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THE USE OF SYSTEM DYNAMICS MODELLING FOR INNOVATION RISK MANAGEMENT[22]

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Abstract: *The paper reviews existing methods of risk assessment and shows their weaknesses related to innovation risk evaluation. The authors identify two main limitations of the methods – the absence of cause-and-effect relations and good representation of the dynamics of the innovation. The aim of the authors in this paper is to prove the necessity to use dynamic method for assessing the innovation risks. System Dynamics as a dynamic modelling tool is presented. Having System Dynamics enabled to acknowledge the time-dependent behaviour of managed systems through qualitative and quantitative models. Describing the risks in non-linear feedback structures with delays allowed to deeply understand the cause and effect relations and the influence of the risks over the innovation system. The paper also presents the current state-of-the-art in the use of System Dynamics in the fields of Project Management, Innovation Management and Innovation Risk Management. At the end, the authors discuss two works related to using the method for assessing risks in innovation environment.*

Keywords: *Innovation risk, risk management, complexity, risk assessment, System Dynamics.*

JEL Codes: *L20, O30, D80*

INTRODUCTION

Nowadays, the companies have to be creative and innovate in order to stay competitive in the dynamic and constantly changing markets. Regardless the type of innovation the company plans to create – a new product, a new service, a new process, marketing or organizational novelty, the management surely meets uncertainty and risks. The innovation system is dynamic, complex and contains a high number of risks. However, the degree of complexity is not only determined by the number of risks. Each system is a set of components – input, process, output, which are linked by so-called "feedback", which provides information on the results of the activities (Nedyalkov, 2019). The feedbacks in the innovation system, as well as the interconnected and interdependent risks make the analysis and management of risks more difficult. Moreover, several risks are linked in non-linear and time delayed manner therefore appropriate risk assessment method have to be found. The purpose of the report is to justify theoretically the link between risk management in innovation activities and system dynamic modelling tool.

EXPOSITION

Risk Management and Methodical Weaknesses

The risk management supports decision making by considering the uncertainty and the possibility of future events and conditions (planned or not) and their impacts on the objectives (ISO,

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2009). Many authors and organizations suggest a standard process for risk management. According the ISO 31010 the risk management process contains the following steps: risk identification, risk analysis, risk evaluation, risk treatment, monitoring and review, communication and consultation. In the risk identification phrase all possible risks should be pointed out. Despite the fact that generality the authors distinguish the risks isolated, they are related and the interconnections should be also included in this step. The next step - risk analysis consist evaluation of the risk consequences and the probability that those consequences can occur. Methods for analyzing risks can be qualitative, semi-quantitative or quantitative (ISO, 2009). Qualitative assessment methods determine likelihood, effects and level of risk ("high", "medium" and "low") and in most cases they are based on experience and descriptions. Semi-quantitative methods are deterministic and use numerical rating scales for consequence and probability and by formula create a level of risk. Quantitative analysis methods are probabilistic and based on mathematical formulas (ISO, 2009).

The critical review of the risk management literature identifies more than 90 methods for risk analysis. Even though some of these methods are highly used in practice, we can point out some methodical weaknesses. The limitations of the methods are summarized on the table 1, using two comparison criteria. Due to the fact that innovation risks exist in complex and dynamic organizations, the methods are assessed by the dimensions "Dynamic" and "Complicacy". "Dynamic" assesses the ability of methods to take into account changes over time. "Complicacy" represents the ability to consider cause-and-effect relationships (Dillerup & Kapple, 2015)

Table 1. Weakness in the methods of risk analysis (authors work)

Methods	Dynamic	& Complicacy	= Complexity
Qualitative:			
Look-up methods: *Checklists, Preliminary Hazard Analysis*	Statically	Comprehensive risk number	Average
Supporting methods: *Brainstorming, Delphy, Structure 'What if?', Human reliability analysis*	Statically	Depends of the experience	Low
Functional analysis: *Failure mode and effects (and criticality) analysis (FMEA) & (FMECA), Hazard and operability studies (HAZOP), Hazard Analysis and Critical Control Points (HACCP)*	Statically	Comprehensive risk number	Average
Semi-Quantitative			
Sensitivity Analysis	No cause effects	Comprehensive scenarios	Average
Scenario analysis: *Scenario analysis (SA), Decision Trees, Event tree analysis (ETA), Fault tree analysis (FTA)*	Statically	Limited number of scenarios	Low
Root cause analysis (RCA), Cause and consequence analysis, Cause-and-effect analysis, Bow tie analysis	Statically	Comprehensive risk number	Average
Multiple-criteria decision analysis: *Analytic network process, Analytic hierarchy process*	Statically	Limited number of alternatives	Low
Quantitative			
Random: *Monte Carlo, Latin hyper cube*	Random walk	Comprehensive simulations	Average
Stochastic (dynamic): *Markov analysis*	Predict future state	Comprehensive risk number	Average
Conditional probability: *Bayesian statistics and Bayes Nets*	Statically	Comprehensive simulations	Average

However, statistical methods give the most detailed numerical results, they are limited mathematical models of reality. This is the reason statistical methods do not achieve some of the requirements of risk assessment. First of all, the risks are uncertain events, which not always occur in well-defined repeatability. In addition, the randomness of the model is not necessary the same as those of the reality. Furthermore, the statistical models need to simplify some aspects of the reality, which possibly changes the results.

