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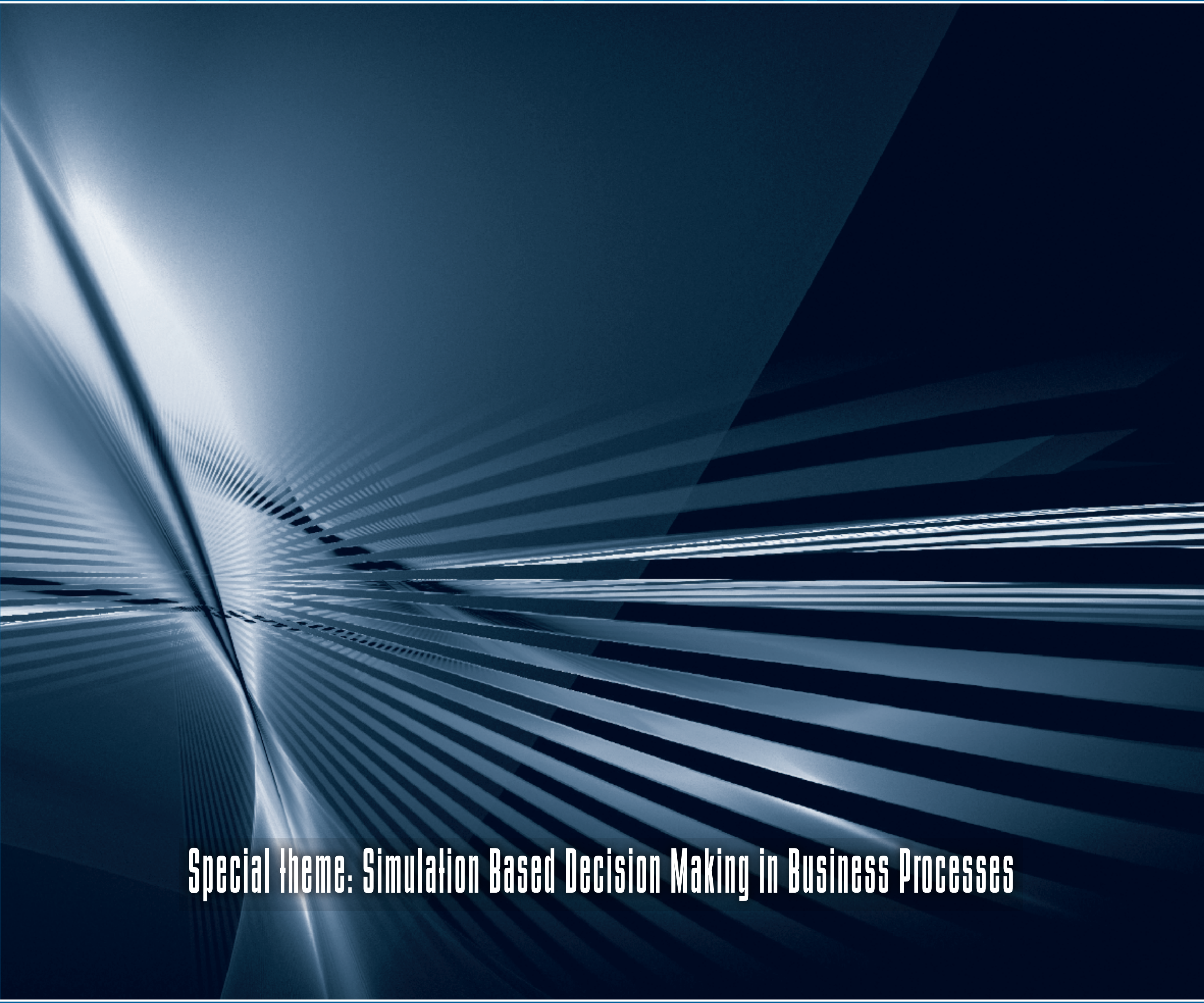

Special theme: Simulation Based Decision Making in Business Processes

Revija za management, informatiko in kadre

ORGANIZACIJA

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Editorial office: University of Maribor, Faculty of Organizational Science, Založba Moderna Organizacija, Kidriceva 55a, 4000 Kranj, Slovenia, Telephone: +386-4-2374295 , E-mail: organizacija@fov.uni-mb.si, URL: http://organizacija.fov.uni-mb.si. Organizacija is co-sponsored by the Slovenian Research Agency.

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Editorial

The aim of this special issue *"Simulation Based Decision Making in Business Processes"* is to continue presenting the research achievement from the area of Systems Approach and Decision Support Systems for assessments of complex problems. The majority of the contributions represents extended and revised papers presented at the *26th, Conference on System Research, Informatics and Cybernetics*, Baden-Baden, Germany, August 4-9, 2014, in the stream Simulation Based Decision Support and Business Intelligence, chaired by *Miroljub Kljajić*. The special issue includes papers dealing with the development of simulation methodology, modeling tools and practice for decision assessment, service systems, control, optimization and agriculture dynamics research. To address those issues above, firm policies need to be established as a result of continued search for a sustainable future.

In that respect, the paper entitled "Sugar beet production: A system dynamics model and economic analysis" describes the system dynamics model for beet production development in order to support decision making and is continuation of previous research. The sugar beet is the main field crop used for sugar production in the temperate climatic zone. Since investment in sugar beet industry are long term and ireversible the decision support and economic analysis are required in order to maximise investment returns. A system dynamics methodology was chosen to model the impacts of regional sugar factory investments. The simulation provides answers to strategic questions related to the total sugar beet production and processing system and will be used for the simulation of different scenarios for sugar production and their impact on economic and environmental parameters at an aggregate level.

The purpose of the paper entitled "How Close to Reality is the „as-is" Business Process Simulation Model?" was the development of a Business Process Simulation (BPS) model based on real-life data. The research has been performed in Polish Telecommunications Company. The authors investigate technical process of expanding cellular network. After elaborating "as-is" model, authors use ADONIS simulation tool to run a series simulations and confront simulation results with actual historical events. The simulation model has been constructed with data from the WfMS database, observations, staff knowledge and their experience. The authors conclude that BPS is not a popular approach for process reengineering and improvement yet. Data collection issues for BPS that require adopting process mining techniques and additional information sources are among the reasons for that.

The paper entitled "Web Application for Hierarchical Organizational Structure Optimization – Human Resource Management Case Study" describes new methodology to prevent oscillation during optimization of parameters in organizational hierarchical structure. The objective was optimization of the flow parameter values in the hierarchical organizational model with genetic algorithms and finite automata. The hierarchical structure was modeled according to System Dynamics. The problem of the undesired oscillatory behavior was addressed with deterministic finite automata, while the flow parameter values were optimized with genetic algorithms. The results indicate that the hierarchical organizational model, genetic algorithms and deterministic finite automata have been successfully implemented with JavaScript as a web application that can be used on mobile devices.

The aim of this paper entitled "Systems Approach to Standardisation, Classification and Modelling of Managed Events for Tourism" is the development standardisation and classification of managed events provides a legislative basis to distinguish events managed for tourism in their characteristics and quality. In the context of a systems approach, the authors used qualitative modelling and constructed causal loop models of the legislative system of events and investments in the events. Article was continued with structure of SD model in a frame of systems dynamics.

In the paper "A Statistical Model for Shutdowns due to Air Quality Control for a Copper Production Decision Support System", a decision support system for copper production for one of the largest mining companies in Australia was developed. Statistical model for shutdowns due to air quality control and some of the data analysis conducted during the simulation project was described. The statistical model made use of a full year of data on daily downtimes and used a combination of techniques to generate replications of the data. The environmental conditions affected greatly the operations of the production facility. A good statistical model was essential for the successful simulation and the high budget expansion decision that ensued.

The last paper of this issue is called "Multi-criteria assessment of vegetable production business alternatives". The article describes oorganic and integrated production of vegetables in Slovenia. The study analyzed two production systems with different cultures as alternatives with the purpose to find the most appropriate variants. The study is based on the development and integration of developed specific technological-economic simulation models for the production of vegetables (growing salad, peppers, salad cucumbers, pickling cucumbers, round and cherry tomato) in greenhouse and multi-criteria decision analysis. The methodology of the study based on the DEX methodology and the analytical hierarchy process (AHP) of organic (ECO) and integrated production (IP) in greenhouse. The evaluation results show that both cultivation methods of commercially attractive vegetables in greenhouse are variable.

The guest editors hope that our selected topics display the state-of-the-art of the research efforts over the world coping with complex problem solving in a holistic way which is characteristic for modern Systems Research and Cybernetics! Moreover, we are very thankful to journal *Organizacija* (*Organization - Journal of Management, Information Systems and Human Resources*) for having given us the opportunity and honour of hosting this special issue as a scientific project and service to the people on earth. We express our gratitude to the Editors of Organizacija, and hope that our special issue will well-demonstrate *Organizacija* being a *premium* journal and of a great scientific and social value!

The Guest Editors:
Miroljub Kljajić and
Gerhard-Wilhelm Weber

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Sugar Beet Production: A System Dynamics Model and Economic Analysis

Črtomir Rozman[1],Miroljub Kljajić[2], Karmen Pažek[1]

[1] University of Maribor, Faculty of Agriculture and Life Sciences, Pivola 11, 2311 Hoče, Slovenia.
crt.rozman@um.si, karmen.pazek@um.si

[2] University of Maribor, Faculty of Organizational Sciences, Kidričeva cesta 55a, 4000 Kranj, Slovenia.
miroljub.kljajic@fov.uni-mb.si

Background and Purpose: The sugar beet is the main field crop used for sugar production in the temperate climatic zone. Since investment in sugar beet industry are long term and ireversible the decision support and economic analysis are required in order to maximise investment returns.
Methodology: A system dynamics methodology was chosen to model the impacts of regional sugar factory investments. We present the basic concepts of system dynamics (SD) models and their development in the case of sugar beet production and processing systems. Sugar beet economics are also analyzed using the static technological economic simulation model.
Results: The simulation provides answers to strategic questions related to the total sugar beet production and processing system and will be used for the simulation of different scenarios for sugar production and their impact on economic and environmental parameters at an aggregate level. Furthermore, the feasibility analysis of sugar beet production revealed that at the current price and intensity levels (yields), we can expect profitable sugar beet production for both white sugar and ethanol.
Conclusion: Preliminary results show that under expected production parameters the sugar beet processing and production would be economically feasible.

Keywords: *sugar beet, modeling, system dynamics, economic feasibility*

1 Introduction

The expected elimination of the sugar quota system in 2017, in the final reform, presents new business opportunities for farmers and investors in countries that have abandoned sugar beet production and the sugar industry as a whole. However, the potential of a wide range of possible business alternatives must be evaluated in order to determine their obstacles and characteristics, and also the benefits with corresponding opportunities which they contribute to the agricultural system. The 2007 European Union (EU) Sugar Reform turned the EU from a major sugar exporter into a major sugar importer, significantly changing the dynamics of the EU sugar market. High international sugar prices have been undercutting the EU's attraction as a favored export destination, while the increased productivity resulting from the reform has led to record EU sugar production beyond the suggested quota (Polet, 2012).

The sugar beet is the main field crop used for sugar production in the temperate climatic zone. Approximately 30% of the world's supply of sugar is now derived from sugar beets (Beta vulgaris), the vast majority of which is produced in industrialized countries. The remaining 70% is derived from sugarcane, which is mainly produced in developing countries with tropical climates (Steinrücken, 2005).

According to Food and Agriculture Organization (FAO) data, the land area required for sugar beet production has decreased as a result of technical advances and higher yields (Steinrücken, 2005). The expected elimination of the sugar quota system in 2017, which is set out in the final reform, presents new business opportunities for farmers and investors in countries that have abandoned sugar beet production and the sugar industry as a whole.

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Since the investments in the sugar industry are long-term and financially demanding, there is a clear need for the use of modern decision support tools and models in order to ensure good decision support before the investment is made (Rozman et al., 2013a,b). However, drastically increasing energy costs and potential sugar trade policy reform threaten the viability of this important industry.

Currently, beet sugar refining byproducts are sold at very low margins. However, a large amount of research aimed at producing high-value goods from these byproducts has been conducted (USDA, 2007). In recent years, energy consumption and global carbon intensity (the ratio between carbon emissions and the amount of energy supplied) have increased worldwide, reinvigorating worries about potential depletion of fossil fuel reserves. Such an increase, accompanied by the growing political instability in oil-producing regions, has prompted many countries to search for alternative forms of energy (Martinelli & Filoso, 2008). Sugar beet crops are grown in most EU countries and yield substantially more bio-ethanol per hectare than wheat. The advantages of sugar beets are a lower cycle of crop production, higher yield, high tolerance of a wide range of climatic variations, and low water and fertilizer requirements. Compared to sugar cane, sugar beets require 35–40% less water and fertilizer (Balat & Balat, 2009). The development of ethanol production (from sugar cane) was first presented by Hu (2012). The system dynamics model applied here will require further research in order to generate insightful results regarding the Brazilian ethanol model. These results will be useful for the expansion of ethanol as a global commodity, as well as in tackling existing unintended consequences resulting from the development of this industry. Biofuels will continue to expand, but the feasibility of their exponential growth patterns remains questionable. The sustainability of the biofuel sector depends on the understanding of this social system, as well as its effect on other systems, such as the food economy.

The renewal of the sugar beet industry was examined in a feasibility study by Rozman et al. (2013a), who estimated the required technical parameters for a new sugar factory in order to achieve positive results in an investment analysis. The success of the industry is based on the economic achievement of all elements in the sugar production chain, where the sugar beet producers are the most important element. Thus, the economics of sugar beet production are essential for a successful sugar industry (Rozman et al., 2013a). Sugar beet economics have been closely studied by Tzilivakis, Jaggard, Lewis, May, and Warner (2005) and Maung and Gustaffson (2011), as well as by the Croatian, German, and Austrian Agricultural Advisory Extension Service.

Models of sugar factories have also been developed. Henke, Bubník, Hinková, and Pour (2006) described the application of the Sugars™ program to model and simulate a sugar factory with subsequent production of bioethanol and animal fodder. The designed scheme was further adjusted and verified using data from the Czech sugar industry (i.e., 10,000 tons of sugar beets processed per day, 17% sucrose content in sugar beets, 2.5% impurities, and 98% effectiveness of ethanol fermentation). Rozman et al. (2013a) developed a spreadsheet technologic economic model for the feasibility analysis of the sugar beet plant. This model is used for the (1) assessment of sugar beet production costs, (2) sugar beet processing costs and factory cash flow projections, and (3) the complete analysis of the required field area necessary for the planned sugar factory. System dynamics (SD) is one of the possibilities for employing computer simulations in order to support the decision-making process in sugar beet processing (Forrester, 1994). The system dynamics was successfully applied in several similar cases (Rehan, Unger, Knight, & Haas, 2014; Rozman et al., 2013a).

This paper discusses the problem of sugar beet economics and processing using causal loop diagram (CLD) and SD methodology for holistic decision support. The paper is organized as follows: first, we analyzed the entire sugar beet processing system using SD principles (causal loop diagram), followed by the analysis of sugar beet production economics. The article concludes with final remarks.

2 System dynamics model of the sugar beet industry

Several methods were used for the evaluation of a sustainable model for region planning development based on sugar production. First, we developed a system dynamic model based on the CLD at different scenarios that represents a different vision of development as well as multi criteria optimization based on the Saaty (1990) analytical hierarchical process (AHP). Such multi methodology is convenient to reflect the sustainable development of region. The fundamentals of system dynamics were defined by Forrester (1958) as a method for the modeling of industrial dynamics. In the early 1980s, at the beginning of the Information Age, the method was renamed system dynamics (SD). The idea of this modeling is based on the assumption that every real system, as well as any business system, can be described with a system of equations that represent interconnected flows or Rates and Stocks or Levels.

Figure 2 provides an example of the SD symbolic representation of described model, in which for example Biological Residue represents the Levels (Stock), Beet Residue the input flow or Rate input, and Gas Power Plant the output flow or Rate output. Each level, *L*, or state element, has its own input rate, R*in*, and its own output rate, R*out*. In Figure 2 for example Desired Beet and Salary represent the decision parameters by which the flows are regulated. The clouds at the beginning and at the end represent the

environment of the model. This is, therefore, our boundary for the modeling of the addressed model. From a formal viewpoint, this method is indeed straightforward and clear, as well as understandable. In the case of a concrete problem as this one, the possible meaning of both the L and R elements are obtained.
The conservation-of-mass principle for the above model could be described with the dynamics equation in the form of difference equation as follows:

$$Bio\,R(k+1) = Bio\,R(k) + \Delta t(Beet\,R(k) - GasPowerPlant(k)) \quad (1)$$

in which k represents discrete time and Δt is the time interval of computation. Each entrepreneur understands that the value of the Level element $L(k+1)$ increases if $R_{in}(k) > R_{out}(k)$; it is unchanged if $Rin(k) = R_{out}(k)$, and decreases if $Rin(k) < Rout(k)$.

Later on in the SD methodology, CLDs were added. CLDs are important for the determination of the model's structure and its parameters. CLDs include directed graphs with polarity. Each Level and Rate element has a directed arrow assigned so that one element represents the cause and the other the consequence. Directed arrows from the cause to the consequence have the "+" sign if both the cause and consequence have the same direction and "–" if the opposite direction exists. Another very important aspect of the SD methodology is the feedback loop. When several consecutive arrows in the CLD return to the initial element, as can be seen in Fig. 1, a closing path or a loop is created, which gives some feedback to the original element; therefore, it is called a feedback loop. There are two kinds of feedback loops: a positive feedback loop (reinforcing loop) and a negative feedback loop (balancing loop). Reinforcing loops tend to grow or decline without limits and can make the system unstable. In contrast, balancing loops tend to adjust themselves to some intended value. Hence, they tend to stabilize the system and guide it to the goal.

The method for problem solving with a system dynamics methodology is similar to that used with the systems approach, and it can be described as a synthesis of the following steps:

- Definition of the problem
- Setting objectives
- Drafting the study
- Formulation of a mathematical model
- Developing a computer program
- Model validation
- Preparation of the experiment (simulation scenario)
- Simulation with an analysis of the results (Forrester, 1994)

In this study, we followed these steps to develop the simulation model of sugar factory development, which will be presented in detail in the next sections.

As stated in the introduction, the investment in new sugar beet processing factories has many advantages for a region: tradition, culture, land availability, and unemployment. However, due to the effects of the financial crisis and the impacts on ecology, a local authority must consider a number of factors in addition to economics when planning future development. Therefore, we decided to use SD methodology for such analyses as one powerful method of decision support. Figure 1 shows a causal loop diagram (CLD) of a new sugar production factory with all relevant implications for development in the region. We can observe several main feedback loops reinforcing and balancing in Figure 1. The reinforcing loops R1, R2, R3, and R4 are typical developmental loops. The investment in sugar production represents a new employment opportunity and increases workforce demand. Therefore, investment in the sugar factory, ethanol factory, and power from the electrical biogas-based power plant will provide new employment opportunities and workforce demand in the sugar production and electrical plant sectors, which has a final impact on regional development for some time following the investment.

This impact is also evident in the demand for special agricultural custom machine services, such as sugar beet harvesting, cleaning-loading, and transport. The sugar industry also contributes to employment in other sectors that support the sugar industry with production inputs (such as the use of lime and fuel), as well as input for sugar beet production in the field. According to Rozman et al. (2013a), a factory with a capacity for 7500 tons of beets/day requires around 30 full-time equivalents (FTE) during the campaign for transport alone. Of course, this figure depends on the market prices of both sugar and electricity. However, the new sugar or bioethanol plant requires land for sugar beet production. Therefore, available land for field crop production is decreased, which influences the capacity of the new plant (balancing loop B3). The sugar beet production area is limited by crop rotation rules. The recommended share of sugar beets in the crop rotation is 20%; higher shares can cause a decrease in yields and sugar content and may also lead to more serious pest problems. There is also balancing loop B2 with a variable sugar price, which influences the decision-makers. Namely, the higher sugar production consequently increases the market surplus and lowers the price of sugar. When this scenario is occurs, the use of beets for bioethanol increases.

Increased sugar production and/or the import of sugar from a free market leads to a decrease in the price of sugar, which can negatively impact farmers' motivation to grow sugar beets and consequently result in a decrease of land for the sugar crop area and also a decreased production level. The B2 and B3 loops are the basis for the planning of the potential capacity of both plants. Biological remains (such as green mass and soil that come to the factory with

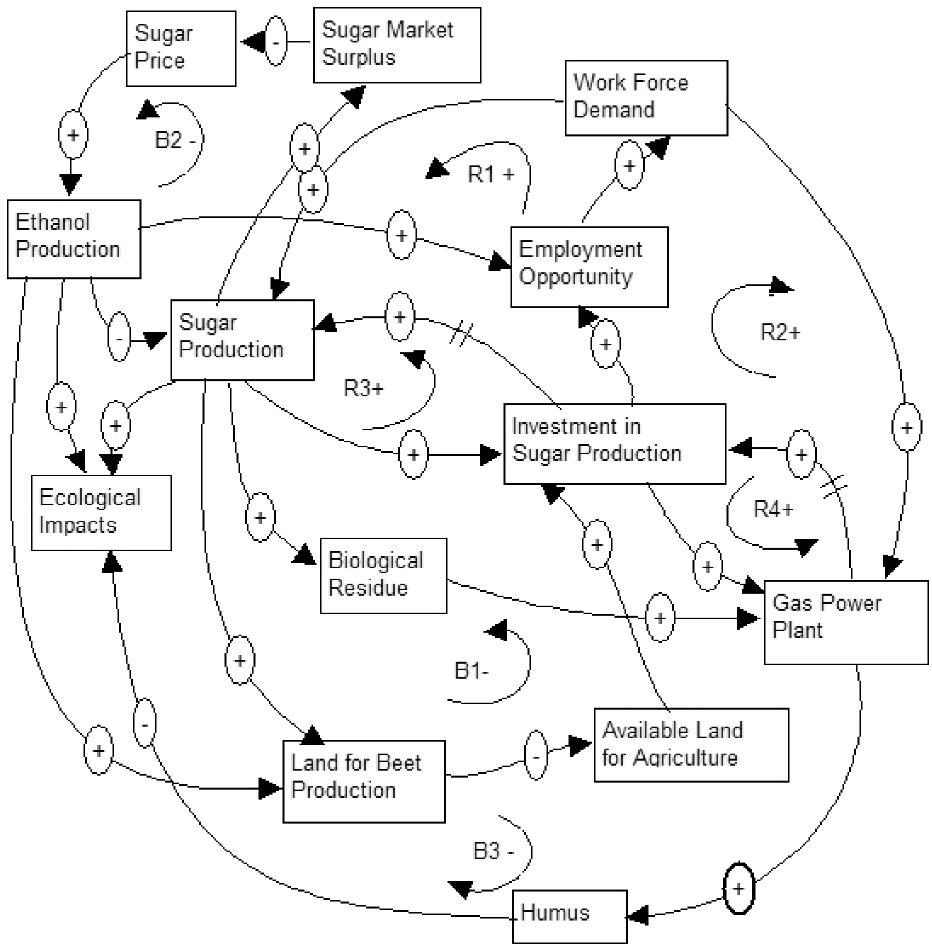

Figure 1: Holistic model of regional development of the new product (sugar and bioethanol)

the beets) can affect the environment; therefore, a biogas plant that produces electric energy and additional employment opportunities should be constructed. In this manner, the negative influence on the environment is decreased (balancing loop B1). The reduction of the negative effect on the environment through loop B1 is also expressed in the use of waste lime, which is produced as a result of the carbonation sugar-cleaning process in one of the stages of sugar production. Waste lime is one of the most effective lime-based fertilizers and, importantly, its use by sugar beet producing farmers contributes to a decrease in soil acidity.

The remains from the biogas plant can also be used as fertilizer. Furthermore, biogas production is usually combined with liquid manure from animal farms. Liquid manure is the source of methane (CH_4), which is an even more damaging greenhouse gas than carbon dioxide (CO_2). In the biogas plant, the CH_4 (produced through methagenic fermentation in the biogas plant reactor) is transformed to less damaging carbon dioxide and water in the gas engine that powers the electric generator. Figure 1 is qualitative and displays important causal loop relationships between relevant factors when choosing an investment. This information can be incorporated into the holistic model in Figure 1; however, several other elements must be considered in further model development, such as annual climatic factors, world sugar production, and price. This paper discusses the problem of sugar beet processing using CLDs; SD methodology for holistic decision support was previously described (Rozman et al., 2014a).

Figure 2 shows the SD model of the sugar beet industry and its impact on the environment as well as on the workforce in local communities. We used the standard stock-inventory model as a basis (Forrester, 1994). The primary driving variable in the model is demand, which determines the operation of the entire system. According to the demand, the sales diminish the sugar stock. In contrast, the demand influences the desired production. One may observe the delay from demand to desired beet and row material is at least one year and is relevant for the process behavior. Another link that influences desired beet and sugar stock is the sugar price, which was included in this model as the average market value. The sugar beet stock is dependent on the sugar beet delivery, which increases the sugar beet stock. Conversely, the intensity of the production decreases the sugar beet stock. The sugar stock is therefore dependent on the production, as well as on the capability to provide a sufficient sugar beet stock supply. The structure represents a negative feedback loop with reference, which is primarily determined by the sugar demand. The financial aspects of a new investigation were modeled in Powersim software as a continuous simulation

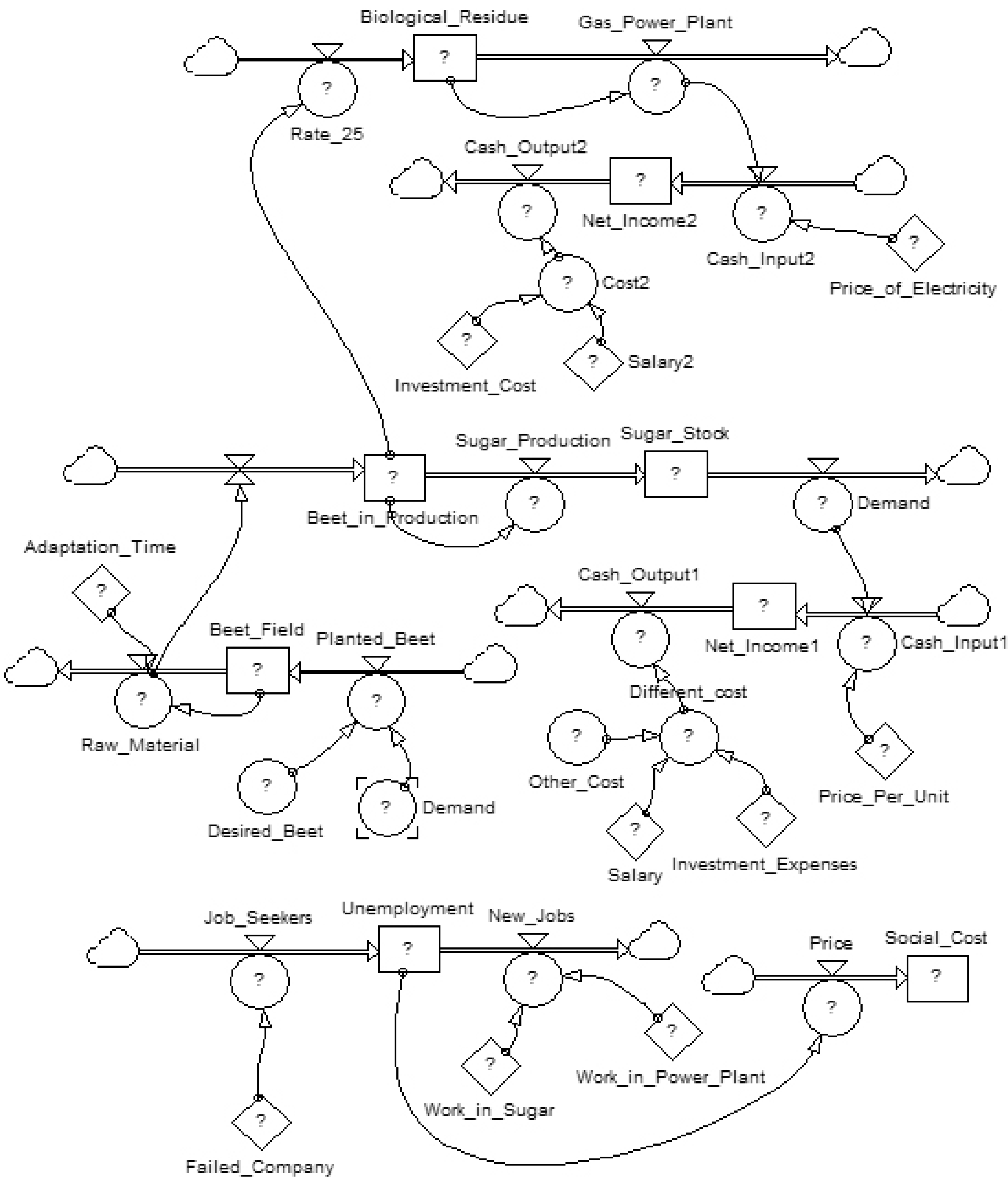

Figure 2: The preliminary SD model to support investment decisions

model based on SD methodology. The model will be used to test different business strategies in order to define the appropriate mixture of price and costs for anticipated market demand with respect to production constraints. However, the main variables for regional decision-makers were the net incomes, as follows: Net Income1, which represents the financial aspect of sugar production, and Net Income2, which represents the financial aspect of gas electrical production and social transfer cost.

$$\begin{aligned}
&BP(k+1) = BP(k) + \Delta t(RM(k) - SP(k)) \\
&SS(k+1) = SS(k) + \Delta t(SP(k) - D(k)) \\
&BF(k+1) = BF(k) + \Delta t(PB(\varphi(D, DB)) - RM(k) \\
&BioR(k+1) = BioR(k) + \Delta t(BeetR - GPP(k)) \\
&U(k+1) = U(k) + \Delta t(JS(k) - NJ(k)) \\
&NI_1(k+1) = NI_1(k) + \Delta t(D(k) * C_1 - CO_1(k)) \\
&NI_2(k+1) = NI_2(k) + \Delta t(GPP(k) * C_2 - CO_2(k)) \\
&SC(k+1) = SC(k) + \Delta t(U(k) * C_3)
\end{aligned} \qquad \textbf{(2)}$$

Where of Level in equation (2) means; BP (k) = Beet in Production, SS (k) = Sugar Stock, BF (k) =Beet Field, BioR (k) = Biological Residue, NI_1 (k) = Net Income of Sugar, NI_2 (k) = Net Income of Gas Power Plant, and SC (k) = Social Cost.

