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Editorial

In Memoriam Professor Emeritus D.Sc. Miroljub Kljajić

In December 2016 our esteemed colleague, dear friend, mentor, and father, *Professor Emeritus D.Sc. Miroljub Kljajić*, suddenly had passed away. This was a shocking news for all who knew him as a man full of life, creativity, wisdom, humour, and kindness. Sometimes it felt he was greater than the life itself.

Prof Mirojub Kljajić was born on November 4th, 1943 in a little village Vražogrnci in the south of Serbia, then Yugoslavia. His childhood was marked by extreme shortages in the post-war Yugoslavia. At the age of 15, dreaming to become a pilot and being an outstanding student, he was enrolled in the military school, which was the only schooling his family could afford. Harsh childhood experiences marked him for life. He was hard working, strict to himself and his colleagues, and never gave up. His thirst for knowledge, especially in natural and technical sciences, but also profound love for art, drove him to seek possibilities for further studying. After finishing military school, he got his first employment in the army. During that time, and in different cities (Kraljevo, Belgrade, Split, and Pula), he finished the classical gymnasium and enrolled as a part time student at the dislocated unit of Visoka tehniška šola (Hihger Technical School) of Maribor, in Pula. After graduation, he enrolled as a full time student at the Faculty of electrical engineering, University of Ljubljana, while still working at the military airport in Pula. In his last year of studies, he was placed in Ljubljana, graduated and finally demobilized from the military. He started to work as a postgraduate researcher at the Institute Jožef Stefan in Ljubljana, Section for automatics, bio-cybernetics, and robotics. He finished his master studies under supervision of Prof Dr France Bremšak. In 1973, he obtained his PhD in the field of bio-cybernetics, from University of Ljubljana, Faculty of Electrical Engineering, under supervision of academician Prof Dr Lojze Vodovnik.

In 1976, he started to work at the Faculty of Organizational Sciences half time and half time at the Institute Jožef Stefan. Since 2000 he was fully engaged with the Faculty. For many years, he was a chair of the Laboratory for Cybernetics and Decision Support Systems, transferring ideas from the field of automation, cybernetics and robotics to the world of organizational sciences. With his kindness and pedagogical instinct, he attracted and encouraged many excellent young researchers. Besides mentoring many undergraduate and graduate students, he also supervised 10 PhD students. His laboratory was always full of vibrant discussions, ideas, and hard work, sometimes, if needed long into the nights.

During his long and fruitful research years, he has published over 100 original scientific papers, 29 in esteemed journal with impact factor. According to the Web of Science, his work was cited more than 500 times. Prof Miro's research interests were very wide, and reflected his beliefs that topics are interconnected as in a complex system, which he understood on a top level, yet with a full attention to the fine details.

Prof Miroljub Kljajić was recognized by renown international scientific circles, and thus, he has held special symposiums at various international conferences. His most prominent symposium, *Simulation Based Decision Support*, was held in Baden-Baden, Germany, for many years at the InterSymp conference, organized by The International Institute for Advanced Studies in Systems Research and Cybernetics. Lately, he was a member of the editorial team of the journal *Organizacija*, and a co-founder and an editor of the *International Journal of Information Technologies and Systems Approach*. His meticulous research eye was a reason for being a prominent reviewer in renown international scientific journals and conferences.

Having an outstanding scientific background and being a social persona with an exceptional ability to connect people with different backgrounds, he was a founder and a long-time head of the research group "Decision Support Systems in Electronic Business" at the Faculty of Organizational Sciences, University of Maribor. Research group offered supportive environment to outstanding senior and junior researchers and PhD students from the wide area of System approach research to solve complex managerial decision problems in the environment of rapid technological developments and electronic interactions. The wide plethora of research streams, brought together under one umbrella within this research group, describes Miros' personality best.

His main research interest, Simulation Based Decision Support, refers to the research stream originating from cybernetics, where systems can be efficiently managed by information, both feedback and feedforward. Therefore, organizational systems, inherently being complex in their nature, comprising of people, processes and technology, are the focus of this thematic issue. Thus, it is not surprising that this area has attracted scholars from all over the globe and from various fields of research, such as Mathematics, Organizational sciences, Computer Science, Information Systems, Operational Research, etc. Although the research topics presented in this issue are diverse, we believe that they are well balanced and harmonized under a common denominator, the Systems Approach Methodology, which makes this issue innovative and unique.

Prof Miroljub Kljajić has left well-established flourishing research garden where his successors can further develop and build upon his noble ideas. We believe that this thematic issue of Organizacija issue is only the first step.

Guest editors
Mirjana Kljajić Borštnar, Davorin Kofjač, Andrej Škraba, Gerhard-Wilhelm Weber, Andreja Pucihar

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Industry 4.0 and the New Simulation Modelling Paradigm

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Background and Purpose: The aim of this paper is to present the influence of Industry 4.0 on the development of the new simulation modelling paradigm, embodied by the Digital Twin concept, and examine the adoption of the new paradigm via a multiple case study involving real-life R&D cases involving academia and industry.
Design: We introduce the Industry 4.0 paradigm, presents its background, current state of development and its influence on the development of the simulation modelling paradigm. Further, we present the multiple case study methodology and examine several research and development projects involving automated industrial process modelling, presented in recent scientific publications and conclude with lessons learned.
Results: We present the research problems and main results from five individual cases of adoption of the new simulation modelling paradigm. Main lesson learned is that while the new simulation modelling paradigm is being adopted by big companies and SMEs, there are significant differences depending on company size in problems that they face, and the methodologies and technologies they use to overcome the issues.
Conclusion: While the examined cases indicate the acceptance of the new simulation modelling paradigm in the industrial and scientific communities, its adoption in academic environment requires close cooperation with industry partners and diversification of knowledge of researchers in order to build integrated, multi-level models of cyber-physical systems. As shown by the presented cases, lack of tools is not a problem, as the current generation of general purpose simulation modelling tools offers adequate integration options.

