APPLICATION OF MONTE CARLO SIMULATIONS IN ENTERPRISE PERFORMANCE FORECASTING

[1]Jana FABIANOVÁ, [2]Jaroslava JANEKOVÁ, [3] Peter MICHALIK

[1]Technical University of Kosice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Kosice, Slovak Republic, EU, jana.fabianova@tuke.sk

[2]Technical University of Kosice, Faculty of Mechanical Engineering, Kosice, Slovak Republic, EU, jaroslava.janekova@tuke.sk

[3]Technical University of Kosice, Faculty of Manufacturing Technologies, Prešov, Slovak Republic, EU, peter.michalik@tuke.sk

Abstract

Forecasting of parameters of variable nature is always accompanied by a high degree of risk. Questionable reliability of such forecasts, and the effort to eliminate or reduce the impact of factors that adversely affect the accuracy of the forecast lead to the use of software tools utilised in the field of risk management. The article presents the application of Monte Carlo simulations in the development and analysis of the enterprise performance forecast. Analysis of simulation results points out what is the reliability of the forecast and what are the key risk factors.

Keywords: Monte Carlo simulation, performance forecasting, risk analysis

1. INTRODUCTION

In the decision-making process, many methods are used for data processing and optimizing decision-making. Forecasting is one of them. Quick and reliable forecasts can help to make the right decisions, reduce financial and time costs, save sources. The quality of forecasting is extremely important for the accuracy of the results and in turn company future [1,2]. Many scientific works of theoretical and application character deal with this topic. Srivastava et al. [3] review various methodologies for short-term load forecasting. The possibilities of sale forecasting by the comparison are discussed in [4]. Forecasting enterprise performance is significant for financial planning and budgeting. Operating performance is an important reference by investors in their decision-making [5]. Nevertheless, enterprise performance is affected by a number of factors. Know the nature and significance of the individual factors is important for performance control. In addition, how to select a set of representative indicators is an important issue for performance evaluation [6]. The use of modelling and simulations is common also in forecasting. Simulation is a promising approach to predict performance of a business process. Based on prediction results, design alternatives can be compared and verified against requirements [7]. Business process modelling methods that are amenable to simulation are introduced in [8-11]. One of the widely used simulation techniques is Monte Carlo. Monte Carlo simulations have their widespread use in decision-making [12], in prediction [13,14], planning [15,16], as well as, in project risk assessment [17,18]. This paper aims to introduce the use of Monte Carlo simulations in enterprise performance prediction. Knowing the probably development of performance helps to make the right decision and use the right tool to achieve the goal.

2. CASE STUDY DESCRIPTION

The subject of the research is the analysis of the economic results of the Košice Transport Company and the prognosis for the future period. The company provides two types of transport, thus bus and tram. The company is a joint stock company. In addition to income from its own activities, the company is subsidized every year

from the city of Kosice funds. The development of the economic results in recent years has a worsening trend mainly due to extensive reconstruction works on tram tracks. The input to the analysis is the data on revenues, costs and subsidies drawn from annual reports published on the Internet.

3. METHODS AND MATERIALS

3.1. Monte Carlo simulation technique

The Monte Carlo simulation is a quantitative method which, in its calculation, uses statistical simulation of random numbers. The method developed itself also in time. At first, it was only considered as a method, but eventually it became a science discipline. The Monte Carlo simulation creates a task that is structurally similar to a real problem. The solution is the probabilistic estimation of the resulting variable. The output of the simulation is numerical and holds a number of other important information that can be used to analyse risks.

The Monte Carlo simulation procedure is as follows:

- Selection of evaluation criteria that are subject to simulation.
- Determining the dependence of the selected criterion on the input variables.
- Determining the main risk factors.
- Defining probability distributions for risk factors.
- The simulation process itself.