Flow elements: RM=Row Material, PB = Planted Beet, SP = Sugar Production, D = Demand, DB = Desired Beet, BeetR = Beet Residue/per time, GEP = Gas Power Plant, JS = Job Seekers, New Job = Number of Sugar Workers + Workers in Gas Power Plant and C_1 = D(k)* Price per Unit, C_2 =Gas Power Plant*Price of electricity, CO_1 = Investment cost, Salary and Other cost, CO_2 =Investment cost + Salary and U(k)*C_3 =Number of Unemployment * Average salary of unemployment.

In equation (2) for simplicity we use first character of capital words in assignment of equation notation.

3 Economic feasibility of sugar beet production

For the financial and technological analysis of the sugar beet production on Slovenian farms, an integrated deterministic computer process simulation was developed for the purpose of conducting a sugar beet renewal feasibility study. The model consists of various sub-models that represent each segment of the sugar beet growing process. The sub-models are based upon deterministic technologic economic simulation (Csaki, 1985; Rozman et al., 2002), where the technical relations in the system are expressed with a set of equations or with functional relationships.

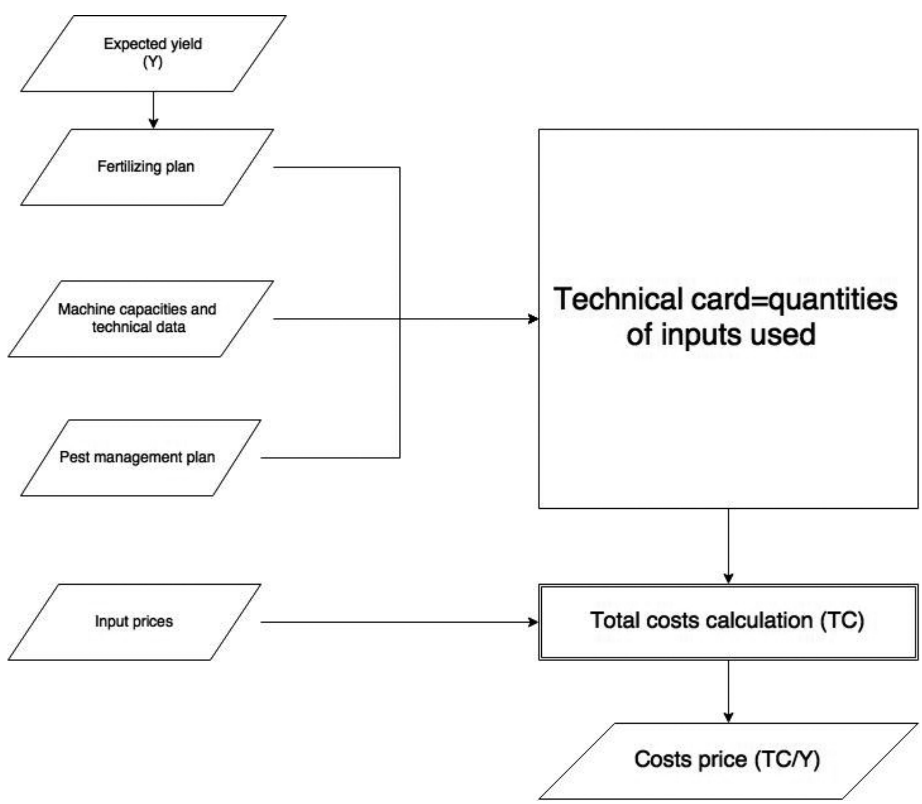

Figure 3: Main elements of the sugar beet production process model

The amount of inputs used was calculated as a function of the given production intensity, while the production costs are ultimately calculated as dot products between the model's estimated inputs' usage and their prices. The model structure is shown in Figure 3.

The system as a whole represents a complex calculation system, and each sub-model indicates in a specific sub-calculation. Through a special interface, the system enables simulation of different alternatives at a farm level. All iterations (calculations for individual alternatives) are saved in a database and can be used for further analysis. The simulation system is constructed in an Excel spreadsheet environment and upgraded with Visual Basic code in order to ensure better functionality of a user-friendly calculation system.

Using this model, we simulated different production scenarios in order to assess the cost price, which is calculated as follows:

$$CP = TC / Y \quad (3)$$

where:

- CP: cost price (€/t);
- TC: total costs (€/ha);
- Y: expected yield (t/ha).

A comparison of the cost price and market price is used to estimate the economic feasibility of sugar beet production. We used five different yields levels both with irrigation and without irrigation (Table 1).

Table 2 shows the sugar beet market prices for white sugar in the region for 2014.

Table 1: Cost price of sugar beets

With irrigation		Without irrigation	
Yield t/ha	Cost price €/t	Yield t/ha	Cost price €/t
60	28.92	50	30.12
66	26.62	55	27.79
72	24.69	60	25.85
78	23.07	65	24.20
84	21.67	70	22.79

Table 2: Expected market prices for sugar beets (white sugar) in the region

Country	Market price (€/t) from 2009–2013	Market price (€/t) from 2014
Germany	48.7	36.7
Austria	51.4	N/A
Croatia	46.18 (2012)	31.69

Table 3: Expected market prices for sugar beets (ethanol) in the region

Country	Market price (€/t) from 2009–2013	Market price (€/t) from 2014
Germany	33.2	25.5
Austria	36.7	36.8 (in 2013)

Table 4: Break-even yields for different sugar beet prices

Price (€/t)	25	30	45
Break even yield (t/ha)	63.81	53.18	35.45
Break even yield with irrigation (t/ha)	64.63	50.44	40.46

Based on Table 2, we can observe that the calculated cost prices are below the market prices of beets used to produce white sugar. Therefore, sugar beet production is economically feasible assuming that the expected production parameters (yield) are achieved. In the case of beets used for bioethanol, the expected market price is around 27 €/t. As a result, the sugar beet grower must achieve higher yields in cases of bioethanol production.

We can also calculate the break-even yield (BEY) as a coefficient between the total costs and the expected price. For the BEY, the net return for the farmer is zero. The BEYs are shown in Table 4.

The historical data (Rozman et al., 2013a) and current production data from the region (Germany, Austria, and Croatia) indicate that the BEY has been exceeded.

4 Results and discussion

The decision problem of the model (2) could be considered as follows: Max expected utility of the criteria function equation (4).

$$J = Max(NI_j(k) + NI(j-1)(k) - SC(k)) \quad for\ j = 1,2 \tag{4}$$

where j=1 indicates investment only in Sugar production and j=2 stands for an investment in Sugar production + Gas power plant. The Social Cost variable is cumulative and could be present in equation (4) for both scenarios j=1,2. However, the main scenarios should be created according to variables φ (D, DB) in equation (2) defined as follows:

φ(D, DB) = φ(Demand, Desired Beet, Price of Sugar, Existing Crop Rotation, Bioethanol, Electrical price, etc.) (5)

Equation (5) represents the global scenarios for decision-makers in regards to regional planning. An expert group should determine the unit sale price and market demand function, according to the different production scenarios and properties of the alternatives. In fact, investigations exist in the mentioned region in separate subsystems for the electrical power plant based on organic residue. However, many of the installed parts do not work properly.

With investment in the sugar factory and adequate organization of existing parts in the systems, it is possible to create satisfactory functioning in the local community in an economic, ecological, and employment sense. This task has to be negotiated at a local and also a government level, and it is the most difficult task. According to an economic analysis of the investment in the previous paragraph and the CLD model expert group considered utility of investigation by multi criteria decision-making.

Alternatives are analyzed according to the AHP methods (Saaty, 1990) as a multi criteria decision. The set of criteria (Net Income, Ecology, Social Cost, and Investment Risk) along with its weights (0.522, 0.200, 0.078, and 0.200) were respectively considered. The weights of the Values of Net income criterion for AHP assessment were estimated using Equation 4. Namely, the failed company resulted in new unemployment, which created a higher expense for the government for social transfer. However, the new investment could also reduce the number of social transfers by employment in a new industry. A similar concept of sectorial policy reforms was considered in Gohin and Bureau (2006).

The set of alternatives (Sugar, Sugar + Biogas, Existing Crop Rotation Sugar + Bioethanol) along with their weights was determined for each criterion. Based upon the group decision of experts, we obtained a range of alternatives with their weighting as follows:

- Sugar + Biogas = 0.418
- Sugar + Bioethanol = 0.263
- Sugar = 0.172
- Existing Crop Rotation = 0.147

Therefore, the most attractive alternative, at the moment of decision, was Sugar + Biogas. However, the developed model enables the management of a local community the chance to easily control the type of regime of the systems without influencing employment or ecology and without requiring any additional investigation.

5 Conclusions

In this paper, we employed a preliminary SD model to simulate the sugar beet processing method. The presented SD model enables the modeling of different policies, and it is comprehensible to a wide range of users who are involved in the decision-making process. The holistic model presented the main feedback loops and dynamics of the main elements in the case of regional investment in the sugar industry. In addition to negative feedback loops that keep some parameters in equilibrium (price, sugar beet production area), there are also important reinforcing feedback loops that promote the social and ecological impacts of a sugar beet production system.

In this way, we can simulate the effects of the investment in a sugar factory on the regional economy (workforce) and environment. This way we can simulate the effects of the investment in a sugar factory on the regional economy (work force) and environment. Further consideration must be given to the interaction between elements in the main feedback loop in the system, which determines the system performance and provides the means for proper definition of control strategy.

Furthermore, we analyzed sugar beet production economics using a spreadsheet process simulation model with different production parameters. According to current sugar beet market prices and expected yields, we can expect economically feasible sugar beet production. The multi-criteria AHP analysis showed that sugar and biogas is the most suitable alternative for investment planning.

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Črtomir Rozman conducted his postgraduate studies at University of Zagreb and achieved his Ph.D. at University of Maribor, Faculty of Agriculture. He is active as Full Professor for Farm management in the Department for Agriculture Economics and Rural Development (Faculty of Agriculture and Life Sciences, University of Maribor). His research includes development of decision support systems for farm management (simulation modeling, multi criteria decision analysis, machine learning) and economics of agricultural production. He is also involved in teaching activities and as thesis supervisor at post graduate study programs and multiple national and international research projects. He is author or coauthor of 69 scientific papers including 28 papers in journals with impact factor.

Karmen Pažek achieved her Ph.D. at University of Maribor, Faculty of Agriculture in 2006. She is active as Associated Professor for Farm management in the Department for Agriculture Economics and Rural Development on Faculty of Agriculture and Life Sciences, University of Maribor. Her research includes development of decision support tools and systems for farm management (simulation modeling, multicriteria decision analysis, option models) and economics of agricultural production. She is involved in teaching activities as thesis supervisor at postgraduate study programs and involved in national and international research projects. She is author or coauthor of 41 scientific papers including 20 papers in journals with impact factor.

Miroljub Kljajić completed his Ph.D. at the Faculty of Electronics, University of Ljubljana in 1974. He is a Professor Emeritus at the Faculty of Organizational Sciences in Kranj in the area of Systems Theory, Cybernetics and Computer Simulation. His main fields of research include decision support systems in global e-commerce and methods of modeling and simulation of organizational systems. He has been the principal investigator of many national and international modeling and simulation projects. As author and co-author, he has published more than 40 scientific articles recognized in SCI with more than 400 citations.

Pridelava sladkorja in sladkorne pese: Model sistemske dinamike in ekonomska analiza

Ozadje in namen: Sladkorna pesa je glavna kultura, ki se uporablja za proizvodnjo sladkorja v zmernem klimatskem pasu. Ker so naložbe v predelavo sladkorne pese dolgoročne in ireverzibilne, je z uporabo ustreznih orodij potrebno odločitve pretehtati.
Metodologija: Metodologija sistemske dinamike je bila izbrana za podporo odločanju na regionalnem nivoju pri planiranju investicij v predelavo sladkorne pese. Predstavljamo osnovne pojme sistemske dinamike (SD) in razvoj modela pridelave in predelave sladkorne pese in predelovalnih sistemih. S pomočjo tehnološko ekonomskega simulacijskega modela pa analiziramo ekonomiko pridelave sladkorne pese.
Rezultati: Model ponuja odgovore na strateška vprašanja, ki so povezana s predelavo sladkorne pese in bo uporabljen za simulacijo različnih scenarijev za proizvodnjo sladkorja in njihovega vpliva na gospodarske in okoljske parametre na agregatni ravni. Analiza ekonomske upravičenosti proizvodnje sladkorne pese je pokazala, da pri sedanjih cenah in intenzivnosti pridelave (pričakovan pridelek), lahko pričakujemo dobičkonosno proizvodnjo sladkorne pese tako za beli sladkor kot etanol.
Zaključek: Preliminarni rezultati so pokazali, da ob doseganju predvidenih parametrov lahko pričakujemo ekonomsko upravičeno pridelavo in predelavo sladkorne pese.

Ključne besede: *sladkorna pesa, modeliranje, sistemska dinamika, ekonomska upravičenost*

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How Close to Reality is the „as-is" Business Process Simulation Model?

Bartlomiej Gawin, Bartosz Marcinkowski

University of Gdansk, Department of Business Informatics, Piaskowa 9, 81-864 Sopot, Poland,
bartlomiej.gawin@ug.edu.pl, bartosz.marcinkowski@ug.edu.pl

Background and Purpose: Business process simulation (BPS) model is based on real-life data form sources like databases, observations and interviews. It acts as "as-is" business scenario can used for reengineering. The main challenge is to gather relevant data and to develop simulation model. Research aims to elaborate BPS model and to systematically assess how close to reality it is.
Design/Methodology/Approach: The research has been performed in Polish telecommunications company. Authors investigate technical process of expanding cellular network. After elaborating "as-is" model, authors use ADONIS simulation tool to run a series simulations and confront simulation results with actual historical events. After this, assessment whether computer simulation model can precisely map real-life business process – and consequently act as credible basis for process improvement – is made.
Results: The simulation model has been constructed with data from the WfMS database, observations, staff knowledge and their experience. Fully equipped simulation model is found to allow reconstructing the historical execution of business activity with low margin for error. Some limitation were identified and discussed.
Conclusion: BPS is not a popular approach for process reengineering and improvement yet. Data collection issues for BPS that require adopting process mining techniques and additional information sources are among the reasons for that. In our study, computer simulation outputs are compatible with historical events. Hence the model reflects the business reality and can be taken as a reference model while redesigning the process.

Keywords: *business process, business process simulations, data acquisition, workflow systems*

1 Introduction

Business Process Management (BPM) is an attention-attracting topic for management staff, enterprise modeling communities and scientists. BPM framework supports the design, enactment, control, analysis and improvement of business processes. The procedure has been designated by E.C. Deming and W. Shewhart as the PDCA method (Moen and Norman, 2009). The PDCA method can be used as a basis for practical solutions that are developed by business software vendors for supporting complex business processes management. Finally, the business process management cycle has been enriched by business process simulation (BPS) phase. This stage is usually supported by an IT simulation tools and is an important part of the evaluation of (re)designed processes (Tarumi, Matsuyama and Kambayashi, 1999; Suzuki et al., 2013).

Computer simulations of business processes apply to both newly created processes and processes that are already in operation in commercial environments (Workflow Management Coalition, 2013). In the former case – design time analysis (Van der Aalst, Weijters and Maruster, 2004), simulation is mostly focused on examining abstract steady state situations called "to-be" scenarios, which is helpful for initial design for business processes but is still less suitable for operational business process execution (Rozinat et al., 2008).

So, the a-priori simulation model consists of theoretical inputs, such as the shape of business process model, organizational structure and some parameters including activity costs and duration times as well as decision point probabilities, resources availability, etc. Because analysts have direct access to all mentioned theoretical inputs, they can explore different contrived scenarios with respect to the theoretical effect. In the latter simulation case – runtime analysis (Van der Aalst, Weijters and Maruster, 2004)

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business process has been commercially executed for a long time and this enactment is supported by information systems – Workflow Management Systems (WfMS).

Usually, WfMS engine performs the workflow logic based on an implemented process model. Every commercial execution of the process model is called business process instance. WfMS performs process instances and, simultaneously, archives sets of information in a database (Gawin, 2009). Thus, produced event logs usually contain data about cases (process instances) that have actually been executed in an organization. Event logs record the times at which tasks were executed, the persons or systems that performed the task and other kinds of data. Such logs are the starting point for process mining (Van der Aalst, Weijters and Maruster, 2004) which means discovering knowledge about processes and discovering data that can power simulation models.

While powering data comes from the workflow management system database, the simulation model reflects the "as-is" situation (Rozinat et al., 2008). One of the main challenges is to create simulation models that accurately reflect the real-world business process executions. For the "as-is" situation, both the simulated and real-world process should overlap as much as possible.

The real business continuously needs process improvements to achieve better performance (e.g., better response times, less costs, higher service levels) (Van der Aalst, 2010). By modifying real parameters and performing various scenarios of simulations, analysts can estimate business results of the process time requirements and costing, staffing needs to be established, the identification of bottlenecks as well as calculation of resource loads, with which the company intends to carry out the process. With the use of simulation, the (re)designed processes can be evaluated and compared. Simulation provides quantitative estimates of the impact that a process design is likely to have on process performance, and so a quantitatively supported choice for the best design can be made (Jansen-Vullers and Netjes, 2006). The most popular information tools for business process modeling and simulation include ARIS, ADONIS and iGrafx, but the simulation experience is still limited. Some organizations – e.g. Wipro (Srivastava, 2010), Qwest (Teubner, McNabb and Levitt, 2008), Slovenian Ministries (Jaklic and Stemberger, 2005) and Motor Company (Hauser, 2007) provide case studies of projects involving simulation tools and a number of these projects have proved successful.

This paper seeks to identify, systemize and elaborate implementable techniques of preparing a business process model based on the historical data, which truly reflects the real process behavior. The remaining part of this paper is organized as follows. Section 2 overviews related work on business process simulation types, tools and process mining techniques. Business case study along with research process is presented in section 3. Section 4 discusses data inputs for business process assessment and powering business process simulation model. In section 5 authors execute multi-instance business process simulation to compare simulation results with historical process outputs. Research is discussed in section 6, followed by conclusions.

2 Related Work

2.1 Business Process Simulation on PDCA Cycle

Business process simulation integrates seamlessly with the PDCA cycle and can be performed in two stages: between process modeling (*Plan*) and execution (*Do*), as well as between process revision (*Check*) and practical improvement (*Act*). Figure 1 illustrates the proposal of PDCA cycle extension with BPS (Business Process Simulation) actions. Output of the PDCA Plan stage allows abstracting real business needs and representing them in graphical or/and

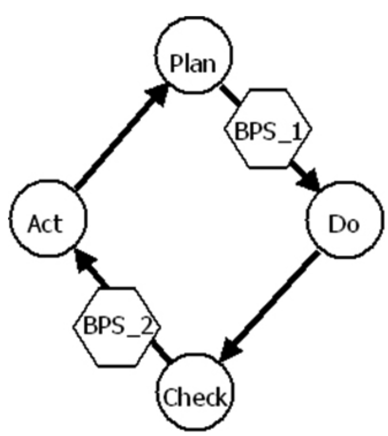

Figure 1. Extended PDCA cycle

descriptive form (Becker, Kugeler and Rosemann, 2003). The most popular visual notations include BPMN (Object Management Group, 2013), eEPC (Scheer, 1992), IDEF3 (Mayer et al., 1995) and UML Profile for Business Modeling (Johnston, 2004).

To perform the first BPS action (described as *BPS_1*), the graphic model must be enhanced with quantifiable data. At this stage, *BPS_1* aims to achieve the vision and estimated values (Workflow Management Coalition, 2013) of the business process, which means theoretical (pre-execution) process costs, execution times, resource utilization, etc. In the process implementation/execution stage (*Do*), the business process is enacted on WfMS and outcomes are recorded in a database to be analyzed in the succeeding phase (*Check*). In the latter, experts, analysts and managers review executed processes and evaluate them with regard to strategy. They operate on real data – historical execution values (Workflow Management Coalition, 2013) from WfMS database and consider also comments from process participants. Collected data and information power the "as-is" simulation model (stage *BPS_2*) to "catch the reality" in digital form. By defining KPIs and creating business cases, analysts and managers identify the requirements to create and implement enhanced processes (post-execution optimization). But, before commercial launch of corrected workflows, the *BPS_2* stage allows many "what-if" simulation scenarios which reflect planning business reality based on real historical data.

BPS can be shown as a simple function: $y=f(x)$, where function f presents a model that transforms inputs x to the result (output of that model) y (Bosilj-Vuksic, Ceric and Hlupic, 2007). By entering different x values, function f generates different y results and can be considered as "what-if" simulations. Another way is to conduct "what-if" optimizations by setting a target value for y, then searching for the values of x that result in the target value for y. Simulation allows to capture process dynamics and helps to investigate random variable influence on process development.

Process simulation could play an important role in supporting business process change management approaches such as TQM, Just-in-Time, Business Process Re-engineering, Process Innovation and Knowledge Management (see Hlupic and Vreede, 2005). In this context, simulation can be used to investigate knowledge management processes, to simulate missing data needed for knowledge management, or to evaluate alternative models of knowledge management strategies.

Simulation is used to describe a broad range of capabilities. These involve reproducing or projecting the behavior of a modeled system (Barnett, 2003). Models for simulation can be classified based on system of interest: a physical system (e.g. supply chain or production line), a management system (e.g. CRM or workflow process) or a meta-model (e.g. rules that establish whether a model is formulated properly).

In 2013, Workflow Management Coalition (WfMC) has published Business Process Simulation Specification (BPSim) (Workflow Management Coalition, 2013). Authors stress how important it is to simulate and analyze business processes in a safe isolated environment before they are deployed and identify reasons for simulation and analysis still not being systematically used in most process improvement projects. Lack of mature standards for BPS in contrast to standards for simple process modeling is pointed out as the main reason. Framework BPSim introduces a standardized specification that allows process models to be augmented with data in support of rigorous methods of simulations and analysis. Provided meta-model is captured using UML and supports both pre-execution and post execution simulations.

2.2 Process Simulation Types and Tool Support

The main idea of business process simulation is to execute the model repeatedly to reflect the real business behavior. Contemporary IT literature distinguishes two types of BPS (Russell et al., 2005; Van der Aalst, 2010): Transient analysis and Steady-state analysis. In the former case, answers for operational questions (i.e. times, costs and probabilities predictions) in the near future are provided. When the transient analysis starts with initiated (and still not completed) process instances, then the model takes into account queues of work and temporary resources unavailability. For steady state, the initial state is irrelevant – the simulation model resets any cases in progress and it takes time to fill the system with tasks. Steady state is relevant for answering strategic and tactical questions rather than predicting the near future.

Simulation types have become a practical rather than theoretical domain. Software vendors provide copyrighted simulation algorithms that differ regarding parameterization. Generally, process-oriented software falls into three types of tools (Jansen-Vullers and Netjes, 2006): business process modeling tools, business process management tools (BPM) and BPS tools. The former enable creating multidimensional process models in one or more available notations. As a result, static reports can be generated for process documentation, manuals, instructions, functional specifications. BPM systems can be perceived as tools that support managing business processes across the whole PDCA life-cycle (i.e. FLOWer).

The core part of BPM system is workflow engine. BPM is defined as supporting business processes using methods, techniques and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information (Van der Aalst, Ter Hofstede and Weske, 2003).

BPS tools support for process measurement and simulation, based on diverse techniques and providing broad range of outputs. BPS practitioners appreciate modeling flexibility, animations and simulations effects, statistical capabilities, variety of output reports and how user-friendly a simulation tool is. (Bradley et al., 1995) propose seven different categories to evaluate BPS tools, i.e. general capabilities, hardware and software features, documentation, user-friendliness, modeling-oriented potential, simulation capabilities as well as output analysis capabilities.

2.3 Process Mining and "as-is" Simulation Model

With reference to Figure 1, it can be said that in case of *BPS_1* analysts need fictive inputs, mostly needed by business simulation model to design and predict future behavior. While performing *BPS_2*, they need a simulation model which captures historical process shape and parameters, because "as-is" simulation models should reflect the reality as strictly as possible. In order to obtain useful simulation model to perform different process scenarios, process mining techniques extracting relevant data regarding processes from WfMS database are often used.

WfMS operates with Business Process Participants in a client-server architecture, where the client side is usually a web browser (rarely a separate application) that can be operated from the employee's device. Based on the process definitions, workflow engine executes process models as flows of forms and documents that contain information regarding the tasks for employees. The aforementioned forms – Transaction Sets – are managed in accordance with defined routes. In commercial use, dedicated business processes are initiated on the engine several times, but based upon a single process definition. Running the same process numerous times means that workflow systems sequentially record process instances in the database. Process instances, recorded over the years in the event log, contain a huge amount of workflow data. Exploration of the data, also known as Knowledge Discovery in Databases, is a multi-step process that involves raw data transformation from the event log into actionable knowledge about the organization. In addition to the actual projection of the company's operations, the data may also be used to feed the simulation-oriented computer process models.

The process mining method involves discovering knowledge about business processes, which are, by nature, dynamic phenomena. Business process analyses are reasonable provided that observations refer to attribute values not at specific moments, but over a long term. The discovery process involves the transformation of raw data into useful information which is used at a later stage to improve the systems and processes. The most valuable knowledge on organizations involves the hidden patterns, rules, trends and correlations in data structures, which are formed automatically over a long time period during data archiving in database systems. Discovery of these non-trivial relationships between attributes provides unique insight into the operation of the company, inaccessible using less refined methods of assessing business processes (Van der Aalst, 2007).

Workflow mining algorithms allow detailed analysis to be carried out, taking into account four perspectives, each dedicated to discovering different aspects of process-related knowledge: Control Flow Perspective, Organizational Perspective, Case-Related Information Perspective as well as Conformance Checking Perspective (see Business Data Collection and Process Analysis section). Results provided feed analysis stage (*Check*), process simulations (*BPS_2*) and process definitions improvement (*Act*) to achieve improved workflow definitions.

3 Case Study

3.1 Business Domain Description

The case study involves the workflow system which supports execution of business processes in the telecommunications organization in Poland. The investigated company provides mobile telecommunications services (voice, data transfer, internet) across the whole country and its internal structure is divided into four regions: Maritime, Mountainous, East and West. The analyzed case study was performed in one of them (Maritime Region). The investigated database comes from the workflow Action Request System (ARS) provided by BMC Software company from Houston (USA, Texas).

The workflow ARS tool has been collecting instances of business processes since 2002. Because of big volume of recorded data in database, the event log investigated in our research reflects one-year activity. The instances concern the following business areas: planning, building and operating mobile telecommunication network and our case study concerns an event log which reflects three types of workflow processes:

1. *Parameters Changing*: setting telecommunication devices parameters, e.g.: transmitted radio frequency, radio transmission power, number of available voice channels;
2. *Order Advice*: transmission network modifications like radio link tuning, light pipe building and testing, equipment software updates, redirecting antennas;
3. *Planed Work of Base Transceiver Stations*: activities that require commercial service interruption to perform necessary modifications.

Investigated processes relate to planning, operating and maintaining telecommunication services and physical infrastructure. All of them have been originated by personnel responsible for planning the telecommunication network and then executed by teams responsible for network operation and maintenance.

Workflow instances flow between two departments: *Planning Department* and *Executing Department*. Workflows can also take place between teams within the department. Table 1 introduces data regarding teams of employees, which are involved in planning, building and maintaining telecommunication network.

Relevant workflows can proceed according to different scenarios: employees of *GPST_1* can take decisions regarding the need for extension/modification of the telecommunication network. Then, depending on the set of tasks, projects can be expanded (by *GPST_2*) with more data, or can be passed directly to *Executing Department*, where projects are run and implemented. Both the employees involved in the preparation of projects and in their implementation can take advantage of specialized tools, which are usually purchased from suppliers of telecommunications equipment. Employees also use IT, measurement equipment and service cars to perform site surveys. During the flow of work, the employee uses workflow system to obtain information, documents and work description to perform assigned tasks. After completing contracted work, people forward process instance to another contractor. If the worker performs the last step of the process, then the process initiator checks the implementation of project and after this completes a particular instance of the process in workflow system.

3.2 Research Description

Our research aims to elaborate guidelines which can help to answer the question how close to reality is the "as-is" computer simulation model. To develop our approach we use process mining – which enables discovering knowledge about processes, evaluating discovered information and powering the simulation model with data. We extend reality assessment by observations based on business process simulations (*BPS_2* included in extended PDCA cycle). After performing simulations (*BPS_2*) we indicate some additional techniques that help compare simulation process model with the real business process execution.

The idea of business process management (BPM) provides continuous improvement of business processes, but this cycle requires useful simulations on models which capture the real business processes. In this paper, we skipped details regarding process mining algorithms, focusing on process mining results that can help assess the reality of discovered data. We also do not discuss the details of simulation algorithms. Both topics have been addressed in previous work (Gawin, 2009; Gawin and Marcinkowski, 2013; Marcinkowski and Gawin, 2014). Figure 2 overviews line of research.

Research process involves a recurrent cycle, which, like the Deming wheel, provides for the continuous monitoring and improvement of business processes in companies. *Workflow Management System* is based on theoretical models of business processes and coordinates the execution of these processes in the enterprise. Process instances are recorded in the database and contain attributes reflecting the actual information regarding performed activities. These data include identifiers of personnel involved, durations of activities, invoked external applications and options selected in decision-making that influence the further course of the process instance. The database distinguishes subsequent instances by a unique number allocated by the workflow system on process instance start.

