1 and X2, consequently. Unit price for piston assemblies is 11.76 Euros and for cylinder liners 14.49 Euros, so the function of maximum profit will have the form:

$$F(X)_{max} = 11.76 \cdot X_1 + 14.49 \cdot X_2$$

Constraints stemming from available machinery capacities are:

$$X_1 \leq 300{,}000$$
$$X_2 \leq 150{,}000$$

Personnel and material resources are not a limiting factor, in this case.

The analysis of balance sheet and success for the year 2012 proved that variable costs amounted to 1,798,637.4 Euros. Total expenditures amounted to 5,322,637.5 Euros, from where it follows that fixed costs were 3,524,000.1 Euros. At given utilization level of machinery capacities, maximum profit would amount to:

$$F(X)_{max} = 11.76 \cdot 300{,}000 + 14.49 \cdot 150{,}000$$
$$F(X)_{max} = 5{,}701{,}500$$

Total costs for this business variant is:

$$T = T_v + T_c = 3{,}524{,}000.1 + 1{,}798{,}637.4 = 5{,}322{,}637.5$$

Profit is calculated as a difference between total revenue and total costs, which amounts to:

$$P = F(X)_{max} - T_v - T_c = 5{,}701{,}500 - 5{,}322{,}637.5 = 378{,}862.5$$

The same procedure is applied for others production program variants with different quantity of product. Figure 1 displays the results of risk sources values for all analyzed production program business strategies.

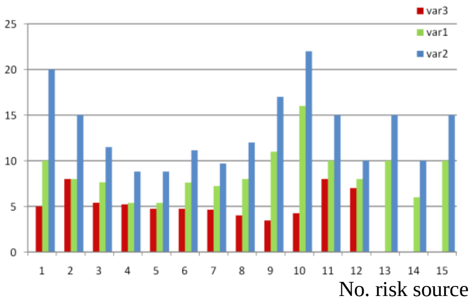

***Figure 1.** – Comparison of results for the values of interdependent risk sources for analyzed variants of the production program business strategy*

5. CONCLUSION

The investigation reported in this paper was the choice of business variant of the production program using the method of risk management. Multiple criteria decision making was used to define the business strategy variant of production program. The starting point in defining the model of risk management integration for the choice of production program was to define the objective function and real constraints.

The objective of a general model of identified risk sources for calculating total risk of the observed business strategy variant of the production program is to facilitate the procedure for calculating risk for a chosen concrete enterprise. Aside from identifying risk sources that influence the realization of the observed production program variant, the general model of identified risk sources also yields interdependencies that exist between risk sources.

Experimentally, the initial hypothesis was confirmed, indicating that it is possible to develop an integrated model of risk management and multiple criteria analysis of production program. Comparative analysis with other models for multiple criteria decision making of production program found that an integrated model of risk management and multiple criteria decision making of production program offers an insight into the level of risk for production losses in the chosen production program variant implementation and the risk sources management in terms of exploring possibilities to reduce the influence level of identified sources of risk.

REFERENCES:

[1] Chen, J. C., Chen, T. L., Pratama, B. R., & Tu, Q. F. (2016). Capacity planning in thin film transistor–Liquid crystal display cell process. Journal of Manufacturing Systems, 39, 63-78.

[2] Fleischmann, B., Meyr, H., & Wagner, M. (2015). Advanced planning. InSupply chain management and advanced planning (pp. 71-95). Springer Berlin Heidelberg.

[3] Florian, M., & Sørensen, J. D. (2015). Planning of Operation & Maintenance Using Risk and Reliability Based Methods. Energy Procedia, 80, 357-364.

[4] Lee, C. Y., Li, X., & Xie, Y. (2013). Procurement risk management using capacitated option contracts with fixed ordering costs. IIE transactions, 45(8), 845-864.

[5] Liu, B., & Chen, X. (2015). Uncertain multiobjective programming and uncertain goal programming. Journal of Uncertainty Analysis and Applications, 3(1), 1-8.

[6] Liu, S., & Papageorgiou, L. G. (2013). Multiobjective optimisation of production, distribution and capacity planning of global supply chains in the process industry. Omega, 41(2), 369-382.

[7] Osborne, A., Risk Management Made Easy, Andy Osborne & Ventus Publishing ApS, Bookboon, 2012.

[8] Senussi G. Improvement of the production program planning process in business-production systems, Doctoral thesis, Faculty of Mechanical Engineering University of Belgrade, Belgrade, 2014.

[9] Shahryar M., Nikoo M. R., Fasaee M.A., Adamowski, J., A novel multi criteria decision making model for optimizing time-cost-quality trade-off problems in construction projects. Expert Syst. Appl. 42, 6 (April 2015), 3089-3104.

[10] Velasquez, M., & Hester, P. T. (2013). An analysis of multi-criteria decision making methods. International Journal of Operations Research, 10(2), 56-66.

[11] Yu, Y., Xiong, W., & Cao, Y. (2015). A conceptual model of supply chain risk mitigation: The Role of supply chain integration and organizational risk propensity. Journal of Coastal Research, 73(sp1), 95-98.