

MANAGING RISK WITH THE USE OF COMPUTER SIMULATION

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Abstract: Internal and external risk management has become an important issue in today's global business environment, which is fraught with health, natural, political, economic and technical threats. This article deals with the design of a methodology for problem-solving and risk management in connection with computer simulation. The risk management methodology proposed by us consists of individual steps, which are summarized into three stages - risk assessment, risk analysis and risk management. The proposed computer simulation methodology consists of several steps, for example creating a parametric simulation model, designing experiments, analysis of the simulation model results or the evaluation of the simulation results. These steps are described in the article. After completing the previous steps, we describe the points of an action plan and what it must contain to avoid consequences and the impact of risks at the lowest possible level. An example of the use of computer simulation is the risk situation associated with the fluctuation of employees. In the end, the proposed methodology is supported by the results of our research and its further direction.

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Introduction

The current times are full of turbulence and unexpected changes in the ecological, economic, political, demographic, and environmental or medical facilities development. Risks emerge on a daily basis, both domestically and internationally, and are associated with new technologies, innovations, natural elements, diseases and many other sources or factors. "Future manufacturing will produce products tailored to the requirements of a particular customer, highly sophisticated, complex, and capable of offering new functionality; therefore, it will require an entirely new manufacturing environment" (Grznár et al., 2020). "Digital evolution of lean thinking increases visibility along the whole value chain" (Pekarčíková et al., 2020). Risk is a term that defines an uncertain outcome with a possible adverse condition or consequence for example on production. Production risks can be described in detail through their gradual identification and subsequent classification according to the levels of risk, or by means of questionnaires processed by designated employees. According to the economic system, risks may be divided into three levels of strategic, tactical and operational risks. "From the production point of view, these may involve, e.g., production factor risks, production processes risks and product risks" (Klöber-Koch et al., 2017). A typical example of a production process risk is a deviation from the planned production cycle times or the production of more/less products than planned. The risks posed by products or semi-finished products are the failure to achieve the quantitative and qualitative objectives of the product or semi-finished product, which may be caused by poor quality of the input material (raw material). Risk management must be understood as a continuous and iterative activity.

Literature overview

Impact of risks and uncertainties on production planning

In his work, Hamzeh (2009) examined the planning processes in the systems of construction production and focused on the application of The Last Planner™ System and reduction of the risk impact on a construction project. Popp (2015) investigated how lead times affect issues related to the so-called static-dynamic uncertainty strategy. Random interruptions during production planning and how to compensate

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for them with the help of fuzzy systems is the topic addressed by Petrović and Duenas (2006). In his dissertation, Weig (2008) focused on creating the concept of integrated risk management in designing processes and structures of production planning projects. Hu and Hu (2016) also deal with planning, developing a model for batch sizing and planning with respect to the uncertainty that comes from changing market demand, different times and resource pools. Geiger and Reinhart (2016) developed an approach to production planning that takes into account the uncertainty throughout the course of carrying out customer orders.

Risks and uncertainties' impact on production

Wang et al. (2010) sought to reduce the likelihood of product recall, specifically in the food industry, through the use of a planning algorithm. Müller, (2008) examines the interdependence between products and production processes during the initial phase of product development and planning. In their work, Bonfill et al. (2004) develop an approach to risk management for planning in plants arising from uncertain market demand. In their respective work, Shamsuzzoha et al. (2012) developed an approach to monitoring and managing events in a non-hierarchical business network. In his work, Steinmetz (2007) identified various concepts that can reduce risks in the production environment, e.g., supplier management concepts.

Supply systems

An intelligent agent is defined as a computer or a natural system able to perceive its surroundings and then perform actions based on monitoring the same. The "agents" approach was applied to risk management in supply chains by Smeureanu et al. (2012). Giannakis and Louis (2011) examined the inherent risks in both the supply and the demand side of the supply chains. Raghavan and Mishra (2011) described discussions with retailers and manufacturers in supply chains that involved the risk of dangerous inventories. Information systems also involve high levels of risk, e.g., Hahn et al. (2009) focused on the risk of outsourcing the management of information systems. Chen et al. (2009) described a discussion of the risks of implementing enterprise resource planning (ERP) systems in an enterprise system.

Data mining

Technological development has enabled artificial intelligence, machine learning and many software applications to be deployed for data mining (search, track, and process data). Application of data mining techniques help to find hidden relationships with high influence on the planner's final decision (Bubenik & Horák, 2014). Shiri et al. (2012) applied data mining tools to corporate finance. Jans et al. (2010) focused their study on data mining on the risk of internal fraud in a company. In other industries, e.g., Nateghi et al. (2011) used data mining techniques to predict power outages. Ghadge et al. (2012) examined various data mining applications focusing on supply chain risk management support.