Table 1: Technical departments and teams involved in the execution of business processes

Department	Technical team	Abbrev.	Responsibilities
Planning Department	Design_team_1	GPST_1	Estimating the deployment of telecommunications equipment in the field (base stations locations) and telecommunication equipment parameterization (base stations transmitting capacity, radio signals frequency etc.)
	Design_team_2	GPST_2	Estimating the deployment of transmission telecommunication equipment in the field, (locations of radio lines, fiber optic), transmission parametrization (radio link transmission power, optical line attenuation etc.) and setting core parameters (e.g. for Mobile Switching Exchange)
Executing Department	Maintenance_team_1	GUST_1	Implementing telecommunication projects (especially BTS part)
	Maintenance_team_2	GUST_2	Implementing telecommunication projects (especially transmission part)
	Maintenance team_3	GUST_3	Implementing telecommunication projects (especially core part)

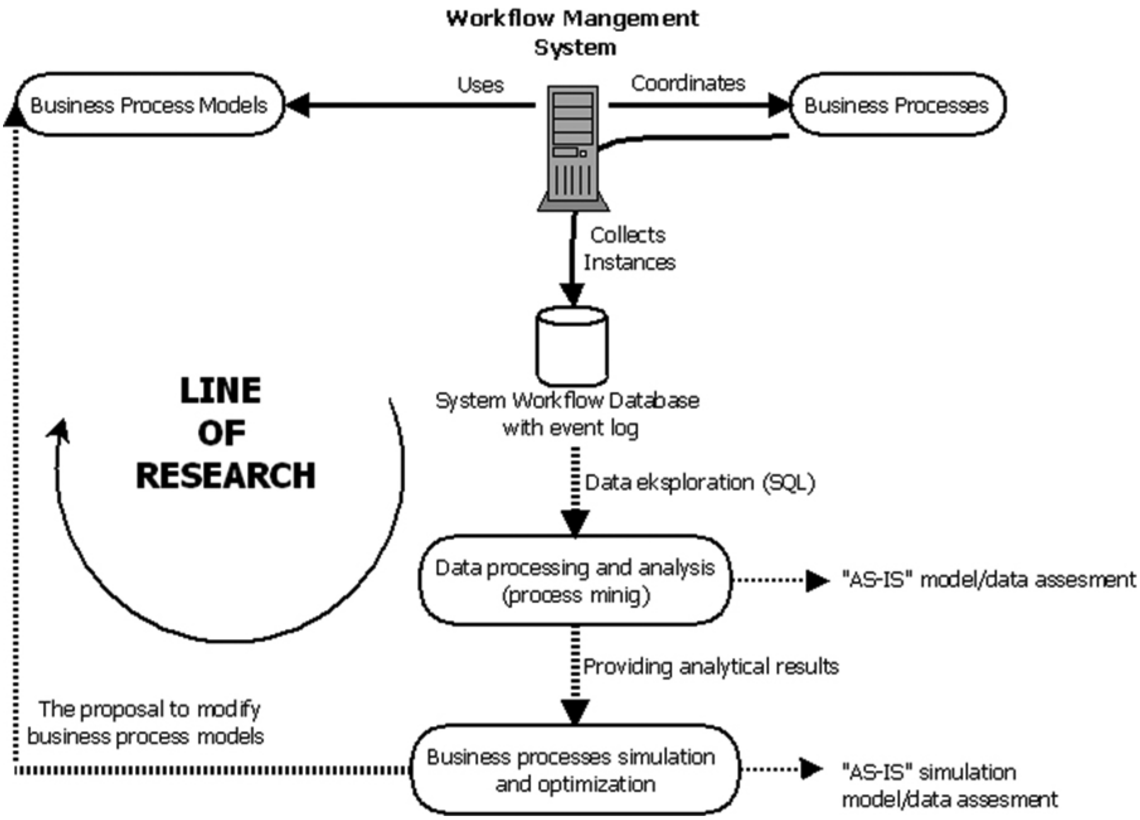

Figure 2. Line of research

Table 2: Data from workflow database

Discovered data	Data type	Data source	Additional information
Graphical model of the business process	Processed data	Workflow mining – Control Flow Perspective	Based on hierarchically stored phases of each process instance, workflow mining algorithms reconstruct graphical process model
Organizational structure	Processed data	Workflow mining – Organizational Perspective	Workflow mining algorithms analyze database and discover who and how many times performed process activities
Time-related parameters	Raw data	Basic statistic	Basic statistic provides information how long every activity and every process instance has been historically executed; min., max and average statistics are available as well
Number of business process occurrences within the chosen time period	Raw data	Basic statistic	Number of occurrences comes directly from SQL query, limited to a specific period of time
Probabilities for outgoing workflows from decision points	Raw data	Basic statistic	Probabilities comes as a mathematical quotient of all running instances with respect to those affected by the selected path

Research begins with the *Data exploration* stage. At this stage process instances are explored from workflow management database. Then, we analyze them with process mining techniques which come from Eindhoven University of Technology. For this purpose, ProM (Process Miner) IT tool is used. Subsequently, we analyze mining results in different perspectives and assess how close to reality the discovered information is. Based on mining results, we construct an "as-is" simulation model for selected business process. Without any model transformation, we execute the "as-is" simulations to verify whether results might be helpful in assessing the reality of computer model.

Business process simulation models allow to perform some process scenarios that enable us to predict the future behavior in a company. Simulation results can enable introducing changes in business process definitions (Figure 2: *Business process simulation and optimization* and then *The proposal to modify business process models*). In our research, further simulations involving modifying business process parameters were performed, yet remain out of the current paper's scope.

3.3 Data Collection Methods

Simulation of business processes requires a process model interrelated with additional models (e.g. organizational structure) as well as powered with data regarding durations, costs, path probabilities etc. Most models and parameters can be discovered from the WfMS database, but some of them come from the "people knowledge" about the organization. A set of data to be collected depends on simulation tool, which shall execute "as-is" simulation model. Market investigation and evaluations led to selecting ADONIS Process Management tool provided by BOC. Research involved collecting data both from WfMS and from process participants.

3.3.1 Data exploration from WfMS database

The workflow system records all events in the event log, from which the complete history of the process can be reconstructed. Seeking to achieve "as-is" simulation model for one of the available telecommunications company processes, the authors identify data and knowledge from database singled out in Table 2.

All aforementioned data can be discovered WfMS database with ProM tool. Before performing analysis, data should be imported from database and transformed into the acceptable by ProM file format (see Figure 3).

Required information regarding instances are transferred to MXML format using four intermediate Microsoft Access tables. MXML file contains many process instances and its attributes and enables performing workflow mining analysis to reconstruct the process model, as well as the organizational model of organization (Gunther and Van der Aalst, 2006). Raw data comes as ProM Basic Statistic and do not require any additional actions. Processed data are subjected to process mining algorithms, what leads to constructing business process simulation model.

3.3.2 Data exploration from personnel knowledge

BPS_2 specificity (see Figure 1) requires additional information that cannot be collected from WfMS. Some of them are mandatory (as mandatory inputs for simulation algorithms), and some help to understand people's behavior and business rules in the company. Table 3 includes information that should be obtained from process participants along with techniques that may be used to obtain the information.

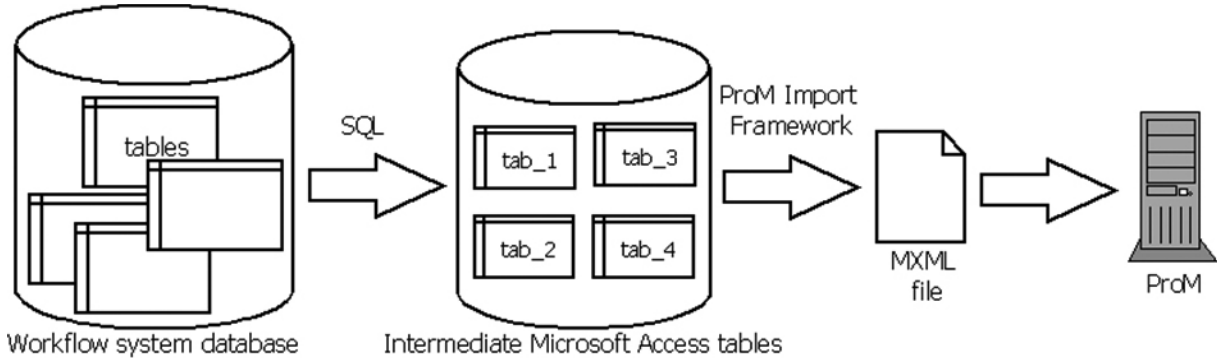

Figure 3: Simulation data preparation

Table 3: Information regarding business process and company provided by staff

Information	Collection technique
Business process description from employees' point of view	observations, interviews
Official business process model and business activity description	official documentation analysis, interviews
Actual organizational structure	official documentation analysis
Availability of staff	individual management interviews
Number of hours per working day	individual management interviews / official documentation analysis
Number of working days per year	individual management interviews / official documentation analysis

Official documentation provides general overview of business processes. Additional documents include information regarding organizational structure, including "tree view" of departments, teams and employees along with full names and organizational roles.

Generally, observation enables business analysts to access information that are not provided by any class of IT in a company. Elimination of intermediate links in the process of data collection which may contribute to increases in the probability of misinterpretations may be regarded as an advantage of observation. Research carried out involved combining diverse range of observation types (see Gray, 2013). Authors participated in business processes and observed rather non-controlled employees' behavior. Additionally, not all employees were aware of research conducted. Knowledge obtained with the technique enabled supplementing workflow management system with data regarding phone calls, mails and meetings, leading to executing process instances as best as possible.

Research process involved performing interviews with management staff. Interviews are a practical alternative to observation as a method of collecting data without the use of IT support. They involve approaching respondents with more or less formal questions within a particular issue area. Interviews boiled down to the reciprocal flow of information and may be carried out using different procedures (see Sztumski, 2010). Researchers were allowed to perform face-to-face, unstructured interviews with management staff – rather groups than individual. It contributed to good understanding of actual business process instances in telecommunication company, ability to interpret research results properly and identify potential areas for optimization.

4 Business Data Collection and Process Analysis

4.1 Control Flow Perspective

To achieve transparent results, the event log from the investigated WfMS database has been limited to a single business process – *Order Advice*. Because of a considerable volume of process instances stored, an additional filter was included to investigate cases limited to a single year. The initial workflow mining analysis – control flow perspective of a process – establishes interdependencies among activities. The goal of mining the perspective is to provide a visual, diagram-oriented presentation of all possible process instances historically executed. From a business point of view, managers responsible for workflow processes in an organization can review reconstructed diagrams and answer certain questions: How are the cases actually being executed? Are there any parallel executions? Are there any loops? What is the process model that summarizes the flow followed by cases in the log?

ProM supports various plugins to mine the control flow perspective of process models. From available algorithms, three techniques were tested: Fuzzy Miner (Gunther and Van der Aalst, 2007), Alpha (Medeiros et al., 2004) and Heuristic Miner (Van der Aalst et al., 2007). Finally the latter one was selected due to the fact Heuristic Miner algorithm can deal with noise and incompleteness of event log. Additionally, the algorithm has options to focus on the main process paths instead of attempting to model the complete details of the behavior reported in the event log as well as wide parametrization capabilities.

Heuristic net for *Order Advice* process (Figure 4) visualizes the reconstructed model that includes all the 71 instances (superposed). Every rectangle denotes a process activity and incoming/outgoing transitions indicate flow of work. Activities are assigned activities descriptions, identifiers of organizational groups responsible for execution,

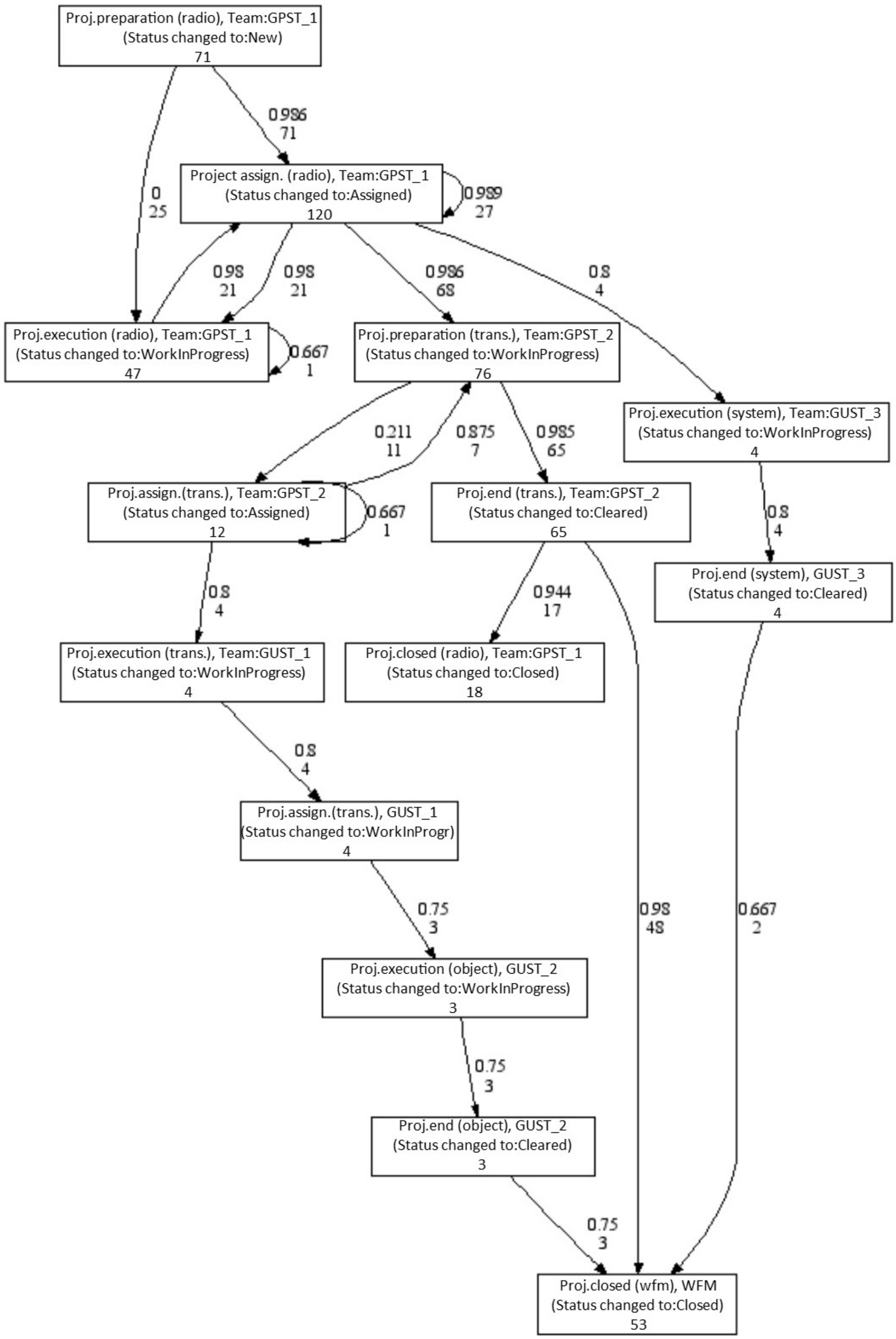

Figure 4: Heuristic diagram of business process Order Advice.

activity status changes as well as the number of times the activity was performed.

Both WfMS documentation and employees' statements confirmed that workflow system did not support parallel workflow executions, so multiple outgoing transitions from a single activity denote alternative flows. From the business point of view, lack of parallel paths caused numerous organizational issues during the process execution. To synchronize some parallel activities, employees used mails, phone conversations and meetings – what caused numerous relevant data to be processed outside the WfMS. The first decimal value assigned to transitions between activities indicates certainty level regarding existence of direct dependency between two activities. The value is always between -1 (not really sure) and 1 (completely sure). The second value provides information regarding number of flows through the transition between activities that were identified.

The Heuristic Miner algorithm also enables testing the discovered process model. The result can be assess with the continuous semantics fitness (CSF) parameter. Based on discovered model, CSF algorithm parses actual process instance from the WfMS. Should any instance not precisely fit the model, algorithm indicates an error and continues processing. Errors correspond to Heuristic Miner discovery issues, especially in case the event log recorded noise, uncompleted instances and complex flows. The maximum value of CSF is 1 and indicates that model discovered from database 100% fits to instances from event log. In our case, the result of the parsing provided CSF value of 0,964 – Heuristic Miner coped well with the events log and almost perfectly mapped the instances from database into the visual model.

4.2 Organizational Perspective

The process data can also be examined from an organizational perspective. It was the ProM Social Network Miner algorithm (Van der Aalst, Reijers and Song, 2005) that was found the most attractive for discovery of social network. The algorithm enables employee-oriented analysis; managers can observe who is mostly transferring work to whom, as well as who mostly begins, who ends the instances and how the work flows among performers.

The organizational perspective provides also additional research that classifies people in terms of activities performed and organizational units. Organizational Miner (Song and Van der Aalst, 2008) is responsible for discovering and automatically grouping people carrying out similar tasks. Mined groups should coincide with the real organizational units from telecommunication company. Table 4 includes discovered organizational structure and activity assignment for *Order Advice* business process.

Table 4 data indicates that in a single calendar year 19 people participated in 71 instances of business process. Employees executed a total of 897 process steps arranged into 14 coherent activities (ACT numbers from 1 to 14). Total number of process steps, in which employees were engaged and the percentage of employees' engagement in the execution of process steps were included as well. For the purposes of this study, the real names of the process participants were encrypted in ORIG.nr form. Based on the interviews with the staff, we have confirmed that the Organizational Miner algorithm properly organized employees into groups (based on similar tasks) as well as accurately assigned employees to activities – the matching was flawless.

4.3 Other Data Collection

4.3.1 Basic simulation inputs

The ADONIS Process Management tool selected to support research process provides the following types of simulations: times and costs, accounting analysis, path analysis, capacity analysis as well as workload analysis (incorporating both steady state view and fixed time period) (more BOC Group, 2013). Each simulation algorithm needs some basic set of input data that allows initiate simulation scenarios. Table 5 summarizes the parameters required to carry out the simulations. The suggested technique of collecting values for the individual parameters was specified in each case; the upper part of the table lists the inputs that can be extracted from the workflow system database, while the lower part contains the data to be collected using other, non-IT techniques for gathering information about processes.

Activity execution time, during which the current activity is executed, can be provided for every process step from ProM tool as basic statistic information. Alternatively, the metric might be extracted from Case-Related Information Perspective. Research is based on average activity execution times form ProM basic statistic across 71 process instances. Similarly, *number of instances within the chosen time period* can be reached in both ways. Also *probabilities of initiating individual outflows of decision points* come from ProM tool and enable assigning transition probabilities to all connectors leaving decision points (XOR logic). The sum of all transitions probabilities of the connectors equals 1.

Cost parameters are considered optional for simulation and collecting them can be challenging in practice. *Number of hours per working day* serves in combination with the value in the field *number of working days per year*, in which instance can be executed. Process and staff calendars aren't taken into account in the capacity analysis algorithm that was used in research. *Availability of staff* specifies whether a performer works full-time or part-time in the business process. This parameter takes the value between 0 and 100% - the latter indicates full engagement in

Table 4: Organizational structure and task assignment for business process Order Advice

No.	Employee identity	Organizational group identified by the algorithm	Performed activity identifier	Actual organizational group	Participation in the process	
					Quantity	%
1	ORIG.0	minedGroup0	1,2,10	GPST_1	289	32.22%
2	ORIG.2	minedGroup4	8,4,9	GPST_2	156	17.39%
3	ORIG.3	minedGroup4	8,4,9	GPST_2	80	8.92%
4	ORIG.1	minedGroup0	1,2,3,10	GPST_1	69	7.69%
5	ORIG.7	minedGroup0	1,2,3	GPST_1	68	7.58%
6	ORIG.9	minedGroup4	8,4,9	GPST_2	62	6.91%
7	ORIG.4	minedGroup5	7	SYSTEM	53	5.91%
8	ORIG.5	minedGroup0	2,3	GPST_1	40	4.46%
9	ORIG.8	minedGroup0	2,3	GPST_1	20	2.23%
10	ORIG.11	minedGroup2	13,14	GUST_2	12	1.34%
11	ORIG.6	minedGroup3	5,6	GUST_3	12	1.34%
12	ORIG.14	minedGroup4	8,4	GPST_2	8	0.89%
13	ORIG.10	minedGroup1	11,12	GUST_1	4	0.45%
14	ORIG.12	minedGroup1	11,12	GUST_1	4	0.45%
15	ORIG.13	minedGroup3	5,6	GUST_3	4	0.45%
16	ORIG.15	minedGroup1	11,12	GUST_1	4	0.45%
17	ORIG.16	minedGroup0	2,3	GPST_1	4	0.45%
18	ORIG.17	minedGroup1	11,12	GUST_1	4	0.45%
19	ORIG.18	minedGroup0	2,3	GPST_1	4	0.45%
Sum	-				897	100%

a single business process without any out-of-the-process activities.

Capacity analysis algorithm enables simulation business processes while taking into account the corresponding working environment. That leads to the observation of workloads within the current organizational structure. Also the total execution time of all instances can be observed. Should the simulation model be based on reliable process behavior – as well as accurate organizational structure and other set of parameters (see Table 5) – then the simulation results reflect business scenarios that occurred in the past. So, results of capacity analysis can be taken into account while assessing the reality of "as-is" business process simulation model.

4.3.2 Algorithm parametrization

Tuning-in the capacity analysis algorithm to meet research goals requires providing additional statistic from databases as well as some information from process participants (see Table 6). First parameter, *Number of instances within the chosen time period*, can be fed directly from heuristic diagram of business process, as it is assigned to initiating activity during mining process (see Figure 4). Special consideration should be given to *Availability of staff*, as assessing the value of the parameter proven a challenging task for management being interviewed. Consensus was met at 20% level. Regarding the *Number of simulation*, increasing the value of parameter improves the accuracy of the results while increasing the simulating device's CPU load. Value of 1000 allowed running simulations without significant delays.

Participant-related information for simulation model are summarized in Tables 7 and 8. Please note that some activities in Table 7 – *ACT_2, ACT_8*, *ACT_12* – have no human resources assigned. This is due to incorrect WfMS deployment in the investigated company; the aforementioned activities represent periods of time when instances were awaiting next process participant (scheduled to perform succeeding activities in the process instance). Nowa-

Table 5: Data inputs for various simulation algorithms

Algorithm / Inputs	Time and costs	Analytical evaluation	Path analysis	Capacity analysis	Workload analysis: Steady state	Workload analysis: Fixed time period	Technique suggested for collecting data
Business process model	X	X	X	X	X	X	Process mining (Control Flow Perspective)
Working environment model	–	–	–	X	X	X	Process mining (Organizational Perspective)
Activity execution time	X	X	X	X	X	X	Process mining (Case-Related Information Perspective) or basic statistic
Number of instances within the chosen time period	–	–	–	X	–	–	Process mining or basic statistic
Probabilities of initiating individual outflows of decision points	X	X	X	X	X	X	Process mining (Case-Related Information Perspective)
Cost indicators (per activity)	X (opt)	X (opt)	X (opt)	X (opt)	X (opt)	X (opt)	Interview / Observation
Cost indicators (per performer)	–	–	–	X (opt)	X (opt)	X (opt)	Interview / Observation
Number of hours per working day	X	X	X	X	–	–	Interview / Observation
Number of working days per year	X	X	X	X	–	–	Interview / Observation
Process instance initiation calendars	–	–	–	–	X	X	Interview / Observation
Performers' calendars	–	–	–	–	X	X	Interview / Observation
Availability of staff	–	–	–	X	–	–	Interview / Observation
Number of simulations	X	–	X	X	X	X	Scientist decision

Table 6: Additional parametrization

Parameter	Value
Number of instances within the chosen time period	71/year
Number of hours per working day	8
Number of working days per year	260
Availability of staff	20% (for every employee)
Number of simulations	1000

days, WfMS do not allow for designing waiting periods as separate activities – the system should monitor and store time between activities as transition attributes to estimate bottlenecks in the process instead. *Total number of employees in the group* comes from general knowledge of the process and determines the maximum number of resources of a given organizational unit (which theoretically can be involved in the implementation of business process execution). *Number of people involved in the process* is determined based on organizational perspective, while *Avg. execution time* may be established in process mining research as well as ProM basic statistics.

Table 8 provides more detailed information from WfMS database that refer to the historical performance of the business process execution. Data include number of times each participant took part in the execution of a process step (see organizational perspective). Both summarized metrics and summaries excluding activities with no resources assigned are provided. Some differences between values provided in Tables 4 and 8 can be observed.

While both refer to the same phenomena – number of tasks performed by employees – task assignment in Table 4 captures how many times employees recorded beginning/ending individual tasks by clicking start/stop buttons in the WfMS. Data in Table 8 reflects how many times employees actually participated in activities. Some activities involved one-click records (*ACT_1*, *ACT_7*, *ACT_10*) because this activities relate to the initiating/concluding the whole process instance. Remaining activities involved two-click records – at the beginning and at the end of the single activity. Process simulation algorithm accepts only the actual participations in the process.

Aside from personnel, in many cases company IT is also engaged in performing certain activities. In telecommunication company, it was WfMS (codename *ORIG.4*) that performed *ACT_7* as many as 53 times – the latter being a codename for closing the process instance (see Table 8). Cause for that was violating some business rules by employees from GPST_1 team – after completing the process, the person who initiated instance should verify whether ordered work was done correctly. After verification, the same person should close the processes instance. Since instances were rarely close manually, WfMS automatically concluded them after two weeks.

4.3.3 Construction of simulation model

After collecting information regarding *Order Advice* business process, target simulation model is to be built. The control flow perspective provided a business process model which was adopted for ADONIS. Additional data – from organizational perspective/ProM basic statistics/personnel knowledge – enabled constructing fully parameterized simulation model and tuning it in to perform capacity analysis. Figure 5 illustrates heuristic net that was redrawn to ADONIS process model.

Activities *ACT_2*, *ACT_8*, *ACT_12* representing waiting times for undertaking next activity in the process are modeled as notes indicating the place of their placement. The aforementioned activities are correctly implemented as additional time parameters for adjacent activities. So, the execution time of *ACT_2* is entered as resting time for *ACT_1*, while *ACT_8 ACT_12* are represented respectively as waiting and resting time for *ACT_11*. Teams involved in the business process are modeled as pools. In accordance with Tables 4 and 8, each process activity was assigned dedicated resources as non-notational properties, which simulation algorithm can use for simulating process activities executions.

5 Business Process Simulation to Achieve “as-is” State

After preparing a business process simulation model, the simulation was performed with capacity analysis algorithm. Simulation has been initiated as 71 process instances in accordance with explored data. Output generated by the simulation tool for aforementioned number of instances included total execution time of *01:071:21:30:18*. Thus, business process simulation results may be interpreted as follows: executing the process 71 times requires a total of 1 year, 71 days, 21 hours, 30 minutes and 18 seconds.

The result is an approximation of the historical executions of this process. To verify simulation results, actual initiation time of the first instance – that took place at 10:39, 20XX-02-12 – was explored from WfMS database. The end of the last instance has been recorded next year - on 3:15, 20XY-02-12. Based on real-life data from WfMS database it can be concluded that the actual delivery time for 71 process instances was 365 days. So, the difference between the simulation result and information from WfMS database is approximately 70 days.

Table 9 outlines ADONIS simulation results that relate to the employees’ involvement in the execution of each activity. The comparative analysis of simulation results (Table 9) against actual historical data (Table 8) allows to address the question whether simulation results of the business process coincide with the results that have been developed historically in the real-life implementation of the process.