Another direction, that we can turn our attention to, is the use of Business Intelligence (BI) instruments for risk assessment. The term Business intelligence is used to devote systems and tools for business analysis, which covers processes for extracting, summarizing, transforming and analyzing a large amount of data in order to support management in making business decisions (Boneva, Petkov, Nedyalkov, Sheludko, & Vitliemov, 2017). All the data collected by the BI system could be useful for risk analysis, but it is still necessary to set an appropriate algorithm for risk prediction, based on risks interconnections and time-dependence.

Based on the literature review, we can conclude that the existing methods for risk analysis have some weaknesses in assessing innovation risks. Two main directions can be highlighted. First, the innovation risks are interconnected, which is still not well developed in risk management process. In fact, most of the authors and methods define isolated risks or statistically connected risks, then the broad view of the risk situation remains incomplete. Second, as far as the innovation company is a dynamic system, the innovation risks are going to change over time. System Dynamics could be the solution for fulfilling the following limitations.

System Dynamics and Innovations

System dynamics, together with discrete event simulation and Agent-based simulation, are the three main schools of simulation practice methods. According to Davis, Eisenhardt, & Bingham (2007, p. 483) “simulation is especially useful for theory development when the focal phenomena involve multiple and interacting processes, time delays, or other nonlinear effects such as feedback loops and thresholds”. In addition, Ivanov (2017) summarize that system modeling methods are priceless tools for establishing logical and quantitative relationships in the business process when other research methods are not available. Moreover, this group of methods offers some other advantages like limited observations of real system, as well as limited costs for surveying, opportunities for modifications of the process and reproduction of results.

System Dynamics as method presenting a time-dependent relationships in a system have 4 main goals: 1) to describe the system, 2) to identifying how information feedback change over time by using qualitative and quantitative models, 3) redesign the information feedback structures in order to make them stronger, 4) to support control policies through simulation and optimization (Mehrjerdi & Dehghanbaghi, 2013).

The first main task when start using System Dynamic is to define the problem. The next step is to create a model, which should clarify the problematic point in the system. Two modeling tools should be used in the System Dynamics model: a qualitative, known as "causal loop diagrams" (CLDs), which are used to identify the main feedback loops leading to growth in the system; and a quantitative, known as "stock and flow diagrams" (SFDs), which are used to create formal simulation models for policy testing and redesign (Maldonado & Grobbelaar, 2017). On the fig. 1 and 2 are presented examples of the two main modeling tools.

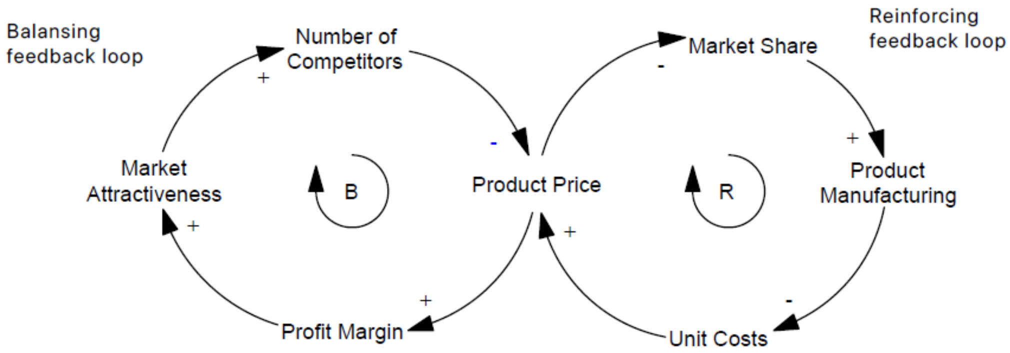

Fig.1. Example of a causal loop diagram (CLD) with two feedback loops (Maldonado & Grobbelaar, 2017)