Software supporting risk-associated problem resolution

From among dynamic simulation software, this could be, e.g., a software package Siemens Tecnomatix (e.g., Tecnomatix Plant Simulation software) or Simio software from Simio LLC. "The use of process simulation software helps to design new, as well as to optimize already established processes" (Krajčovič, Plinta, 2012).

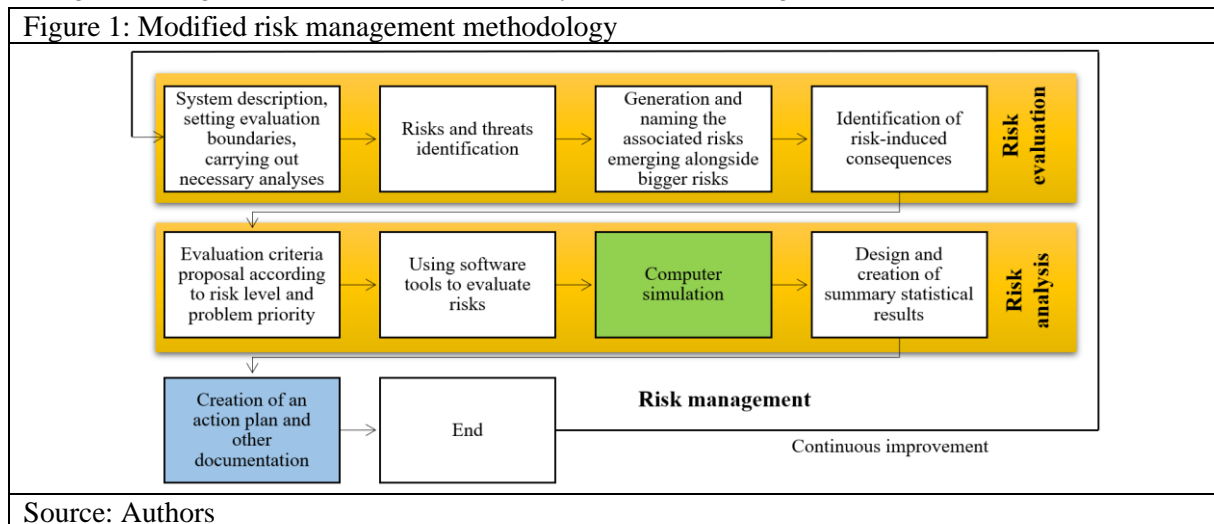
Methodology for interconnecting risk management with computer simulation

As the previous chapter made obvious, many ways in which risks in a company can be addressed exist, and yet they will continue to fall short as it will be always possible to look at them from a different perspective. In the advanced industrial engineering field, the Department of Industrial Engineering concerns itself with the development of computer simulations for deployment in several areas. One of these areas constitutes risks that may affect production, logistics and planning processes in small and medium-sized enterprises, which are the ones most prone to these risks.

Computer Simulation

Computer simulation has a number of advantages, but also disadvantages. The simulation software disadvantage in our case is that the models have to be prepared in advance, because the process of their preparation is time consuming and also expensive. Therefore, companies sometimes use support of an external company or students from academia in the creation of models. 2D models are also a good tool for visualization, companies can create 3D visualizations themselves or use the resources of external

companies. “Part of the drawing documentation from the manufacturer is also utilized in modelling” (Kužma et al., 2016). Many companies also offer documentation with the purchase of software tools and they these tools can be used to create 3D computer simulations. Another advantage is that by parameterizing the simulation model, it is no longer available only to an expert but becomes accessible to any basically instructed worker. The statistical results of a computer simulation are much more extensive and accurate than in other static simulations. Computer simulation cannot be applied to everything, and it does not give direct answers to questions, however, its results are an important support tool in decision-making. Figure 1 shows our proposal of risk management steps that include the use of computer simulation and the creation of an action plan. We divided this methodology into three risk management stages - risk assessment, risk analysis and risk management.