Keywords: *simulation and modelling; automated modelling; Industry 4.0; Digital Twin; SME; multiple-case study*

1 Introduction

Simulation modelling is the method of using models of a real or imagined system or a process to better understand or predict the behaviour of the modelled system or process. As an analogue representation, a physical, mathematical or another type of model is constructed. As such, the simulation and modelling is at least as old as the first use of wooden or stone pieces to represent military units in a chess-like game. However, when referring to the history of simulation, we generally refer to the modern era of mathematics-based simulation. The first modern mathematical model and the first documented use of the Monte Carlo method, as it is known today, is generally considered to have originated with the Buffon-Laplace "needle experiment" in 1777. The experiment is to "throw" needles onto a plane with equally spaced parallel lines in order to estimate the value of π (Goldsman, Nance, & Wilson, 2010).

However, the "golden era" of simulation modelling has arrived in the mid-1940s, when two major developments set the stage for the rapid growth of the field of simulation - construction of the first general-purpose electronic computers such as the ENIAC and the work of Stanislaw Ulam, John von Neumann, and others to use the Monte Carlo method on electronic computers in order to solve certain problems in neutron diffusion that arose in the design of the hydrogen bomb (Goldsman, Nance, & Wilson, 2010).

Today, the use of simulation modelling in science and engineering is well established. In engineering, simulation modelling helps reduce costs, shorten development cycles, increase the quality of products and greatly facilitates knowledge management. A great body of scientific and professional body of literature on various aspects of simulation modelling, e.g. system dynamics, cybernetics

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and system theory, is available, from seminal works such as (Forrester, 1961) and (Kljajić, 2002) to newer publications, for example (Law, 2014) and (Borshchev, 2013).

The aim of this paper is to present the developments within the Industry 4.0 and the 4th industrial revolution leading to the new simulation modelling paradigm, embodied by the Digital Twin concept, and verify the adoption of the new simulation modelling paradigm in the industrial and scientific communities via a multiple case study involving real-life cases of the application of Industry 4.0 methods and technologies. The presented cases introduce methodologies and solutions which allow the automation of general purpose / off-the-shelf simulation modelling tools by using ERP/MES (Enterprise Resource Planning, Manufacturing Execution System) data and standards, and the development of Digital Twin based solutions with widely available sensor technologies.

2 Industry 4.0

The »Industry 4.0« term was coined by the German federal government in the context of its High-tech strategy in 2011. It describes the integration of all value-adding business divisions and of the entire value added chain with the aid of digitalisation. In the "factory of the future", information and communication technology (ICT) and automation technology are fully integrated. All subsystems, including R&D as well as sales partners, suppliers, original equipment manufacturers (OEMs) and customers, are networked and consolidated. In other words: all relevant requirements concerning manufacturing and production capacity are already confirmed during product development. The entire process can be holistically considered and managed in real time from the very first step, including seamless quality assurance in production. (KPMG, 2016)

According to KPMG (2016), networking and transparency in manufacturing provide for a paradigm shift from "centralised" to "local" production. Today, manufacturing already works with "embedded systems", which collect and pass on specific data. In the "factory of the future", a central computer coordinates the intelligent networking of all subsystems into a cyber-physical system (CPS), able to work with increasing independence. Through human-machine interfaces, the physical and the virtual worlds nevertheless work closely together: The human operator defines the requirements, while the process management takes place autonomously. The term CPS describes the networking of individual embedded software systems that collect and pass on specific data. A paradigm shift from "centralised" to "local" production thus takes place: a central information system manages intelligent networking while taking into consideration physical factors such as inputting requirements through human-machine interfaces and allows independent process management. The close interaction between the physical and virtual worlds here represents a fundamentally new aspect of the production process. When this is related to production, we talk of cyber-physical production systems (CPPS). Today, the key enabling technologies and development trends in Industry 4.0 include:

- Green IT,
- Big data and analytics,
- Autonomous robots/systems,
- Horizontal and vertical system integration through new standards,
- Cybersecurity,
- Augmented reality,
- The Industrial Internet of Things,
- Additive manufacturing,
- The cloud, and
- Simulation modelling.

The position of SMEs (small and medium-sized enterprises) in Industry 4.0 is of particular concern, as the level of automation in SMEs is typically low and their funds limited. Industry 4.0 presents several challenges and opportunities to SMEs, which account for a significant share of employment and value creation (GTAI, 2016). SMEs stand to benefit from emerging Industry 4.0 networking and integration standards and open standard architectures as many still use older, proprietary systems. This will allow SMEs to drastically reduce production management efforts and respond to market requirements significantly faster. By joining larger networks, SMEs can become temporary production networks with precisely calculated value added contributions. Furthermore, additive manufacturing (3D printing) and flexible machinery allow the production of very small series and personalized products to be produced at unit costs historically only possible in mass production (GTAI, 2016).

2.1 The 4th industrial revolution

According to the visionary work of Schwab (2016), contrary to the previous industrial revolutions, the 4th industrial revolution is evolving at an exponential rather than linear pace and not only changing the 'what' and the 'how' of doing things, but also 'who' we are. We are witnessing profound shifts across all industries, marked by the emergence of new business models (Marolt, Lenart, Maletič, Kljajić Borštnar, & Pucihar, 2016), the disruption of incumbents and the reshaping of production, consumption, transportation and delivery systems. The big upheavals that this revolution brings are the changes in the economies and jobs: by automating processes, certain jobs disappears, but at the same time new jobs are developed, which are better paid, but also require new skills that allow rapid adaptation, entrepreneurship and innovation. The unstoppable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) is forcing companies to re-examine the way they do business. With the development and dissemination of technologies for universal connectivity and autonomous, cyber-physical systems, Industry 4.0 is the driving force behind the 4th Industrial revolution.

