The building blocks of risk theory and methodology

N. Kovács, K. Koppány & D. R. Szabó
Széchenyi István University, Hungary

Abstract

The study aims to present a brief summary of the results of a methodological research carried out within the GOP project "Research and development of risk evaluation services in the construction industry". The first part of the study elaborates the literature of risk management process, the logical framework of the development, the concepts of risk and uncertainty, and the measurement and quantification of risks. The second part presents the interpretation of risks and risk analysis techniques used by us. The most important building block of our model is the stochastic network analysis and the Monte Carlo simulation which can generate the distributions of the durations and costs of projects, the two essential characteristics of construction projects. Our method can be mainly used for the collection and aggregation of the knowledge about the existing risks, as well as for analyzing the risks at enterprises, however, it's also suitable for building up of hard statistical data.
Keywords: risk management, project management, Monte-Carlo simulation, construction industry.

1 Aims of research and development

During the development of a construction risk analytics software, we had a product in mind, that is consistent with the risk management process specified in the ISO 31000 standard, effectively supporting the processes, as a whole, with an emphasis on risk assessment processes. The parts of the risk management process were as follows: exploring relations, risk assessment, risk management, monitoring and communication, supporting throughout the entire process.

WIT Transactions on Modelling and Simulation, Vol 59, © 2015 WIT Press
www.witpress.com, ISSN 1743-355X (on-line)
doi:10.2495/CMEM150171

2 On swampy grounds: risk vs. uncertainty

As a first step of the implementation of the application, in order to fund conceptual clarity we carried out an exploration of the literature, since the identification and analysis of risks can only be successful with a consistency of terminology. However, behind the appearances, according to the results of our research, there is no consensus on the concept of risk measurement methods; however, there is a prolificacy of writings on the topic of risk calculations. We would like to show this with a summary of a selection of works, that we consider as relevant and essential of this topic.

In Hungarian, relatively only a few works has been made on this subject. The handbook of Farkas and Szabó [1] provides guidance on the risk management of companies, and accordingly, after the description of the conceptual basis, it deals with the process of risk management and tools, used for the management of risks. About the possibilities and methods of risk quantification, the reader can gather further insight in the appendix made by Krisztian Koppány. A few years after the release of the handbook of Farkas and Szabó, several studies have been published. In addition to the works of Bélyácz [2–5], other authors, such as Dömötör [6], and Badics [7], Kovács [8], Krekó [9], Medvegyev [10, 11], Száz [12] have also published works in this topic. The birth of these works may be explained mainly by the questions, the changes in thinking and the search for answers, brought to the surface by the financial crisis. Other authors analyze the crisis and risk management relationship. Some of these works can be seen as mainstream [13–16], while others are using alternative approaches [17–20]. The cited authors agree, that in the observed economic and financial problems, and in their reflections on the economy, the inaccurate, confusing, not sufficiently nuanced terminology used by the actors has been playing an important role, their development should be a major objective. Medvegyev [10] finds that the clarification and proper use of concepts is important, to distinguish what we mean, when we are working with risks, by using clear terminologies and having conceptual clarity, due to their methodological consequences. Medvegyev [11] also emphasizes that for the application of statistical methods, independent events, identical distributions and large number of observations is needed. Regarding the concepts of risk and uncertainty, he assumes the approach of Knight [21] declaring that uncertainty occurs when the decision-making parameters cannot be revealed, and we can talk about risks, when there's a sufficient number of observations and statistical methods available. Also, under uncertain circumstances, making the right choice can be the application of the principle of "two heads are better than one", during the use of statistical methods the validity of objective criteria and the circle of drawn conclusions can be seen as limited. Száz also finds that the accurate and consistent use of terminology is substantial regarding the exploration, measurement and management of risks and in the cases of risks likelihoods and uncertainties, the term "chances" should be used [12]. According to Kovács, from a statistical point of view, risk can be seen as a latent concept, which cannot be measured directly. Kovács also highlighted the importance of the Bayesian estimation, which can be seen as an alternative paradigm, beside the Frequentist

Theory [8]. According to the concepts of measurement, management of risks, there's an observable lack of consensus, however several discussions on this topic and a wide range of recommendations also can be found in the international literature.

