MANAGEMENT OF RISKS AND UNCERTAINTIES OF BUSINESS PROCESSES BY MEANS OF STOCHASTIC APPROACHES

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Abstract

The purpose of the paper is to present an advanced approach to the analysis and management of risks and uncertainties of business processes within a framework of Industry 4.0. Risks and uncertainties are meaningful factors that are closely tied with company business processes. Unless treated properly they may both hamper company financial performance and shake company competitive position. The effectiveness and validity of managerial decision-making are thus weakened. The goal of this paper is to develop and demonstrate the functionality of SW based decision-making tool that significantly enhances the quality of managerial decision-making. The solution uses stochastic simulation of key process risks represented by risk factors by means of the replacement of their deterministic values by probability distributions. The prerequisite for successful application of this approach is the possibility of development of mathematical model describing direct relationships between independent and dependent variables. Theoretical framework for the development of simulation software comes out of Business Model Canvas (BMC) which provides illustrative lay-out of processes that are instrumental in company management. The software development applied Business Process Modelling Notation Approach (BPMN) that is popular among programmers and fully suits the purpose. The software was validated on examples of selected business processes.

Key words: stochastic simulation, risk, BPMN, Business Model Canvas, simulation software

JEL Code: O14, O31

Introduction

Industry 4.0 is viewed as a new paradigm where industrial processes that are almost completely digitalised are driven by cybernetics systems within an environment of Internet of Things (IoT). These systems operate in environment where intelligent analytics and cyber physical systems are mutually interconnected to form new thinking about production management and factory transformation. Company processes are stepwise transformed from their generic concept into tailor-made ones. Kagermann et al. (2013) see the nature of Industry 4.0 in Smart factories where series production is inseparably tied with line-level personalisation. This phenomenon is alternatively termed as Intelligent factory or Intelligent production. Industry 4.0 is also featured by the possibility of identification and localization of products and processes on ongoing basis where the products are easily traceable. The systems operating within Industry 4.0 are prone to treat complexity in more effective way that makes them less vulnerable as compared to previous generation ones. In terms of the effectiveness of material usage, energy consumption or human labour exploitation these Industry 4.0 related systems are also superior to their predecessors (Wildemann, 2014). Increased intelligence level of these systems is supported by their vital interactions with various surrounding systems that converts regular machines into more intelligent ones. This effective conversion is achieved by development of fundamental innovations (Lee, Kao and Yang, 2014). Despite operating more sophisticated intelligent machines the subjects operating under the umbrella of Industry 4.0 are still challenging risk and uncertainties. That is why the companies are searching for optimum performance that would be balanced by acceptable risks. One of the possible solutions to the treatment of risk and uncertainties tied with paradigm Industry 4.0 are simulation approaches to business processes management.

This paper aims to develop and demonstrate the functionality of SW based decision-making tool that significantly enhances the quality of managerial decision-making. This goal was achieved through process modelling and programming methods. For this purpose, stochastic simulation appeared to be the most suitable method which allow to analyse the systems with great many of risk factors that might be even mutually stochastically dependent. The logic which stands behind this concept is based on Business Model Canvas (BMC) that illustrates nine building blocks that compose business model (BM). The solution was tested on the examples of companies operating in production, trading, and service sector.

1 Literature review

1.1 Risk factors, their identification and analysis

Risks and uncertainties are accompanying phenomena of all business processes. Proper risk identification, analysis, measurement as well as the implementation of risk mitigation provisions are inseparable features of operating any business. Regarding the risks the authors often speak about risk factors that represent stationary or non-stationary phenomenon which might significantly influence the performance of a business process. Usually, the managers are usually confronted with the situation where they have to make decision upon the existence of great many of risk factors. These factors can vary continuously and moreover they can be statistically dependent. Risk management handles various tools that are effective both in risk analysis (sensitivity analysis, risk matrix) and risk measurement (variance, standard deviation, value at risk).