While Industry 4.0 is originally a German project, and German government and economy are still the driving force behind it. However, we should keep in mind that Industry 4.0 and the 4th industrial revolution are not a German phenomenon, but are global in nature, as horizontal networking in value chain networks is not limited to just one company or country.

2.2 Development trends in Industry 4.0

Highest levels of Industry 4.0 implementation can be seen in Germany and in multinational technology corporations. Companies such as Siemens, General Electric and Mitsubishi already possess a broad portfolio of production and automation solutions. Manufacturing and automation technology developers such as DMG Mori, Wittenstein, Bosch, Rockwell, Omron, Schneider, Stäubli, Yaskawa, Krones, PSI and Software AG already market many technologies and solutions as "Industry 4.0".

But even without specialized vendors, many of the building blocks necessary for the implementation of Industry 4.0 concepts – including the simulation modelling concepts, are already available, e.g. digital and networkable sensors and control elements (actuators), cloud computing, tablets as human-machine interfaces, integrated software solutions and (industrial) communication networks. New Green IT (Baggia, et al., 2016) power saving technologies allow the construction of large, battery powered, sensor networks. A major deficit, however, is the widespread lack of standards. Many aspects of the technology that is used in Industry 4.0 are already in place, but some areas still require internationally binding standards. Industry 4.0 is currently more of a concept than a reality, and certainly not a product or service that you can buy. This is in part due to the imprecise definition of the term "Industry 4.0" and the exaggerated expectations of customers. What is certain, however, is that Industry 4.0 requires products: industry and management software (e.g. CAD, virtual simulation tools, ERP, MES, PLM), processors (e.g. SCADA, DCS, PLC) and devices (e.g. Ethernet, robotics, RFID, motors and drives, relays, switches, sensors) (KPMG, 2016). These devices require specialist expertise in information and communication technology (ICT) and automation technology, which presents both a challenge and an opportunity to the educators and trainers of the future work force.

3 Modern simulation paradigm

In the past few decades, computer simulation has become an indispensable tool for understanding the dynamics of business systems. Many successful businesses intensively use simulation as an instrument for operational and strategic planning. In the modern simulation paradigm (Kljajić, Bernik, & Škraba, 2000), the connectivity of a simulation model typically involves integration with a static database of business variables, a user friendly front-end and additional decision support tools such as expert systems (ES) or group decision support systems (GDSS). The schematic of such a system is shown in Figure 1.

Simulation has been mostly used to develop standalone solutions with a limited scope and lifetime (Harrell & Hicks, 1998). However, the penetration of computer simulation into various areas of business processes has resulted in the need to connect the simulation models used in different parts of an organization (Kljajić, Bernik,

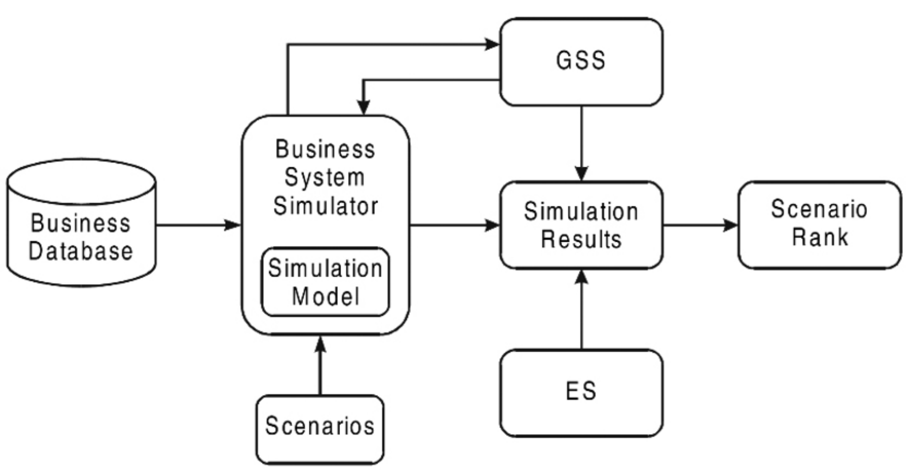

Figure 1: Schematic of a typical simulation modelling based DSS system (Kljajić, Bernik, & Škraba, 2000)

& Škraba, 2000). Also, the trend in simulation development has shifted from purely analytical and optimisation oriented models to integrating simulation models into decision support tools to be used recurrently. For example, by integrating models of various parts of an organization, a joint distributed simulation system can be built to conduct large-scale business system simulations, giving an overview of the modelled organization. This development has brought changes in the requirements for simulation model design. Stand-alone models, accessible only to simulation experts are to be replaced by models that can be connected to various data sources and destinations and controlled or even modified via user-friendly front-ends or other applications (Rodič & Kljajić, 2005).

3.1 The need for a new simulation modelling paradigm

Since the first general engineering applications of in 1960s, simulation modelling has developed from a technology accessible to mathematical and computing experts to a standard tool in an engineer's portfolio, used to solve a range of design and engineering problems. Simulation based decision support tools allow solution development, validation and testing for systems and individual elements of systems, and form the basis of the model-based systems engineering (MBSE) approach.

However, with the increased integration of simulation modelling in the product life cycle management, the user requirements have changed considerably. Increasing product variants and customisable products require more flexible production systems. The advent of the Industry 4.0 paradigm has brought changes to the simulation modelling paradigm as well. The Industry 4.0 paradigm requires modelling of manufacturing and other systems via the virtual factory concept and the use of advanced artificial intelligence (cognitive) for process control, which includes autonomous adjustment to the operation systems (self-organization). The new simulation modelling paradigm is best surmised by the concept of "Digital Twin", which we examine in the following chapters. The concept of Digital Twin extends the use of simulation modelling to all phases of the product life cycle, where the products are first developed and tested in full detail in a virtual environment, and the subsequent phases use the information generated and gathered by the previous product life cycle phases. Combining the real life data with the simulation models from design enables accurate productivity and maintenance predictions based on the realistic data. Table 1 shows the main aspects of the evolving simulation paradigm from 1960s until today.