Knight attempted to explore the nature of business processes and profit in his work "Risk, Uncertainty, and Profit" [21]. He distinguished the concepts of risk and uncertainty. The probability distributions of risks can be recognized; the probabilities of occurrences and the expected effects of risks can be calculated, while in case of uncertainty, there are no available statistical–mathematical methods and also there is no real basis for the classification of the alternatives. The uncertainty of Knights is usually called structural uncertainty (see Bélyácz [2–5] and [21]). From the three main elements of Keynes' probabilistic approach [22], the first is the logical connection, which can be seen as objective, the second is the knowledge of logical relations, and the way the decision-makers perceive these connections, which can be relative and subjective, and the third is the evidence of the central statements, the premises of knowledge, which can be seen as subjective. Keynes says that decision-makers are rather making their decisions on the basis of their common sense rather than statistical probabilities. Their past experiences and choices can serve as the underlying reasons [23] (also cited by Kovács *et al.* [24]). Keynes acknowledged the valuable role of experience, but also found it to be insufficient, thinking about it as rather having a supportive role, and the probability of uncertain events' occurrence cannot be approached by their relative frequencies. Long-term projections, based on historical data are strained with uncertainty, because exogenous conditions can vary in so many ways, that on the basis of present knowledge about final events, it makes long-term forecast of future events meaningless. Independently from Knight, Keynes considered an event to be uncertain, if its probability cannot be calculated. He thought that an economic system is too complex to be properly modeled, from which he concluded that economic theory is a simplified presentation of complex relations and not an exhaustive presentation of the whole (see more [2–5] and [22]]).

In the works of the post-Keynesian, the understanding of the world, full of uncertainties, are not based on probability distributions. Only Shackle [25] made an attempt to establish a formula, suitable for being an explicit replacement, substituting the term of probability with the term of possibility, based on the concept of potential surprises. Possibility means mutually exclusive alternatives ([25] also cited by Bélyácz [2]). The potential surprise is an ordinal concept: the alternative options can be arranged on a scale, with the degree of potential surprises all the way up, from the minimum to the maximum, which are the events that are considered to be impossible to assign. In the logic of Shackle, perfect foresight is not possible. Davidson [26] takes a generally very similar position, when he says that neither the efforts being made on the analysis of past data, nor an examination of the current market situation is expected to provide reliable statistically or assist in the intuitive understanding of the future. According to the post-Keynesian thinking, neither the objective probabilities, based on relative frequencies, nor subjective probabilities are enough to make the future foreseeable, the future is uncertain [2].

3 Risks are measurable, aren't they?

Some of the works of the related literature strongly questions the measurability of risks and in line with economic decisions, discourses about uncertainty that cannot be measured, and there's also a direction, which attempts to quantify the risks, merging the concepts of risk and uncertainty. We feature some index-numbers of risks based on Bélyácz's works. As a measure of risks, variance was first used by Fisher [27], then the variance and standard deviation appeared in the portfolio theory of Markowitz [28] and in the works of Rudd and Clasing [29], as well (cited by Bélyácz, too [2]). In 1938, Marschak [30] suggested the use of the average rate of return and the covariance matrix of consumer goods, while Rothschild and Stiglitz [31] recommended the average-retaining scattering as a measure of risk indicators. For investors, any quantifiable degree of risk and uncertainty can only be an approximation, highlighting a factor of the real risk. With regards to the indexes listed here, it should be also noted that each of them belongs to the category of frequency-based probability. Despite of their prevalence, we believe that their validity is limited, since sufficient data, and homogenous and stable populations behind the data are needed, and in reality, these can be very rarely facilitated [8]. In economics, it's difficult to defend the approach of probability objectivity with reasons [2]. In addition to the objectivist approach, in some cases, the subjectivist approach can be used for the measurement of risks. According to the advocates of the subjective probability theory, probability is none other, than the degree of sentiment in respect of a given statement and the probability of an event is the extent to which one is willing to execute an action. According to Ramsey, subjective probability can only be affiliated to personal knowledge and it is controlled by sentiment and the unincorporated knowledge [32]. Subjective probabilities can also be interpreted as values that reflect the sentiments of the actors' objective probabilities [33].