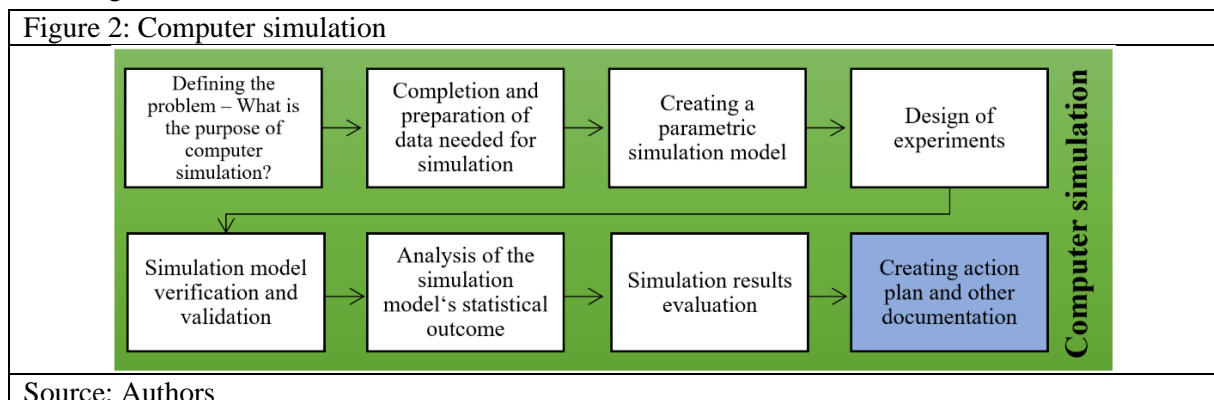


The risk assessment description is a very important step because it informs the decision on whether the assessed situation is really a risk or whether it is the cause of risk. Each company defines the levels of these risks for itself, so the methodology (Figure 1) is described in more detail in the next steps so that it can be used in an unexpected event:

System description, setting the assessment boundaries, performing the necessary analyses - In this step it is necessary to precisely define the system that is affected by risks, e.g., the maintenance process, the assembly process, the warehousing processes, the logistics processes, the production process, etc.

Identification of risks, threats and associated risks generation - In this step it is necessary to describe in more detail the ongoing processes as well as the researched processes, using methods such as brainstorming and workshop, to generate as many risks as possible. If the process is already affected by risks, then to try to classify them into either risks or the risk causes.

Description of consequences - it is necessary to classify the generated risks and assign the consequences resulting from them, e.g., it is necessary to determine the scale of risk from low risk to critical risk, causes, opportunities and then for example, identify priority issues. This step may trigger motivation to solve further problems, such as hidden problems or problems the addressing of which has been delayed for a long time.



Risk assessment proposal - to propose evaluation criteria and methods, e.g., in the form of lists, questionnaires, electronic assessment, etc.

Using Software Tools - In Figure 2: a description of the steps that must be taken when using a computer simulation to address risk problems is shown.

Computer simulation necessitates data:

Data completion and preparation for the purpose of creating a simulation - to simulate the selected process, it is necessary to add detailed information about the selected process (e.g. workplace location, dimensions, ergonomics, assembly plans, etc.), handling equipment (e.g. number of handling equipment units, their speed, charging method, etc.), operators (e.g. routes of the workers' movement, speed of operators' movement, performance, etc.) or method of planning (e.g. use of software ERP or SAP), etc.

Parametric simulation model creation - By parameterizing a simulation model it is possible to, e.g., change data values from a clear dialog box or enter data into a table created by simulation software or the users.

Design of experiments - If the risks from the previous steps of the methodology are known and it is known what the consequences on the processes may be, this will speed up and streamline the whole process of creating and modifying the simulation model. It is thus possible to design experiments of the type, e.g., how a different number of workers in the workplace will affect the performance of the production system, how many workers are needed to operate the warehouse, how will the assembly process be affected by an unexpected high priority order, etc.

Simulation model verification and validation - During the verification process, it is possible to check if the computer model is in line with the objectives for which it was created and whether its results are sufficient to make decisions about assessing the impact of risk on business processes. Validation will then be used to compare the actual data with the model outputs, provided the company has such data available.

Analysis of the simulation model results - The software enables the use of countless objects and modules that yield statistical results, e.g., Tecnomatix Plant Simulation Neural Networks, Distributed Simulation, Fuzzy Logic, Genetic Algorithms, Scheduling and Layout optimization, etc., random number generation (e.g., Confidence Intervals, Sequential Sampler, Variants Generator, etc.),

Evaluation of simulation results - The final simulation report must contain a detailed description of the simulation model created, together with all its elements and settings, evaluation of the input data collection, results of simulation iterations, conclusions from verification and validation processes, proposals for corrective measures, etc.