Due to shortened product development cycles, manufacturers have to move from traditional design processes and practices, that used a "build it and tweak it" approach and must instead take a more systems-design approach that has proven to be an essential part of the design process within the aerospace and automotive industries for many years. Through formal requirements management, and the development of high-fidelity dynamic models used in simulations of the system, manufacturers can validate the design against the requirements in the early stages of the process. The resulting high-fidelity model from this process is typically referred to as the Digital Twin, a concept borrowed from space programs. In space missions, any changes can be fatal, therefore all modifications of a vehicle, probe or rover on a mission, are tested on a detailed simulation model of the system to ensure the change produces the desired effect. (Goossens, 2017)

Currently, automated model development is more common with methods that allow easier and more standardized formal description of models, e.g. Petri nets (Conner, 1990), (Gradišar & Mušič, 2012). Automation of model construction and adaptation can significantly facilitate the development of models of complex systems (Lattner, Bogon, Lorion, & Timm, 2010), (Kannan & Santhi, 2013) and generation of simulation scenarios. Optimisation through modification of model structure can be performed by constructing several versions of the model and input data (i.e. scenarios) and comparing simulation results. To

Table 1: Evolution of simulation modelling paradigm (adapted from (Rosen, von Wichert, Lo, & Bettenhausen, 2015))

Individual application:	**Simulation tools:**	**Simulation-based System Design:**	**Digital Twin Concept:**
Simulation is limited to very specific topics by experts, e.g. mechanics.	Simulation is a standard tool to answer specific design and engineering questions, e.g. fluid dynamics.	Simulation allows a systemic approach to multi-level and multi-disciplinary systems with enhanced range of applications, e.g. model based systems engineering.	Simulation is a core functionality of systems by means of seamless assistance along entire life cycle, e.g. supporting operation and service with direct linkage to operation data.
1960+	**1985+**	**2000+**	**2015+**

accelerate the development of model versions and scenarios one can construct algorithms that build or modify simulation models according to model input data. This is especially useful in cases of large simulation models and if the model variants are prepared by an algorithm, e.g. an optimisation algorithm. Automated model building and modification however requires that the model structure can be modified with an algorithm without manual interventions. (Rodič & Kanduč, 2015)

These three points summarize the main changes to the simulation and modelling paradigm in the change from stand-alone simulation-based decision support system to the Digital Twin:

- Connectivity and integration in a wider IS (manufacturing or enterprise resource planning (MRP, ERP) is the norm,
- The modelled system is modelled with a holistic, multi-level/resolution approach, which includes physical modelling. Several aspects of the simulation model require a high level of details and low level of abstraction,
- Construction and modification of models is automated (data-based) to the highest degree.

4 The Digital Twin: Digital Master and Digital Shadow

Industry 4.0 envisions interlinked and autonomous manufacturing systems self-organizing the production of small batch sizes down to lot size 1. To realize this vision, new design paradigms in manufacturing system design are necessary. A definition of a Digital Twin, proposed by researchers of Fraunhofer IPK and TU Berlin provides a separation of usage data and models for simulation: "A Digital Twin is the digital representation of a unique asset (product, machine, service, product service system or other intangible asset), that alters its properties, condition and behaviour by means of models, information and data". (Stark, Kind, & Neumeyer, 2017)

Today every instance of an individual product or production system produces a "digital shadow", which is the name for the structured collection of data generated by operation and condition data, process data, etc. Hence an instance of a Digital Twin consists of: Digital Master - a unique instance of the universal model of the asset (machine), its individual Digital Shadow and intelligent linking (algorithm, simulation model, correlation, etc.) of the two elements above (Stark, Kind, & Neumeyer, 2017). This is the foundation of a CPPS.

The simulation and validation of complex CPPS with a high amount of CPS will need abstracted behaviour models of systems and sub-systems to avoid long simulation runs. Digital Twins can ensure reliable simulation results, but the design of Digital Master according to their Digital Shadow must be defined first. With help of holistic behaviour modelling, a simulation model for validation of future usage of CPPS is available: the simulation environment can provide the "Digital Master" of the CPPS with the capability to interlink usage data and sensor values. A "Digital Twin" for evaluation of the interaction of a CPPS within an interlinked, autonomous production and linked capability simulation is possible (Stark, Kind, & Neumeyer, 2017).

An important aspect of the Digital Twin concept is the accumulation of knowledge - the information created in every stage of the product lifecycle is stored and made available to the following development stages. This greatly improves the knowledge management aspect of product development.

A high fidelity simulation models - Digital Twin of a process or part of process has several potential uses in an organization (Goossens, 2017):

- An in-line Digital Twin allows an operator to train on a virtual machine until they have the skills and confidence needed to operate the real machine, without the expense of a dedicated training simulator. Using an in-line Digital Twin accelerates the learning process and minimizes the risk of damage to the machine.
- Using optimal control and model-predictive control techniques, combined with advanced machine-learning capabilities, a Digital Twin can also be used to identify potential issues with its real machine counterpart. A high-fidelity physics model running in parallel with the real machine can immediately indicate a potential malfunction in the real machine by detecting a drift between the machine's performance and the behaviour of the model. The information could be used to stop and service the malfunctioning machine or use the model to provide a strategy for compensating for a decrease in performance without slowing or stopping production.
- An embedded Digital Twin would provide the basis for increasing the self-awareness of the machine, allowing it to optimize its own performance for given duty cycles, diagnose and compensate for non-catastrophic faults, and coordinate operation with other machines with minimal input from the operator.