In reality, we are very often confronted with insufficient data available for the calculation of objective probabilities, in which case other factors should be considered for the effective management of risks; like the existing knowledge about the processes or other subjective concepts. The subjective judgment plays a very important role when the knowledge regarding risks, present in the organization, should be collected, analyzed, and evaluated in the risk management process. The value judgment, experience of experts can have an important role in the proper preparation of decisions for the future. As an example, the regulatory changes in the community-wide electricity sector can be mentioned, in which the system's exposure to risks on the basis of expert criteria was reduced [34]. The examples, without attempting to be comprehensive, clearly show the absence of a consensus in the works of economic sciences, dealing with risks. We accept the idea that the concept of risk and uncertainty should be distinguished from each other. Risks can be quantifiable with the use of objective or subjective probabilities, and limited and carefully though, they may be taken into account, when making decisions. We should attach importance to subjective probabilities in those cases when there is no past, empirical data on individual, not certain events, however, at the same time, we would like to bring the gained experiences forward and return them to the surface in some form.

4 Using Monte Carlo for simulation in construction projects

The use of Monte Carlo simulation can be seen as popular in the risk analyses of construction projects, which we also relied on in the quantification of risks. The use of Monte Carlo simulation may take place in stochastic modeling, when the output is a frequency distribution instead of being a specific number. The use of simulation methods for measuring the risks of projects goes back to the 1960s. It should be noted, the aim of the study is not the precise presentation of the mathematical methods.

Hertz's work can be considered as a basis for the analysis of risks, giving the probability distribution of the NPV (net present value) as a result [35]. Today, this approach appears to be relatively popular; several risk analysis softwares are based on this logic. Dailami *et al.* developed an algorithm for computer simulation, that can be used for the risk management of finance transactions of infrastructure projects. The substance of their algorithm, using Monte Carlo simulation was to generate key indicators, like the probability distribution of the NPV, IRR, yield coverage and debt-service coverage, their possible values, intervals, and the likelihoods of their occurrence [36]. According to Groenendaal and Kleijnen [37], project risks, financial and technological risks should be separated, and sensitivity analyses based on statistical factorial design can bring to more robust estimates, even with lower information needs, and it is able to allay the decision makers' need for information better, than the method of Hertz. Borgonovo found that the uncertainty of the input parameters' values, observed during the measurement of risks, strengthens the uncertainty of the estimates. He introduces a sensibility parameter, which can be identified by correlation between the variables, and which shows the impact of the uncertainty observed in the model's input variables, on the full distribution of the output variable [38]. Schonberger examined the possibility and the necessity of simulations regarding the project flow and the determination of critical paths. In his view, regardless of using, the more complex projects with volatile activities are the more significant of the delay of the project could be [39]. Kwak and Ingall emphasize the role of Monte Carlo simulation in the measurement and analysis of risks and uncertainties of projects. Monte Carlo simulation provides an opportunity for project managers to quantify the impacts of risks and uncertainties. They see as a disadvantage that it does not manage the managerial interventions (such variables can be incorporated into the model), and its highly demand for data and information, too, which are difficult to obtain on the one hand, on the other hand, this information could be on several occasions uncertain [40].

According to the study of Golenko-Ginzburg and Goni, those project networks with a simulation procedure, considering random effects are really promising [41]. The study of Pich *et al.* interprets the project as a payoff function, which depends on the environmental variables (political, economic, social, legal), as well as on the selected network of the actions (processes). They identified three fundamental project management strategies; instructionism, learning and selectionism [42]. Akhavian and Behzadan present a new dynamic data-driven simulation method which based on real time and on-site data collection [43]. The study of Zhi presents a method that can be successfully used for the management of foreign construction projects, regarding its probability-based analysis of risks and measurement of the impacts of risks [44]. The study of Thevendran and Mawdesley presents a short series of questions, which were used during the interviews with professionals involved in the implementation of projects. The study provides good guidance on the measurement of human construction risks [45].

Zou *et al.* find that there isn't really a holistic approach that would register and analyze the risks by taking into account the development processes of a project as a whole. They identified that which risks are associated with the key actors of a project [46]. Simu presents a methodology for the risk management of small-sized construction projects [47] Nelson's study gives an excellent summary of significant and pioneer stochastic simulation methods used in the management sciences [48]. Banaitiene and Banaitis emphasized the importance of risk management during a recession. They highlighted certain skills, according to the authors, the improvement of these domains can reduce the risks of projects [49]. The study of Ward and Chapman clarifies the basic algorithms and rules of the analysis of project risks and outlines an algorithm for management, which can help in minimizing the risks of projects [50]. Sung and Kuo explored the risk analysis of construction projects with BOT structure (the abbreviation of build, own and transfer). They found that the use of Monte Carlo simulation can help to identify the project risks, the use of the NPV method is justified by long running of BOT projects [51]. Attarzadeh and Chua analyzed the risks of long-term PPP BOT-structured projects as well, with the NPV being target variable, by applying the Monte Carlo simulation as the simulation methodology [52]. Öztaş and Ökmen applied Monte Carlo simulations in the modeling of time and cost risks [53].