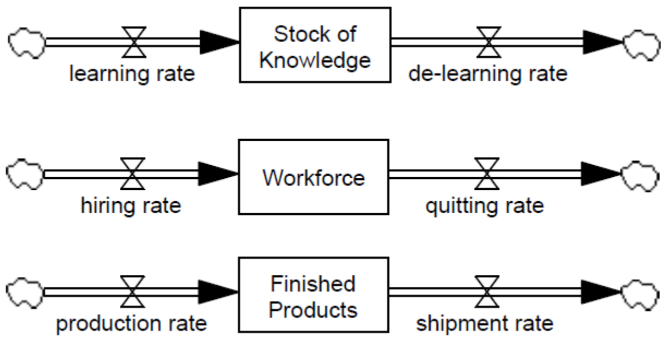

Fig.2. Three example of stocks and flows (Maldonado & Grobbelaar, 2017)

When the model is created, it has to be checked and tested. As the traditional model validation's main purpose is to evaluate how well the model adjusts to real data, in system dynamics the main goal is to validate how well the structure and behavior of the model match the real system. The last step is to formulate policies, assess what-if scenarios and check the response of the system to different policies (Maldonado & Grobbelaar, 2017).

Several studies describe System Dynamic's models in the field of Innovations and Project Management. For example, Lyneis & Ford (2007) summarize existing application on System Dynamics in the context of Project Management. The authors categorize the structures that system dynamics have used to model projects in four groups based on the central concept that they integrate into project models. The four groups are: project features, a rework cycle, project control, ripple and knock-on effects. Another literature review article is written by Maldonado & Grobbelaar (2017), who present the current state-of-the-art in the use of system dynamics in the innovation systems field. They explore six groups of models, includes the dynamics of: R&D expenditure; innovation diffusion/technology adoption; knowledge creation and absorption; science and technology; learning and innovation and regional agglomeration.

Galanakis (2016) deepen the field of Innovation systems by creating a detailed System Dynamic model. The model's main accents are: the Core Innovation Process in which research is carried out and knowledge is created; the New Product Development Process, which transforms knowledge into a new product, and the Product Success in the market, where distribution, quality and functionality of the product, as well as the price are important. The complicated model called 'Creative factory' contains four significant influence diagrams, which drive the whole system. They are as follow: finance of corporate R&D influence diagram, new product development influence diagram, success of new products influence diagram, firm's success and corporate strategy influence diagram. Galanakis' model focus on whole innovation system and contains the most important aspects of the innovation process, but does not take into account the risks that affect the process.

Lyneis & Ford (2007, p. 176) in their paper conclude that "the full power of the strategic perspective possible with system dynamics has not been used to design or analyze risk strategies that apply several risk management tools or integrate with existing risk management theory". In this sense, Mehrjerdi & Dehghanbaghi (2013) and Dillerup & Kapple (2015) have been created System Dynamic models that solve problems related to risk management.

Dillerup & Kapple (2015) build a Holistic Innovation-Risk-Net for the Machinery and Plant Engineering in Germany. Their model is designed by using validated generic business models in the fields of Innovation, Market, Knowledge management and Project management. The final complicated structure outlines seven main aspects of innovations - Technology Leadership, Competitive Price, Quality, Development Time, Internal Capacity, External Capacity, Technical Qualification, Knowledge transfer. Although the authors have structured the model in such a way in order to cover more different risks from the whole innovation process, the created architecture is complex, multicomponent, abstract and difficult for understanding.

On the other hand, Mehrjerdi & Dehghanbaghi (2013) specialize their work on the process of new product development. After a prioritization of risks related to new product development process, the authors build a model explaining the impact of these risks on the innovation system. The risks in the model are political risk, investment risk and supplier risk. When they alter over time, they change six main variables: sales, revenue, production, inventory, quality and customer satisfaction. Multiple simulations with different risk values are performed and depending on the degree to which the risks change the variables, the greater the impact of a given risk on the system. Mehrjerdi and Dehghanbaghi's model is consistent, coherent, easy to understand and follow, but its limitation is that it covers only the process of new product development, not the whole innovation process.

To sum up, according to literature review limited number of authors use System Dynamic modelling for managing risks in innovation process. Due to the fact that innovation system is complex and contains many different activities, the existing models are also comprehensive and multicomponent, which makes them difficult to understand, validate and test. Although the good relation between risks and time dependency, the current structures are excessively complex and it will be hard to implement them in a real company.

CONCLUSION

Traditional risk assessment methods have two main limitations when we deal with innovation risks. The first weakness is the lack of interconnectedness between the risks and the second is the not good representation of the risks' dynamic change over time. System Dynamic could overcome these shortcomings by qualitative and quantitative tools. Several authors argued that System Dynamics can be used to explore system behavior and to combine various perspectives on risk. However, their models are too complex, multicomponent and confusing to be applied in practice. For this reason, the authors are working on a creation of a System Dynamic model for innovation risk assessment. The future model should be built in order to help Bulgarian chemical industry to manage properly risks in their innovation process.

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