Table 7: Values of process activities' attributes

Activity	Identifier	Responsible organizational group	Total number of people in the group	Number of people involved in process	Avg. execution time dd:hh:mm:ss
Proj. preparation (radio)	ACT_1	GPST_1	7	3	00:00:02:36
Project assign. (radio)	ACT_2	-	-	-	10:03:38:49
Proj. execution (radio)	ACT_3	GPST_1	7	6	00:00:09:19
Proj. preparation (trans.)	ACT_4	GPST_2	6	4	03:09:25:37
Proj. execution (system)	ACT_5	GUST_3	9	2	00:00:23:25
Proj.end (system)	ACT_6	GUST_3	9	2	09:12:06:19
Proj. closed (wfm)	ACT_7	WfMS	1	1	00:00:00:00
Proj. assign. (trans.)	ACT_8	-	-	-	02:00:14:00
Proj.end (trans.)	ACT_9	GPST_2	6	3	13:07:22:22
Proj. closed (radio)	ACT_10	GPST_1	7	2	00:00:00:00
Proj. execution (trans.)	ACT_11	GUST_1	6	4	00:00:26:22
Proj. assign. (trans.)	ACT_12	-	-	-	104:03:03:5
Proj. execution (object)	ACT_13	GUST_2	13	1	00:00:00:48
Proj.end (object)	ACT_14	GUST_2	13	1	14:17:09:10

Table 8: Number of activities performed by process participants as process-mined from organizational perspective

Employ-ees	Availability of staff (%)	ACT_1	ACT_2	ACT_8	ACT_12	ACT_5	ACT_6	ACT_3	ACT_4	ACT_11	ACT_13	ACT_9	ACT_14	ACT_10	ACT_7	**Sum_1**	Sum_1 without ACT: 2, 8, 12
ORIG.0	20	68	68											17		**153**	85
ORIG.1	20	2	18					14						1		**35**	17
ORIG.7	20	1	17					16								**34**	17
ORIG.5	20		10					10								**20**	10
ORIG.8	20		5					5								**10**	5
ORIG.18	20		1					1								**2**	1
ORIG.16	20		1					1								**2**	1
ORIG.2	20			3					39			36				**78**	75
ORIG.3	20			3					20			17				**40**	37
ORIG.9	20			4					15			12				**31**	27
ORIG.14	20			2					2							**4**	2
ORIG.10	20				1					1						**2**	1
ORIG.12	20				1					1						**2**	1
ORIG.15	20				1					1						**2**	1
ORIG.17	20				1					1						**2**	1
ORIG.11	20										3		3			**6**	6
ORIG.6	20					3	3									**6**	6
ORIG.13	20					1	1									**2**	2
ORIG.4	20														53	**53**	53
Sum_2	**-**	**71**	**120**	**12**	**4**	**4**	**4**	**47**	**76**	**4**	**3**	**65**	**3**	**18**	**53**	**484**	**348**

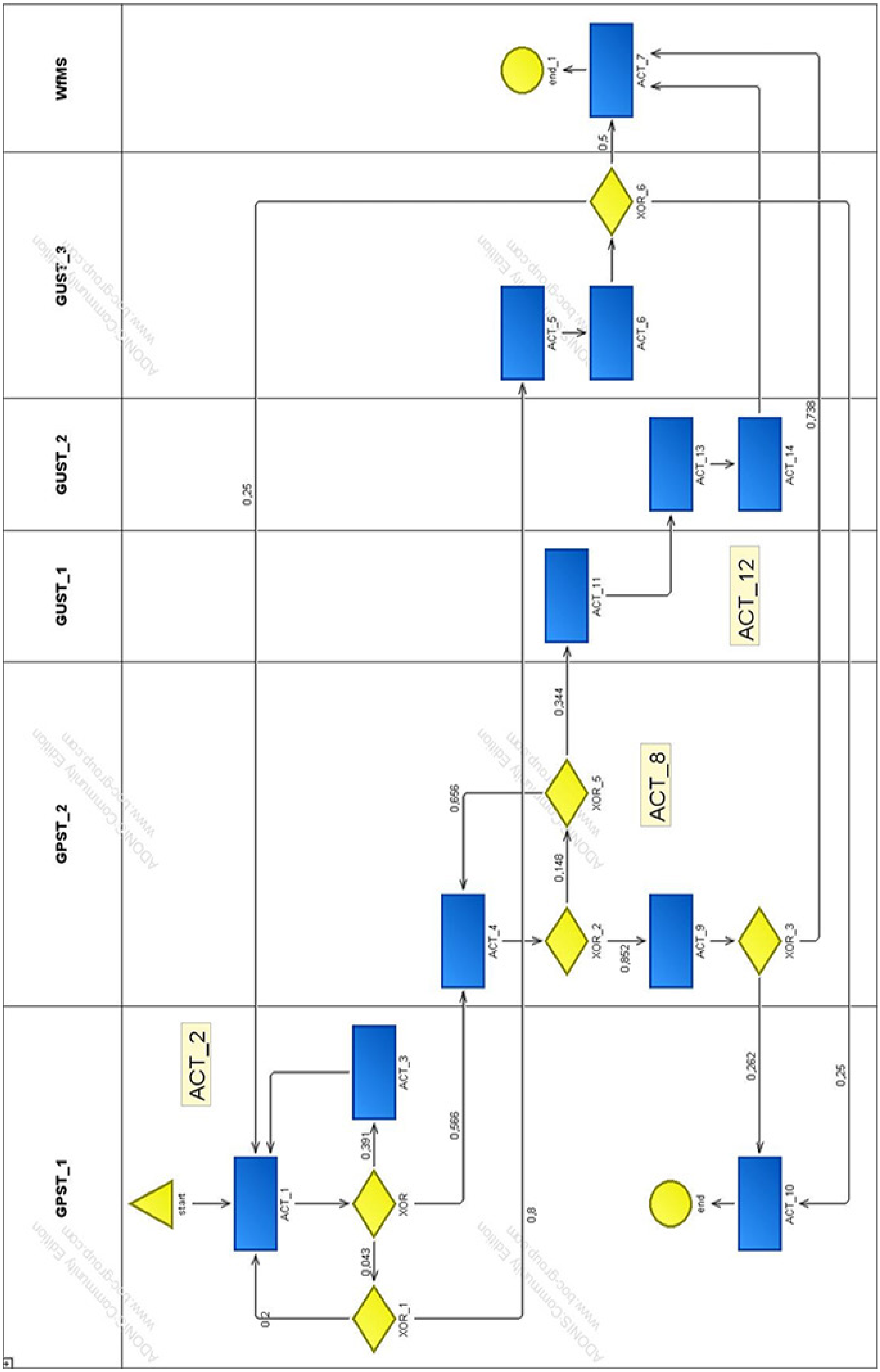

Figure 5. ADONIS model of Order Advice business process

Table 9: Process simulation results – quantitative participation of employees in the execution of individual activities

Employees	ACT_1	ACT_5	ACT_6	ACT_3	ACT_4	ACT_11	ACT_13	ACT_9	ACT_14	ACT_10	ACT_7	**Sum_3**	Total working time	Capacity
ORIG.0	43									9		**52**	00:000:01:51:48	0.004479
ORIG.1	32			11						7		**50**	00:000:03:05:41	0.007439
ORIG.7	44			8								**52**	00:000:03:08:56	0.007569
ORIG.5				10								**10**	00:000:01:33:10	0.003733
ORIG.8				7								**7**	00:000:01:05:13	0.002613
ORIG.18				8								**8**	00:000:01:14:32	0.002986
ORIG.16				3								**3**	00:000:00:27:57	0.00112
ORIG.2					21			21				**42**	01:120:00:47:39	7.309601
ORIG.3					18			22				**40**	01:121:03:53:10	7.336265
ORIG.9					16			22				**38**	01:113:01:01:56	7.175558
ORIG.14					20							**20**	00:083:04:32:20	1.607065
ORIG.12						1						**1**	00:000:00:26:22	0.001056
ORIG.17						2						**2**	00:000:00:52:44	0.002113
ORIG.11							3		3			**6**	00:048:03:29:54	0.931486
ORIG.6		2	3									**5**	00:031:05:05:47	0.608405
ORIG.13		2	1									**3**	00:010:04:53:09	0.204052
ORIG.4											55	**55**	00:000:00:00:00	0
Sum_4	**119**	**4**	**4**	**47**	**75**	**3**	**3**	**65**	**3**	**16**	**55**	**394**		

The first result of the computer simulation to be considered is the sum of the events that have "passed" through the entire model of the process and have reached the end of the diagram, i.e. steps *ACT_ 7* and *ACT_10* as depicted at Figure 5. Historically (Table 8), combined value of *Sum_2* for these activities is 71 (two highlighted cells containing values of 18 and 53 respectively) and coincides with the number of events recorded by the simulation algorithm (Table 9, two highlighted cells for *Sum_4* with values 16 and 55 respectively). The next outputs to be analyzed are total values in rows *Sum_2* (Table 8) and *Sum_4* (Table 9). Both reflect the number of times that a given activity was carried out by individual employees. For activities with identifiers 3-7, 9-10 and 13-14 assigned, values in both tables are very similar.

However, process mining issues require individual interpretation of results for *ACT_2*, *ACT_8*, *ACT_11* as well as *ACT_12*. It can be seen in Table 9 that the algorithm has registered 119 occurrences of *ACT_1*. ADONIS allows to implement the definition of the duration of the *ACT_2* as waiting time parameter for *ACT_1*. So, the result of 119 occurrences of *ACT_1* coincides with the actual number of *ACT_2* occurrences as shown in Table 8 (120). In case of *ACT_8* that had its execution time modeled as waiting time for *ACT_11*, one should not that *ACT_8* is in fact a "straight through" stage and the historically achieved values were distributed by the simulator among *ACT_4* and *ACT_11*. Number of *ACT_12* events was recorded by the simulator in the *ACT_11* cell.

Comparing values of *Sum_3* (Table 9) with *Sum_1* and *Sum_1 without ACT: 2, 8, 12* (Table 8) it is worth to notice that the couple of employees (*ORIG.10* and *ORIG.15*) were not occupied during the process simulation. This phenomenon – as well as related summary values – ought to be interpreted in relation to the distribution of work performed by the simulation algorithm that allocates incoming tasks randomly to resources being assigned to individual tasks. Assignment during simulation takes into account the *Availability of staff* (see Table 8). Most likely the value of 20% (as estimated by management staff across all process participants) does not accurately reflect the actual mechanism of division of labor. However, the degree of simulation results' conformity with historical data justifies analyzing workloads of individual employees of the telecommunications company.

The remaining two columns of Table 9 include simulation results regarding total working times of individual employees at various stages of the process as well as utilization ratios of employees. The latter was estimated based on three components: the number of working days per year declared (260 days), hours per working day (8 hours) and the percentage of availability (20%). If the value of this parameter is close to 1, then the employee is assigned optimal amount of tasks (see BOC Group, 2013). Analyzing the values calculated for individual employees, it can be stated that all employees from *GPST_1* team (Tables 4 and 9) are heavily over-loaded because the relevant *Capacity* values exceed 7. This is due to performing numerous *ACT_4* and *ACT_9* tasks, which translates into long workflows. In contrast, all *GPST_1* and *GUST_1* engineers are strongly under-loaded, because in their cases the values of *Capacity* are very low.

6 Discussion and limitations

In the paper, authors focused on combining approaches, leading to constructing business process model that reflects the actual behavior in the company. The research is based on the telecommunications company that continuously expands mobile networks and extends mobile services on one of the major European markets. While methods introduced proved to be applicable in real-life cases, a number of limitations were identified.

First of all, reliance of process mining on the precision of actual data may be considered a natural limitation. In the organization under investigation, logging infrastructures were faulty. Generally, if the business process management goes wrong (e.g. because of inadequate managers' involvement or lack of analysts' knowledge regarding BPM) business process activities can be executed outside the system. If the WfMS does not support process definitions and is out of optimizations, the employees initiate additional paths of communications, e.g. mails, phone calls, meetings, shared files. Activities which were not registered by WfMS cannot be taken into account for process mining analysis. This results in loss of vital information regarding processes and a decrease in the quality of analysis results (Weerdt et al., 2013). An "as-is" business process model elaborated with process mining algorithms reflects the behavior from the "system point of view", which in such case would differ from the actual process instances.

Secondly, process mining techniques still struggle with process implementation in a workflow system. Conducting research, authors came across faulty implementation of activities – a result of analysts modeling waiting times as independent tasks. Additionally, management staff did not put pressure on updating process definitions in WfMS, thus business and system process models differ.

It caused a number of issues while interpreting simulation results and necessitated additional meetings to resolve confusions. While process mining can provide novel and powerful ways to analyze business processes, academic research should focus even more on how process mining techniques can be improved (Weijters and Ribeiro, 2011) to discover information about processes and provide a view of how the processes are being executed.

Thanks to process mining algorithms providing information about staff involvement in the *Order Advice* business process, a fully equipped simulation model may be confronted with the historical execution of business activity. The overall results enable the simulation model to be taken into account as a reference model while planning modifications in the process. Having said that, a number of limitations regarding building the simulation process model as well as performing the simulation scenario should be pointed out:

1. Instance generator did not take seasonal fluctuations into account. In real-life, the number of initiated instances increased/decreased seasonally in a specific place and time – e.g. in the summertime mobile network capacity should be extended in the seaside locations.
2. Data presented in Table 6 may slightly differ from the actual data – e.g. the availability of staff might be tuned-in should all the processes and their participants be analyzed.
3. Number of process instances available for analysis was restricted.
4. Activity execution time is an average value estimated by ProM; the value at hand reflects timestamps recorded by WfMS while clicking start/stop buttons that may differ slightly from actual processing time.
5. Human resources were modeled in a simplified manner (Van der Aalst, 2010). In reality, different people can do the same work – but in a different style. Route-cause analysis of differentiation may be conducted: people do not work at a constant speed and they tend to divide work into multiple parts. Moreover, employees are usually involved in simultaneous business processes, so they accumulate tasks from different processes and perform them at the same time. In effect, it makes it challenging to precisely assign human resources to the activities in simulation models. This problem still requires ongoing research, still it is noteworthy that over 40 resource patterns were identified to describe the functionality of resource allocation mechanisms (Russell et al., 2005) and few of these patterns are supported by business process simulation tools presently available.

The capacity analysis algorithm estimate "as-is" state of business process execution. By applying numerous additional simulations algorithms (e.g. workflow analysis) and adjusting the parameters of the model, a set of implementable process variants can be developed. It is also possible to estimate workloads and identify bottlenecks and deadlocks. The aforementioned actions lead to the development of new business process definitions that – after being implemented within the structure of the company – shall improve its operation. As a result, the optimized model makes a strong basis for the workflow system. Adapting this redesigned process definition to the workflow engine leads to the organization being run in accordance with an elaborated and validated computer model.

7 Conclusions

Business organizations' competiveness is determined to a large extent by monitoring processes and carrying out simulations/optimization in a rapidly changing business environment. Process management is based on decisions about the need to change and proposals for improving processes which – prior to implementation in business practice – should be simulated within dedicated environments. Performing various business scenarios requires simulation model that is digitalized and powered with data which reflecting not the analyst's intuition but a real-life operation of the company.

BPS_2 (see Figure 1) is not a popular approach for process reengineering and improvement yet. Traditional business process reengineering (Hammer and Champy, 1993) focuses mostly on clarification as well as rationalizing processes/resources rather than producing implementable and computational models. While some organizations implement *BPS_1* approach for new processes, such organizations tend not to push forward the Deming cycle; and so the analytical stage (*Check*) is reduced to basic process investigations rather than deep process analysis. Difficulties with collecting data for *BPS_2* constitute one of the possible reasons for this. Data extraction requires adopting both process mining techniques and human source-related information sources.

Research conducted lived to see the feedback from the management of telecommunication company. Mainly, process mining results were discussed: discovered process paths as well as human resource allocation to the individual activities. Time parameters of activities raised attention as well. During post-research meetings considerable amount of out-of-the-paper-scope results were verified. For instance, evidence was provided that WfMS allows for some undesirable behavior like ignoring tasks or violating business rules. Flow of work between process participants was discussed in detail as well. Generally, research had encouraged managers to take a closer look while designing and improving processes, as well as to improve their decision-making while mapping processes into WfMS.

Simulation-oriented part of research was verified with staff as well. While multi-step process of achieving simulation-ready models proved to be a challenge for management staff, capacity analysis output generated an interest in simulation algorithms. Various business scenario simulations with other ADONIS algorithms are under consideration.

Ongoing research is advancing in multiple directions. First of all, additional case studies in various industrial domains are carried out. Process mining analysis is the prime subject, focused on discovering information regarding processes and powering simulation models. Other mining tools (e.g. DISCO) are used and evaluated. Secondly, other simulation algorithms/tools to evaluate simulation models and compare simulation results with historical data are evaluated.

Especially, authors attempt to elaborate new factors that help to assess the quality of the simulation model. Additionally, research aimed at refining the process generation mechanism to better (closer to reality) reflect process instances in a simulation model is carried out. Finally, running process simulation not only to assess the simulation model but to predict future behavior in the company as well is a research direction under investigation. The latter concerns primarily workloads and possibilities of executing some processes in a limited period of time.

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Bartlomiej Gawin - R&D Manager at SESCOM S.A., researcher at the Department of Business Informatics, University of Gdansk. Deals with issues of modern techniques / tools for designing, simulating and analyzing business processes as well as related IT solutions. Author of scientific papers and books. Actively participated in projects regarding development, implementation and usage of business applications and analytical techniques. Gained professional experience in the following sectors: telecommunications, IT and facility management.

Bartosz Marcinkowski - researcher at the Department of Business Informatics, University of Gdansk and a certified Cisco / Object Management Group instructor. Has extensive experience concerning business process modeling & improvement through simulation as well as information systems analysis & design. Author and co-author of leading books covering aforementioned areas on Polish market as well as over sixty other publications. Contributed in 11 European projects related to IT development and training. Member of Association for Information Systems, Polish Chapter.

Kako blizu realnosti je „kot-je" simulacijski model poslovnega procesa?

Ozadje in namen: Simulaciski model poslovnih procesov (Business Process Simulation - BPS) temelji na virih resničnih podatkov, kot so podatkovne zbirke, opazovanja in intervjuji. Deluje kot dejabski („kot-je") poslovni scenarij in se lahko uporablja za reinženiring. Glavni izziv pri tem je zbrati ustrezne podatke in razviti simulacijski model. Namen raziskave je razviti BPS je model in sistematično oceniti, kako blizu realnosti je**.**
Metodologija / pristop: Raziskava je bila izvedena v okviru poljskega telekomunikacijskega podjetja. Avtorji raziskujejo tehnični proces širitve mobilnega omrežja. Po izdelavi „kot-je" modela so avtorji uporabili simulacijsko orodje Adonis da so izvedli serijo simulacij in primerjali rezultate simulacije z dejanskimi zgodovinskimi poteki. Nato so ocenili ali simulacijski model dovolj dobro preslika realnost in - posledično – je uporaben kot verodostojna osnova za izboljšanje procesa.
Rezultati: Simulacijski model je bil izdelan s podatki iz podatkovne zbirke WfMS, opazovanj zaposlenih in avtorjevih znanj in izkušenj. V celoti razvit simulacijski model omogoča rekonstrukcijo zgodovinskega poteka poslovne dejavnosti z nizko stopnjo napake. Ugotovljene in komentirane so nekatere omejitve.
Zaključek: BPS še ni eden od priljubljenih pristopov za proces za prenovo in izboljšanje poslovnih procesov. med Med razlogi za to je dejstvo, da zbiranje podatkov za izvedbo BPS zahteva, da uporabimo tehnike rudarjenja podatkov in dodatne vire informacij. V naši raziskavi so se računalniški simulacijski rezultati pokazali skladni z zgodovinskimi dogodki. Zato model odraža poslovno realnost in se lahko uporabi kot referenčni model pri prenovi procesa.

Ključne besede: *poslovni proces, simulacija, zajemanje podatkov, sistemi delovnih tokov*

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Web Application for Hierarchical Organizational Structure Optimization – Human Resource Management Case Study

Davorin Kofjač, Blaž Bavec, Andrej Škraba

University of Maribor, Faculty of Organizational Sciences, Kidričeva cesta 55a, 4000 Kranj, Slovenia
davorin.kofjac@fov.uni-mb.si, andrej.skraba@fov.uni-mb.si, blazbavec@gmail.com

Background and Purpose: In a complex strictly hierarchical organizational structure, undesired oscillations may occur, which have not yet been adequately addressed. Therefore, parameter values, which define fluctuations and transitions from one state to another, need to be optimized to prevent oscillations and to keep parameter values between lower and upper bounds. The objective was to develop a simulation model of hierarchical organizational structure as a web application to help in solving the aforementioned problem.
Design/Methodology/Approach: The hierarchical structure was modeled according to the principles of System Dynamics. The problem of the undesired oscillatory behavior was addressed with deterministic finite automata, while the flow parameter values were optimized with genetic algorithms. These principles were implemented as a web application with JavaScript/ECMAScript.
Results: Genetic algorithms were tested against well-known instances of problems for which the optimal analytical values were found. Deterministic finite automata was verified and validated via a three-state hierarchical organizational model, successfully preventing the oscillatory behavior of the structure.
Conclusion: The results indicate that the hierarchical organizational model, genetic algorithms and deterministic finite automata have been successfully implemented with JavaScript as a web application that can be used on mobile devices. The objective of the paper was to optimize the flow parameter values in the hierarchical organizational model with genetic algorithms and finite automata. The web application was successfully used on a three-state hierarchical organizational structure, where the optimal flow parameter values were determined and undesired oscillatory behavior was prevented. Therefore, we have provided a decision support system for determination of quality restructuring strategies.

Keywords: *hierarchical organizational structure, genetic algorithms, deterministic finite automata, system dynamics, optimization, human resources*

1 Introduction

Human resource management in larger organizations presents a complex problem that cannot be addressed properly without using the quantitative methods. One example of a complex human resources management problem is a hierarchical human resource problem, which can be found in the army. It is supposed that a person can be promoted from a lower to a higher rank, without skipping ranks and never in an opposite way. Therefore, such a problem represents a kind of "supply chain" in which a change in a particular element of the chain affects all subsequent elements.

The key issue that need to be addressed in the aforementioned problem are: a) the time variability of parameter limits, b) oscillations in the acquired strategies, and c) an understanding of the hierarchical model of human resources. The described problem has been addressed in the context of several studies (Mehlman, 1987; Grinold and Marshall, 1977, Vajda, 1978; Bartholomew et al., 1991; De Feyter, 2007; Huang et al., 2009), but the variable lim-

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its and the undesired oscillations (Škraba et al., 2011) have not yet been adequately addressed.

The main objective of the research presented in this paper is to develop a web application that will enable the determination of strategies on a hierarchical model of human resources. When developing the application, we have used using genetic algorithms, finite automata, and modeling according to the principle of system dynamics. The application can be used to define strategies, which consider variable parameters' limits and undesired oscillations in the acquired strategies. The system was implemented as a web application with the JavaScript/ECMAScript programming language, and can be accessible worldwide. The system also addresses visualization, via which the optimization process should be displayed, as well as the results. The solution also aims to adequately explain complex concepts for educational purposes, the transparency of results, and is easy to use.

2 Hierarchical organizational structure model

In order to develop a web application for optimization of the hierarchical organizational structure, a model of the structure needed to be developed first. The model was developed using the principles of system dynamics (Forrester, 1973). System dynamics (SD) is used to understand the behavior of complex systems, usually over time.

In a hierarchical organizational structure, it is assumed that the transitions between different ranks (classes) are possible only from a lower to a higher rank without skipping ranks. We also assume that the degradation is not possible, however, an individual may leave the system (fluctuation). Ranks, i.e. classes, are represented with stocks, while the transitions and fluctuations are modeled with rates. The causal loop diagram of the model is presented in Fig. 1, while the corresponding system dynamics model, modeled with Powersim, is presented in Fig. 2.

Each state ($X1$, $X2$, $X3$) represents the number of people in a particular rank. Each state has an inflow and an outflow. Inflow A to the state $X1$ represents the initial recruitment, while the inflows $R1$ and $R2$ to states $X2$ and $X3$ represent the transitions from the previous states (ranks) that at the same time represent the outflow from those states. Flow A is represented in a tabular way, i.e. at each time step a different recruitment value is required. Flows $R1$, $R2$, and $R3$ are determined by the values of $X1$, $X2$, and $X3$ and coefficients from *R1_table*, *R2_table*, and *R3_table*, respectively. The coefficients in *R1_table*, *R2_table,* and *R3_table* are represented in a tabular way, i.e. at each time step a different transition coefficient value is required. Each state also has the fluctuation outflow ($F1$, $F2$, $F3$), where people depart the rank for different reasons (new job, retirement, etc.).

Flows $F1$, $F2$, and $F3$ are determined by the values of $X1$, $X2$, and $X3$ and coefficients *F1_table*, *F2_table*, and *F3_table*, respectively. Similarly to the *Rx_table* coefficients, the *Fx_table* coefficients are represented in a tabular way, i.e. at each time step a different fluctuation coefficient value is determined. The coefficients in A, *Rx_table* and *Fx_table* are originally obtained from historic statistical data in order to model and analyze the current situation. However, during the optimization process, as explained later in the text, these coefficients are determined with genetic algorithms to ensure an optimal system response.

The *CSE* (Cumulative Square Error), and the connected elements, measure the integral of root mean squared error of deviation (distance) of the system's state ($X1$, $X2$, $X3$) from the desired state defined by *Z1_table*, *Z2_table*, and *Z3_table*, respectively, in which the desired values of $X1$, $X2$, and $X3$ at each time step are stored in a table. An example of tabular values for the elements *R1_table*, *F1_table*, and *Z1_table* is presented in Table 1.

There are six balancing loops in the model, which can be observed in Fig. 1. The loops interconnect the following elements: $F1$ and $X1$, $F2$ and $X2$, $F3$ and $X3$, $R1$ and $X1$, $R2$ and $X2$, and $R3$ and $X3$. The balancing loops are crucial for the system's behavior, and their role is to guide the system's state towards its desired state.

The following is the mathematical model of the hierarchical model in discrete time. For example, state vari-

Table 1: An example of tabular values for the elements R1_table, F1_table and Z1_table

R1_table		F1_table		Z1_table	
Time step	Value	Time step	Value	Time step	Value
1	0.16	1	0.1	1	85
2	0.14	2	0.01	2	80
3	0.08	3	0.01	3	75
4	0.07	4	0.02	4	75
5	0.07	5	0.03	5	75
6	0.07	6	0.03	6	75

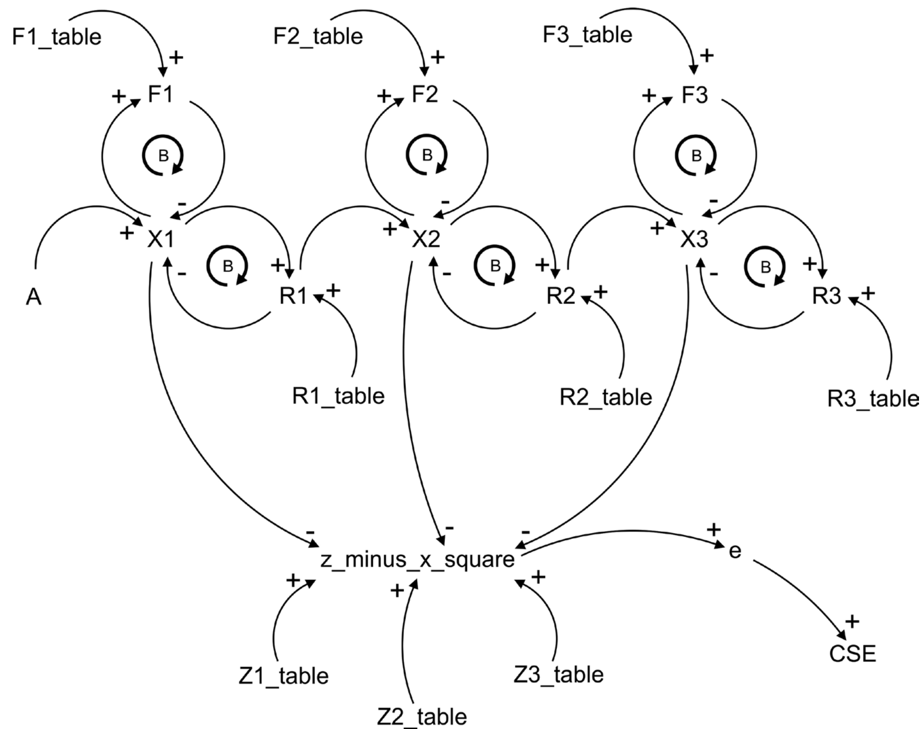

Figure 1: Causal loop diagram of a hierarchical model with three states

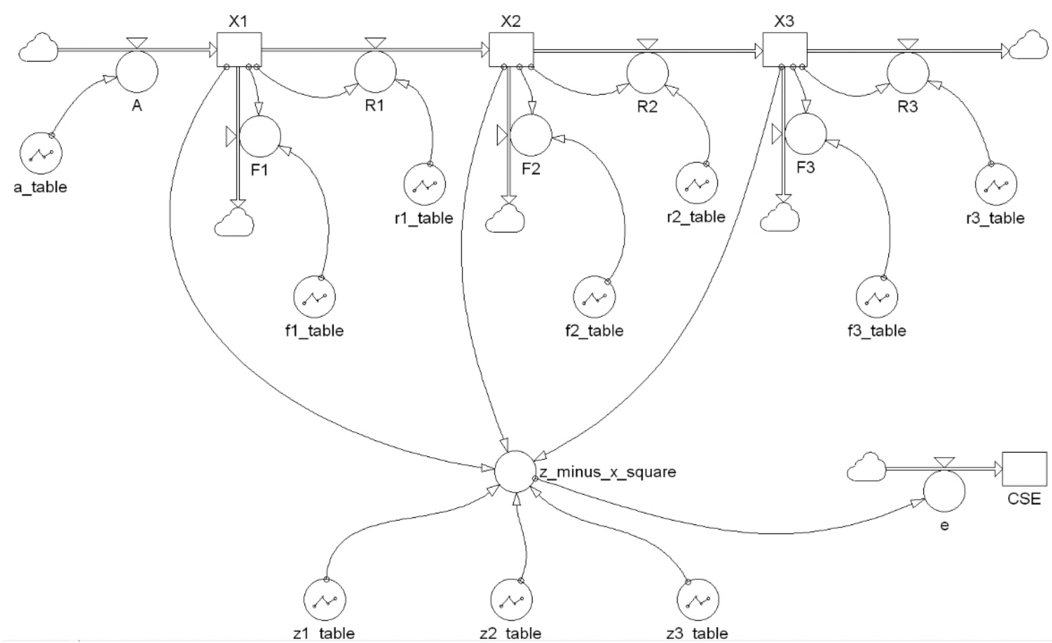

Figure 2: Hierarchical model with three states modeled by the principles of system dynamics

able $X1(k)$ represents the number of persons in the first rank at the current time k. In order to compute the value of the state variable in the next time step ($k + 1$), one must take into account the present state value $X1(k)$ to which the present inflows are added and from which the present outflows subtracted. In our case, the $A(k)$, as the present recruitment inflow variable, is added, while the present transition and fluctuation outflow variables, $R1(k)$ and $F1(k)$, are subtracted. The values of the state variables $X2$ and $X3$ are obtained similarly.

With the defined model, we can now formulate the problem that we address in this paper: to determine how to define recruitment, transitions between ranks and fluctuations to reach a new, i.e. the desire, organizational structure.

$$X1(k+1) = X1(k) + (A(k) - R1(k) - F1(k))\Delta t$$
$$X2(k+1) = X2(k) + (R1(k) - R2(k) - F2(k))\Delta t$$
$$X3(k+1) = X3(k) + (R2(k) - R3(k) - F3(k))\Delta t$$
$$CSE(k+1) = CSE(k) + e(k)\Delta t$$
$$X1(0) = X1\_init\_value$$
$$X2(0) = X2\_init\_value$$
$$X3(0) = X3\_init\_value$$
$$CSE(0) = 0$$
$$F1(k) = F1\_table(k) \cdot X1(k)$$
$$F2(k) = F2\_table(k) \cdot X2(k)$$
$$F3(k) = F3\_table(k) \cdot X3(k)$$
$$R1(k) = R1\_table(k) \cdot X1(k)$$
$$R2(k) = R2\_table(k) \cdot X2(k)$$
$$R3(k) = R3\_table(k) \cdot X3(k)$$
$$z\_minus\_x\_square(k) = (Z1\_table(k) - X1(k))^2 + (Z2\_table(k) - X2(k))^2 + (Z3\_table(k) - X3(k))^2$$
$$e(k) = z\_minus\_x\_square(k)$$
$$k = 0,1,2,...$$

3 Optimization methods

The aforementioned problem formulation, in which merely the minimization of the distance to the target function by considering the boundaries, is insufficient and may result in a possible undesired oscillatory solutions (Škraba et al., 2011). To overcome undesired oscillations, the Finite Automata (FA) was utilized. Further, genetic algorithms (GA) were used to define the optimal flow coefficients.