The Digital Twin is the natural result of adopting a system-design approach to product development and can be readily integrated into the final product for training, in-line diagnostics, and performance optimization and beyond. Most industrial automation platforms support the Functional Mock-up Interface (FMI) as a way of integrating a real-time implementation of the Digital Twin so it can be run in-line with the real machine. By using simulation software, engineers can construct a virtual prototype of the machine design, directly from the CAD representation, and integrate it as a Digital Twin on their real-time platform as a Functional Mockup Unit (FMU). (Goossens, 2017)

According to Goossens (2017), the cost to create dynamic models of multi-disciplinary systems has declined considerably over the past few years with the advent of powerful and easy-to use mathematical systems-modelling tools and general purpose modelling tools such as Maplesim, Matlab and Anylogic. Identifying and addressing design issues early in the design process saves huge costs and associated disruption to the project schedule in late-stage design requests, therefore, the return on the up-front costs for tools and expertise to implement this process is very quickly realized. Manufacturers are beginning to implement rigorous systems-design processes that accommodate the complexities of developing multidisciplinary systems, with high-fidelity virtual prototypes, or Digital Twins, at the core of the development process. An example of a Cyber Physical Production System incorporating simulation modelling via Digital Twin is shown in Figure 2.

In such a systems, the business system simulator contains a Digital Twin model of the business process. The Digital Twin is used to supply the array of decision support tools with a detailed, dynamically update digital representation of the real-life business process (e.g. a manufacturing plant). The process data is gathered real-time by the array of sensors and smart machines in the business process, stored in the business database and then transferred to the Digital Shadow. The Digital Master model's operation is adjusted according to the data in the Digital Shadow, allowing on-line optimization and decision support, and control of the process automation, creating a controlling feedback loop, which is the basis of cybernetic systems (Kljajić, 2002).

5 Methodology

To explore the adoption of the new simulation modelling paradigm based on the Digital Twin concept we have conducted an explorative multiple-case study of simulation modelling oriented research projects implementing the Industry 4.0 paradigm. As the adoption of the Industry 4.0 paradigm is slowest among SMEs (GTAI, 2016), we have selected cases aiming to develop Industry 4.0 approaches and methods feasible for implementation within SMEs.

Case study research, through reports of past studies, allows the exploration and understanding of complex issues and can be considered a robust research method particularly when a holistic, in-depth investigation is required (Zainal, 2007). As noted by (Robson, 1993), a case study is the study of an arbitrary contemporary phenomenon or phenomena, with the researcher/s studying not affecting the study subject. Most case studies are qualitative in their nature (Bengtsson, 1999). Multiple case studies can be used in most situations in preference to single case studies to achieve more robust results (Bengtsson, 1999) and strengthen the findings from the entire study (Yin, 2017). The goal of conducting multiple case studies is analytical generalization, not statistical generalization (Robson, 1993). The multiple cases can be used to represent confirmatory cases (i.e., presumed replications of the same phenomenon), and present value beyond the circumstanc-

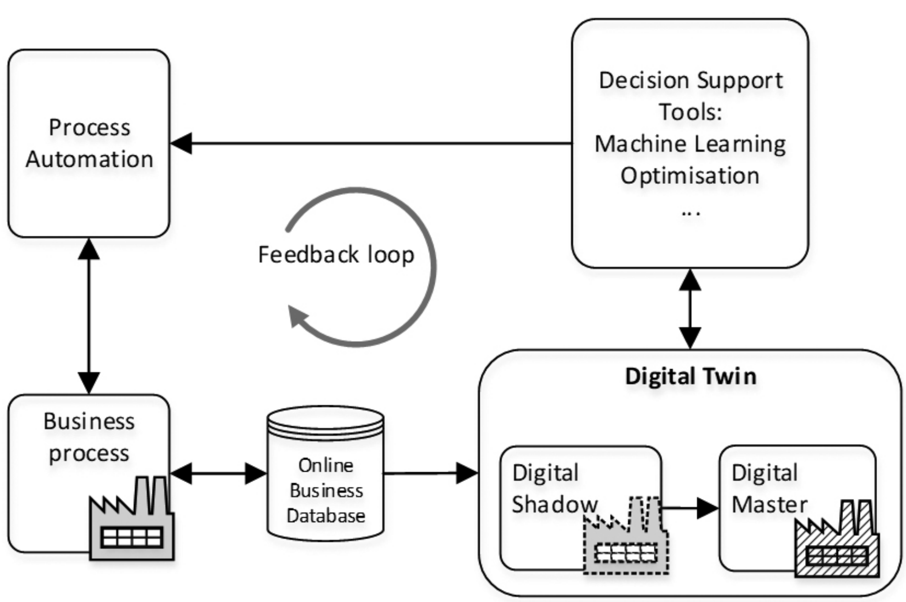

Figure 2: Schematic of a system implementing the new simulation modelling paradigm: a Cyber Physical Production System incorporating the Digital Twin

es of the single case, which can be viewed as unique and idiosyncratic (Yin, 2017). Further recommended reading on case study design includes (Yin, 2017) and (Merriam, 1998).

In this case, we present a holistic multiple-case study, aiming to explore and reason about the global phenomenon: *the new simulation modelling paradigm based on the Digital Twin concept*, and try to draw conclusions about the phenomenon, specifically about *the adoption of the new simulation modelling paradigm within projects for the industry*. In the following sections we present individual cases with focus on the simulation modelling aspect, the summary of the cases in the context of the new simulation paradigm, and the main lessons learned.

6 Cases of the adoption of the new simulation modelling paradigm

Implementing the new simulation modelling paradigm and the Industry 4.0 remains a serious challenge for researchers and companies. There are however novel ways to improve the integration of models built in general purpose simulation modelling tools, automate their construction and modification, and implement such solutions without major financial investments, which is a very attractive prospect especially for the SMEs. In this chapter we will examine multiple real-life cases of the implementation of the new simulation modelling paradigm, ranging from the development of a new methodology for high-level modelling automation to the development of a Digital Twin concept for SMEs.