5 Methodological building blocks of risk assessment procedures based on the expert-reviews

The relevant literature makes clear that in the analysis of risks, subjective evaluations of uncertain events are of great importance, since the criteria of objectivity – i.e. a sufficient number of observations, the homogeneity of the population behind the data, and the criteria of unchanged conditions – are extraordinary. Prior to the development activities, the results of our market research revealed that there are no regulated and regularly applied risk management processes at the majority of the players of the highly concentrated Hungarian construction industry, however, there's a noticeable need for a decision support and preparation process, supporting the organization and the use of the existing professional knowledge, helping to reach objectives of the risk management. For a part of the results, see more details in [54, 55]. The lack of controlled processes also means that the players of the industry have no databases

– or have only ones with limited availability – that would be well suited for the risk analysis of projects. As a result of the literature and market research and the brainstorming of professionals, it also became clear that for only a small proportion of risks, affecting the success of construction projects, are available from the perspective of the corporate, endogenous or exogenous databases. Consequently, the options for objective risk calculations are limited. With the described conditions, our goal was to develop a decision support process and a software prototype, which allows the users to: to build/develop a risk management approach at their companies; to easily deliver attractive and useful analysis results in a short time; to get aesthetic and effective output charts and tables, which, as part of the analysis can be directly integrated into reports, presentations, proposals. The described objectives of the development can be achieved by the proper linking of three disciplines – project network methods, probability theory and corporate finance. The choice of methodological components was assigned to these objectives. The components of the methodology are the following.

5.1 Project planning

Activities in construction sector are predominantly project-oriented. The project network planning methods are well suited for the systematization of activities, for taking into account their inter-relatedness and for modeling the time courses for sets of activities. We chose the CPM network, for which we developed an algorithm in order to analyze the critical path and to determine the total duration of projects.

5.2 Risk interpretation

The execution time of each activities and thus the entire project, costs and cash flows can differ from the projected values, both in favorable (concerning the plans, the implementation of the project is succeeded sooner and/or with lower costs) or in unfavorable directions (the scheduled time and budget is exceeded). So the differences between the plans and the reality can have positive and negative values, which correspond to the definition of symmetric, speculative risks [56].

5.3 Stochastic project network planning, Monte Carlo simulations

With fixed projected numbers, and with the interpretation of the actual/projected changes or the actual data interpreted as a variable with a chosen distribution, we can run Monte Carlo simulation on the project network.

5.4 The treatment of costs and cash flows

Activities have not only needs for time, but for other resources, too. These are approached in summarized forms, by their values, i.e. by their costs. A cash-flow-based management of the project budget has been developed, as well. According to the cost-approach, at the beginning of the set of activities the costs of the project start at zero, the individual elements of costs can incur at the beginning, at the end or evenly during the set of the activities, increasing the total cost of the project gradually with time, until the end of the project, all costs incur.

5.5 Risk register and activity-risk matrix

Usually more risk factors contribute to the positive or negative differences of the duration and cost plans. As part of a multi-round brainstorming, with the involvement of experts, these factors and their main characteristics has been registered, including their contribution to certain stages of projects. We have developed a precedence diagram, that can be used – unless after some modification of activity – for most of the construction projects. It was obvious that nor the risk factors, nor the detailed system of activities would be suitable for getting holistic expert evaluations quickly and efficiently, regarding the whole project stages or the risks of the projects. According to the goals of our software, we have developed an activity-risk matrix, with a manageable number of factors, containing a total of 12 project phases (activity), 7 risk factors groups and 84 cells to be evaluated. This matrix would be the basis of the expert queries and is included in the basic version of the risk analysis software, as well. The risk-action matrix is perfect for the collection of professional subjective risk assessments and it allows their aggregation. There are three versions of it that should be used for data collection.

5.6 The aggregated distributions of time and cost by project activities

From the user settings, reflecting the potential impacts of risk factor groups, only a single time and cost differential distribution should be generated. On the basis of expert reviews, there's a triangular distribution available for each risk factor group per activity groups, with which the expert evaluated the impacts of the given factor solely on the project time and cost plans, assuming that the effect of other factors will not apply.