Prognosis of the performance of the selected business is carried out in the following steps (**Figure 1**):

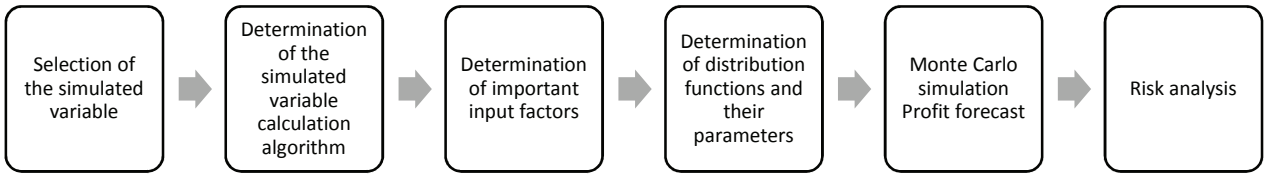

Figure 1 Monte Carlo simulation flowchart [own processing]

3.2. Used materials and data analysis

The input data for forecasting are drawn from the company's annual reports. By analyzing the data of the profitability of the company for the last 10 years, the worsening trend of the overall economic results is determined (**Table 1**). The impact of respective components of cost and revenues is of varied intensity, and also the trend of the individual input variables is of different character. This character can be defined by a suitable distribution function and transferred to the simulation process at prognosis creation. On the other hand, the impact of certain items, despite their trend, may be negligible and others dominant. It depends on their relative share on total costs or revenues and mathematical relations. The Monte Carlo simulation is then able to obtain not only the final prognosis of the economic result but also its probability profile. In the context of the flowchart (**Figure 1**), the first step is to select a simulated variable and determine the calculation algorithm. The simulated variable is the profitability. Its method of calculation is given by the formula (1).

$$P = \sum_{i=1}^{n} R_i - \sum_{j=1}^{m} C_j \quad (1)$$

where:

P - profitability (EUR)
R -revenue item (EUR)
C - cost item (EUR)
i - number of revenue items
j - number of cost items

Total revenues will not include subsidies, as they are not market variables, but they are annually granted from the city budget. Input revenue variables are individual revenues from traffic, asset yields and other revenues. Cost input variables are the cost of consumed purchases (material, fuel, energy, goods), services, personal costs, depreciations and other costs. The structure and development of revenues and costs are presented in detail in **Figure 2** and **Figure 3.** Total revenues, costs and profit are in **Table 1.**

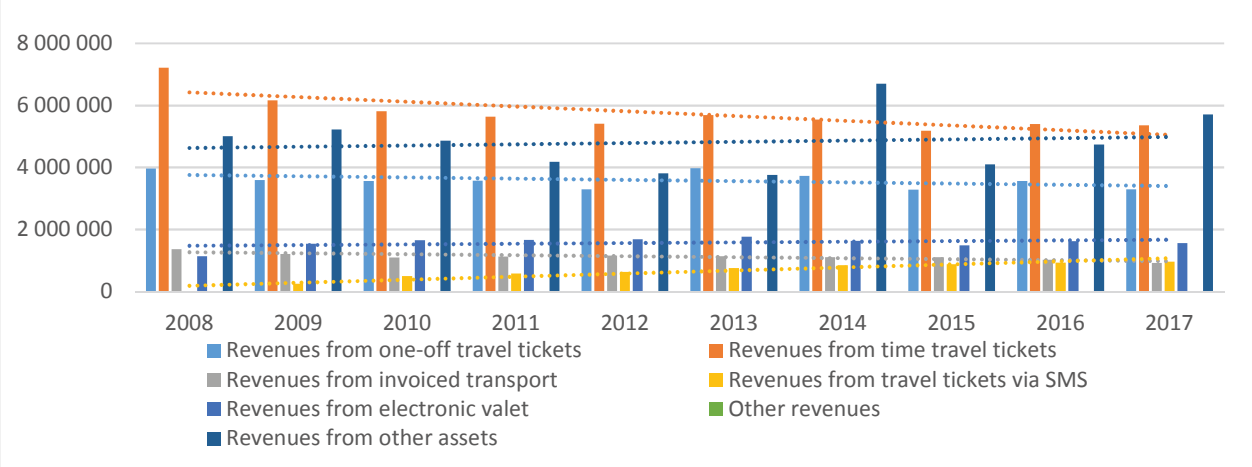

Figure 2 Revenue components in 2008-2017 with trend lines [processed according to 19]