3.1 Finite automata

FA is an abstract machine that considers all the possible system states while taking into account a sequence of input symbols (Hopcroft et al. 2001). The transition between states occurs when a certain condition is fulfilled. The system controls the sequence of state transitions and identifies an illegal state, which may be used to trigger an event. The allowed states are called terminal states.

For our purposes, the deterministic finite automaton (DFA) is considered, which is used to solve complex problems, such as design and development of distributed simulation for evaluation of supply chains (Venkateswaran and Son, 2004), time-optimal coordination of flexible manufacturing systems (Kobetski and Fabian, 2009) and symbolic string analysis for vulnerability detection (Yu et al., 2014). The DFA in our example contains the following components:

- set of possible states $S = \{S_0, S_1, S_2, S_3, S_4, S_5\}$,
- comparison alphabet $CA = \{f, e, g\}$,
- initial state $i = S_0$,
- set of terminal states $T = \{S_0, S_1, S_2, S_3, S_4\}$,
- transition table δ.

An illegal state in our example is the S_5. If the DFA reaches this state during the simulation run, it means that the response of the system is following undesired oscillatory behavior. The undesired oscillatory behavior occurs if the system's response trajectory is going "up-down-up" or "down-up-down". If the DFA stops in any of the terminal states at the end of the simulation run, the response of the

Table 2: The transition table δ for the DFA

State	Comparison alphabet		
	f	e	g
S_0	S_2	S_0	S_1
S_1	S_3	S_1	S_1
S_2	S_2	S_2	S_4
S_3	S_3	S_3	S_5
S_4	S_5	S_4	S_4
S_5	S_5	S_5	S_5

system is following the desired trajectory. An example of the transition table δ used in this research is presented in Table 2, while the DFA graph is shown in Figure 3. A more detailed explanation of the DFA can be found in Škraba et al. (2011).

3.2 Genetic algorithms

To determine the flow parameters (recruitment, transitions, fluctuations) in the model, genetic algorithms (GA) were used. GA belong to the evolutionary algorithms, which are used for solving complex optimization problems, e.g. optimization of manpower in hierarchical systems (Škraba et al., 2015), optimization of the health care system (Steiner et al., 2015), design of a production strategy (Mitsuyuki et al., 2014), or optimization in production scheduling (Kofjač and Kljajić, 2008).

GA are used when optimal solutions are not known, and the user is satisfied with near optimal solutions. GA are based on natural selection where the fittest individuals can survive (Gen and Cheng, 1997). The individuals in GA are represented by a chromosome. A chromosome is composed of genes. The next generation of individuals is selected by a selection strategy from the previous generation, and the selected individuals are subject to crossover and mutation operations. Crossover and mutation operations are used to produce new individuals from the existing ones. Crossover takes two parents and produces a new individual, while the mutation operation produces new individuals by changing genes of one individual. The fitness of an individual is assessed by a criteria function.

Let us present the implementation of GA in our case. The chromosome is encoded with a binary representation. The chromosome is composed of several sub-chromosomes; each sub-chromosome represents a value of a particular flow element. The number of genes in a particular sub-chromosome is dependent on the lower and upper boundaries of the flow element. The larger the interval, the more genes are needed to represent those values with binary encoding. The candidate chromosomes are selected with a roulette wheel selection. Furthermore, elitism is utilized to carry the best *n* chromosomes into the next generation. The mutation utilized in our implementation is bit-flip at random places. The crossover operator used here is a one-point crossover. The fitness function in our case is represented as an integral of the root mean squared error of deviation of the system's state from the desired state.

4 Web application

The web application was implemented using the HTML and JavaScript programming languages, which enables the development of solutions for different platforms. The web application was developed on a Windows 7 platform running a WAMP server. JavaScript is an interpreted programming language with object-oriented capabilities (Flanagan, 2006). Almost every desktop computer, tablet or smartphone has a JavaScript interpreter, thus making this programming language ubiquitous. Also critical is that every Internet browser supports JavaScript, thus enabling the solutions developed in JavaScript to be accessible virtually from anywhere.

The architecture of the proposed web application is presented in Fig. 4. The user interface was implemented with HTML5/CSS. The main web application (data input and results output) is implemented with JavaScript to ensure real-time output of optimization results via tables and graphs. The main application then calls the Optimization module, providing it with input parameters for optimization. On the basis of input parameters, the Optimization module interacts with the GA module, the DFA module, and the SD Model module. The results of optimization are then reported back to the main web application by the Optimization module and displayed on the user interface.

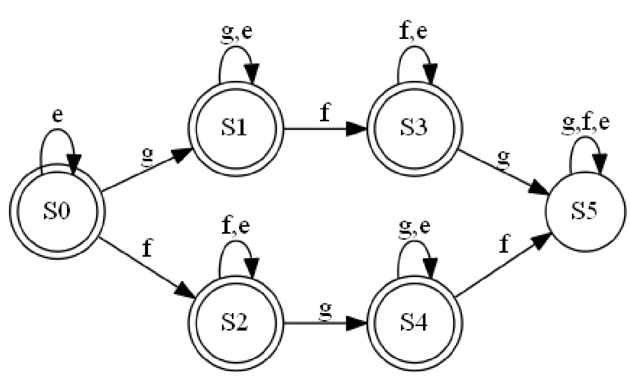

Figure 3: The representation of the DFA as a graph

5 Results

The GA were tested and validated with several well-known problem instances, for which the analytical solutions are known, such as:

- Elliptic paraboloid:

$$z(x,y) = x^2 + y^2 + 10, \text{ where } \max z(0,0) = 10$$

- 3D Wave:

$$z(x,y) = -\left(0.5 + \frac{\sin\left(\sqrt{2x^2+2y^2}\right)^2 - 0.5}{1+0.1\left(x^2+y^2\right)}\right), \text{ where } \max z(0,0) = 0$$

- Rastrigin's function:

$$z(x,y,p,q) = 10 - 20\left(\left(x+p\right)^2 - 10\cos\left(2\pi\left(x+p\right)\right)\right) + \left(\left(y-q\right)^2 - 10\cos\left(2\pi\left(y+q\right)\right)\right),$$

$$\text{where } \max z(-\frac{1}{3}, -\frac{1}{4}, \frac{1}{3}, \frac{1}{4}) = 410$$

To test GA on the aforementioned instances, GA were initialized with the following values:

- Population size: 100,
- Mutation rate: 0.5,
- Crossover rate: 1,
- Maximum number of generations: 500,
- Stopping condition: maximum number of generations.

The GA were able to reach an optimal solution for the elliptic paraboloid and the 3D wave function, and a near-optimal solution for the Rastrigin's function within 0.0001% deviation, due to the resolution of the binary encoding. Therefore, we can conclude that GA were verified and validated successfully.

The web application was tested on the hierarchical model described earlier. The recruitment, inflow and outflow boundaries were set to [5, 8], [0.01, 0.16], [0.01, 0.1], respectively. The initial values for states $X1$, $X2$, and $X3$ were set to 100, 70, and 50, respectively. The desired values for the aforementioned states were set to 75, 95, and 40, respectively. The goal was to determine such recruitment, inflow and outflow rates that the system would reach the desired state values. In order to test the GA on the hierarchical model, the following settings were used:

- Population size: 100,
- Mutation rate: 0.01,
- Crossover rate: 1,
- Maximum number of generations: 500,
- Stopping condition: maximum number of generations.

The optimization results without DFA and with DFA are presented in Fig. 5 and Fig. 6, respectively. Coulours are visible in the internet version of the paper available from http://dx.doi.org/10.1515/orga-2015-0012.

Each graph is presented by two axes. X-axis (blue line) presents the number of simulation steps, while the y-axis (green and/or red line) shows the value of state and/or flow elements. For example, if observing the upper left graph in Fig. 5, number 0 presents the origin, while the numbers 5 and 100 show the maximum value on the x-axis and y-axis, respectively. The curve marked with a red color shows the desired trajectory defined by $Z1$, while the green curve presents the simulated trajectory of the state element $X1$. One can observe, that the trajectory of $X1$ is closely following the desired trajectory $Z1$, meaning that the web application has successfully optimized the $X1$ trajectory.

The upper part of the figures presents the trajectories for state elements $X1$, $X2$, and $X3$ and their corresponding desired trajectories represented by $Z1$, $Z2$, and $Z3$. The middle part shows the trajectories of transition flow elements $R1$, $R2$, and $R3$. The bottom part of both figures

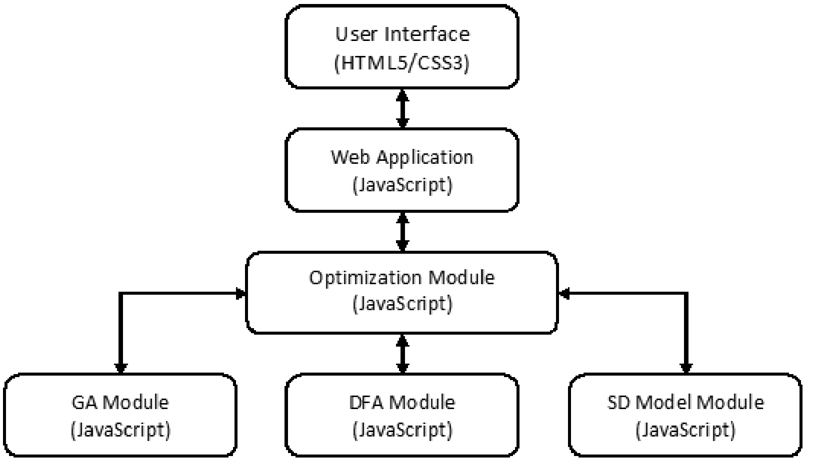

Figure 4: The architecture of the web application

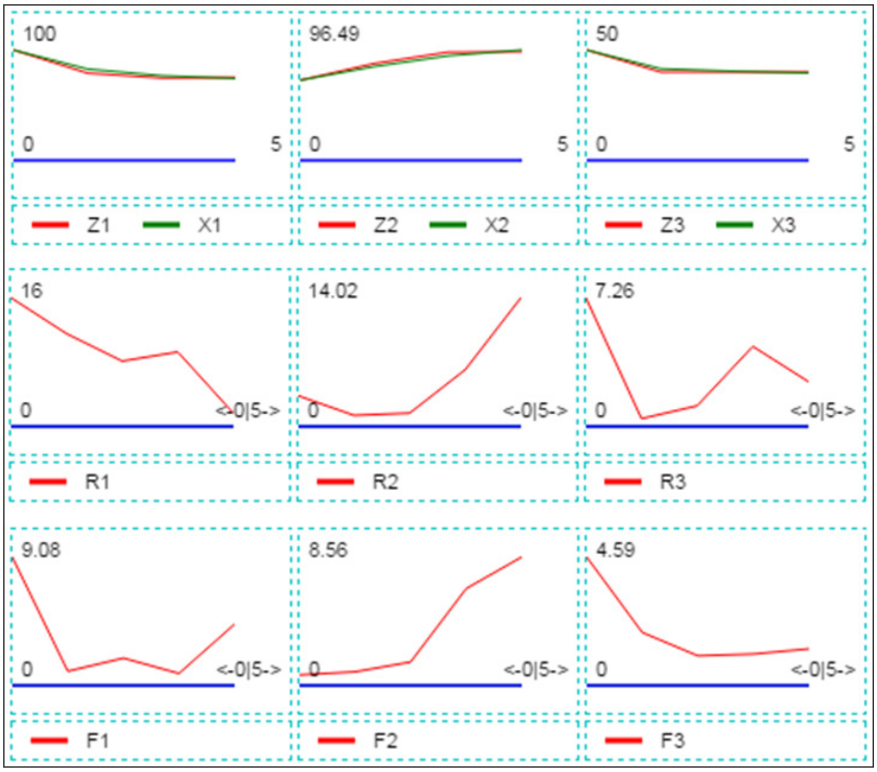

Figure 5: A comparison of trajectories of state and flow elements achieved without DFA

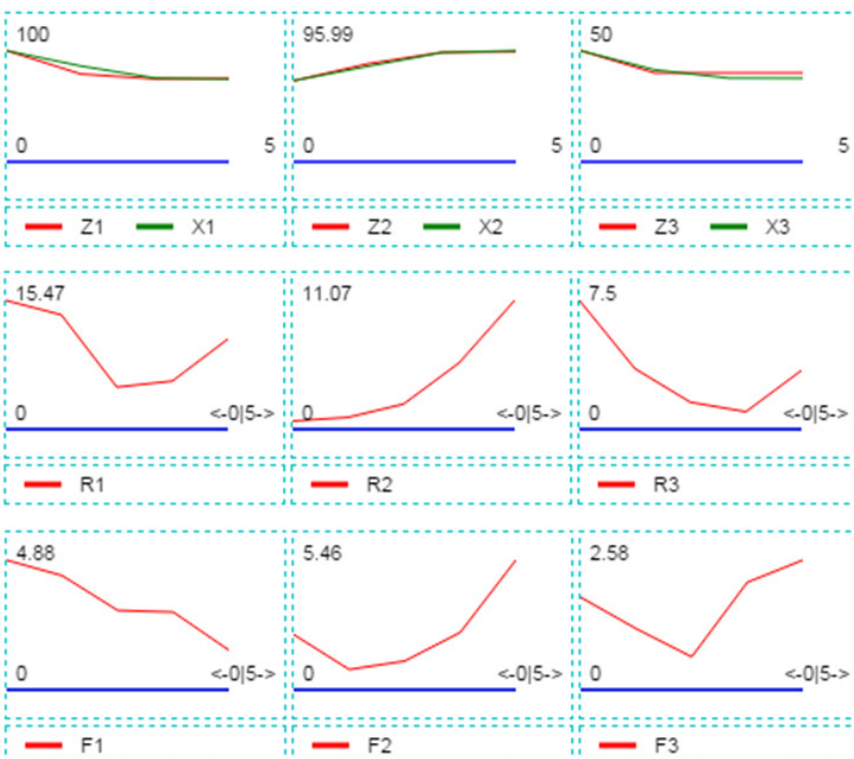

Figure 6: A comparison of trajectories of state and flow elements achieved with DFA

Figure 7: Web-based application displayed on a mobile device. Coulours are visible in the internet version of the paper available from http://dx.doi.org/10.1515/orga-2015-0012

presents the resulting trajectories for the fluctuation flow elements $F1$, $F2$, and $F3$. Both optimizations, with and without DFA, achieve the desired values for the state elements $X1$, $X2$, and $X3$. However, the desired state values are achieved in a different way. When observing the results for the flow elements in Fig. 5, one can observe there are undesired oscillations for the $R1$, $R3$, and $F1$ elements, due to the fact of the DFA not being used. In contrast, the use of DFA results in trajectories of flow elements without undesired oscillations, as shown in Fig. 6.

The example of the application can be observed in Fig. 7, where a system is run on an Android mobile device. The GUI consists of three sections: Simulation control, Output, and Graph/Table display.

Simulation control section of the GUI is used to input the following simulation parameters:

- Max. generations – the maximum number of generations produced by the GA.
- Mutation rate – the share of individuals in a population, which are mutated.
- Mutation type (0 or 1) – the type of mutation used in the mutation process.
- Population size – the number of individuals in a population for GA.
- FA – determines if finite automata is used in optimization.
- Table output – determines if simulation results of parameters for each generation are displayed.
- Sim. table output – determines if simulation results of parameters for each generation and each simulation step are displayed.
- Verbosity – determines if the results are output as text.
- Fitness func. output – determines if a fitness function values per generation are displayed.
- Best strategy – determines if only the simulation results of parameters for the best solution are displayed in the table.

Further, Simulation control section offers four buttons for simulation control:

- Start – starts the simulation run.
- Stop/Resume – pauses and resumes the simulation run.
- Step – performs one simulation step.
- Reset – clears the simulation results and initializes simulation parameters.

In the Output section, the current numerical results are displayed dynamically, including the current GA generation and simulation step. The start time and the elapsed simulation time are also shown. Finally, the main simulation results are shown: current fitness function value and current level variable values for $X1$, $X2$, and $X3$.

The bottom part of GUI presents the simulation results via graphs and tables. The values presented in graphs are time dependent. The first graph presents the change of the best fitness function value over time. The following graph presents the CSE value over time. Following are the graphs where the comparison of state variables (green line) with their desired values (red line) is shown. Next, graphs with rate element values and rate coefficients are presented, respectively. Finally (not shown in Fig. 7), the numerical simulation results are presented in tables.

6 Conclusion

We have successfully implemented the web application for hierarchical organizational structure optimization and tested it on a three-state hierarchical human resources structure. All components of the web application, including the hierarchical organizational structure model, genetic algorithms and finite automata, were implemented with the JavaScript programming language.

First, the JavaScript System Dynamics modeling library was developed, thus enabling simple and efficient implementation of System Dynamics models with any desired number of states and flows. Next, the hierarchical organizational structure model was developed by the principles of System Dynamics. The genetic algorithms were successfully tested on well-known problem instances, where the analytical solution is known, and used to optimize the hierarchical model flow parameters. The finite automata method was used to prevent oscillations that might occur at transitions between structure's states.

With the developed application, the user is able to optimize the flow parameters, i.e. define strategies, where dynamic parameter boundaries are considered as well as oscillations in the acquired strategies. By applying such approach, it is possible to keep the organizational structure stable and robust. Based on the abovementioned, the developed web application represents an approach, which can be used in the restructuring of large hierarchical organizational systems, such as the armed forces.

Because the system is implemented with JavaScript as a web platform, it can be used on mobile and other devices, enabling to control the organizational structure anywhere around the globe. The user is not limited to use the application only on a desktop computer in an office and is able to analyze the organizational structure's current state and quickly respond to possible challenges at any time.

In the future, our goal is to test the application on an organizational structure with more states in order to determine the impact of an increased number of states, and consequently flow parameters, on computational time. Application implemented with JavaScript programming language might prove computationally costly, because JavaScript has been traditionally implemented as an interpreted language. Applications implemented with interpreted languages are typically slower than the ones that need to be compiled. Finally, because the model presented in this paper is highly similar to a supply chain structure, we want to extend its application to similar structures.

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Davorin Kofjač obtained his Ph.D. from the University of Maribor in the field of Information systems management. He is a researcher and an assistant professor at the University of Maribor, Faculty of Organizational Sciences at the Cybernetics and DSS Laboratory. His main research interests include modelling and simulation, decision support systems, operational research and artificial intelligence. He was involved in many EU, NATO, bilateral and national projects and is an author of more than 120 publications in international journals, monographs and conferences. He is a member of ACM, INFORMS and SLOSIM.

Blaž Bavec gained his M.Sc. from the University of Maribor in the field of complex support system management creation. He finished his degree, while he was working on several projects at the Cybernetics and DSS Laboratory at the University of Maribor, Faculty of Organizational Sciences. His main research interests include systems' creation, implementation and management.

Andrej Škraba obtained his Ph.D. in the field of Organizational sciences from the University of Maribor. He works as a researcher and an associate professor at the University of Maribor, Faculty of Organizational Sciences in the Cybernetics and DSS Laboratory. His research interests cover modeling and simulation, systems theory and decision processes. He is a member of the System Dynamics Society and SLOSIM.

Spletna aplikacija za optimizacijo hierarhične organizacijske strukture – študija primera upravljanja človeških virov

Ozadje in namen: V kompleksnih striktnih hierarhičnih organizacijskih strukturah se lahko pojavijo neželene oscilacije stanj, kar do sedaj še ni bilo zadovoljivo naslovljeno. Da preprečimo neželene oscilacije je potrebno optimirati vrednosti parametrov, ki določajo prehode med stanji strukture in fluktuacije iz stanj. Hkrati je potrebno obdržati vrednosti parametrov znotraj določenih meja. Cilj je bil razviti simulacijski model hierarhične organizacijske strukture v obliki spletne aplikacije, ki bi pomagal pri reševanju prej omenjenega problema.
Metodologija: Hierarhična struktura je bila modelirana po principih sistemske dinamike. Problem neželenih oscilacij je bil naslovljen z uporabo determinističnega končnega avtomata, medtem ko smo vrednosti parametrov pretoka optimirali z genetskimi algoritmi. Vsi omenjeni pristopi so bili implementirani kot spletna aplikacija z JavaScript/ECMAScript programskim jezikom.
Rezultati: Genetski algoritmi so bili testirani na znanih problemskih instancah za katere so znane optimalne analitične rešitve. Deterministični končni avtomat je bil verificiran in validiran na hierarhičnem organizacijskem modelu s tremi stanji, kjer smo z njegovo uporabo uspeli preprečiti oscilacije v organizacijski strukturi.
Zaključek: Rezultati nakazujejo, da smo uspešno implementirali hierarhični organizacijski model, genetske algoritme in deterministični končni avtomat z JavaScript programskim jezikom v obliki spletne aplikacije, ki se lahko uporablja na mobilnih napravah. Razvito spletno aplikacijo smo uspešno uporabili na hierarhičnem organizacijski strukturi s tremi stanji, kjer smo določili optimalne parametre pretoka in fluktuacij ter preprečili neželene oscilacije stanj. S tem smo zagotovili sistem za podporo odločanju, ki omogoča določanje kakovostnih strategij za prestrukturiranje organizacij.

Ključne besede: *hierarhična organizacijska struktura, sistemska dinamika, genetski algoritmi, deterministični končni avtomat, optimizacija, človeški viri*

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Systems Approach to Standardisation, Classification and Modelling of Managed Events for Tourism

Tadeja Jere Jakulin[1], Aleksandra Golob[2]

[1] University of Primorska, Faculty of Tourism Studies Portorož – TURISTICA, Obala 11a, SI - 6320 Portorož, tadeja.jerejakulin@upr.si

[2] Šentvid pri Grobelnem 29a, SI- 3231 Grobelno
aleksandra.golob@gmail.com

Background and Purpose: The standardisation and classification of managed events provide a legislative basis to distinguish events managed for tourism in their characteristics and quality. The systems approach to standardisation and classification of managed events is a unique, holistic view of event management quality and event organization in tourism. It enables a clear overview of a researched topic and provides adequate support to design and decision-making. In this paper, we explain the meaning of standardisation and classification for Slovenian legislation related to event management. We present the importance of a systems approach methodology for event categorization and classification as it relates to the quality of event management organization, the quality of staff, the quality of the event program and the quality of event services.
Objectives: Provide an overview of events in tourism, related definitions and information gathered from scientific authors, which serves as current systems approach principles with which we want to achieve the desired results, positive changes in legislation; in our case—in the field of managed event quality for tourism through standardisation and classification of events on the national level in Slovenia.
Method: A descriptive method and systems approach methods are fundamental methodological principles in our analysis. In the context of a systems approach, we used qualitative modelling and constructed causal loop models (CLD) of the legislative system of events and investments in the events. We also used context-dependent modelling (SD model) in a frame of systems dynamics.
Results: We present the most appropriate solution to eliminate our problem or question about how to achieve high quality and unique events within event tourism and with event management, thereby creating added value to an event legislative system. We explain suggestions for achieving triple-bottom elements through well-designed quality standards and classification of events, which leads to an optimal categorization of events.
Conclusion: From a systems point of view, event tourism processes, including event management, are systems consisting of people and technologies with the purpose of designing, producing, trading and deploying the idea of an event. It is necessary to transform the current Slovenian legislative system of events and prepare a document which standardizes and classifies events based on systems approach methodology.

Keywords: *systems approach, standardization and classification, tourism, managed events, modelling*

1 Introduction

»*Basically, we can put it this way: there are people principally interested in studying planned events and people who get involved with events while studying something else; there are topics that are at the core of event studies, and many others that are of interest*« (Getz, *2012, p.5)*.

In this paper we will talk about optimising event management quality with a help of a systems approach and from a systems point of view. A systems approach can achieve the highest level of event management quality. Events in its system meaning are organised and planned

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performances (elements or parts) within the process of event management. They are organised to reach common goal: to create a base for event tourism. This sentence follows Getz's definition of events, which describes one system feature: every event has a purpose and goals; it is a transforming process, not an end in itself. In addition, due to its attractiveness and diversity, event tourism attracts crowds of visitors and tourists to a particular destination (Getz, 2010a).

In order to achieve optimal quality of event management, we must find an optimal methodology for organising and planning processes. We chose systems theory and a systems approach, which are applied to various fields of science: cybernetics (Kljajić, 1994), mathematics, biology (Maturana and Varela, 1998) and tourism (Jere Jakulin, 2009). They are presented particularly in connection with tourism systems (Leiper, 1990; Baggio, 2013), tourist destination (Vodeb, 2010) and a system of sustainable development (McDonald, 2009; Ars and Bohanec, 2010; Nguyen, Bosch and Maani, 2011; Camus, Hikkerova, and Sahut, 2012). Furthermore, they represent an approach to innovation or otherwise a systemic perspective to management concepts (Fatur and Likar, 2009; Ropret, Jere Jakulin, and Likar, 2014) and others.

Systems approach finds its application in various forms, which would be taken to be the very paradigm of thinking holistically (Checkland, 2000). Event tourism fits with a systems approach due to the connectivity among planning, development and marketing of events as tourist attractions, catalysts for other developments, image builders and animators of attractions and destination areas; event tourism strategies should also cover the management of news and negative events (Getz, 1997). It also covers the management of responsible and sustainable events and the value or worth of events. Since the main aim and purpose of events is to create positive economic, social and environmental outcomes, which affect development of the destination and the quality of life of local people, we determined that building a causal loop diagram (CLD) model in a frame of system dynamics (SD) is an appropriate methodology to achieve the aim of this paper—through a systems approach define standardisation and classification of events and build models for an optimal event management quality. This methodology also fulfils the requirements of a triple-bottom (economic, social and environmental) line way of evaluating events.

2 Method

"Folks who do systems analysis have a great belief in "leverage points." These are places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything". (Donella Meadows, Places to Intervene in a System in Systems Practice: How to Act in a Climate Change World, p.62).

The method of description of managed events' standardisation and classification for tourism within a systems approach is followed by methods of system dynamics modelling, CLD and SD models, as well as discussion of the relation among subjects, model and phenomena of tourism events.

2.1 Standardization and Classification of Managed Events

According to Getz (2010), the common classification of events pertains to their form, or the "social construct" of what people expect in terms of programme and setting. Events are also classified according to their function, or the roles they play as instruments of public policy, and corporate and industry strategy. A systems approach as a methodology allows events to be classified optimally and distinguished from other events. We usually classify events based on their form, or programme. These are, in fact, social constructs. They increase the number of visitors at tourism destinations in a sustainable, holistic way. In this way, the benefits of a systems approach can be described in a triple bottom way: the event organisers (economy), environment, and visitors (social) components. With their participation in various events, visitors gain new knowledge, and as observers, they value their own experience within the event: active or passive participation in the event. This is called the deeper meaning of a visitor's experience, by answering the specific needs provides an opportunity for the visitor to experience the event in a deeper way. Csikszentmihalyi (1990) goes even further when he describes the theory of 'flow', where he suggests individuals seek the optimal arousal, leading to an experience of flow. »Flow is the way people describe their state of mind when consciousness is harmoniously ordered and they want to pursue whatever they are doing for its own sake« (Csikszentmihalyi, 1990, p.6).

A visitor's experience can be defined as an intangible element of event, which can help in event standardisation and classification. We can classify events according to their content as historical, ethnologic, geographic, sports, music, etc. The content can be sung, filmed, performed and revived in a certain place and time. The purpose should address, and be compatible with, the stated objectives of the event organizational institution (Jere Jakulin, 2004).

Globalisation brought new trends, which are tending towards the standardization of names and forms (Getz, 2010a). Event management has emerged as a quasi-profession and a fast-growing field of studies in universities around the world (Getz, 2010a). The abundance and diversity of events and the development of event tourism drive the need for a system of quality assurance, the need for the standardization of events. This would prevent good events on the market from getting lost in the critical mass and flood of similar events. Ţară-Lungă (2012, p.760) talks about standardization of special events in the context of defining major special events. She discusses “the identification of a clear accepted typology, which is necessary for the research to bring its contribution to the establishment of the special events industry.” Moreover, this standardization allows the recognition of particularities and the understanding of the aspects of organization which have a strong impact on the goal, objectives, processes and procedures on which the event manager must focus. We claim that her definition can equally be applied to events in general. When we discuss quality of events, we must know what the expectations of the event customers are. Getz (Getz, 2010b) mentions in his studies that the customer has many experiences with events and demands ever-unique experiences and ever-higher standards and quality. Because of increasing demand, we have come to the point where we have to regulate events through the classification and standards. This is explained on case of hotel classification by Cvikl (2008, p.10), where the author describes that establishment and implementation of quality systems in accordance with the standards as the objective of quality control activities in the company.

Standards are important for harmonization, mutual recognition and a quality system that meets the standards and provides several benefits. A standard defines and provides quality and a criterion for achieving the requisite quality (adapted from Cvikl, 2008). The Meriam Webster dictionary defines classification as: “the act or process of classifying or systematic arrangement in groups or categories according to established criteria.” (http://www.merriam-webster.com/dictionary/classification). Therefore, individual events are classified by individual criteria. Since there is a lack of events legislation (presented by standardisation and classification) in Slovenia, the highest quality of managed events (regarding international standards) is not achieved.

The managed event weaknesses are also results of the weakness of existing legislation. Only events organized by state, municipal and other public organisations are mentioned in the existing legislative system, which should actually include following criteria: investors, sponsorships, visitors, locals, environment and its behavioural relationships. We propose that these criteria relate to the volume and the level of events (local, regional, national or international events), the size of the organizing team, and the legal organizational structure of the organization (private/profit, non-profit/voluntary, government agencies/public and private groups), which deal with events as well as a type of events. There are various reasons for such characteristics. In the first place, because of the diversity of the organizers of events and also because of the diversity of institutions that deal with the organization of events, consequently, this is also due to the diversity of events, according to the type (Getz, 1997) of event, as presented in Table 1.

The typology of events requires a classification which will be interesting enough to motivate sponsors and companies. Festivals celebrate community values, ideologies, identity and continuity (Getz, 2010b, p.2). O’Hagan and Harvey (2000) present in their study, “Why Do Companies Sponsor Arts Events? Some Evidence and a Proposed Classification,” motivations for corporate philanthropy and corporate sponsorship of events. Their study suggests that the dominant motivation by far for sponsorship is related to promotion purposes, chiefly promotion of company image or name.