5.7 Joint distributions, Monte Carlo simulations

Joint distribution can be formed by taking all of the possible combinations of the outputs of triangular distributions, belonging to the group activity and by multiplying them with their corresponding probabilities. By that, the definition of probabilities would be solved; however, the aggregation of the impacts and differences, generated by a certain group of factors would remain problematic. Both additive and multiplicative aggregation can raise serious problems. In case of multiplicative aggregation of risks, the theoretical upper limit of the joint distribution would be too high to be compatible with the practical experience. Another problem is that shape of the joint probabilistic distribution, generated according to the probabilistic rules, does not meet the practical experience

5.8 The "heuristic" approach: weighted superpositions

We are trying to satisfy the previously defined expectations by superimposing i.e. by superpositioning of distributions. We think that our initial distributions, by being based on the reviews of experts – despite their "heuristic" nature – are more expedient and their results are more compatible to the practical experience. The core of the method can be best described by starting from a risk-free situation; then the planned and actual difference rate is 0% with 100% probability. If at a group of factors a risk occurs (the probability of positive and/or negative deviation incurs), the probability of the 0% difference would decrease. The question is: to what extent? With the importance weights, we can set the rate that represents the given group of risk factors per unit of the probability. To ensure the progressivity, we take the sum of the natural exponential function's values adjusted for each risk factor groups of the groups of activities, and by that, we divide the exponential of the weight of the given factor. The weights determine the role of individual risk factors in the difference between plan and reality. The distributions of the time and cost differences, generated by the weighted superposition of the seven activity groups, are named as super distributions. These form the basis of the risk calculations in the basic version of the software.

6 Conclusions

Some of the economic theories dealing with issues of risk and uncertainty, on the grounds of measurability, distinguish the concepts of risk and uncertainty. From a mathematical point of view, some of the uncertain events can be measured objectively, while others only subjectively. Objective evaluation requires the homogeneity and stability of the population behind examined data, for the subjective evaluation and assessment experience, credibility, a sharp eye and mind are needed. In this study, we introduced the methodology based on professional experience and subjective risk assessment, and also gave a taste into the development of our software. We also gave an insight into our development results of the objective assessment of risks, too. With our work, we would like to contribute to the development of risk management's literature and to the business practice, as well. To be continued.

References

[1] Farkas, Sz. & Szabó, J., *A vállalati kockázatkezelés kézikönyve*, Dialóg Campus Kiadó, Pécs, 2005.

[2] Bélyácz, I., Kockázat vagy bizonytalanság? Elmélettörténeti töredék a régi dilemmáról. *Közgazdasági Szemle*, 57(7–8), pp. 652–665, 2010.

[3] Bélyácz, I., Kockázat, bizonytalanság, valószínűség. *Hitelintézeti Szemle,* 10(4), pp. 289–310, 2011.

[4] Bélyácz, I., Kockázat és bizonytalanság a döntésbeli alkalmazhatóság tükrében. *Hitelintézeti Szemle*, 10(4), pp. 379–385, 2011.

[5] Bélyácz, I., Várakozások, bizonytalanság, valószínűség. Értekezés a kockázat számszerűsítésének korlátairól. *Közgazdasági Szemle*, 57(7–8), pp. 652–665, 2013.

[6] Dömötör B., A kockázat megjelenése a származtatott pénzügyi termékekben. *Hitelintézeti Szemle*, 10(4), pp. 360–369, 2011.

www.witpress.com, ISSN 1743-355X (on-line)