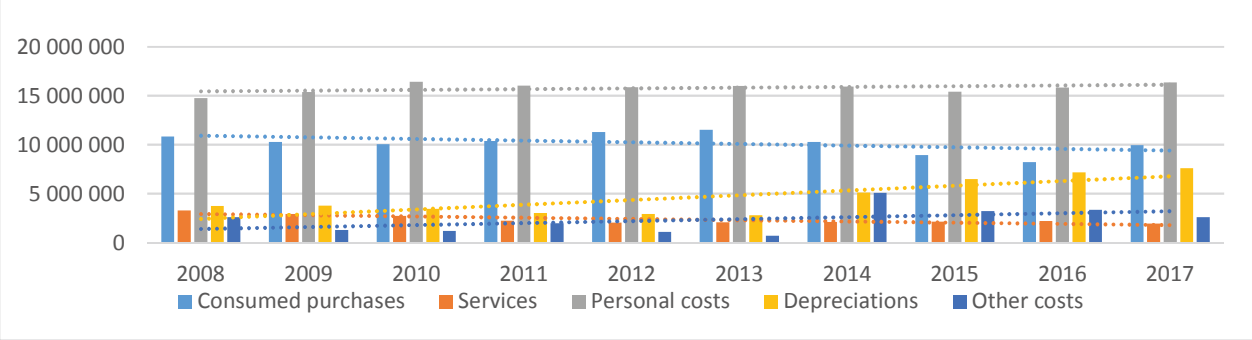

Figure 3 Cost components in 2008-2017 with trend lines [processed according to 19]

Table 1 Total revenue, costs and profit for the period 2008-2017 [19]

Parameters [10^3 EUR]	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Revenues total	18,697	17,981	17,484	16,762	15,997	17,088	19,554	16,041	17,295	17,804
Costs total	35,219	33,635	33,827	33,656	33,215	33,106	38,505	36,165	36,729	38,446
Subsidy	13,893	15,269	16,139	15,500	16,700	16,020	16,670	17,750	17,620	19,741
Profit (without subsidy)	-16,522	-15,654	-16,343	-16,894	-17,218	-16,018	-18,951	-20,124	-19,434	-20,642
Profit (with subsidy)	-2,629	-385	-204	-1,394	-518	2	-2,281	-2,374	-1,814	-901

Input variables that are considered as risk factors influencing the value and reliability of the prognosis are stated in **Table 2**. As a suitable distribution function for these variables is determined the betaPERT. The betaPERT distribution is often used in project risk analysis as a "smoother" alternative to the triangular distribution. For the likeliest values, the actual values for the last period are considered. Min and max values are estimated based on the development of the given parameter in the monitored period.

Table 2 Distribution functions for revenues and costs [own processing]

Variable		Statistical characteristics	Distribution function
Revenue variables	One-off tickets	Likeliest 589.20; Min. 585; Max. 610	BetaPERT
	Time tickets	Likeliest 589.20; Min. 585; Max. 610	
	Invoiced transport	Likeliest 589.20; Min. 585; Max. 610	
	SMS tickets	Likeliest 2,914,059; Min. 2,600,000; Max. 3,200,000	
	Electronic valet	Likeliest 589.20; Min. 585; Max. 610	
	Other revenues	Likeliest 589.20; Min. 585; Max. 610	
Cost variables	Consumed purchases	Likeliest 4.3; Min. 4; Max. 4.6	
	Services	Likeliest 0.04; Min. 0.04; Max. 0.05	
	Personal costs	Likeliest 57,500; Min. 51,750; Max. 63,250	
	Depreciations	Likeliest 589.20; Min. 585; Max. 610	
	Other costs	Likeliest 589.20; Min. 585; Max. 610	

4. RESULTS AND RISK ANALYSIS

By the Monte Carlo simulation is determined the forecast as the average profit for the coming period. The mean value of the simulated variable "Profit" is EUR -20,994,811, which is EUR 353,008 less than the profit achieved in the last year (**Figure 4**).