6.2 Case: Methodology for High-level Modelling Automation

Thiers et al. (2016) describe the results project in a global aerospace company (Boeing), which aimed to improve the design of their production systems by addressing key questions earlier in the product lifecycle. These question have historically required the manual development of several statistical, discrete-event simulation, and optimization analysis models. Statistical, discrete-event simulation, and optimization analysis are capable of answering critically-important questions, but the time, cost, and expertise requirements for their usage in the status quo can be prohibitive for all but the largest companies. The developed solution automates several steps in the construction of these models, while allowing high customisation through the provision of requirements data by users. The company requirement was that the models are generated in commercial off-the-shelf (COTS) tools for automatically-formulated simulation models including Simio and Tecnomatix Plant Simulation. Authors have used the "personal assistant" (PA) user experience paradigm in the manner of Apple Siri/Microsoft Cortana/Google Voice Search in order to make their solution user-friendly and intuitive.

6.1.1 Problem description

The key challenge that authors (Thiers, Graunke, & Christian, 2016) describe was the automation of analysis formulation and solution. In parallel to PAs on mobile devices, answering questions about driving directions is possible because PAs already have detailed knowledge of civilian transportation networks. PAs no knowledge, however, of an arbitrary company's proprietary products, processes, resources, and facilities - and even if they did have access to the company's information systems, those are not complete, nor can commonly function in the required role of an experimental design environment.

There have been attempts automate engineering workflows, following the paradigm of separating system description from system analysis, authoring system descriptions in a presumably-easier way, and then automatically transforming them into the semantics and syntax of a particular analysis language as-needed. The authors however found none of the examined system description languages for productions systems is sufficient, and have decided to devise a way to accommodate a plethora of similar-but-different languages. Further obstacle was the lack of a canonical language for discrete-event simulation analysis. (Thiers, Graunke, & Christian, 2016)

6.1.2 Results

The methodology described by Thiers et al. (2016) places most of the transformation "intelligence" in the model-to-model transformations themselves, but introduces a small step forward by building simulation models to the greatest extent possible using model library blocks which are executable versions of bridging abstraction model elements. To enable the translation of requirements into model structure authors have introduced an intermediary step, called the "Bridging Abstraction Model". The novel modelling automation methodology schematic is shown in Figure 3. The Bridging Abstraction Metamodel is an abstract creation capturing the underlying commonalities shared by all discrete-event logistics systems – manufacturing systems, supply chains, warehousing & distribution systems, transportation & logistics systems, healthcare delivery systems, and more. The Bridging Abstraction Model is introduced to mediate a fundamental tension between concrete and abstract - a System Model should be as concrete as needed for accessibility, the Bridging Abstraction Model should be as abstract as possible for robustness and reusability, and efficacy depends on easily created and maintained mappings between the two. (Thiers, Graunke, & Christian, 2016).

The methodology's novelty is in its methods and tools which address large research challenges exist to make this work for systems engineering (Thiers, Graunke, & Christian, 2016):

- The Bridging Abstraction Metamodel: an explicit, analysis-neutral, and human- and machine readable metamodel which captures the underlying commonalities shared by all discrete-event logistics systems.
- Model-to-model transformations: to transform a System Model to a Bridging Abstraction Model in Figure 3, the mechanism has evolved from UML stereotype application, to declarative specifications in general-purpose transformation languages including QVT and ATL, to a custom model-to-model transformation language and engine.
- Understanding the space of questions about production systems and the analyses capable of answering them: This challenge is intimately related to deep domain knowledge. If and when an implementation of the methodology supports a critical mass of routine feasibility questions, a new challenge will arise - how to make productive use of a "question-answering genie" by asking the right questions. The authors envision that this will require capturing higher-level processes (diagnosis, continuous improvement, design, etc.) and the questions asked during each step of those processes' execution.

Authors (Thiers, Graunke, & Christian, 2016) also present a pilot case of modelling automation methodology use, wherein the developed the proof-of-concept software generates answers to the following engineering questions:

- What is the (expected) (Raw Cycle Time) of a certain (Job)?
- What is the (expected) (Throughput) of regularly executing a certain (Job)?
- What is the (expected) (Throughput) of making certain (Product)/s in a certain (Facility)?
- What is the minimum number of resources needed to support a certain throughput?

6.2 Case: Automated XML model building

This paper's relevance stems from the use of a novel automated DES model construction method, using the customer order data obtained with SQL queries to modify the XML (Extensible Mark-up Language) file containing the simulation model, thus altering the default model structure. The paper presents the methods and results obtained in a manufacturing process optimisation project. Authors used discrete event simulation (DES) to build a model that reflects the current manufacturing processes and allows them to test optimisation methods. Due to the large number of products and their manufacturing processes they have developed an automated model construction method that uses customer order data and manufacturing process database to build an ad-hoc simulation model. The model and method were tested in the optimisation task: reduction of product travel distance through modifications of factory layout, using a novel heuristic optimisation method based on force directed graph drawing. (Rodič & Kanduč, 2015)

6.2.1 Problem description

Construction of a DES simulation model requires that the data that describe the manufacturing processes are obtained, analysed, extracted and prepared in a suitable format for the model. In order to maintain model accuracy despite changes in manufacturing processes, integration of simulation software, auxiliary applications and databases