1.2 Business Process and its modelling

Business process (BP) is the vehicle which is conditional for overall company performance. According to Damij et al. (2016) "*A Business Process (BP) is defined as a collection of related and structured activities with the aim to create outputs that are produced to serve customers.*" BP are the key building blocks of any process-oriented companies irrespective of its size and industrial branch. The optimization of BP performance thus became an essential part of company prosperity which is contingent upon the use of proper modelling techniques and simulation tools. Business Process Modelling (BPM) can be viewed as the set of technologies and standards for the design, execution, administration, and monitoring of business processes (Harvey, 2005). BPM reinforces the integrity between business operations and information systems through visualization of business requirements (Kumagai, Araki and Ono, 2014). Moreover, BPM enables the company to have a deeper insight into process structure and thereby helps reduce risks and optimize processes. BPM also creates a framework within which the process efficiency can be assessed by means of purposefully developed process metrics (Cernauskas and Tarantino, 2009). BPM also leads to better formalizing of existing processes, more effective on-spot needed improvements, more efficient process flow, increasing productivity, decrease in number of employees, simplifying regulations and compliance problems (Havey, 2005). There are several approaches to process modelling that attracted the interest of professional process modelers.

Notwithstanding variety of process modelling techniques there is still pending issue how to choose the most suitable one. Curtis, Kellner and Over (1992) hold the view that four perspectives should be taken into account while approaching BPM:

- *Functional perspective* – where the process elements to be included into modelling are identified;
- *Behavioural perspective* – examines the allocation of process elements as well as related actions to be performed;

- *Organizational perspective* –determines who performs process elements and where;
- *Informational perspective* – clarifies what informational entities are produced by a process (data, documents etc.).

Following approaches to BPM are worth mentioning - UML, XPDL, RAD *(Rapid Application Development)* or ARIS *(Architecture of Information Systems)* developed by Prof. A.W. Scheer. RAD compensates for the rigidity of a classic waterfall model and complements the model on ongoing compliance with requirements occurring during the execution of the project. Similarly, ARIS builds on HOBE *(House of Business Engineer)* to address BPM in a holistic way that consolidates organizational and IT perspectives under one umbrella. ARIS offers simple and instructive model for analysing, evaluating, and creating business processes (Tbaishat, 2018).

Business Process Model and Notation (BPMN) that has been in use since 2001 represents the basics for the illustration of company processes by a graphic form. Currently BPMN is perceived as an accepted standard for graphic notation. It illustrates the sequence of steps that compose business process. In addition, it provides users with comprehensive business process modelling capabilities integrated into unified environment. According to Silver (2009) graphical elements of BPMN can be classified into five categories: flow objects, connecting objects, pools and swim lanes, data objects, artefacts (i.e., a product created or modified by the enactment of a process element). In addition, BPMN facilitates the transfer of the model into Business Process Execution Language (BPEL) which helps communicate with other applications. According to Nurcan et al. (2005) placing emphasis on strategy-driven BPM enhances overall effect of process modelling. By this way goal-perspective and map-driven processes can be effectively illustrated. These improvements ensure better interconnection of goals with trajectories that show how to achieve the goals. Some attention is devoted to the implementation of environment which reinforces smooth collaboration between business and its users to develop executable business process models.

1.3 Business process simulation

Business processes are inevitably tied with variety risks and uncertainties that might undermine their performance. Business Process Simulation (BPS) represents one of the viable solutions to these problems. It might be used both during process analysis and process implementation phase (Patig and Stolz, 2013). BPS can be also conducive to the facilitation of decision-making processes where all possible decision variants can be analysed from the risk point of view prior to their implementation. In addition, BPS can help foresee the performance of the system while being tested under several possible scenarios predefined by a decision-maker. The most important advantage of simulation approaches rests in reflecting process dynamics. BPS pays attention to two key aspects of the system (Greasley, 2003):

- *Variability* – which can be manifested in both key quantitative parameters of the system and duration of the processes.
- *Interdependence* – which means mutual stochastic dependence of input variables.