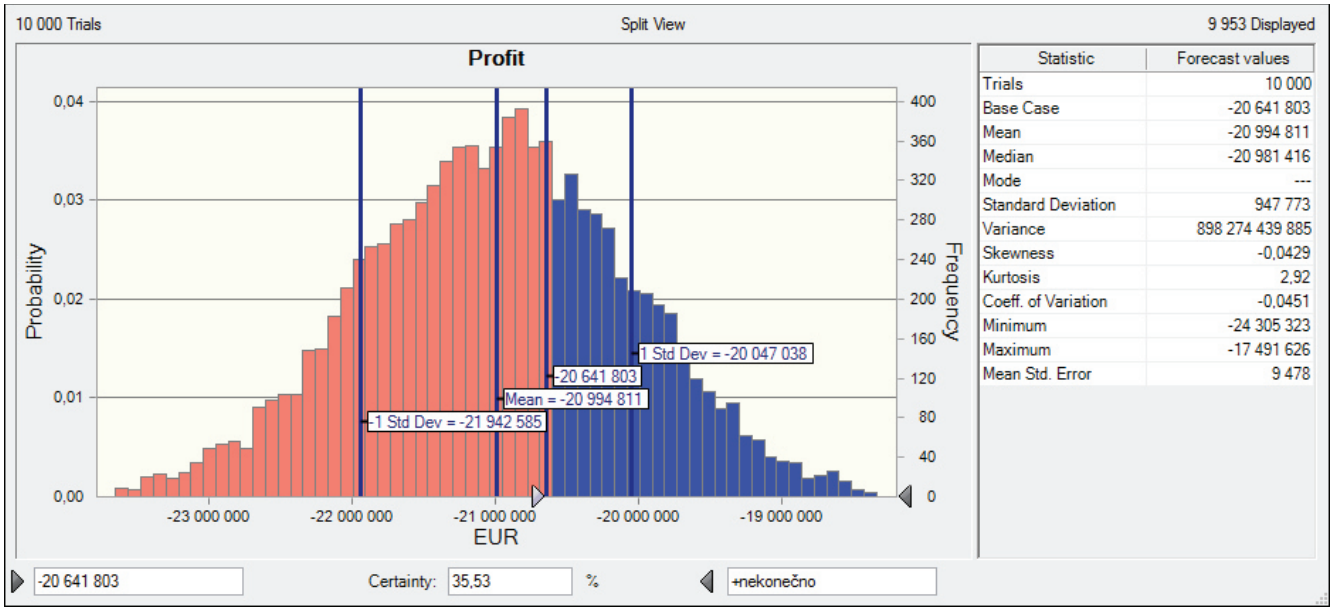

Figure 4 Histogram of enterprise profit forecast [own processing]

The negative impact of the development of revenue and cost items is also confirmed by the low probability that the profit will exceed the value of the last year (certainty only 35.53 %). The reliability of this prognosis is defined mainly by standard deviation. The standard deviation of EUR 947,773 indicates that future profit will be with probability of 67 % in the range of EUR -21,942,585 to EUR -20,047,038.

The Tornado chart informs about the strongest input variables in terms of the uncertainty of the resulting prognosis (**Figure 5**). The highest level of uncertainty in the resulting forecast is the labour cost, which is hard to stabilize in this sector. Therefore, these costs are changing to a larger extent which is also reflected by the

distribution function. Other influential variables include consumed purchases and depreciations. This is due to the constant need to renew, repair and maintain the fleet. From the revenues of transport services are most variable the time ticket sales. In this area, there is room for the introduction of tools for stabilization (possibly also increase the share) of travellers by urban public transport and to make it more attractive compared to automobile transport. Transport by own automobile is still highly preferred, and it causes congestions in rush hours in many parts of the city.