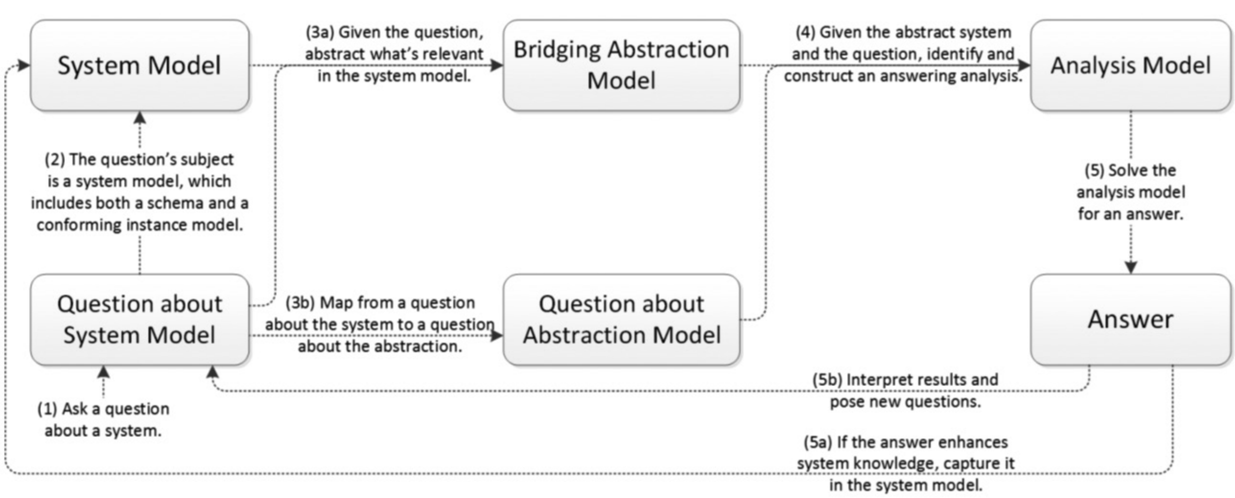

Figure 3: Novel modelling automation methodology described by Thiers et. al (2016)

is necessary. Optimisation through modification of model structure can be performed by constructing several versions of the model and input data (i.e. scenarios) and comparing simulation results. To accelerate the development of model versions and scenarios one can construct algorithms that build or modify simulation models according to model input data. This is especially useful in cases of large simulation models and if the model variants are prepared by an algorithm, e.g. an optimisation algorithm. Automated model building and modification however requires that the model structure can be modified with an algorithm, without manual interventions. (Rodič & Kanduč, 2015)

Developing a static simulation model that would cover all possible (i.e. 30,000) products that may appear in client's orders is not realistic as it takes approximately 15 minutes to complete a model of a process for each product, and a model containing 30.000 process also exceeds the memory limitations of the modelling tool used (Anylogic, http://www.anylogic.com/). Manual modifications of the simulation model can be time consuming, especially if a large set of variations of the model needs to be built. In Anylogic, simulation model is typically constructed by adding different blocks and connections to the canvas by "click and drag" technique. Instead, a method for ad-hoc model construction for each set of open orders was developed. The method works by modifying the XML file containing the Anylogic model. (Rodič & Kanduč, 2015)

6.2.2 Results

As orders change continuously, authors have developed a method and application in Java that automatically builds the model from a model template, the database of technical procedures and the database of currently open orders. Based on the list of ordered products and technical procedures only the necessary machines are placed in the model. Anylogic stores the models as standard XML files, which allows easy manual or algorithmic modifications of the model. Anylogic XML simulation model file stores information on standard and user-defined blocks and agents, connectors between blocks, statistical monitors, input readers, output writers, etc. The data are stored as elements (nodes) and nested in a tree-like structure. An element can contain several attributes, describing type of the element and all the parameters describing element properties. The attributes can contain several lines of programming code describing how the block operates in different situations and states. (Rodič & Kanduč, 2015)

The developed Java application manipulates XML code to change data on machines and all other relevant abstract objects such as connectors, sources and sinks that are connected to the blocks of machines. Specifically, the Java application reads the blocks in the template file and copies them according to input data. A new element (block) is added to the model by the following procedure:

- find a node representing a template block in XML tree according to the searched attributes,
- copy the node and connect it to the parent of the original node,
- change the data of the copied block (name of the block, position on the canvas, properties of the block, part of the programming code, etc.).

The resulting XML structure is then saved to a new Anylogic file. Products and carts play a role of transactions in DES and are therefore constructed dynamically during simulation. The resulting modelling and simulation system, shown in Figure 4 is composed of four main elements

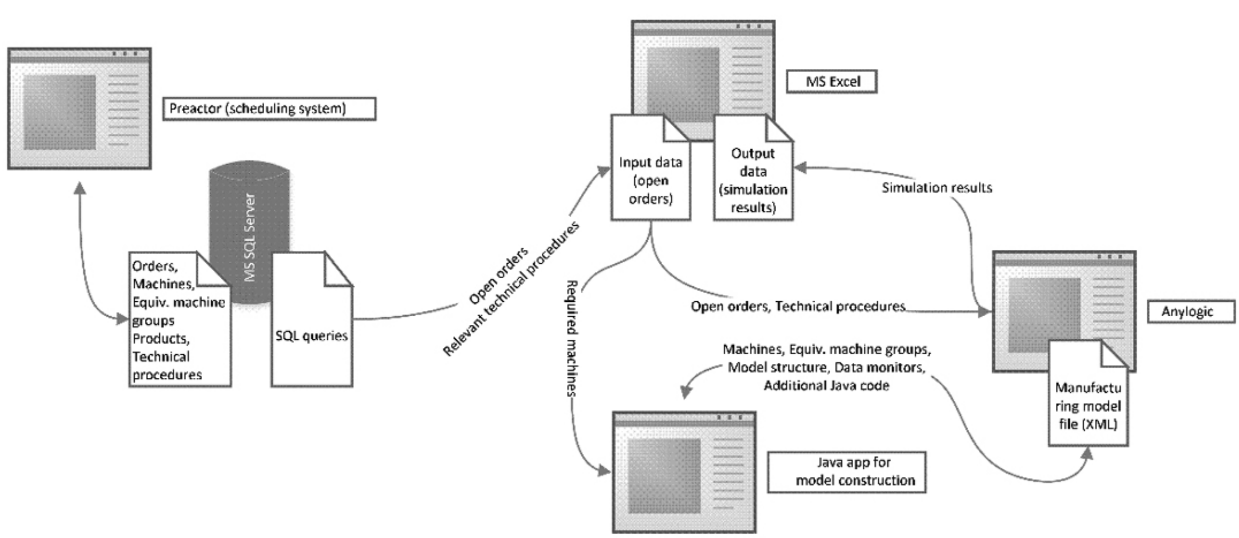

Figure 4: Schematics of a system implementing automated DES modelling (Rodič & Kanduč, 2015)

(Rodič & Kanduč, 2015):

- Core manufacturing process simulation model in Anylogic environment. Layout of the machines and paths was generated from the AutoCAD model of the factory.
- Java application that constructs XML Anylogic model from a template file.
- MS Excel as an intermediate input and output data storage, and analysis tool. MS SQL server database describing technical procedures and client's orders.