BPS is prevalently applied in processes that are exposed to high level of risks and uncertainties. By this way key indicators of company financial performance like net profit or cash flow can be tested (Kazakova, Zayarky and Medvedev, 2019). BPS can also improve quality of company change process by the measurement and analysis of process performance (Greasley, 2003). As for simulation SW there are several commercially available SW tools. Business Model Simulation Software (BPSs) includes modelling tools, tool to execute simulation, tool to support experimentation, optimization, result interpretation and presentation, or links to other software (Pidd and Carvalho, 2006).

2 Methodology

Methodology is based on triangular approach that combines several research methods. In this particular case content analysis, process analysis, process modelling and contextual interviews with risk managers and investment experts were used. Six interviews which were recorded manually were conducted. Interview time varied from 40 to 50 minutes; open coding being used. Basically, interviews were aimed at processes-related problematics like: (i) key business processes, (ii) process risk assessment (iii) risk measurement and (iv) risk mitigation approaches. The outcomes of interviews enabled to identify processes with the highest risk exposure like investment process, new product development, launch of a new product, ways of product delivery, increase in production capacity were put into spotlight. This analysis laid the grounds for process modelling that was performed by Business Process Modelling Notation (BPMN). Modelling started with initial events that represented trigger points for the design of entire process. Consequently, activities, intermediate events showing operability of the process and end events were incorporated into model of the process. BPMN includes the dynamics of the process modelling through mutual interconnections of processes, subprocesses and activities. Eventually, the processes were subjected to stochastic simulation where quantifiable input variables (risk factors) entering the model were replaced by their probabilistic distribution. In a similar way, dependent (output) variables were obtained as probabilistic distribution curves as well. Risk factor identification was carried out by either expert method (contextual interviews with risk and investment managers), creative methods (e.g. brainstorming, Delphi) or sensitivity analysis.

3 Design of innovative BPS software

Simulation approach to process risk analysis enables to analyse accompanying process risks in more effective way. Simulation is a method of choice if there are many risk factors which are prevalently of continuous character. Moreover, many of them are mutually statistically dependent. Simulation is thus superior to both deterministic and scenario approaches. The former illustrates one possible solution that may come into effect the latter necessitates the elaboration of excessive number of scenarios what is usually impracticable. SW solution elaborated takes into account statistic dependence among input variables (any costs, capital expenditure, production capacity rate etc) and output variables (profit, economic value added, net present value etc). Simulation builds on mathematical model which is the backbone of the method (see equation 1)