1. The following motivations gathered from the study are: Corporate philanthropy, following Young and Burlingame (1996), is seen as contributing to the ability of the firm to make profits. They have the so-called ethical/altruistic model based on an understanding that corporations and the societies they operate within are interdependent. Here we can see the same characteristics as we find in systems theory definitions and systems approach principles—the principle of extreme interdependency among the elements of a whole.
2. Corporate sponsorship
   - Promotion of the image or name of the company, where the event provides an opportunity for direct promotion of the brand. This is more advertising than sponsorship. Sponsorship as the funding or promotion of an event might be seen when is not intrinsically linked to the sponsoring company’s core products (O’Hagan and Harvey, 2000).

Table 1. Typology of Events (Getz, 1997)

Political	*Sports*	*Recreational*	*Educational*
Summits, Royal occasions, Political events, VIP visits	Amateur/professional Spectator/participant	Sport or games for fun	Conferences, Seminars, Clinics
Cultural	*Business*	*Entertainment*	*Private*
Festivals, Carnivals, Commemorations, Religious events	Meetings, conventions, Consumer and trade shows, Fairs, Markets	Concerts, Award ceremonies	Weddings, Parties, Socials

- Supply-chain cohesion, which captures the idea that the company wishes to improve the goodwill of its own employees or its suppliers toward the company (O'Hagan and Harvey, 2000).
- Rent seeking, in order to enhance demand (e.g. by restrictions on competition) or to reduce costs (e.g. by subsidies). We distinguish between direct and indirect rent seeking. Direct rent seeking involves using sponsorship of an arts event directly to lobby decision-makers. Indirect rent seeking means altering the environment in which decisions affecting the company are made. A company that promotes a benevolent and worthy image among the public may obtain a higher return on its other direct lobbying activities than one that has a poor public image. Sometimes, "a company might be more concerned with local planning regulations than with national policy variables, so that the geographical scope of the event would not be useful in determining the extent of any rent seeking. On the other hand, the presence of direct lobbying would provide some indication that political goodwill (as opposed to product goodwill) might be the motivation" (O'Hagan and Harvey, 2000, p. 212).
- Non-monetary benefit to managers or owners. This is actually a form of philanthropy that provides a non-monetary benefit to its managers or owners. (O'Hagan and Harvey, 2000).

Slovenian legislation adds to the typology public events, which are organized gatherings of people for a cultural, sport, entertaining, educative or religious reason, or other activity execution in a way that the participation is unconditionally or under different conditions allowed to everyone.

From all these we can claim that proper legislative policy is needed to establish the overall worth of events (not just economic and tourism related).

2.2 Event Specialization for Building the System Model of Event Quality

Quality is defined as excellence or superiority. For events, it is very difficult to determine and assess the level and quality of supply. Cvikl (2008) considers it extremely difficult to evaluate and assess which are the most important features of a customer's services and the extent to satisfy their expectations about quality, because of the intangible services. Different visitors perceive the quality completely differently, whether because of their beliefs, values or motives. There are more typical groups of visitors, tourists with different needs and expectations. It is easier for event organizers to ensure better quality when they are organizing events for a specific target group, so they can take into account their needs and expectations. This can be achieved only through the specialization of events, which helps to increase confidence in a tourism product on the market. Specialization of events is mostly done because of knowledge that the whole range of events needs to be closer to the wishes and needs of participants.

Visitors will know what type of event it is through the symbols of specialization of event organizers. In this manner, event organizers can better meet their expectations and requirements. The main purpose of specialization is to achieve: greater visibility of supply, building trust in the quality of events, increased competitive ability, better understanding of the price difference, better marketing to a known target group, targeting information and advertising, and designing a unique and specific event (Golob, 2011). According to the steps of the modelling process (Sterman, 2000), we can state the real problem and find a systems modelling solution, as presented in Table 2.

According to Sterman (2000), Table 2 presents five steps in the modelling process: (1) articulating the problem to be addressed, (2) formulating a dynamic hypothesis or theory about the causes of the problem, (3) formulating a simulation model to test the dynamic hypothesis, (4) testing the model until we are satisfied it is suitable for our purpose and (5) designing and evaluating policies for improvement. The modelling process presents modelling tools to help event organizers.

Because of dynamics, complexity and a variety of variables, "the modelling is inherently creative" (Sterman, 2000, p. 87). Given our proposals, procedures and model building, then follows the model testing and designing of all measurable indicators for policy improvement. The combination of all this is one of the optimal paths to excellence (number of sponsors and investors, safety of the visitors, the number of sold tickets, quality and satisfaction of employee and volunteers, quality of events and its programme, etc.).

Quality also depends on the observer or decision-making group who observes the event and event legislation (either service or a product). In Fig. 1, we in parallel present observer (decision-making group) as the subject, event as an object (event legislation) and model (quality of model) as the defined quality of an event. The relation between the *Subject* and the *Object* is of essential significance in the cognitive method. The observer is a person, with all his cognitive qualities, while the object of research is the manifested world, which exists by itself, regardless of how we describe it. In this case, the object and the system have the same meaning. The third article of the triplet, *Model,* is the consecutive one and represents a model or a picture of the analysed system *Object*. (Kljajić and Jere Jakulin, 2005).

The *Object* ↔ *Subject* relation in Fig. 1 indicates the reflection of human experiences to concrete reality. This cognitive consciousness represents our mental model. The relationship *Model* ↔ *Subject* represents the problem of present knowledge, respectively the translation of

Table 2: Steps of the modelling process (Source: Sterman, 2000)

1. Problem Articulation (Boundary Selection) *Theme selection:* What and why is the problem? *Key variables:* What are the key variables and concepts we must consider? *Time horizon:* How far in the future should we consider? How far back in the past lie the roots of the problem? *Dynamic problem definition (reference modes):* What is the historical behaviour of the key concepts and variables? What might their behaviour be in the future?
2. Formulation of Dynamic Hypothesis *Initial hypothesis generation:* What are current theories of the problematic behaviour? *Endogenous focus:* Formulate a dynamic hypothesis that explains the dynamics as endogenous consequences of the feedback structure. *Mapping:* Develop maps of causal structure based on initial hypotheses, key variables, reference modes, and other available data, using tools such as model boundary diagrams, subsystem diagrams, causal loop diagrams, stock and flow maps, policy structure diagrams, other facilitation tools.
3. Formulation of a Simulation Model: Specification of structure, decision rules. Estimation of parameters, behavioural relationships, and initial conditions. Tests for consistency with the purpose and boundary.
4. Testing *Comparison to reference mode***s**: Does the model reproduce the problem behaviour adequately for your purpose? *Robustness under extreme conditions:* Does the model behave realistically when stressed by extreme conditions? *Sensitivity:* How does the model behave given uncertainty in parameters, initial conditions, model boundary, and aggregation?
5. Policy Design and Evaluation *Scenario specification:* What environmental conditions might arise? *Policy design:* What new decision rules, strategies, and structures might be tried in the real world? How can they be represented in the model? *"What if. . ."* analysis: What are the effects of the policies? *Sensitivity analysis:* How robust are the policy recommendations under different scenarios and given uncertainties? *Interactions of policies:* Do the policies interact? Are there synergies or compensatory responses?

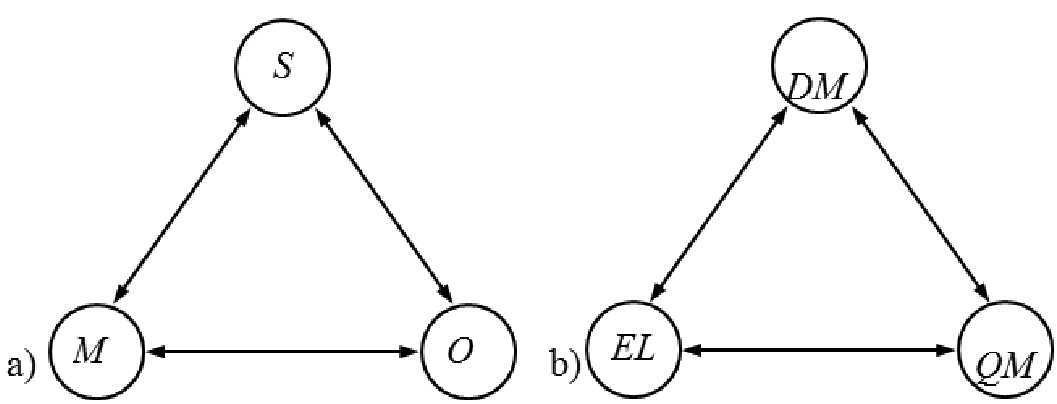

Fig. 1 (a and b): Subject (observer and decision-making group) in a modelling process (Source a: Kljajić, 1998) the mental model into the actual model. The *Object* $\leftrightarrow$ *Model* relation represents the phase of model validation or proof of correspondence between theory and practice, which render possible the generalization of experiences into rules and laws. The *Subject* $\rightarrow Object \rightarrow$ *Model* relationship is nothing else but an active relation of the subject in the phase of the object's cognition.

The $M \rightarrow O \rightarrow S$ relation is nothing more than the process of learning and generalization. As we can talk about the complexity of *Object*, we can also talk about the state, goals and estimations of *Subject*, about homomorphous and isomorphic connection between a model and the original. One can also understand *Subject* in a triplet as a strategic planning team or decision-making team. *Object* represents an event with all its complexity, and *Model* represents the picture of quality of event (an analysed event). Fig. 1b represents relations among decision-making, the event legislation and its quality model simulation.

According to Getz (1986), one can describe theoretical models as 'descriptive,' where the model simply defines the system's main elements, 'explanatory,' where the model looks at the relationships between components, without necessarily specifying causality, and 'predictive,' where the relationship of causality is explored to permit forecasting. By modelling, we understand an activity enabling us to describe our experiences within a concrete procedure (mental model) with one of the existing languages in the framework of a concrete theory. From a pragmatic point of view, a system is defined by the double $S = (E, R)$, where $e_i \in E \subset U, = 1,2,..n$ represents the set of elements, $R \subseteq E \times E$ the relation between the elements, and U the universal set. The construction of concrete systems requires certain knowledge $K(e_i) \in E$ (property of elements) in order to identify the elements of the systems (including those from environments) and a theory $T(e_i, e_j) \subset R$ to find relationships among the elements. Each element e_i can be a set, as well as $R_j \in R, j = 1,2,...m$, defining different relations between the elements. In fact, such a procedure is inductive and represents the model of a real system. (Kljajić and Jere Jakulin, 2005) Using systems methodology backed by a systems approach was a fundamental methodological principle in our analysis.

3 Results

3.1 Development of CLD model

Appropriate modelling always supports the systems approach; therefore, below we will show the construction of a qualitative cause and effect causal loop diagram (CLD)

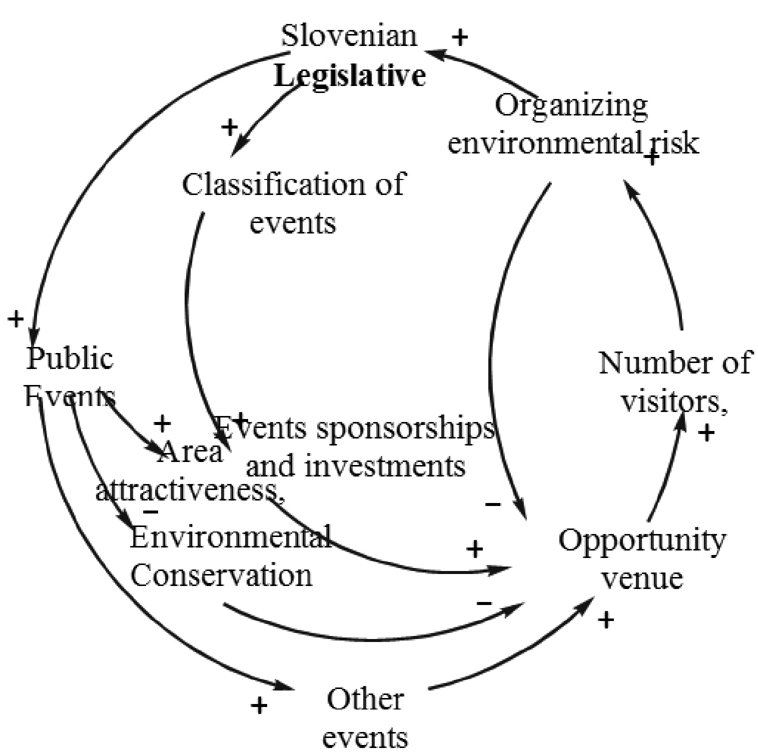

Figure 2: Construction of the CLD model in the field of the legislative system of events (Golob, 2011)

in the domain of the legislative system of events. The created CLD model (Figure 2) shows the appropriate system solutions to eliminate the risk of all varieties of events described in Table 1.

We have developed a causal loop diagram (CLD) model which presents the Slovenian legislative system that has a positive impact on public events (+). Public events, in turn, have a positive impact on other events (private, sports, recreational, cultural, educational) (+), and also on the area attractiveness environment (+). The legislative system has a positive impact (+) on the classification of events, which in turn has a positive impact (+) on investments in events and sponsors. Sponsors, in turn, positively influence (+) the attractiveness of an opportunity venue. The area attractiveness increases the opportunity venue (+), and this increases number of visitors (tourists, locals) (+), which causes an increased uncertainty (risk) of a venue (+). The risk, in turn, reduces the attractiveness of the environment (-). Public events have a negative impact on the conservation of the environment (-), which in turn reduces the opportunity venue (-). Circles of positive feedback mean development, but it must be stressed that any downfall in the circle is followed by growth.

We can say that causal loop diagrams emphasize the feedback structure of a system (Sterman, 2000). For example, if an environment is ecologically unsafe, therefore less preserved, this reduces the attractiveness of the area. This is necessarily followed by a chain reaction that reduces the number of visitors, followed by the expected loss of revenue from admissions, followed by a reduction in investment in the event. It is important to be able to assess risks and benefits wherever the circles with negative feedback and positive—the circles with positive feedback—meet.

3.2 Simulation Model

According to Sterman (2000), policy design is much more than changing the values of parameters, such as a tax rate or mark-up ratio. Policy design includes the creation of entirely new strategies, structures and decision rules. Since the feedback and structure of a system determines its dynamics, most of the time high leverage policies will involve changing the dominant feedback loops by redesigning the stock and flow structure, eliminating time delays, changing the flow and quality of information available at key decision points, or fundamentally reinventing the decision processes of the actors in the system (Sterman, 2000). A causal loop diagram, which we described, represents a qualitative model of Slovenian event legislation system and classification model.

Causal loop diagram represents qualitative diagram, which is followed by a system dynamic model. A system dynamics model is actually a simulation model. The difference between the causal loop diagram and system dynamics model is in the quantity of parameters and concrete data needed for simulation, which are gathered in system dynamics. When we discuss different scenarios, we are approaching the creation of a development strategy.

In system dynamics, modelling dynamic behaviour is thought to arise due to the Principle of Accumulation. More precisely, this principle states that all dynamic behaviour in the world occurs when flows accumulate in stocks. System dynamics modelling is discovering and representing the feedback processes, which, along with stock and flow structures, time delays and nonlinearities, determine the dynamics of a system (Sterman, 2000). The stock-flow structure is the simplest dynamical system in the world. Stock and flow diagrams emphasize their underlying physical structure (Sterman, 2000).

According to the principle of accumulation, dynamic behaviour arises when something flows through the pipe and faucet assembly and collects or accumulates in the stock. In system dynamics modelling, both informational and non-informational entities can move through flows and accumulate in stocks. Stocks usually represent nouns, and flows usually represent verbs. They do not disappear if time is (hypothetically) stopped (i.e., if a snapshot were taken of the system). Flows do disappear if time is (hypothetically) stopped, and they send out signals (information about the state of the system) to the rest of the system.

Figure 4 shows a system dynamics model depicting the interaction among dependencies on event legislation, classification of events, the number of visitors and sponsorships and investments in events and event development. In the experiment, this model is defined to be the "real world system." Next, an exact copy of the "real world system" is made. The "model" is good in the sense that its nonlinear stock-flow-feedback structure, its parameters, its distribution of random variables, and its initial values are identical to those of the "real world system."

Fig. 3 presents the SD diagram of an event classification and legislation macro-model. From this diagram, one can derive the dynamic equations that are necessary for a computer simulation. System dynamics uses a particular diagramming notation for stocks and flows. Rectangles represent Stocks (suggesting a container holding the contents of the stock). A pipe or arrow represents an Inflow pointing into (adding to) the stock. Pipes pointing out of (subtracting from) the stock represent Outflows. Valves control the flows. Clouds represent the sources and sinks for the flows.

A source represents the stock from which a flow originating outside the boundary of the model arises; a sink represents the stock into which a flow leaving the model boundary drains. Stocks or Levels show a variable type and a model object in Powersim models, used to represent the state variables of a system. Levels accumulate connected flows. Stock and flow diagrams emphasize their underlying physical structure (Sterman, 2000). The array Stock has one dimension with different elements, and flows in a

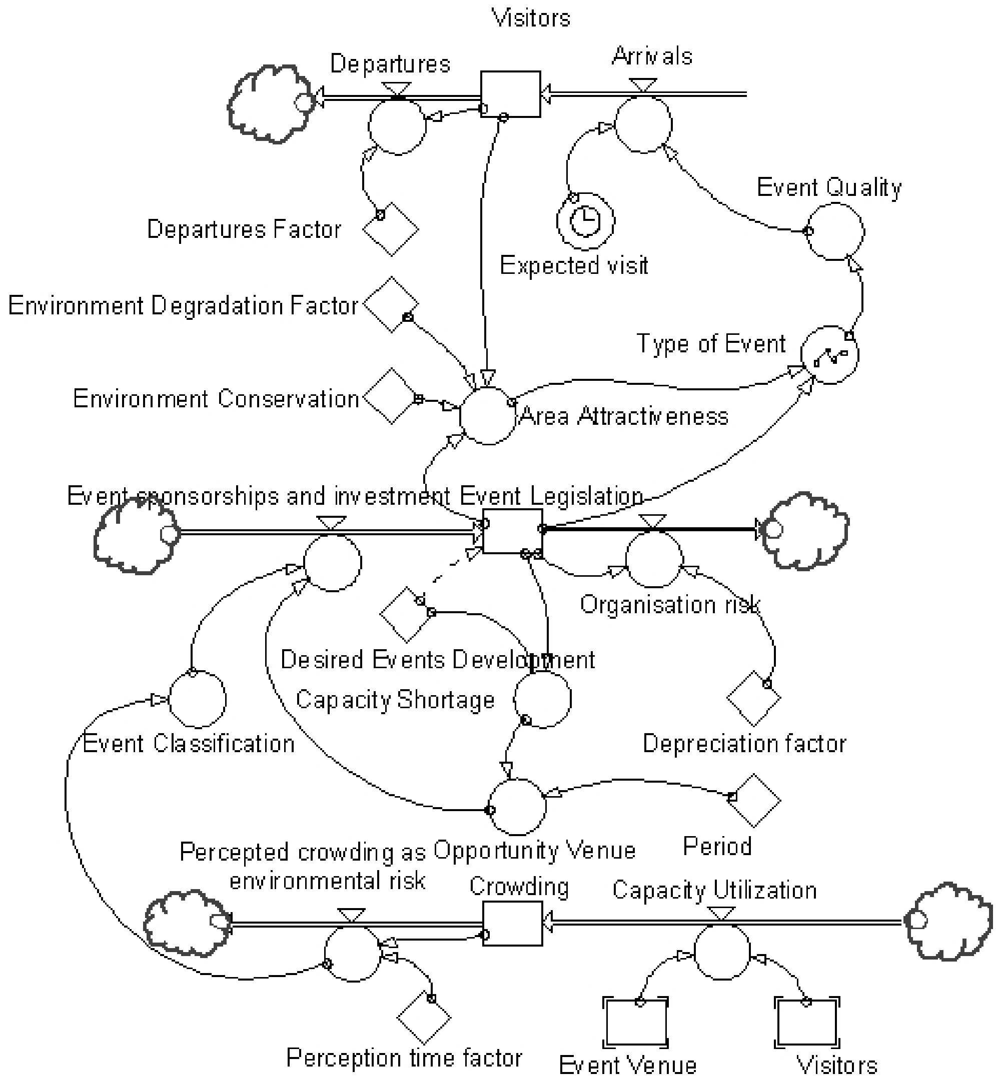

Figure 3: SD diagram of simulation model for decision-making support at event classification

Powersim model represent the transport of quantities to, from and between levels, whereas connectors are links to establish an influence from one variable to another.

Using simulations, companies can test out tactical decisions and experiment with marketing or product-development strategies. The purpose of simulations is to help people understanding the basics of business and, in particular, the financial implications of various decisions. The processes of parameter identification and model validation are in progress.

4 Conclusions

A systems approach always aims to understand the problem and to find an optimal solution. This paper has attempted to present a concept for a meaningful set of a system of simulation methods, techniques and expert systems as a functional part of an event-friendly legislative system. A standardisation and classification of events has been provided. We have discussed the use of a systems methods for the event as system—system dynamics and modelling in a frame of systems methodology.

We also discussed the depth of the visitor's experience when describing the flow, characterized by a deep involvement in and intense concentration on the event.Several benefits can be claimed by this paper considering systems dynamics methodology. In qualitative modelling, we were looking for the most appropriate solution to eliminate our problem or question about how to achieve high quality and unique events, thereby creating added value to an event legislative system. We have come to a simple solution. It is necessary to transform the current legislative system of events and prepare a document of standardization and classification of events. The qualitative data, which is important for the strategy, can be readily incorporated into the model we developed.

The adoption of the Act on Standardization and Classification of Events is a great asset, because it creates a direct benefit for all events. This will differentiate us from the competition. The fact is that we always talk about quality events and events that are creating a positive image, which consequently increases the number of visitors to venues of events and, thereby, to the tourist destination (Golob, 2011).

Because of these facts, we shall not suppress the future development possibilities in the field of regulation of the legislative system of events, particularly sustainably oriented events, as sustainable development is the priority area in tourism (SRST 2012–2016). In reviewing the current Slovenian legislation, we found that it is fragmented, opaque and unavailable to event organizers. This confirms the assumption on the system approach treatment of topics, which allows a holistic interpretation. This is the only way to cross disciplinary boundaries and enable an understanding of dynamic event management and managing the chaos and complexity. To manage this, it is necessary to establish the system that will provide information, management and operation of the system as a whole. System dynamics modelling, over the more traditional statistical correlation modelling, provides qualitative data, which are important in the strategic planning as an anticipation of the future.

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Tadeja Jere Jakulin obtained her PhD in the field of Organisational Sciences at the Department of Information Systems from the University of Maribor. She is an associate professor, serves as the Vice-Rector of the University of Primorska, and teaches Tourism Systems at the Faculty of Tourism Studies of the same university. Her research interests cover systems theory, systems thinking and decision-making processes. She is a member of IIAS (International Institute for Advanced Studies in Systems Research and Cybernetics), and of UNWTO Knowledge Network.

Aleksandra Golob has conferred the title of Master of Tourism at the University of Primorska, Faculty of Tourism studies – Turistica in 2011 with the assignment Systematic approach to Act on Standardization and Classification of Events. She is a doctoral student at the same faculty. She is active in organizing various events of local and regional importance. She has a great interest in events in the area of tourism, systems theory, system approach to decision making and modeling.

Sistemski pristop k standardizaciji, klasifikaciji in modeliranju upravljanja s prireditvami v turizmu

Teoretični pregled in namen prispevka: Standardizacija in klasifikacija za upravljanje prireditev predstavljata pravno osnovo za razlikovanje turističnih prireditev glede na njihovo kakovost. Sistemski pristop k standardizaciji in klasifikaciji organiziranih prireditev je edinstven, celosten pogled na upravljanje z dogodki oziroma prireditvami v turizmu. Omogoča jasen pregled raziskovanega področja in zagotavlja primerno podporo pri oblikovanju odločitev povezanih s prireditvami v turizmu. V prispevku obravnavamo pomen standardizacije in klasifikacije prireditev za slovensko zakonodajo, ki obravnava upravljanje prireditev. Prispevek obenem predstavlja pomen metodologije sistemskega pristopa, ki se nanaša na kakovost organizacije prireditev, kakovost zaposlenih, kakovost programov prireditev in kakovost storitev na prireditvah.
Cilji raziskave: Zagotoviti pregled prireditev v turizmu, povezava definicij in informacij zbranih iz znanstvenih prispevkov, kar služi kot sedanji sistemski pristop po načelih, s katerimi želimo doseči želene rezultate, pozitivne spremembe v zakonodaji; v našem primeru na področju upravljanja kakovosti prireditev v turizmu skozi standardizacijo in klasifikacijo prireditev na nacionalni ravni v Sloveniji.
Metodologija: Metoda deskripcije in metoda sistemskega pristopa so temeljna metodološka načela v pričujoči raziskavi. V okviru sistemskega pristopa smo uporabili kvalitativno modeliranje in oblikovanje vzročno-posledičnega modela (CLD) zakonodajnega sistema prireditev in investiranja v prireditve. Uporabili smo tudi kontekstno odvisno modeliranje (SD) v okviru sistemske dinamike.
Rezultati raziskave: Predstavljamo najbolj ustrezno rešitev za odpravo problema ali vprašanj o doseganju visoke kakovosti in edinstvenosti prireditev v okviru prireditvenega turizma, s pomočjo upravljanja prireditev; s tem ustvarjamo dodano vrednost zakonodajnega sistema prireditev. Razložimo predloge za doseganje elementov trojnega izida, kar vodi k optimalni kategorizaciji prireditev.
Zaključek: Od sistemskega vidika, prireditvenih procesov v turizmu, vključno z upravljanjem prireditev, so sistemi sestavljeni iz ljudi in tehnologij z namenom oblikovanja, proizvodnje, trgovanja in razporejanja idej o prireditvi. Potrebno je spremeniti sedanji zakonodajni sistem prireditev v Sloveniji in pripraviti dokument standardizacije in klasifikacije prireditev, ki bo temeljil na metodologiji sistemskega pristopa

Ključne besede: *sistemski pristop, standardizacija in klasifikacija, turizem, upravljanje prireditev, modeliranje*

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A Statistical Model for Shutdowns due to Air Quality Control for a Copper Production Decision Support System

Khalid Aboura

University of Dammam, College of Business Administration,
Department of Quantitative Methods, Dammam, Saudi Arabia.
kaboura@uod.edu.sa

Background: In the mid-1990s, a decision support system for copper production was developed for one of the largest mining companies in Australia. The research was conducted by scientists from the largest Australian research center and involved the use of simulation to analyze options to increase production of a copper production facility.
Objectives: We describe a statistical model for shutdowns due to air quality control and some of the data analysis conducted during the simulation project. We point to the fact that the simulation was a sophisticated exercise that consisted of many modules and the statistical model for shutdowns was essential for valid simulation runs.
Method: The statistical model made use of a full year of data on daily downtimes and used a combination of techniques to generate replications of the data.
Results: The study was conducted with a high level of cooperation between the scientists and the mining company. This contributed to the development of accurate estimates for input into a support system with an EXCEL based interface.
Conclusion: The environmental conditions affected greatly the operations of the production facility. A good statistical model was essential for the successful simulation and the high budget expansion decision that ensued.

Keywords: *decision support system, simulation, statistical modelling*

1 Introduction

Welgama et al. (1996a) describe a major study conducted for Mount Isa Mines Pty. Ltd. Mount Isa Mines is one of the biggest mining operations in Australia (Mount Isa Mines, 2015). The study involved the use of simulation to analyze options to increase production of a copper production facility. Mount Isa Mines is one of Australia largest underground mines. Mount Isa Mines Limited (MIM) operates the Mount Isa copper, lead, zinc and silver mines near Mount Isa, Queensland, Australia as part of the Glencore Xstrata group of companies. For a brief period in 1980, MIM was Australia's largest company (Wikipedia, 2015). In 1992, MIM commissioned an ISASMELT™ furnace in the Mount Isa copper smelter to treat 104 tons/hour of concentrate containing 180,000 tons/year of copper (Arthur and Hunt, 2005). The throughput was initially constrained because MIM chose to keep one of the two reverberatory furnaces operating and the converters became a bottleneck. The ISASMELT™ plant's throughput had to be restrained to allow enough material to flow through the reverberatory furnace to prevent the matte freezing in the bottom of the furnace.

It was decided in 1997 to shut down the fluidized bed roaster and the reverberatory furnace, and the ISASMELT™ furnace throughput was boosted to more than 160 tons/hour of concentrates by the addition of a fourth Peirce-Smith converter (Player, 1998) and a second oxygen plant (Arthur and Hunt, 2005). The simulation described in Welgama et al. (1996a) provided support for the major expansion decision of MIM. The simulation study involved a detailed and accurate model capturing the factors affecting production and material handling. A decision support system with an Excel interface was developed (Welgama

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et al., 1995). The analysis using the developed software resulted in supporting a decision for a $92M investment to achieve the increase in throughput.

2 The Simulation Model

Welgama et al. (1995), Welgama et al. (1996a) and Welgama et al. (1996b) describe in details the simulation study jointly conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Mount Isa Mines Limited. A detailed and accurate simulation model was developed capturing the factors affecting copper production and materials handling. The study resulted in a SIMAN/ARENA based software support system with an Excel interface (Welgama et al., 1995). About 40 different parameters were included in the Excel spreadsheet which provides a user interface to the simulation model. The user can change these parameter values and conduct experiments. Validation was carried out using known scenarios. The production process modeled can be summarized as follows. In the first phase, ore is processed to produce chalcopyrite concentrate ('cons') which contains about 26% of copper. The second phase process this 'cons' further to produce anode copper, in a copper smelter aisle. The study focused on the second phase. Figure 1 shows the MIM copper production process in this second phase.