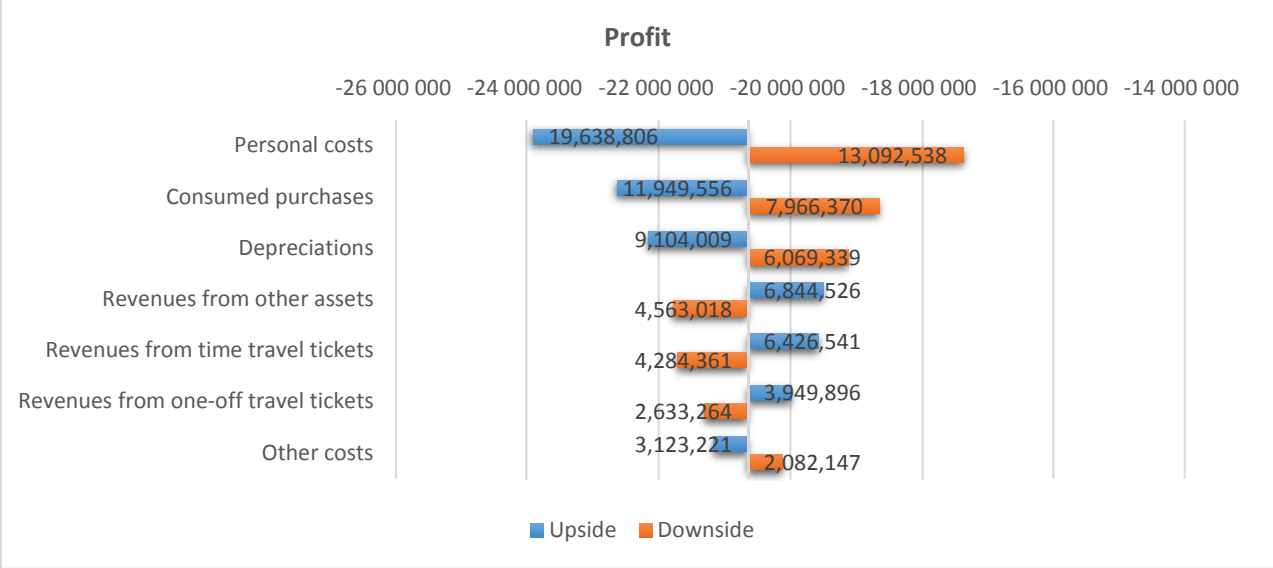

Figure 5 Tornado chart of profit forecast [own processing]

The Spider chart (**Figure 6**) is the result of a sensitivity analysis examining the influence of input variance on the simulated output variable. The graph shows the impact of individual input changes (± 10 and 20 %) on output, expressed in euro. This analysis does not consider into account the real probability of such a change actually occurring. Also, as in the tornado chart, the variable with the strongest impact is the personal cost. From the revenues, the variables with the strongest impact are revenues from other assets and sales of time tickets.

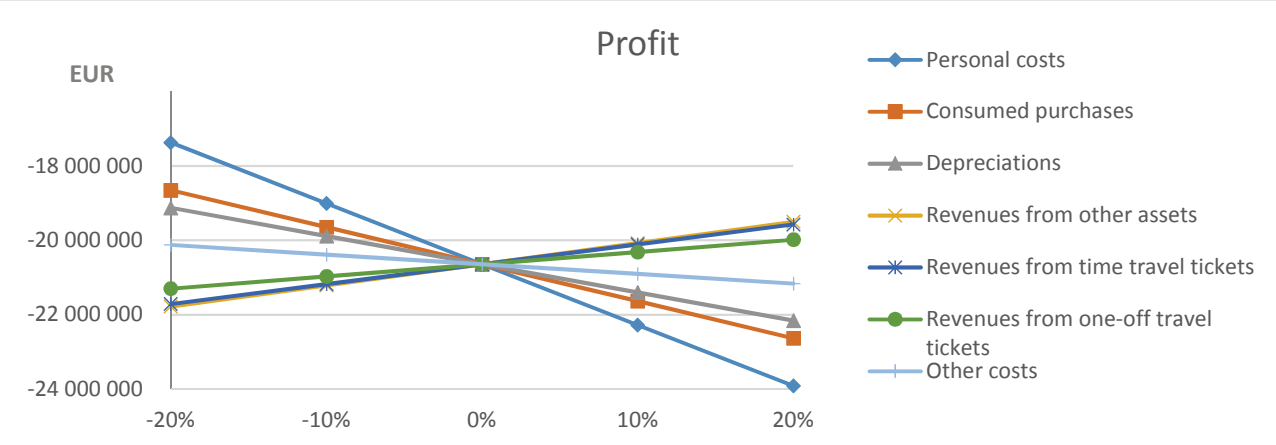

Figure 6 Spider chart of profit forecast [own processing]

The simulation results provide not only the final prognosis, but also other statistical characteristics and indicate the reliability of the prognosis. The sensitivity analysis and tornado graph give information about risk input variables. This information is particularly important in the decision-making process.

5. CONCLUSIONS

Prognosis is an indispensable part of the management process. The use of appropriate simulation techniques and software tools facilitates these processes and makes implementation of effective measures more efficient. The paper presents the possibility of using Monte Carlo simulations in prognosis and risk analysis. The way to apply simulations is demonstrated in a case study on enterprise performance prognosis. Outputs of the simulation, in addition to the forecast itself, provided other useful information about risks and reliability of the prognosis. In particular, Tornado and sensitivity analysis have highlighted risk input variables. The practical usefulness of software tools in the above-mentioned activities is unquestionable. On the other hand, their effectiveness and reliability are strictly dependent on the professional competencies of the user.

ACKNOWLEDGEMENTS

This work has been supported by grant projects KEGA No. 018TUKE-4/2016, KEGA 029TUKE-4/2016, VEGA No. 1/0063/16.

REFERENCES

[1] İNTEPE G., BOZDAG E., KOC T. The selection of technology forecasting method using a multi-criteria interval-valued intuitionistic fuzzy group decision making approach. *Computers & Industrial Engineering*; 2013, vol. 65, pp. 277-285.