[7] Badics, T., Arbitrázs, kockázattal szembeni attitűd és az eszközárazás alaptétele. *Hitelintézeti Szemle*, 10(4), pp 325–335, 2011.
[8] Kovács, E., A kockázat mint látens fogalom. *Hitelintézeti Szemle*, 10(4), pp. 349–359, 2011.
[9] Krekó B., Kockázat, bizonytalanság és modellkockázat kockázatkezelési szemmel. *Hitelintézeti Szemle*, 10(4), pp. 370–378, 2011.
[10] Medvegyev, P., Vélekedések kockázatról és bizonytalanságról (Bevezető). *Hitelintézeti Szemle*, 10(4), pp. 314–324, 2011.
[11] Medvegyev, P., Néhány megjegyzés a kockázat, bizonytalanság, valószínűség kérdéséhez. *Hitelintézeti Szemle*, 10(4), pp. 314–324, 2011.
[12] Száz J., Valószínűség, esély, relatív súlyok. Opciók és reálopciók. *Hitelintézeti Szemle*, 10(4), pp. 336–348, 2011.
[13] Csiszárik-Kocsir, Á., A gazdasági válság hatására kialakult recesszió érzékelése egy kérdőíves kutatás eredményeinek tükrében, *Humánpolitikai Szemle*, 2012 (03), pp. 52–60, 2012.
[14] Csiszárik-Kocsir, Á., A huszonéves fiatalok pénzügyi döntésekhez való hozzáállása egy kérdőíves kutatás eredményeinek tükrében, kgk.sze.hu/images/dokumentumok/VEABtanulmanyok/csiszarik_kocsir_a gnes.pdf.
[15] Borzán, A., Komplex mutatók alkalmazhatósága a térszerkezeti kutatásban. kgk.sze.hu/images/dokumentumok/VEABtanulmanyok/borzan_anita.pdf.
[16] Timár, I. Z., Borzán, A., A bankok és biztosítók együttműködése napjainkban.kgk.sze.hu/images/dokumentumok/VEABtanulmanyok/timar _istvan.pdf.
[17] Szigeti, C., Alternatív mutatók, jólét és fenntarthatóság Magyarországon *Polgári Szemle: Gazdasági És Társadalmi Folyóirat*, 7(3) paper 445, 2011.
[18] Szigeti, C., Ökológiai lábnyom mutató időbeli és térbeli elemzése *Journal Of Central European Green Innovation*, 1(2), pp. 51–68, 2013.
[19] Tóth, G., Miért van szükség új közgazdaságtanra? *Valóság*, 52(5), pp. 68–84, 2009.
[20] Tóth, G., Mi legyen a gyerek neve? A haszonökonómiától a gazdasági teológiáig. *Valóság*, 2013(4), pp. 43–63, 2013.
[21] Knight, F. H., *Risk, Uncertainty, and Profit.* Hart, Schaffner & Marx–Houghton Mifflin Co., Boston, MA, 1921.
[22] Keynes, J. M., *A Treatise on Probability*. MacMillan, London. 1921.
[23] Keynes, J. M., *The General Theory of Employment*, Interest and Money, The General Theory of Employment, Interest and Money (New York and London: Harcourt, Brace and Co., 1936), Part VII of Chapter 12, 1936.
[24] Kovács N., George A. Akerlof & Robert J. Shiller: Animal Spirits: how human psychology drives the economy and why it matters for global capitalism *Tér-Gazdaság-Ember* 1(3), pp. 119–123, 2013.
[25] Shackle, George L. S., *Expectation in Economics*. England Cambridge University Press, Cambridge, 1949.
[26] Davidson, P., Rational Expectations: A Fallacious Foundation for Studying Crucial Decision- Making Processes. *Journal of Post Keynesian Economics*, 5(2), pp. 182–197, 1982.

[27] Fisher, I., *The Theory of Interest*. MacMillan, New York, 1906.

[28] Markowitz, H., Portfolio Selection. *Journal of Finance*, 7(1), pp. 77–91, 1952.

[29] Rudd, A. & Clasing, H. K., *Modern portfolio theory*. Orianda, California, 1992.

[30] Marschak, J., Money and the Theory of Assets. *Econometrica*, 6(4), pp. 311–325, 1938.

[31] Rothschild, M. & Stiglitz, J., Increasing risk: I. A definition. *Journal of Economic Theory*, 2, pp. 225–243, 1970.

[32] Ramsey, F. P., Truth and Probability. In: *The Foundations of Mathematics and other Logical Essays*. London, Kegan Paul, Trench, Trubner and Co., 1931.

[33] Jeffrey, R. C., *The Logic of Decision*. The University of Chicago Press, 1983.

[34] Deutsch, N. & Pintér, É. & Pintér, T., The Effects of Liberalization in Former Regulated Sectors in the *European Union: The case of Power and Financial Industries*. In: Andrássy Gy., Kakönen, J. & Nagy N. (eds.): European Peripheries. Publikon, Pécs, pp. 59–75, 2012.

[35] Hertz, D. B., *Risk analysis in capital investment.* Harvard Business Review, 42(1) pp. 95–106, 1964.