Once all the steps of the methodology described have been completed (Figure 1), it is possible to start creating an action plan. An action plan is a plan for setting out the steps that must be taken in order for a selected group of people to be able to assess the impact of risk without a subjective feeling and to avoid consequences at the lowest possible level. The action plan must contain all the essentials that are important for the division of labor and the achievement of the goal, listed below are some of them:

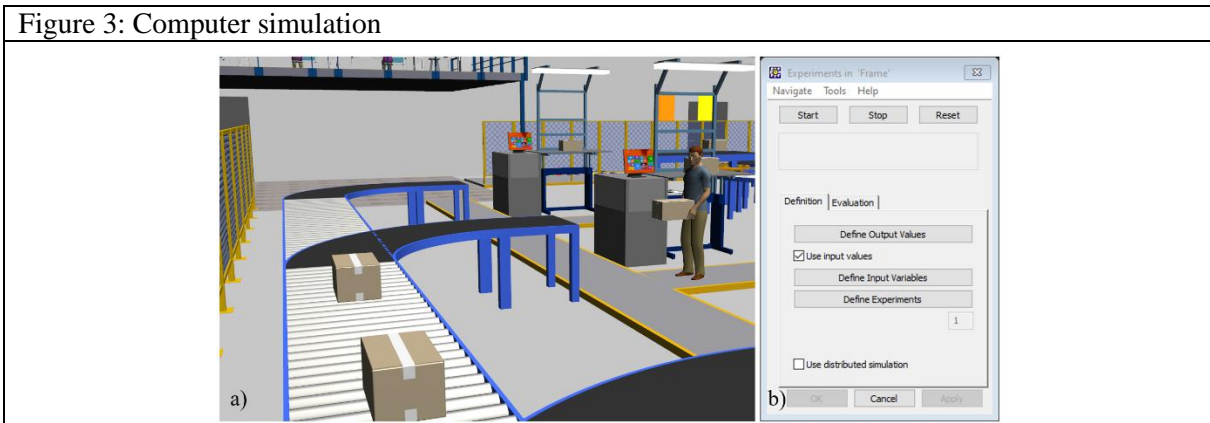
- List of steps (activities) that need to be taken for an objective risk assessment based on the generated proposals (measures, activities aimed at reducing the impact of the risk).
- Evaluation of the risk impact according to a specific risk degree (e.g., a risk posing opportunities, critical risks, associated risks, small - medium risks, business risks, etc.).
- Defining proposed conditions, restrictions, deadlines for carrying out the necessary activities.
- Design of resources needed for the activities (for example, additional staff, material, aids, tools, equipment, finances, etc.),
- Evaluation and definition of expected outputs, evaluation criteria of individual steps
- Identification of specific or potential partners for the implementation of activities to reduce the consequences of the risk impact.
- Setting milestones for reassessing the risk and effectiveness of decision support tools (e.g., computer simulation or static simulation), etc.

The action plan scope, form and documentation are chosen according to the risk level. It may take the form of a simple list, a questionnaire or a multi-page document subject to regular reviews, adjustments and updates.