[2] PANDA A., JURKO J., PANDOVÁ I. *Monitoring and Evaluation of Production Processes*. Cham: Springer International Publishing. 2016. [viewed 2018-09-23]. Available from: DOI: 10.1007/978-3-319-29442-1.

[3] SRIVASTAVA A. K., PANDEY A.S., SINGH D. Short-term load forecasting methods: A review. In: *2016 International Conference on Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES)*, 2016, IEEE, pp. 130-138.

[4] KAČMÁRY P. Possibilities of sale forecasting by the comparison of branch stores results. *TRANSPORT & LOGISTICS*; 2015, pp. 1-4.

[5] HUANG J. C., PAN W. T. Forecasting classification of operating performance of enterprises by probabilistic neural network. *Journal of Information and Optimization Sciences*; 2010, vol. 31, iss. 2, pp. 333-345.

[6] CHENG C. H., HUANG S. F., CHEN C. T. A Study on Enterprise Performance Prediction Model by Reducing Financial Ratio. *Advanced Materials Research*; 2011, vol. 211-212, pp. 1221-1225.

[7] HEINRICH R., MERKLE P., HENSS J., et al. Integrating business process simulation and information system simulation for performance prediction. *Software & Systems Modeling*; 2017, vol. 16, pp. 257-277.

[8] BARJIS J. The importance of business process modeling in software systems design. *Science of Computer Programming,* 2008, vol. 71: pp. 73-87.

[9] DANESHJO N., MAJERNÍK M., KRIVOSUDSKA J., et al. Modelling Technical and Economic Parameters in Selection of Manufacturing Devices. *TEM Journal*; 2017, vol. 6, iss. 4, pp. 738-744.

[10] NERADILOVA H., FEDORKO G. Simulation of the Supply of Workplaces by the AGV in the Digital Factory. *Procedia Engineering,* 2017, vol. 192, pp. 638-643.

[11] FEDORKO, G., NERADILOVA, H., SUTAK, M., MOLNAR V. Application of Simulation Model in Terms of City Logistics. In: *Proceedings of the 20th International Scientific Conference on Transport Means*, 2016, pp. 169-174.

[12] SARABANDO P, DIAS LC, VETSCHERA R. Group decision making with incomplete information: a dominance and quasi-optimality volume-based approach using Monte-Carlo simulation. *International Transactions in Operational Research,* 2019, vol. 26, iss. 1, pp. 318-339.

[13] RICO-CONTRERAS J. O., AGUILAR-LASSERRE A. A., MÉNDEZ-CONTRERAS J. M., et al. Moisture content prediction in poultry litter using artificial intelligence techniques and Monte Carlo simulation to determine the economic yield from energy use. *Journal of Environmental Management*; 2017, vol. 202, pp. 254-267.

[14] GONG H.- F., CHEN Z.-S., ZHU Q.-X., et al. A Monte Carlo and PSO based virtual sample generation method for enhancing the energy prediction and energy optimization on small data problem: An empirical study of petrochemical industries. *Applied Energy,* 2017, vol. 197, pp. 405-415.

[15] LI M., YANG F., UZSOY R., et al. A metamodel-based Monte Carlo simulation approach for responsive production planning of manufacturing systems. *Journal of Manufacturing Systems,* 2016, vol. 38, pp. 114-133.

[16] JANEKOVA J., FABIANOVA J., IZARIKOVA G., et al. Product mix optimization based on Monte Carlo simulation: A case study. *International Journal of Simulation Modelling,* 2018; vol. 17, iss. 2. [viewed 2018-09-23]. Available from: DOI: 10.2507/IJSIMM17(2)436.

[17] HAN Z., PORRAS-ALVARADO J. D., SUN J., et al. Monte Carlo Simulation-Based Assessment of Risks Associated with Public-Private Partnership Investments in Toll Highway Infrastructure. *Transportation Research Record: Journal of the Transportation Research Board,* 2017, vol. 2670, pp. 59-67.

[18] AVEN T. Risk assessment and risk management: Review of recent advances on their foundation. *European Journal of Operational Research,* 2016, vol. 253, iss. 1, pp. 1-13.

[19] Košice Transport Company Annual Reports 2008-2017, [viewed 2018-09-23]. Available from: https://www.dpmk.sk/dpmk/vyrocne-spravy