The copper smelter aisle consists of two primary smelters, called ISASMELT and fluo-solids roaster (FSR), three converters, two anode furnaces and a casting wheel. ISASMELT and FSR produce matte which contains about 56% of copper from cons. Converters produce blister copper which contains about 97% copper, from matte. Anode furnaces produce anode copper from blister copper. Casting wheel produces anodes, which are copper plates weighing 350kg, from anode copper. Smelters, converters and anode furnaces produce exhaust gas, which contains sulphur dioxide, and slag which contains iron, silica and lime. Material transfer between processing units is done by two overhead bridge cranes operating on the aisle. The production system runs 24 hours a day. Primary smelters operate continuously. Each smelter has a matte storage facility attached to it. Converters and anode furnaces operate in batch modes and have operating cycles. Converters are the key element in this copper production system. They pull matte from primary smelters and push blister copper to anode furnaces.

The objective of the study was to evaluate various options to increase copper production by developing a simulation model of the current operations of the copper smelter aisle, considering the uncertainties of the system, such as breakdowns and other forms of shutdowns.

A number of simulation modules covering matte production by primary smelters through to the production of anodes were developed. Modelling was done using the SIMAN simulation language (Pegden et al., 1990; System Modelling Corporation, 1993). Converter operations were modelled in great detail. The full converter cycle was modelled using the rules actually followed in the plant. Converter blow times were calculated using a formula derived by MIM from historical data. Considerable effort was spent in modelling the movements of the two overhead cranes which operate on the same aisle performing all the materials handling tasks.

The special routings available in SIMAN to model automatic guided vehicles were used to model these crane movements accurately avoiding collisions. Both full and empty pot movements were modelled. Crane speeds, distances, loading and unloading times, waiting times and speed changes when travelling across the aisle were also considered. The situation where only one crane is operating while the other crane undergoes repairs or maintenance was also modelled (Welgama et al., 1996a). All downtimes were analyzed and modelled. In addition to downtimes of various processes, matte grades contribute to randomness in the model output. The output values of primary interest are the throughput, copper removal time per converter charge, crane utilization and the percentage stack time, which indicates the time contributed to the production. Animation screens were developed for the purpose of debugging and verification, validation and final presentation. About 40 different parameters were included in an EXCEL spreadsheet which provides a user interface to the simulation model. The user can change these parameter values and conduct experiments.

During the study, vast amounts of failure and maintenance data were collected. Information on time between failures and durations of downtimes was extracted from the data and fitted to probability distributions. Expert opinions were used to improve the estimates of parameters. Expert opinions and past data were also used to represent planned maintenance activities of each process. Plant shutdowns due to environmental considerations were modelled using statistical analysis. The statistical work was described in Welgama et al. (1996b) for most processes involved in the production of copper. In this article, we describe in more

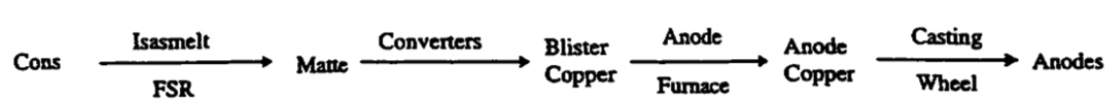

Figure 1: Production process of copper anodes (Welgama et al., 1996b)

details the statistical model built to reproduce shutdowns due to air quality control. The model made use of a full year of data on daily downtimes and used a combination of techniques to generate replications of the data. We also show how an adequate use of expert opinion solved a maintenance data problem and allowed a successful simulation.

3 Statistical Model for Air Quality Shutdowns

Downtimes were caused by planned maintenance shutdowns, breakdowns and environmental effects called air quality control (AQC). When the wind direction changed towards the nearby city, the primary smelters and converters had to be shut down because their exhaust gas contained sulphur dioxide and other air pollutants. A statistical model for AQC Shutdowns was used as an input in the simulation study that generated all related shutdowns which basically amounted to the shutdown of the plant. In this section, we reproduce the statistical model and illustrate with some figures.

As seen in Figure 2, the shutdowns due to AQC followed each other in a random pattern and had durations that followed a seasonal pattern. The ticks on the x-axis of Figure 2 show some pattern of days in the year when there is an AQC shutdown. In essence, they form an arrival process. In one of the days of AQC shutdown in Figure 2, the duration of the shutdown is shown with a vertical line. The curve in the figure shows an approximately sketched theoretical average daily duration. That theoretical average is clearly showing a seasonal effect as the AQC daily shutdown duration grows during the year then diminishes. The data provided estimates of the maximum daily shutdown durations in minutes, along with minimums, illustrated in Figure 2 by a width window.

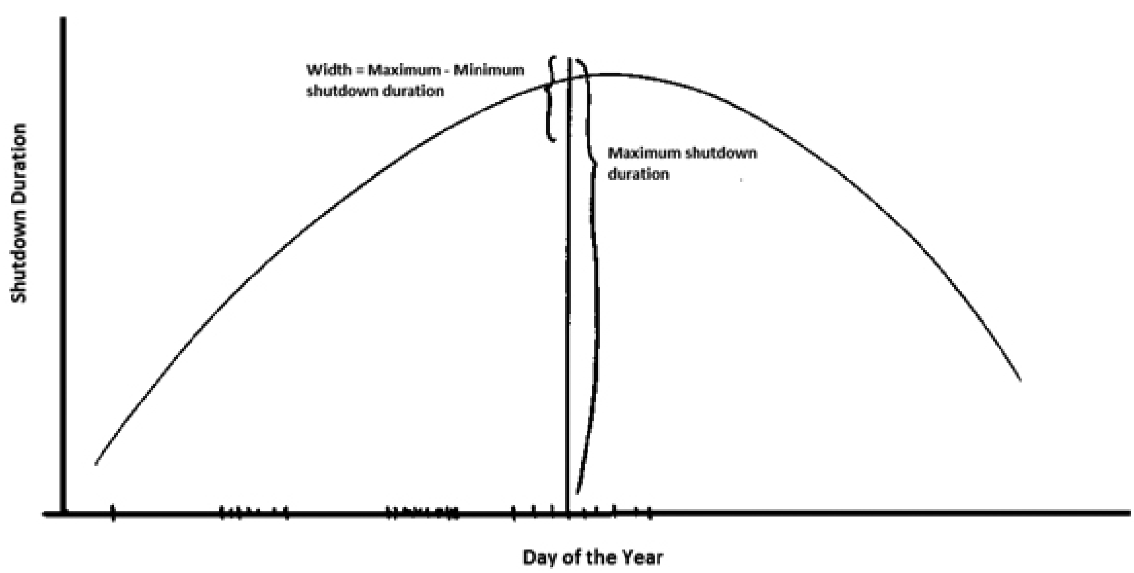

Figure 2: Statistical model for shutdowns due to air quality control

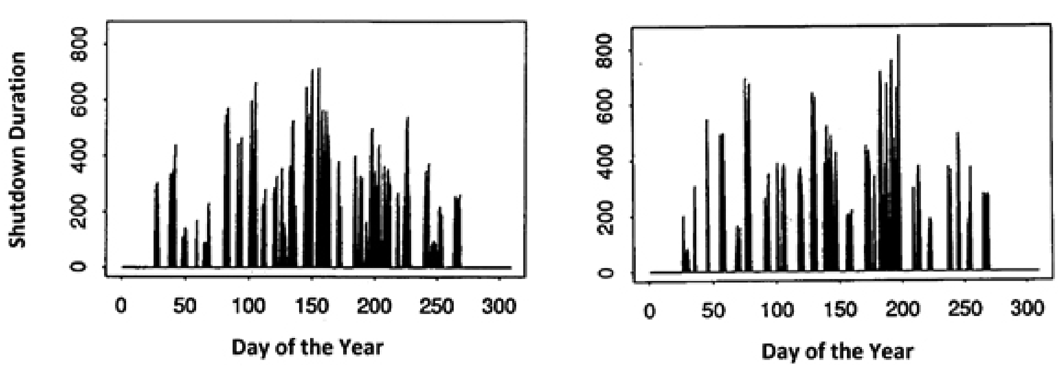

Figure 3: Two independent reproduced shutdowns durations (in minutes) due to AQC for each day of the year

The statistical model used a combined linear regression model using a quadratic mean compounded on the arrival process to generate replications of the data. The arrival process of shutdowns was studied using the data and modeled. Then, upon the occurrence of a shutdown, a magnitude was modeled using a maximum and a minimum value that were regressed on the time of the year using a quadratic formulation. The full statistical model was validated using standard techniques. Figure 3 shows two independent simulation run of replicated data of shutdowns durations (in minutes) due to Air Quality Control for each day of the year. They displayed a strong statistical resemblance to the original data.

Although seemingly simple, the model managed to reproduce the AQC shutdowns. In each run of the simulation, a new AQC set of data was generated that statistically resembled the real scenario. This part of the study was essential as the shutdowns of the plant affected greatly the output. From a simulation point of view, considerable time and effort was spent to establish the model's validity. In the process of validation some of the following techniques discussed in Sargent (1984) were used. The model was used initially to generate and compare several scenarios. Further experiments were made for one scenario with different values of parameters. In all cases the throughput, converter holding times, times that anode furnaces were waiting on blister copper, and times that converters were waiting on matte were recorded and compared. But it remained to run the model under realistic condition of shutdowns due to Air Quality Control. The above statistical model provided an adequate input to the simulation model therefore validating the simulation results.

4 Expert Opinion in Maintenance

In the simulation study, a set of twenty-seven computer data files were provided by MIM. The data files were large and contained information for a one-year period about the sequencing of operations, the downtimes of the various processes, the durations of downtimes, shutdowns due to air quality control and the maintenance of some processes. The first job was to extract information from the maintenance records for input into the simulation model. At first, the records seemed to indicate patterns of maintenance suitable for use in the model. However, a closer look at the data revealed that a change of maintenance policy had taken place for one particular process. The purpose of the simulation was to optimize return on future investment. Therefore the maintenance policies used in the simulation needed to reflect likely future maintenance strategies. It would not have been adequate to make the simulation perform like the data provided if that was not indicative of the future.

At the next meeting with the company, the scientists discussed the maintenance policy for the process in question. It turned out that the maintenance policy had been changed during the period of data collection. Following some renovation, a cautious strategy of preventive maintenance shutdowns had been followed. The maintenance intensity had been gradually relaxed to more steady campaign intervals. In order to make their simulation relevant to the future, the analysts asked the company's technical staff to indicate what maintenance strategy they planned to use in the future. Details of the intended maintenance strategy were used in the simulation model rather than using that derived from the data. Had they not queried the relevance and consistency of the data, the estimates from the simulation model would not have reflected the intended maintenance strategy.

The simulation project involved a large number of daily operational details. A pragmatic approach to the availability of data was essential for completing the simulation study on time. However, even having been provided with masses of data, the analysts still found it necessary to sit down with technical staff and extract further information. In this example, the data were telling only part of the story and, for some purposes, that was enough. But in some cases, the data are telling only part of the story. Confronted with masses of data, many tend to forget to ask themselves whether they have enough or even the right kind of information.

For some purposes, it may be necessary to seek further information from knowledgeable operators and it may be necessary to ignore certain parts of the data. This part of the project was also an essential contribution. Simulation studies usually tackle complex systems that are hard to understand on an intuitive level. If an important input to the simulation model is mishandled, the model may still be validated if the runs ignore the effect of the mishandled input. This can lead to erroneous results when more runs are made in different scenarios. It is imperative that great care be given to the modeling of all inputs to the simulation. As described in this section, this potential fault was avoided because of the close collaboration between the CSIRO analysts and the MIM clients.

5 Conclusions

The Process Development Manager of the company MIM stated that "The SIMAN model of the copper smelter aisle has been used extensively for comparing options for expanding the aisle throughput, and identifying bottlenecks. This is the first model of the aisle with which we feel confident of extrapolating aisle performance". MIM investigated a large number of scenarios. A presentation of the model was made and the animation was shown to the MIM personnel including crane drivers, foremen, engineers and managers. The presentation generated a wide acceptance of the validity and usefulness of the model. The simulation model was used successfully to expand the plant through a major financial investment. The study clearly demonstrated the usefulness of a detailed simulation model for making facilities planning decisions in modern complex manufacturing systems. The stochastic aspect of a real-world large scale simulation using discrete events is very important. Without proper modelling of all random processes, the simulation results can be erroneous.

We mentioned two models, one for environmental modelling which was vital to the simulation and the other an expert opinion elicitation procedure that corrected some maintenance records essential to the validity of the simulation model. A lot of effort was devoted to the simulation programming by Welgama et al. (1996). The authors welcomed the statistical model for AQC shutdowns with enthusiasm, realizing fully that the simulation model would not be effective without a validated AQC shutdowns input into the model. All validations were done in joint work with the MIM managers.

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Khalid Aboura teaches quantitative methods at the College of Business Administration, University of Dammam, Saudi Arabia. Khalid Aboura spent several years involved in academic research at the George Washington University, Washington D.C, U.S.A. He worked as a Research Scientist at the Commonwealth Scientific and Industrial Research Organization of Australia and conducted research at the University of Technology Sydney. Khalid Aboura was a Scientist at the Kuang-Chi Institute of Advanced Technology of Shenzhen, China.

Statistični model zaustavitev zaradi nadzora kakovosti zraka pri proizvodnji bakra: sistem za podporo odločanju

Ozadje: V sredini 1990-ih let je bil razvit sistem za podporo odločanju za proizvodnjo bakra za eno od največjih rudarskih podjetij v Avstraliji. Raziskava je bila izvedena s strani znanstvenikov iz največjega avstralskega raziskovalnega centra in vključuje uporabo simulacije za analizo možnosti za povečanje proizvodnje bakra.
Cilji: Opisan je razvoj statističnega modela zaustavitev zaradi nadzora kakovosti zraka in prikazane so nekatere analize podatkov, izvedene v okviru projekta simulacije. Simulacija, ki je vključevala več modulov in statistični model zaustavitev je bistvenega pomena za veljavnost simulacijskih tekov.
Metoda: uporabili smo statistični model, ki izhaja iz podatkov o dnevnih zastojev za eno leto, in kombinacijo tehnik za ustvarjanje replik podatkov.
Rezultati: Raziskava je zahtevala visoko stopnjo sodelovanja med znanstveniki in rudarsko družbo. Na ta način je bil z uporabo preglednice izdelan vmesnik za vnos ustrezno natančnih ocen v simulacijski sistem.
Zaključek: Okoljske razmere močno vplivajo na poslovanje v proizvodnem obratu bakra. Zato je dober statistični model bistvenega pomena za uspešno simulacijo in podporo odločanju.

Ključne besede: *sistem za podporo odločanju, simulacija, statistični modeliranje*

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Multi-Criteria Assessment of Vegetable Production Business Alternatives

Silvo Pozderec, Martina Bavec, Črtomir Rozman, Jožef Vinčec, Karmen Pažek

University of Maribor, Faculty of Agriculture and Life Sciences, Pivola 10, 2311 Hoče, Slovenia.
Corresponding author: karmen.pazek@um.si

Purpose: Organic and integrated production of vegetables are the two most common production systems in Slovenia. The study analyzed two production systems with different cultures as alternatives with purpose to find the most appropriate variants.
Design/Methodology/Approach: The study based on the development and integration of developed specific technological-economic simulation models for the production of vegetables (salad, growing peppers, salad cucumbers, pickling cucumbers, round and cherry tomato) in greenhouse and multi-criteria decision analysis. The methodology of the study based on the DEX methodology and the analytical hierarchy process (AHP) of organic (ECO) and integrated production (IP) in greenhouse.
Results: The evaluation results show that both cultivation methods of commercially attractive vegetables in greenhouse are variable. In the case of integrated production, the assessment of multi-criteria decision analysis EC and DEXi showed that salad (Donertie F1) proved to be the best possible alternative. In the case of organic production, the multi-criteria analysis assessment of pickling cucumbers (Harmony F1) is the best possible business alternative.
Conclusion: For the further production planning process by decision maker is the ranking with Expert Choice (EC) more useful and precise, while the DEX evaluations are more descriptive.

Keywords: *simulation model; multi-criteria analysis; vegetable; greenhouse*

1 Introduction

Integrated decision support systems and costs studies for the cultivation of commercially attractive vegetables in greenhouse are not sufficiently explored, as can be seen from domestic and foreign literature. The preliminary information about expected costs and returns of the vegetable production in greenhouse is essential for further planning and conducting investments in greenhouses and the production of market-attractive vegetables in greenhouse.

Based on a study of simulation models and the MCDA method carried out by Klajić (2000) and Škraba (2003), it is assumed that simulation modelling combined with MCDA methods could be useful applied for vegetable production decision support. In the field crop production, the modeling of sugar beet and its processing into sugar for purpose of decision support is presented by Rozman et al. (2014). The analysis system dynamics methodology was chosen to model impacts of regional sugar factory investment. Further, the model for decision – making in agriculture is presented by Cardin-Pedrosa and Alvarez-López (2012). The authors explain the process followed to generate the model used as a decision support tool for agricultural production planning in the most agrarian areas in Galicia.

The model includes social, environmental and economic indicators developed using both monographic information and field data. Hayashi (2000) combined in agricultural resource management multi-attribute utility theory and goal programming method for solving multi-objective planning problems. The optimal input use condition in agricultural sector (water irrigation) is evaluating by multi-attribute utility and multi-attribute marginal utility by Gómez-Limón et al. (2004) and Riesgo and Gomez-Limon (2006).

The similar problem is observed by Latinopoulos (2009). Pavlovič et al. (2011) emphasize the support by expert decisions for selection of hybrids in agriculture. The authors expose the amount of available data and the meth-

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ods for describing performance of an individual cultivar. The data summarization process is often the major limitation associated with producers making a good decision. In this way, the AHP can be applied for assessing multifunctional performances of different agricultural systems in a comparative way to other multifunctional economic activities. Parra-López et al. (2007) compare the multifunctional performance of alternative olive growing systems in Andalusia on the basis of the assessments of different groups of experts.

Some examples of using the multi-criteria decision analysis for evaluation or classification of the most suitable sorts or cultivars can be found in literature (Bohanec et al., 2008, Jayakumar and Hari Ganesh, 2012, Mohamed et al., 2012, Dragincic et al., 2015). Hayashi (2000) states that the multi-criteria decision analysis in agriculture helps cope with the multitude of objectives and descriptive comments. Pavlovič et al. (2011) have developed a multifunctional decision making model called DEX-HOP for preliminary hop hybrid assessment. The research was done on common hop (*Humulus lupulus, L.*) since hop significantly contributes to the quality of flavour and aroma in beer. An overview of the use of multi-criteria decision analysis in the field of organic farming can be found in the study by Christensen et al. (2012).

The authors assert that the production and usage of organic products affected the decision problems, characterised by different goals, namely whether the consumer, producer or politician was the main decision maker. Rozman et al. (2013) developed a model of system dynamics for the development of organic farming, which would support the government's decision-making process – a case study in Slovenia. Dragincic et al. (2015) used the methods of Simple Additive Weighting (SAW), AHP and Dong's et al. Cardinal consensus model to study the most appropriate variety of organic table grapes, which would affect the final production performance.

The aim of the study is the development of technologic – simulation model for vegetable production in greenhouse and multi-criteria decision analysis for salad, growing peppers, salad cucumbers, pickling cucumbers, round and cherry tomato production. There are two emphasized goals: development of simulation model (i) and its application in combination with the DEX-i method and Analytical hierarchical process – AHP (Expert Choice (EC) software) on a presented vegetable production in greenhouse (ii). The research question that is followed in the paper is which the most suitable alternative by combining technological-economic simulation modelling and multi-criteria decision analysis in the cultivation of vegetables in greenhouse.

2 Methodology

The essential concept of our study refers to the economics of integrated and organic production of six types of market-attractive vegetables (salad, growing peppers, salad cucumbers, pickling cucumbers, round and cherry tomato) in greenhouse. For this purpose, the first research phase included the development of individual technological-economic simulation models with pertaining calculations of total costs.

These were practically acquired from the inventory of individual phases of the technological process of integrated and organic production of market-attractive vegetables in greenhouse. We are referring to the so called computer assisted deterministic technological-economic simulation models (Tamubula and Sinden, 2000). Multi-parameter decision-making, which is based on the decomposition of the main issue into smaller issues, was selected for the evaluation of production systems. The model is based on the DEX methodology (Bohanec et al., 2013) and the AHP analytical hierarchy process of organic and integrated vegetable production. The observed hierarchical problem structure include four main aspects, i.e criterion (the economic, developmental, technological and environmental criterion) which have an important effect on the individual vegetable production system in greenhouse.

2.1 The development of technological-economic simulation models

For the purposes an integrated technological-economic deterministic simulation model that assesses the economic feasibility of production (Figure 1) were developed. The system comprises of interrelated mathematical-functional relations between technological and economic variables.

By using designed individual models, the computer program calculates the technological parameters of a specific production, which forms the basis of the technological map. By calculating the total costs, data is automatically collected in a single developed simulation model and mathematical equations are performed which calculate specific economic parameters (revenues, financial result, break-even price and break-even point of production, cost price and the economic coefficient) depending on different input parameters (various inputs, prices, fertilizers, various products, areas, percentage of loss etc.). Model evaluated parameters represent the input data for the second phase of research work; development of a multi-criteria decision model based on the DEX method and the AHP analytical-hierarchy process of organic and integrated production of vegetables in greenhouse.

2.2 Multi-criteria decision model

The DEX and AHP method are based on the process of restructuring an issue into smaller and less challenging sub-issues; that is it is based on the decomposition of the

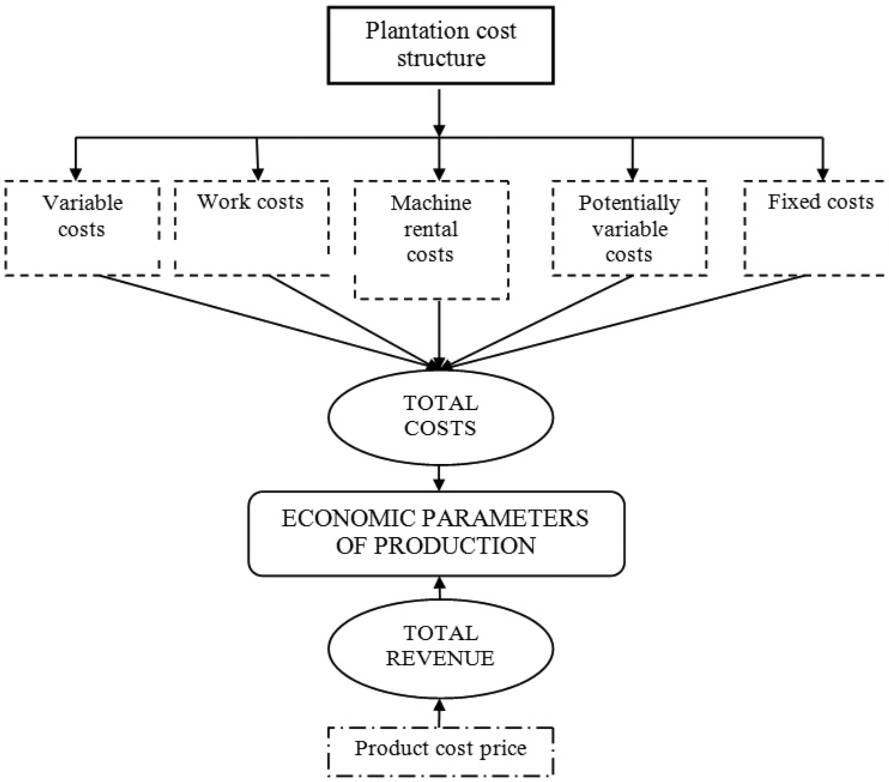

Figure 1: The structure of the developed simulation model

main issue in the form of a hierarchy, where the structure of hierarchy is identical in both models. The differences between methods occur in measurement scales and in the methods of combining the criteria into the final result. The main issue is structured as a hierarchy, while the sub-issues or the interim concepts are illustrated with variables which we interconnect with a structure.

The decision model for integrated and organic production of market-attractive vegetables in greenhouse is comprised of four main criteria on the primarily level and thirteen sub-criteria on the secondary level. The design of the decision model included a classical manual approach. The hierarchy of the decision model for integrated and organic production of six market-attractive vegetables in greenhouse is shown in Figure 2.

3 Results and discussion

3.1 Results of the simulation model for integrated and organic vegetable production in greenhouse

The simulation model was developed on the basis of technological-economic data collected during the individual phases of the technological process of integrated and organic vegetable production in greenhouse. The model analysis has been performed in a greenhouse of one hectare for each individual vegetable. The calculation of individual parameters have been performed with the Microsoft Office Excel 2007 package which represents an electronic table that enables editing, automatic calculation and analysis of data.

Using the developed specific model the computer program calculates the technological parameters of production which form the basis for the technological map with calculations of total costs (Figure 3). The developed model collects input data and performs mathematical equations which determine specific economic parameters (revenue, economic result, break-even price and point of production and the economic coefficient) depending on different input parameters (various inputs, prices, fertilizers, various products, areas, percentage of loss, etc.). All prices collected and included in the models are retail and wholesale prices with value added tax (VAT). To calculate the results we first had to gather the costs that occur during the year in the production of vegetables grown in an integrated and organic manner in greenhouse.
The total revenue was calculated by multiplying the expected amount of produce of each individual production with the sales price of the product that was set according to realistic expectations.

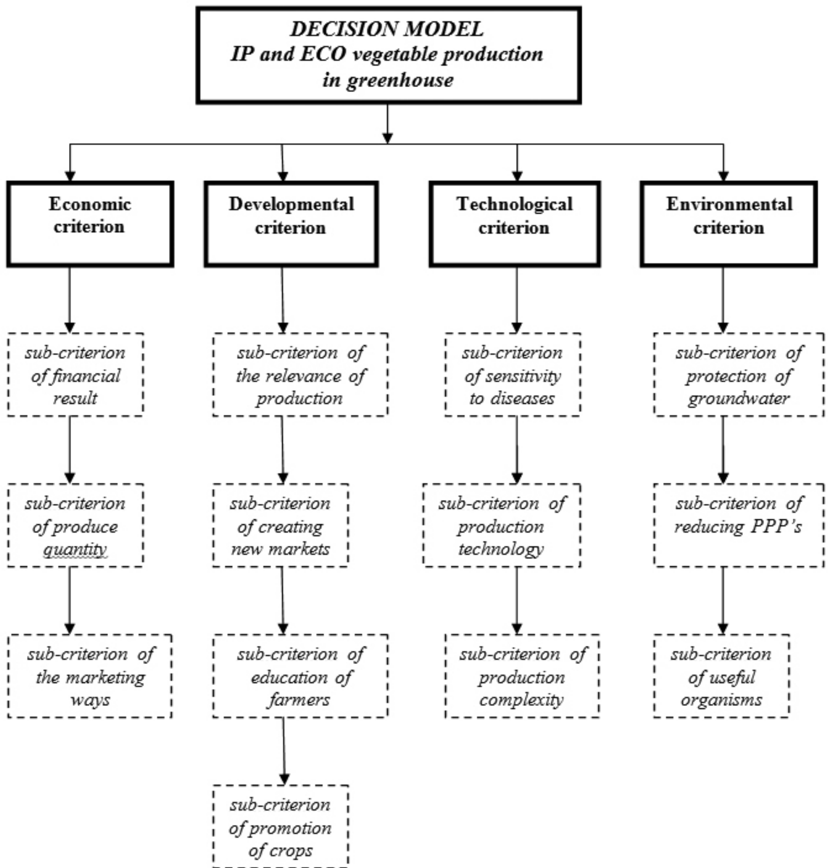

Figure 2: The hierarchy of the decision model for integrated and organic production of six market-attractive vegetables in greenhouse

3.1.1 Economic analysis of integrated vegetable production

In presented case the produced vegetables (growing peppers – *Bianca F1*, salad cucumbers – *Darina F1*, pickling tcucumbers – *Harmony F1*, round tomato – *Amaneta F1*, cherry tomato – *Sakura F1* and salad – *Donertie F1*) were grown in five greenhouses. The production has taken place on five hectares (greenhouse 1/1 ha, greenhouse 2/1 ha, greenhouse 3/1 ha, greenhouse 4/1 ha, greenhouse 5/1 ha). The integrated production has been carried out according to the Rules on integrated production of vegetables (MKGP, 2010).

As seen in Table 1, from economical point of view is the most suitable production of pickling cucumbers, followed by production of cherry and round tomato. Based on gained economic analysis is expected that ranking using both multi-criteria tool will be the same.

3.1.2 Economic analysis of organic vegetable production

Organic vegetables (growing peppers – *Vedrana F1*, salad cucumbers – *Dinero F1*, pickling cucumbers – *Harmony F1*, round tomato – *Rally F1*, cherry tomato – *Sakura F1* and salad – *Noisette F1*) were grown in five green houses. The production takes place on five hectares (greenhouse 1/1 ha, greenhouse 2/1 ha, greenhouse 3/1 ha, greenhouse 4/1 ha, greenhouse 5/1 ha). The organic production is carried out according to the Rules on organic production and processing of agricultural products and/or foods (MKGP, 2014).