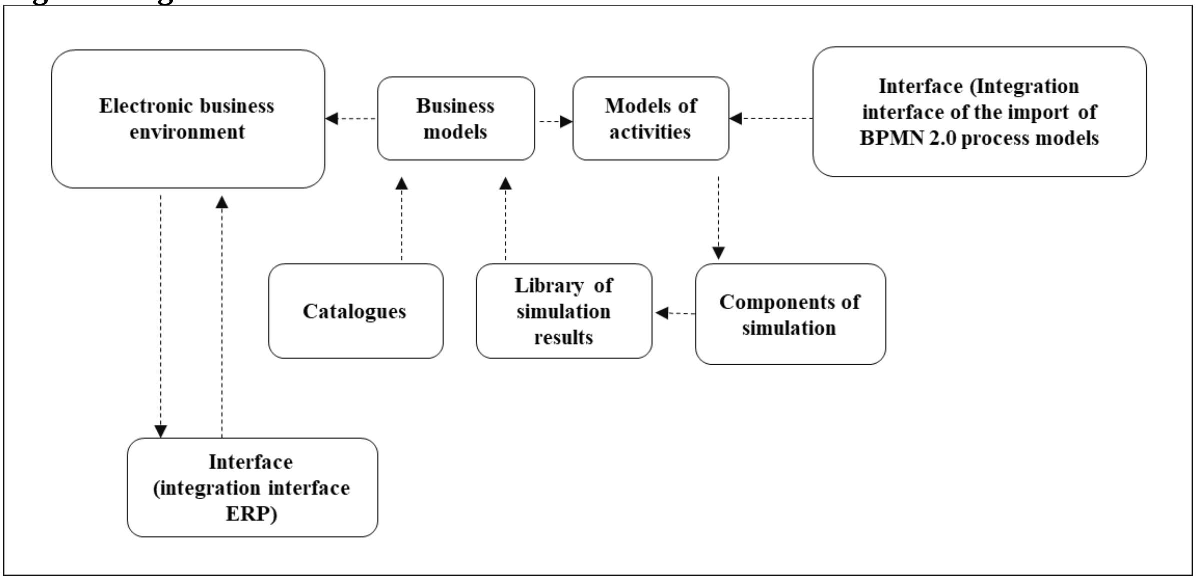
$$Y = f(X_1, X_2, ...X_n) \tag{1}$$

where parameter Y is output (dependent) variable and parameters X1, X2, … Xn are input (independent) variables.

As the first step key risk factors must be identified. Usually historical data tests, expert opinion or sensitivity analysis are applied. To make the model simplistic for managers it is advisable to have a resort to triangular or possibly normal distribution. Especially the use of triangular distribution is advisable because managers can quite easily select minimum, maximum and the most probable values of the distribution. To increase reliability of the model mutual interdependencies among input variables should be determined. This is accomplished by the inclusion of correlation matrix that enables to manually set expected correlation coefficient between the pairs of input variables. When excluding deterministic relationship strong, middle, and weak dependencies can be adjusted. In practice correlation coefficients +/-0,75; +/-0,5 and +/-0,25 are used, respectively. +/- sign stands for direct or indirect correlation. Simulation algorithm is based on repeated calculation of multiple scenarios the number of which varies from ten to hundred thousand. Each scenario represents one specific deterministic model, parameters of which are selected pseudo-randomly. The output (dependent) value is obtained in a form of histogram that indicates the probability of attaining or overcoming desired value.

Design pattern illustrates the links among all key building blocks of the model. Each building block comprises the set of activities that refers to the specific type of business. If these activities can be described by a mathematical model, then they would become adepts for simulation (See Fig. 1).

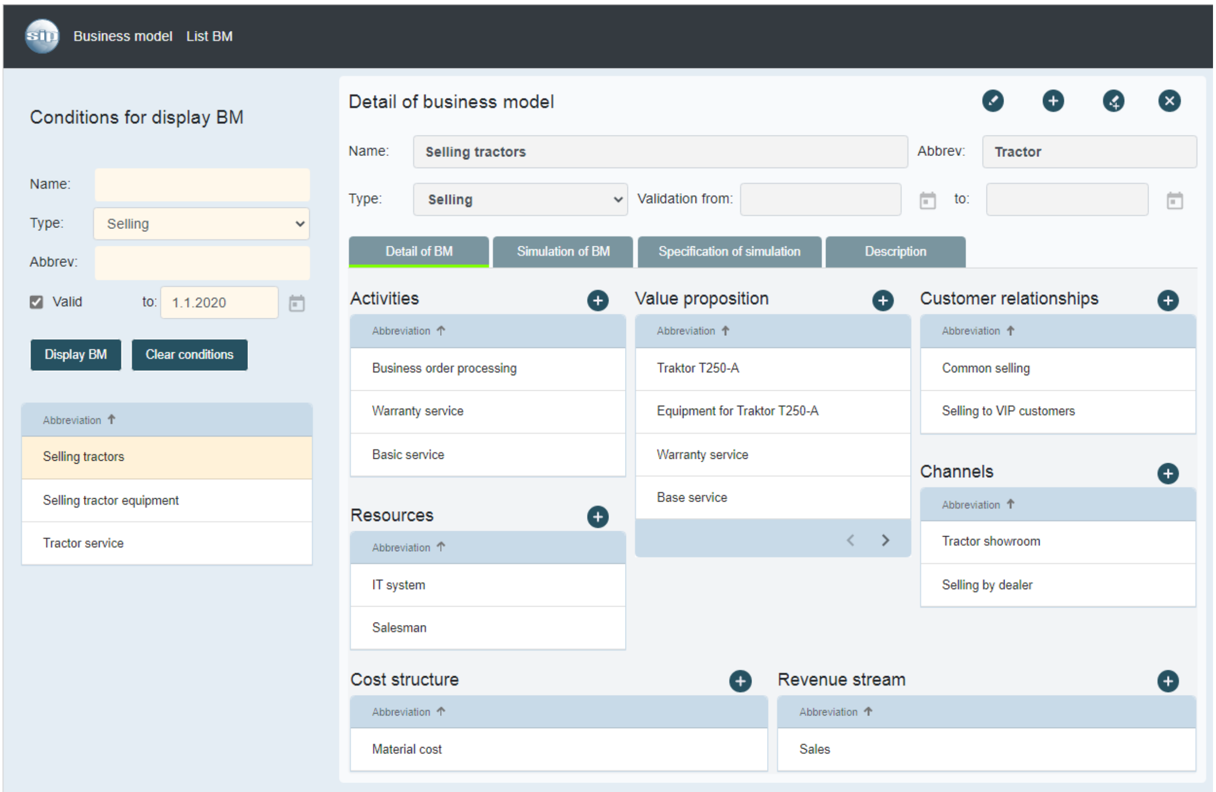
Fig. 1: Design Pattern of the Software Solution to Business Process Simulation