Example of using computer simulation of workers

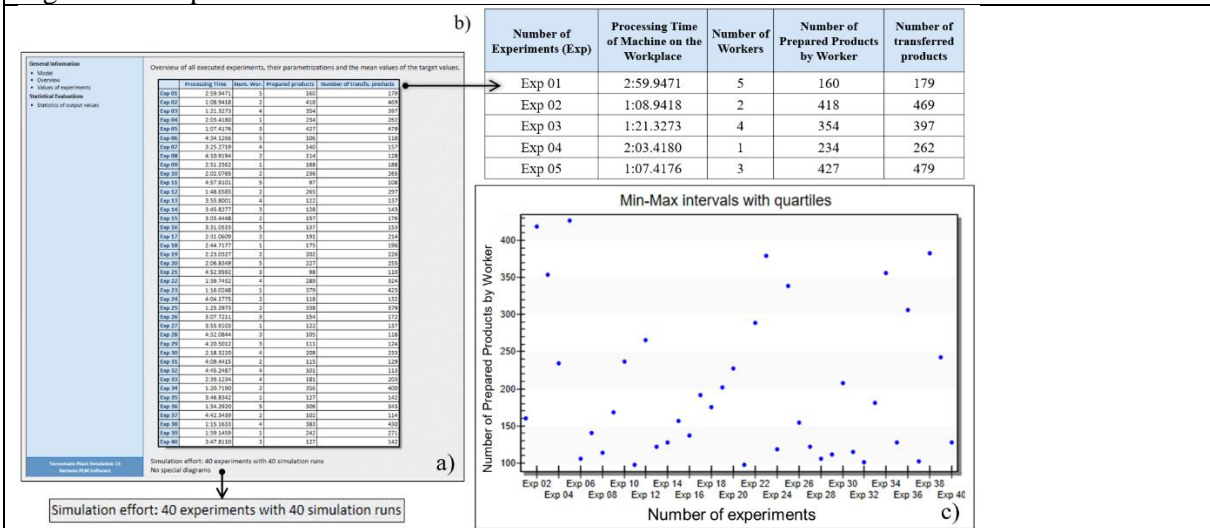
As described above, creating a computer simulation necessitates knowing as much detailed information about the production as possible. Before starting to create a parametric simulation model, the basic information needed about the workers includes, e.g., information on the number of production workers, the shifts, the break time, information on materials, what equipment, ranging from the basic to special is used in the production process, consideration needs to be given to the creation of the labor time studies and detailed descriptions of the work performed. During the simulation model preparation, it is also necessary to obtain specific data on the workers' labor, to evaluate the workers' efficiency [%] and determine (calculate) the speed of the workers' walking pace. We used the Experiment Manager tool in the Tecnomatix Plant Simulation software, version 15, to quickly evaluate a large number of experiments as part of the risk assessment. The more dynamic system options are created, the higher the probability that the most beneficial will be selected. Using the results of this tool, it is possible to evaluate various risk situations concerning workers, e.g., an optimal number of workers in the workplace - what happens when one of the workers does not come to work for various reasons; this decision on the number of workers is important with a view of considering the introduction of multi-machine operation or determining whether each machine will be operated by one worker in order to avoid overloading the workers.

Figure 3: Computer simulation



Source: Authors

Figure 4: Computer simulation



Source: Authors - Bučková, Martinkovič (2021)

Figure 3 offers an illustration of a part of the warehouse (Figure 3 a)), which was created to address the company needs in terms of managing risk situations, mentioned above in the text. When transferring products, it is necessary to set the time span according to the selected statistical distribution setting the range of the time values. In the simulation model, these time values will be written by the Experiment Manager directly into the selected machinery object. In the given example, shown in Figure 3, the range of operating times on the selected machine at the workplace of picking the goods between 1 min and 5

min was determined in the ExperimentManager tool (Figure 3 b)). After 40 simulation iterations, it is possible to evaluate the behavior of the system with different numbers of workers. Figure 4 shows three images marked as a), b), c). Figure 4 a) shows the Experiment Manager output report table. All the 40 experiments are described in this report, and due to its size, it is not possible to provide a detailed view in this paper. Therefore, Figure 4 b) was created, showing the first five experiments. Figure 4 c) shows a graph with the number of experiments on the x-axis and the number of picked goods on the y-axis. Figure 4 a) also highlights the number of 40 experiments conducted and the same number of simulation iterations.

Based on the resulting table, where the first five experiments are shown in Figure 4 b), it is possible to say exactly how the system with different numbers of workers will behave. If the company has set up a parametric simulation model for several workplaces, machines, equipment, or machinery that the worker uses to pick the goods, this is a great advantage. This is how the company can prepare in advance to respond to a sudden outage of workers and simulate several options, whether that is the number of workers in the workplace or a change in the operating times of machines.

Conclusion

Business operation is affected not only by diseases and pandemics, but also by the great shifts in development of the world underway for decades now. These changes are called Megatrends and they appear along with technological and software developments and influence the world events. They help to create digital factories, modular systems, e-learning systems, etc. “Such manufacturing systems should be able to cope with the dynamics of the entire system, with respect to its internal and external stimuli, uncertainties and unexpected changes” (Đurica et al., 2019). Therefore, it is appropriate to use the digital factory tools, e.g., a computer simulation, in order to detect potential risks. Not every risk will cause a company's demise, some risks also reveal a number of opportunities, which can be seen in the extensive literature review that we presented in this article. At the Department of Industrial Engineering, we are gradually discovering the area of computer simulation deployment and risk management modelling. This paper has partially described the problem solved in the company using one of the computer simulation tools, which can be used to evaluate risk events associated with workers (worker absence). The obtained data will then be further processed, creating possible scenarios, the task of which is a reduced impact in the event the risk materializes. Interconnecting risk management, computer simulation and the area of production planning (creation of support methodology) is the subject of a dissertation thesis at the Department of Industrial Engineering.

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