[36] Dailami, M., Lipkovich, I. & Dyck, J. V., Infrisk: *A Computer Simulation Approach to Risk Management in Infrastructure Project Finance Transactions,* World Bank, 1999.

[37] Groenendaal, W.J.H.V. & Kleijnen J.P.C., On the assessment of economic risk: factorial design versus Monte Carlo methods, *Reliability Engineering & System Safety*, 57(1), pp. 91–102, 1997.

[38] Borgonovo E., “a new uncertainty importance measure”, *Reliability engineering and system safety,* 92(2007), pp. 771–784. 2007.

[39] Schonberger, R.J., Why projects are always late: a rationale based on manual Simulation of a pert/cpm network. *Interfaces*, 11, pp. 66–70, 1981.

[40] Kwak, Y. H. & Ingall, L., Exploring Monte Carlo Simulation Applications for Project Management, *Risk Management*, 9(1), pp. 44–57, 2007.

[41] Golenko-Ginzburg, D. & Gonik A., On-Line Control Model for Network Construction Projects, *The Journal of the Operational Research Society*, 48(2), pp. 175–183, 1997.

[42] Pich, M. T., Loch, C. H. & De Meyer A., On Uncertainty, Ambiguity, and Complexity in Project Management, *Management Science*, 48(8), pp. 1008–1023, 2002.

[43] Akhavian, R. & Behzadan, A. H., Dynamic Simulation of Construction Activities Using Real Time Field Data Collection. *Proceedings of the 18th EG-ICE Workshop on Intelligent Computing in Engineering, 6–8 July 2011, Twente, Netherlands,* 2011.

[44] Zhi, H., Risk management for overseas construction projects, *International Journal of Project Management*, 13(4), pp. 231–237, 1995.

[45] Thevendran, V. & Mawdesley, M.J., Perception of human risk factors in construction projects: an exploratory study, *International Journal of Project Management*, 22, pp. 131–137, 2004.
[46] Zou, P. X.W. & Zhang, G. & Wang, J. Y., *Identifying Key Risks in Construction Projects: Life Cycle and Stakeholder Perspectives*: prres.net/Papers/Zou_risks_in_construction_projects.pdf, 1985.
[47] Simu, K., *Risk management in small construction projects*, epubl.ltu.se/1402-1757/2006/57/LTU-LIC-0657-SE.pdf, 2006.
[48] Nelson, B. L., Stochastic Simulation Research in Management Science, *Management Science*, 50(7), pp. 855–868, 2004.
[49] Banaitiene, N. & Banaitis, A., *Management in Construction Projects*, cdn.intechopen.com/pdfs/38973/InTech-Risk_management_in_ construction_projects.pdf, 2012.
[50] Ward, S.C. & Chapman, C.B., Extending the use of risk analysis in project management, *International Journal of Project Management*, 9(2), pp. 117–123, 2004.
[51] Sung, C. H. & Kuo, C., *Financial Risk Analysis of BOT Projects – The Case of ICCTPKH*, www.eurojournals.com/irjfe_42_10.pdf, 2010.
[52] Attarzadeh, M. & Chua, D. K. H., *Performance risk evaluation of long term infrastructure projects (PPP-BOT projects) using probabilistic methods*, www.ppml.url.tw/EPPM/conferences/2011/download/SESSION5/139_144.pdf, 2011.
[53] Öztaş, A. & Ökmen, Ö., Risk analysis in fixed-price design–build construction projects, *Permissions & Reprints Building and Environment*, 39(2), pp. 229–237, 2003.
[54] Kovács N., & Szabó, D. R. & Páthy, Á. & Tóth, P., Főbb kockázat-típusok és ezek megítélése a hazai építőiparban, In: *The Publications of the MultiScience XXVIII. microCAD International Multidisciplinary Scientific Conference*. Miskolc: University of Miskolc, 2014. Paper F9. p. 8, 2014.
[55] Szabó, D. R. & Kovács, N. & Páthy, Á. & Tóth, P., Risks in the Hungarian construction industry: Interpretations, evaluations and patterns In: Dermol V., Smrkolj M., Đaković G. (eds.) *Proceedings of the Management, Knowledge and Learning International Conference 2014.*, ToKnowPress, 2014, pp. 597–603, 2014.
[56] Asztalos, L. Gy., *Biztosítási kézikönyv*. Biztosítás Oktatási Intézet, 1997.