Source: Own Elaboration

The interface is quite similar to the layout that is typical for Business Model Canvas. The SW enables to select generic type of the process with pre-defined categories of parameters (investment process, production process, selling process etc) or to compose a new one. Categories of parameters that are subject to modelling are Activities, Value proposition, Customer relationship, Resources Channels, Cost structure and Revenue streams. Each category is broken down into sub-categories that represent specific activities (e.g. Business order processing, customer groups, customer service etc.). Such a customer friendly interface helps managers cope with risks and uncertainties of processes in a more effective way.

Fig. 2: Interface of the software



Source: Own Elaboration

4 Results and discussion

The paper illustrates sophisticated approach to the management of business processes that are exposed to high level of risk. This SW based approach allows managers to analyse and manage complex business processes which are tied with risks and uncertainties more efficiently. The approach uses stochastic simulation of pre-selected risk factors to deliver output variables that are presented in a form of probabilistic distribution. Moreover, the model makes possible to include mutual statistical dependence of input variables (risk factors) which significantly enhances reliability of the model. The use of this model is limited to cases that are characterized by quantifiable parameters and moreover mutual relationship between input and output variables can be expressed by a mathematical model. Business processes which cannot be described by quantifiable parameters are not suitable adepts for SW risk modelling. This model enables to assess investment effectiveness, company profitability, financial stability, solvency, value creation, marginal indebtedness etc. The model is conducive to the execution of variety of managerial decision to be made under risk and uncertainty. Basically, it deals with the decision about possible closure of production unit, selection of suitable technology process, decision about outsourcing, finding optimum way of assets financing etc. The model was developed in rather simplistic way to be mastered by employees with adequate technical skills in basic statistics after short-time training. In terms of results interpretation the users must be able to cope with statistical expression of phenomena. They must accept a new way of thinking about the processes, characteristics of which are not deterministic but probabilistic. Considering the problematics in this way requires employees to master abstract thinking. E.g., attaining positive values of key economic parameters like net profit, Net Present value or cash flow is expressed with some level of uncertainty which may puzzle a decision-maker. Nevertheless, the model proved its validity while being tested on the example of new product development, investment processes, technology effectiveness assessment process, selection of alternative organizational concept (outsourcing, technology divestment, production termination etc.,), alternatives for assets financing (loan, leasing, equity funding etc). The SW offers the users the set of predefined generic processes (investment process, managing customer’s order, managing complaints, new product development process, supply chain management process etc.) to ease handling this SW.

Conclusions

The main outcome of the research is purposefully developed SW that is based on stochastic simulation of key process parameters. These parameters often called risk factors may hamper process performance which makes management decision less effective. Simulation of key risk factors enables to consider all pre-selected risks and uncertainties and based on mathematical model defined calculate statistic distribution of output variable. By this way managers can simulate various situation which may come randomly into effect during operating company business. The software is adaptable to specific company business and enables to set up company´s own specific processes which are not included in a process library.

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