Compared to integrated production the economy coefficients by organic vegetable production are lower. The ranking of business alternatives is not equal (Table 1 and 2). Salad cucumbers and cherry tomato assess the same value of economy coefficient. The reason are higher sale price and quantity production in integrated production. Production of salad is in both observed alternatives on the last place (relationship between sale and break – even

C	D	E	F
Salad cucumbers (produce ca. 300.000 kg/ha)			
Darina F1 (80x40) / 1 heap			
Costs	**Quantity**	**Price/unit**	**Total**
Variable costs			
Plants (piece)	24.000	0,24	5.760
Protective foil (kg)	580	2	1.160
Irrigation tubing T-tape (piece)	5	160	800
Ties for hanging plants (kg)	200	2,5	500
Clips for attaching (piece)	24.000	0,024	576
Packaging (piece)	40.000	0,75	30.000
Labels (piece)	40.000	0,009	360
Lime (kg)	2000	0,07	140
Organic 3:3:3 (kg)	700	0,225	158
Multicomp base 14:11:23+Me (kg)	350	0,77	270
Polyfeed 11:44:11+Me (kg)	350	1,4	490
Polyfeed 16:8:32+Me (kg)	200	1,5	300
Polyfeed 21:11:21+Me (kg)	200	1,5	300
Calciogreen 0:0:0:34 (kg)	250	8,2	2.050
Multi Ca 15:0:0:21 (kg)	1170	0,38	445
Multi K 13:0:46 (kg)	1000	1,2	1.200
Kendal (l)	28	13	364
Actiwave (l)	35	10	350
Megafol (l)	10	8	80
Bumblebees (piece)	5	100	500
Soil analysis	1	150	150
Protective means		500	500
Total			**46.451,60 €**

H	I	J	K	L	M
Produce	**300.000**	**kg/ha**			
Gross product	300.000	kg/ha			
Loss	0,00%				
Net product	300.000	kg			
Farmland	1	ha			
Sales price	0,55	€/kg			
COSTS			**€ / unit**	**Quantity /ha**	**€ / ha**
Variable costs					
Plants (piece)			0,24	24.000	5.760
Protective foil (kg)			2	580	1.160
Irrigation tubing T-tape (piece)			160	5	800
Ties for hanging plants (kg)			2,5	200	500
Clips for attaching (piece)			0,024	24.000	576
Packaging (piece)			0,75	40.000	30.000
Labels (piece)			0,009	40.000	360
Fertilizers					5.352
Protective means					500
Biostimulator					794
Other material costs					650
Work costs					
- hired manual work					34.096
Contractual work					6.300
Potentially variable costs					44.500
Fixed costs and annual amortisation					7.807

GROWING PEPPERS (IP) | **SALAD CUCUMBERS (IP)** | PICKLING CUCUMBERS (IP) | CHERRY TOMATO (IP) | ROUND TOMATO (IP) | SALAD (IP)

Figure 3: An excerpt from the calculation model for the integrated production of salad cucumbers in greenhouse

Table 1: The economic analysis of integrated vegetable production

	Expected produce (t/ha)	Sales price (€/kg)	Total cost (€)	Revenue (€)	Financial result (€)	Break-even price of production (€/kg)	Break-even point of production (kg)	Cost price with subsidy (€/kg)	Economy coefficient
Growing peppers	150	0,85	106.219	127.500	21.281	0,71	124.963	0,71	1,20
Salad cucumbers	300	0,55	139.155	165.000	25.845	0,46	253.009	0,46	1,19
Pickling cucumbers	150	0,90	77.620	135.000	57.380	0,52	86.244	0,52	1,74
Cherry tomato	170	1,15	128.282	195.500	67.218	0,75	111.549	0,76	1,52
Round tomato	250	0,65	127.528	162.500	34.972	0,51	196.196	0,51	1,27
Salad	60	0,90	46.266	54.000	7.734	0,77	51.407	0,78	1,17

Table 2: The economic analysis of organic vegetable production

	Expected produce (t/ha)	Sales price (€/kg)	Total cost (€)	Revenue (€)	Financial result (€)	Break-even price of production (€/kg)	Break-even point of production (kg)	Cost price with subsidy (€/kg)	Economy coefficient
Growing peppers	110	1,00	101.178	110.000	8.822	0,92	101.178	0,93	1,09
Salad cucumbers	200	0,75	122.768	150.000	27.232	0,61	163.691	0,62	1,22
Pickling cucumbers	90	1,50	100.606	135.000	34.394	1,12	67.071	1,13	1,34
Cherry tomato	120	1,20	118.137	144.000	25.863	0,98	98.447	0,99	1,22
Round tomato	150	0,90	114.106	135.000	20.894	0,76	126.784	0,77	1,18
Salad	35	1,20	40.202	42.000	1.798	1,15	33.502	1,18	1,04

price). In the next chapter it is explained and presented the assessments of primary criteria and secondary sub-criteria of the developed multi-criteria decision model DEX and the AHP of individual vegetable productions alternatives in greenhouse.

3.2 Results of the DEX multi-criteria model

3.2.1 Results of the DEX multi-criteria model for integrated vegetable production

According to the primary level of hierarchy of the DEX multi-criteria decision model, the assessment of integrated vegetable production in greenhouses demonstrated that the best rated criterion was the "developmental criteria" (evaluated as *excellent*) and the "economic criteria" (evaluated as *excellent*) in the production of round tomatoes, and the "technological criteria" (evaluated as *excellent*) in the production of salad. The worst assessment was given to the "developmental criteria" (evaluated as *bad*) in the production of pickling cucumbers (Table 3).

The final multi-criteria assessment of integrated vegetable production in greenhouse (Table 3) demonstrates that the production of growing peppers, salad cucumbers, cherry tomato, round tomato and salad is evaluated as *good*, while the production of pickling cucumbers is rated as *acceptable*.

Table 3: The assessment of integrated vegetable production with the DEXi tool

Option	GROWING PEPPERS	SALAD CUCUMBERS	PICKLING CUCUMBERS	CHERRY TOMATO	ROUND TOMATO	SALAD
ASSESSMENT OF INTEGRATED VEGETABLE PRODUCTION	*good*	*good*	*acceptable*	*good*	*good*	*good*
ECONOMIC CRITERION	average	average	average	average	excellent	average
Financial result of production	average	average	excellent	excellent	excellent	average
Produced quantity	good	high	good	good	high	average
Market ways	average	excellent	average	bad	excellent	average
DEVELOPMENT CRITERION	average	average	bad	average	excellent	excellent
Relevance of production	relevant	potentially interesting	potentially interesting	potentially interesting	very relevant	very relevant
Potential for creating new markets	average	excellent	average	bad	excellent	excellent
Education of farmers	average	average	bad	bad	average	good
Promotion of crops	low	low	low	good	good	good
TECHNOLOGICAL CRITERION	average	average	average	average	average	excellent
Sensitivity to diseases and vermin's	average	average	average	high	low	low
Knowing the production technology	average	average	average	excellent	excellent	excellent
Difficulty of the production technology	high	average	average	high	high	low
ENVIROMENTAL CRITERION	average	average	average	average	average	average
Protection of groundwater	average	average	average	average	average	bad
Reduction of the use phytopharmaceuticals	average	average	average	average	average	high
Possibilities of obtaining useful organism	average	good	good	good	good	bad

3.2.2 Results of the DEX multi-criteria model for organic vegetable production

For organic vegetable production in greenhouses the best rated criteria proved to be the "developmental criteria" (evaluated as *excellent*) in the production of all types of vegetables, "environmental criteria" (evaluated as *good*) in all vegetables except salad and the "economic criteria" (evaluated as *excellent*) in the production of salad cucumbers. The worst assessment was given to the "technological criteria" (evaluated as *bad*) in the production of cherry tomatoes and the "economic criterion" (evaluated as *bad*) in the production of salad (Table 4).

Further, the final assessment of organic vegetable production in greenhouses (Table 4) demonstrated that the production of growing peppers, salad cucumbers, pickling cucumbers and round tomatoes is evaluated as *good*, while the production of cherry tomatoes and salad is evaluated as *acceptable*.

3.3 Results of the AHP multi-criteria model

3.3.1 Results of the AHP multi-criteria model for integrated vegetable production

The final assessment of integrated vegetable production in greenhouse (Figure 3) has demonstrated that the production of salad was evaluated as the best (EC = 0.253), followed by the production of round tomato (EC = 0.220), cherry tomato (EC = 0.163), growing peppers (EC = 0.125), salad cucumbers (EC = 0,121).

As expected from the DEXi model results, the lowest evaluation was given to the production of pickling cucumbers (EC = 0.119).

3.3.2 Results of the AHP multi-criteria model for organic vegetable production

The production of organic pickling cucumbers was evaluated as the best (EC = 0.215), followed by the production of growing peppers (EC = 0.201), round tomato (EC = 0.195), salad (EC = 0.179), salad cucumbers (EC = 0.112). Ats seen in previous figure, the lowest evaluation was given to the production of cherry tomato (EC = 0.098). However, as seen previous results there exist the differences by economical and multi – criteria assessment of vegetable production.

4 Conclusions

For the purposes of our study we have developed an integrated technological-economic deterministic model, enabling the assessment of economic viability of six market-attractive vegetables (salad, growing peppers, salad cucumbers, pickling cucumbers, round and cherry tomato), produced in an integrated and organic manner in greenhouse. To help assess the production of vegetables in greenhouse we have developed a model based on the DEX method and the analytical hierarchy process (AHP) of

Table 4: The assessment of organic vegetable production with the DEXi tool

Option	GROWING PEPPERS	SALAD CUCUMBERS	PICKLING CUCUMBERS	CHERRY TOMATO	ROUND TOMATO	SALAD
ASSESSMENT OF INTEGRATED VEGETABLE PRODUCTION	*good*	*good*	*good*	*acceptable*	*good*	*acceptable*
ECONOMIC CRITERION	average		average	average	average	bad
Financial result of production	average	excellent	excellent	excellent	average	bad
Produced quantity	good	high	good	good	high	low
Market ways	excellent	excellent	excellent	average	excellent	average
DEVELOPMENT CRITERION	excellent	excellent	excellent	excellent	excellent	excellent
Relevance of production	Very relevant	relevant	Very relevant	relevant	Very relevant	relevant
Potential for creating new markets	excellent	average	excellent	average	excellent	average
Education of farmers	good	average	average	average	good	good
Promotion of crops	high	good	high	good	high	good
TECHNOLOGICAL CRITERION	average	average	average	bad	average	average
Sensitivity to diseases and vermin's	average	average	average	high	average	low
Knowing the production technology	average	average	average	average	average	average
Difficulty of the production technology	high	high	high	high	High	average
ENVIROMENTAL CRITERION	good	good	good	good	Good	average
Protection of groundwater	high	high	high	high	high	Good
Reduction of the use phytopharmaceuticals	high	high	high	high	high	High
Possibilities of obtaining useful organism	good	good	good	good	good	average

organic and integrated vegetable production. The assessment results demonstrate that both methods of producing market-attractive vegetables in greenhouse (integrated and organic production) are variable.

In the case of integrated production the multi-criteria decision analysis assessment EC = 0.253 and DEXi evaluation = *good* showed that salad (*Donertie F1*) proved to be the best possible alternative. In the case of organic production the multi-criteria decision analysis assessment EC = 0.215 and DEXi evaluation = *good* showed that pickling cucumbers (*Harmony F1*) are the best alternative. In integrated vegetable production, the worst alternative proved to be the production of pickling cucumbers (*Harmony F1*), which received the multi-criteria decision analysis assessment EC = 0.119 and DEXi evaluation = *acceptable*. In organic production, the worst alternative proved to be cherry tomato (*Sakura F1*), which received the multi-criteria decision analysis assessment EC = 0.098 and DEXi evaluation = *acceptable*. Ranking alternatives (vegetables) with multi-criteria decision models DEX and AHP is basically the same.

Further, unlike the DEXi decision model, where the criteria/sub-criteria are evaluated as the same in different alternatives, the Expert Choice Model also demonstrates more detailed differences in the calculation of total priority of a specific criterion/sub-criterion in individual alternatives. Therefore, ranking individual alternatives by using the AHP multi-criteria model is more accurate and makes it easier for the user to decide on an appropriate alternative. On the other site, the data availability required for used methodological approaches for defined alternatives can be a serious limitation in the planning process. However, the integrated system takes into consideration different independent objectives and enables ranking of different business alternatives. Further research could be made in combinations with the AHP resource allocation theory, where calculated priorities could be used for optimal allocation of business entrepreneurship resources at constrained investments; naturally, the AHP hierarchy should be changed correspondingly. The decision model should be also interrelated to the marketing informatio system (marketing attribute).

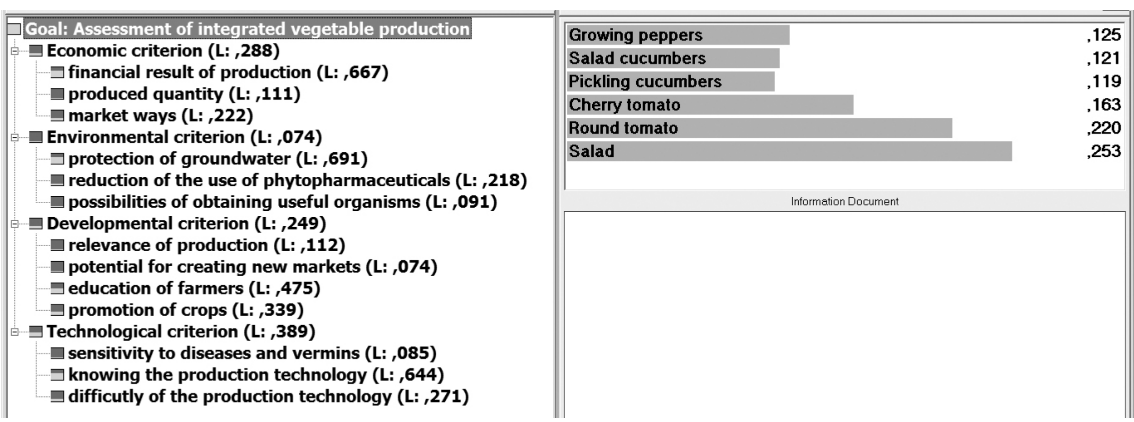

Figure 3: Final assessment of integrated vegetable production with the AHP tool

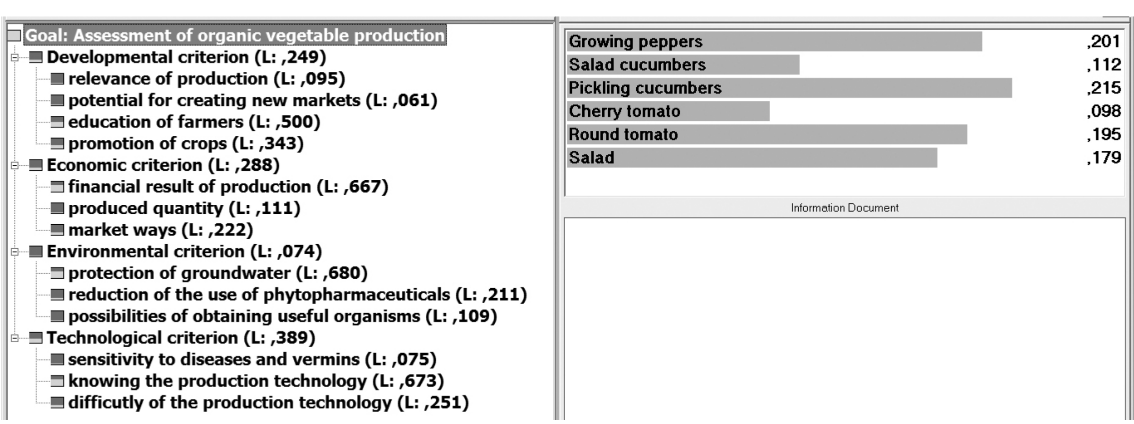

Figure 4: Final assessment of organic vegetable production with the AHP tool

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Silvo Pozderec is a PhD student of Agricultural Economics at Faculty of Agriculture and Life Sciences at University of Maribor. His research priorities are technological-economic simulation modelling and multi-parameter decision modelling in agriculture.

Martina Bavec is full professor of vegetable and field crops and organic agriculture at the University of Maribor, Slovenia. She has been an advisor for vegetable production and organic farming, as well as the main supporter for establishing a national inspection and certification body for organic agriculture. She has led many national and international projects, edited the main national book about organic agriculture, and authored and co-authored 43 research papers, and numerous professional papers. She is a very active presenter of organic agriculture in the community and a key representative of the BSC, MSc, and PhD study programs of organic agriculture at the university where she teaches. She is the co-author of a book »Organic production and Use of Alternative Crops" published by Taylor and Francis CRC Press. From March 2012 to July 2013 she worked on Ministry of Agriculture and the Environment as general Director of Directorate for agriculture being responsible beside daily work also for preparation of draft for Rural development program and decisions basis for pillar I.

Črtomir Rozman achieved his Ph.D. at University of Maribor, Faculty of Agriculture. He is active as Full Professor for Farm management in the Department for Agriculture Economics and Rural Development (Faculty of Agriculture and Life Sciences, University of Maribor). His research includes development of decision support systems for farm management (simulation modeling, multi-criteria decision analysis, machine learning) and economics of agricultural production. He is also involved in teaching activities as Head of Department and as thesis supervisor at post graduate study programs and multiple national and international research projects. He is author or coauthor of 67 scientific papers including 28 papers in journals with impact factor.

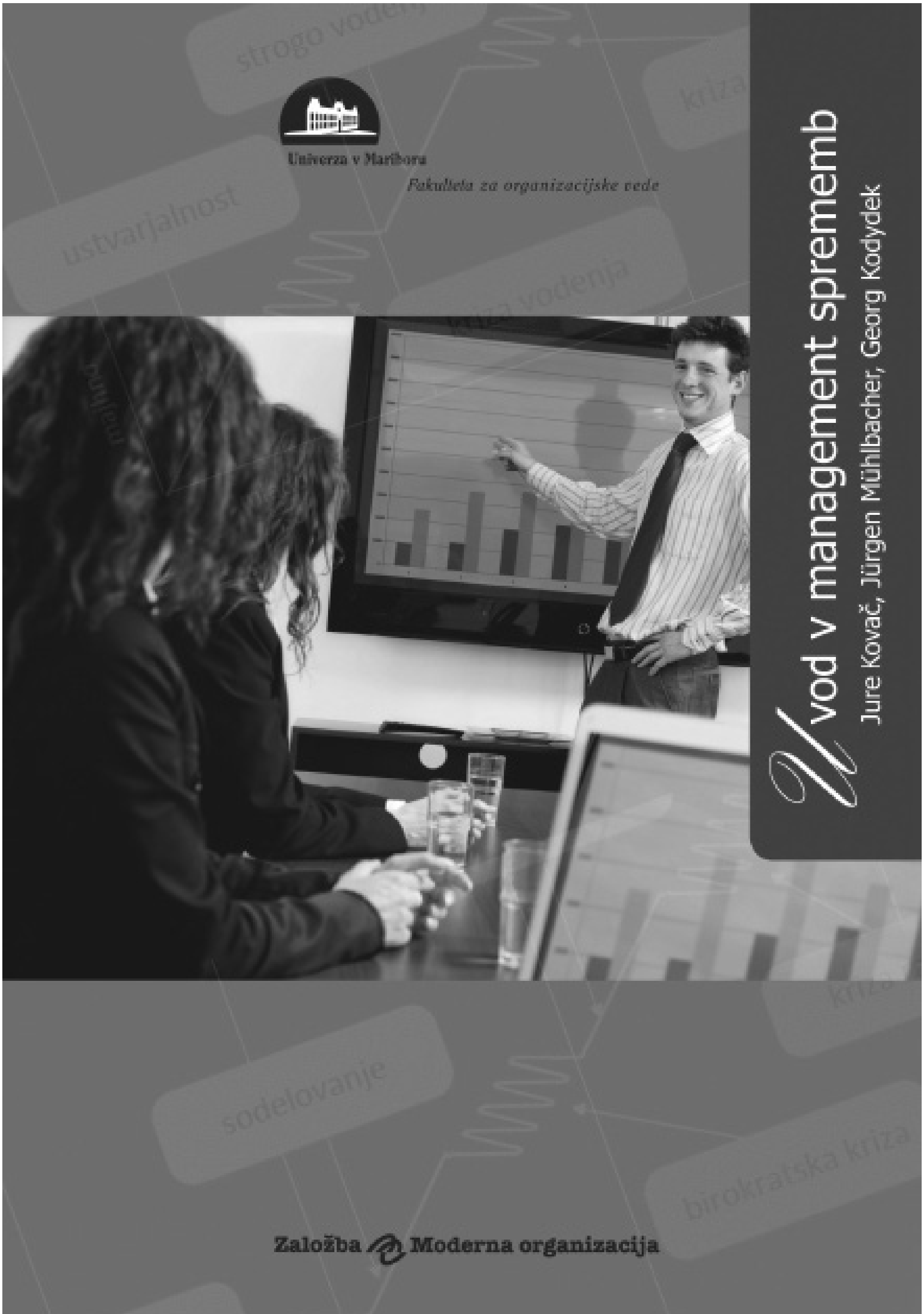
Jožef Vinčec is a PhD student of Agricultural Economics at Faculty of Agriculture and Life Sciences at University of Maribor. His research priorities are Operational research in agriculture and simulation modelling.

Karmen Pažek achieved her Ph.D. at University of Maribor, Faculty of Agriculture in 2006. She is active as Associated Professor for Farm management in the Department for Agriculture Economics and Rural Development on Faculty of Agriculture and Life Sciences, University of Maribor. Her research includes development of decision support tools and systems for farm management (simulation modeling, multi-criteria decision analysis, option models) and economics of agricultural production. She is involved in teaching activities as thesis supervisor at postgraduate study programs and involved in national and international research projects. She is author or coauthor of 45 scientific papers including 20 papers in journals with impact factor.

Več-kriterijska ocena poslovnih alternativ pridelave zelenjave

Namen: V Sloveniji sta ekološki in integriran način pridelave zelenjave med najpomembnejšimi proizvodnimi sistemi. Študija predstavlja analizo dveh proizvodnih sistemov, ki vključujeta pridelavo različnih zelenjadnic. Namen raziskave je več-kriterijska ocena najprimernejše poslovne alternative.
Struktura/Metodologija/Pristop: Raziskava temelji na razvoju in povezavi specifičnih tehnološko-ekonomskih simulacijskih modelov za pridelavo zelenjave (solate, paprike, solatnih kumar, kumar za vlaganje, okroglega paradižnika in grozdastega paradižnika) v zaščitenem prostoru in več-kriterijski odločitveni analizi. Podlaga raziskavi je metodologija DEX in analitični hierarhični proces (AHP) za ekološko (EKO) in integrirano pridelave (IP) omenjenih zelenjadnic.
Rezultati: Rezultati vrednotenja kažejo, da sta za pridelovalca spremenljiva oba načina pridelave tržno zanimivih zelenjadnic v zaščitenem prostoru. Pri integrirani pridelavi se je z oceno večkriterijske odločitvene analize EC in DEXi solata (*Donertie F1*) izkazala za najboljšo možno alternativo. Pri ekološki pridelavi so se kot najboljša možna alternativa izkazale kumare za vlaganje (*Harmony F1*).
Zaključki: Za nosilca odločanja in lažje načrtovanje proizvodnje zelenjadnic v rastlinjaku je tako rangiranje na osnovi EC bolj natančno in koristno kot rangiranje s pomočjo DEXi orodja.

Ključne besede: *simulacijsko modeliranje, več-kriterijska analiza, zelenjava, rastlinjak*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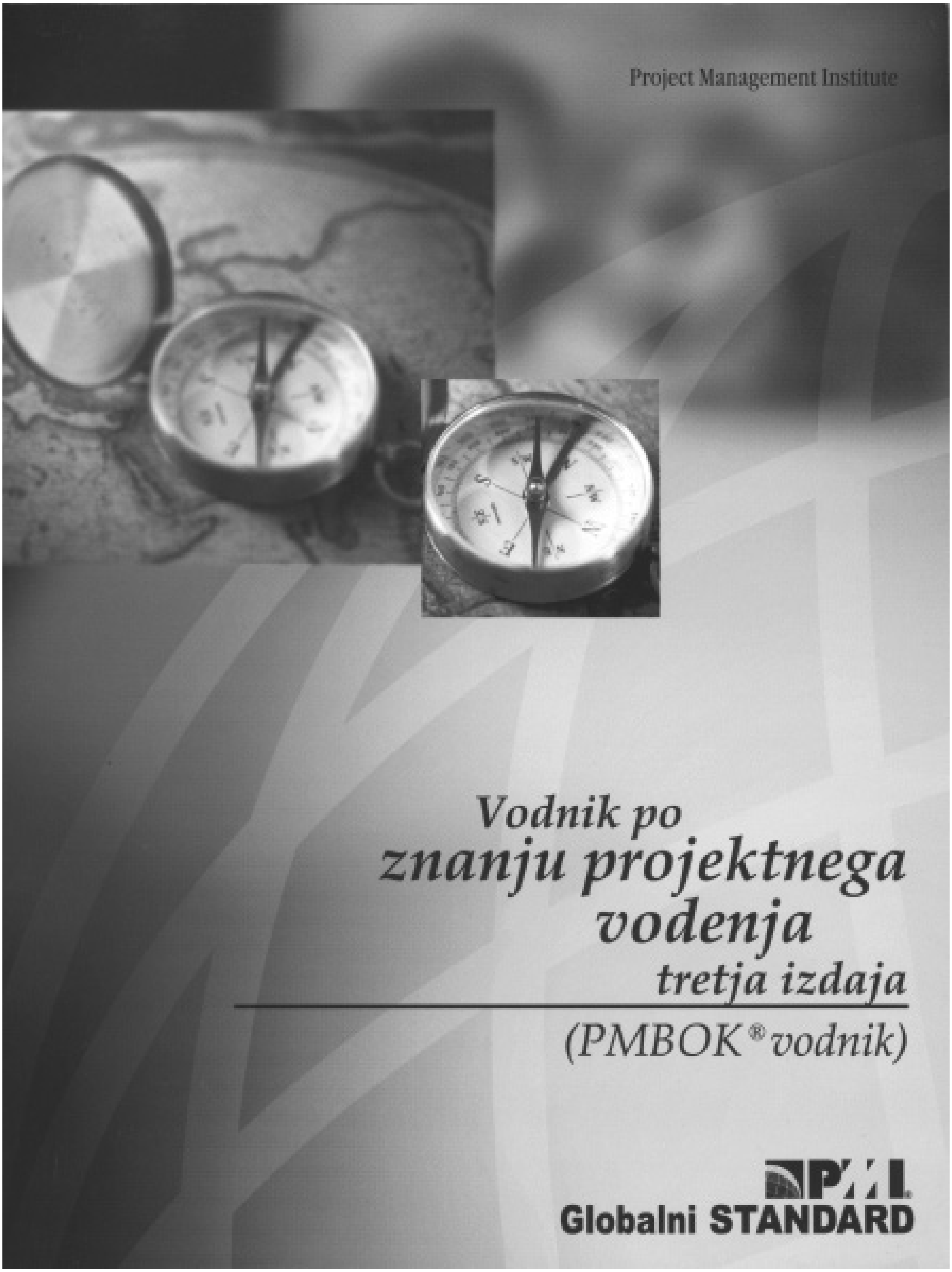
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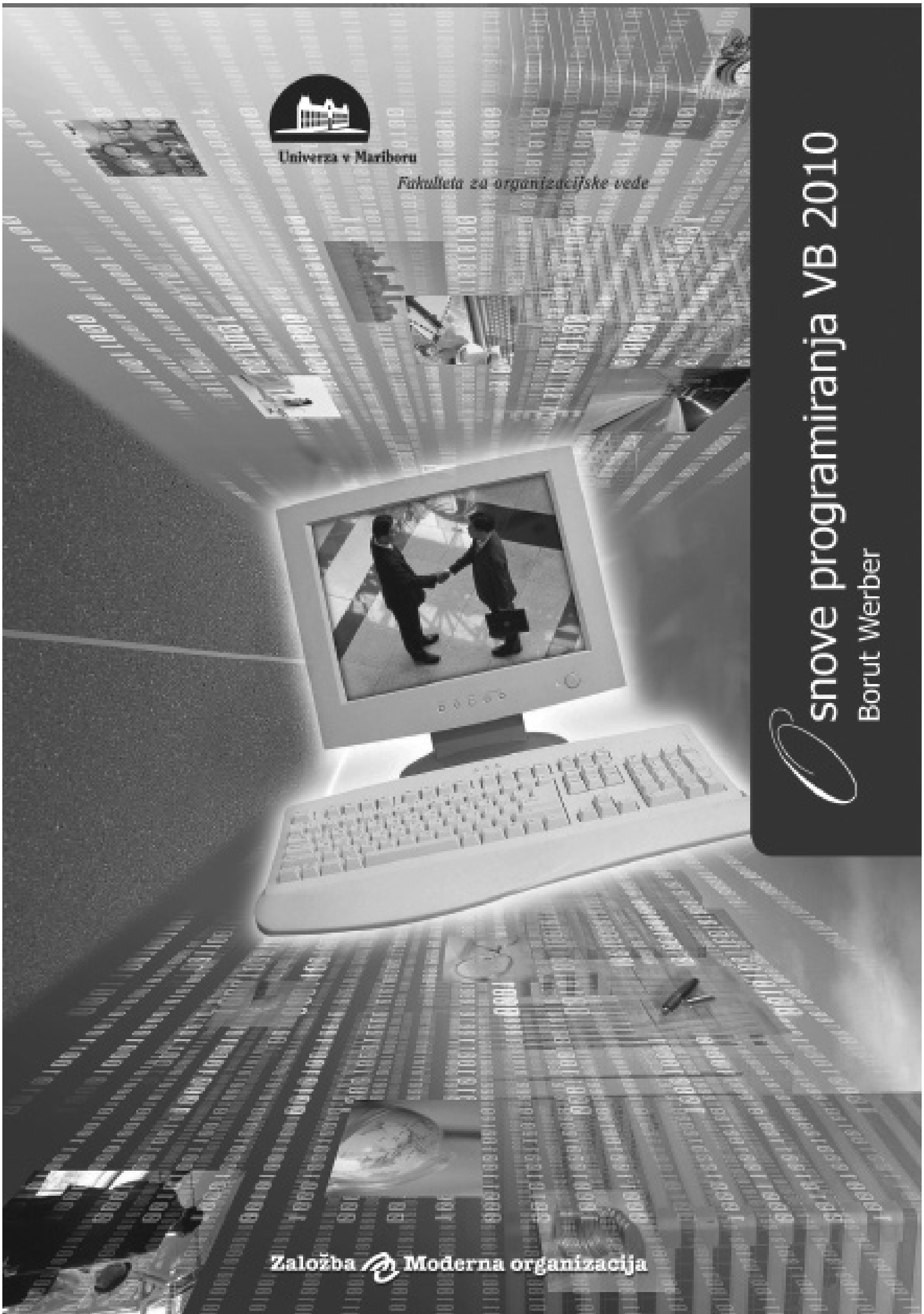
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University of Maribor,
Faculty of Organizational Science
Kidričeva cesta 55a
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Fax: +386-4-2374-299
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Univerza v Mariboru,
Fakulteta za organizacijske vede
Kidričeva cesta 55a
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CONTENTS - 3/2015

Založba Moderna organizacija