6.3 Case: ERP Data-driven Automated Modelling

Kirchhof (2016) describes a practical case in which entire simulation models of a complex and large scale automotive flow shop production are automatically created from an automotive company's SAP ERP and MES systems in order to support operational planning purposes and reduce operational logistical risks.

6.3.1 Problem description

Automatic model generation, the consequential reduction of problem solving cycles and the need for a higher degree of data integration have long been characterized as significant challenges in the field of simulation of manufacturing systems. Especially operationally used manufacturing simulation models re-quire a high degree of modelling detail and thus depend on a significant amount of input data. In many cases, the time and effort required to manually build such a detailed model and keeping it up-to-date are prohibitive. Automatic and on-demand generation of entire simulation models from company data sources would significantly increase the applicability of simulation for operational planning purposes. (Kirchhof, 2016)

6.3.2 Results

In the automotive industry lean production principles are widely implemented, obliging companies to balance cost saving inventory reduction activities and operational risks, such as stock-out situations at the manufacturing line. The purpose of the described simulation model is to act as an early-warning-system and detect potential stock-out situations before they occur so that counter-measures can be assessed and initiated. Therefore, the scope of the model covers the entire in-house logistics processes of the company from the parts retrieval in the warehouse to the consumption at the manufacturing line. (Kirchhof, 2016)

A generic flow shop simulation model template capturing the company's specifics was developed using the SIMIO simulation modelling tool. To enable modelling automation, a custom built extension to SIMIO was developed, that allows modification of a blank model by placing specific instances of the modelling elements according to input data. Extension can generate entire flow shop models by automatically placing, connecting and parameterizing the predefined model objects within the model. The data required to generate the model is extracted from the company's SAP and MES system using a custom built data extractor software which directly retrieves the relevant data from the respective system's databases. The SAP system provides the information to model the manufacturing line, such as details about workstations, routings, bills of materials, shift plans, manufacturing orders, stock levels, material master data etc. The MES system provides detailed information about production sequences and the current and planned production progress per workstation and manufacturing order. The resulting simulation solution is fully integrated into the operational planning process and the IT architecture of the company, and helps planning personnel of the company to prevent logistical problems and production disruptions. Due to the automation of modelling the problem solving cycle is significantly reduced compared to the manual method. The presented approach is suitable for large-scale models with a high degree of modelling detail. (Kirchhof, 2016)

6.4 Case: Standards based virtual factory modelling

Jain and Lechevalier (2016) describe the method and proof of concept for automatic generation of virtual factory models using manufacturing configuration data based on data standard formats such as XML. The virtual factory in this context represents a high fidelity, multi-level simulation. Modelling and simulation has been identified as the key to the advancement of manufacturing by a number initiatives, such as smart manufacturing and Industry 4.0 have identified. Proposals include the use of simulation at multiple levels within manufacturing, with heterogeneous models ranging from physics-based models of the manufacturing process at a very detailed level to DES and SD based high level supply chain models. The method proposed by authors (Jain & Lechevalier, 2016) is aimed at automated construction of a comprehensive, high detail virtual factory model, i.e. a Digital Twin.

6.4.1 Problem description

Currently the development of a Digital Twin requires considerable resources and expertise, limiting the accessibility to bigger companies to the disadvantage of SMEs. Automatic, data-based model generation has the potential to reduce the expertise requirement and thus facilitate the increased use of simulation. The proposed method augments the existing automation solutions by proposing the use of standard data formats for input data describing the subject manufacturing system and widening the generated model scope to a virtual factory model as defined with multi-resolution capabilities rather than the single level model. (Jain & Lechevalier, 2016)

6.4.2 Results

The proof of concept implementation of the method uses Anylogic as the simulation modelling tool, with multi-level modelling implemented by using Java code for the process model, agent based modelling (ABM) to model the machine level, and DES models for the cell/process chain level, similar concept as described in (Rodič & Kanduč, 2015). Integration of different modelling methods is achieved through native capabilities of the Anylogic tool, resulting in a hybrid model. Hybrid modelling has been historically achieved by connecting the models via middleware solutions (Rodič & Kljajić, 2005). The schematic of the proposed method is shown in Figure 5.

The operation of the proposed automatic generation approach is described below (Jain & Lechevalier, 2016):

1. read the manufacturing system configuration data via an interface supporting in a standard format,
2. read in machine parameter and process level data,
3. assemble the factory or cell level logic network based on the input process plans data,
4. link the factory or cell level logic network to individual machine and corresponding process,
5. generate the model using the corresponding models available in the library,
6. render the layout of the facility based on the information from the configuration data with links to the logic network,
7. execute the model with selected parameters such as resolution level and output formats selected by users via run-time interaction.

The data-based modelling interface uses data in CMSD format, which is based on XML. A Java parser has been developed to go through a CMSD file for the machine shop and collect the information required to automatically build the corresponding virtual factory model. The author's (Jain & Lechevalier, 2016) objective is to automatically generate a virtual factory model, using data from the real factory in applicable standard formats, with the capability of generating output data streams based on other applicable standards formats. The automatic generation of the virtual factory model is intended to go beyond the previous efforts involving automatic generation of single level factory simulations by generating a multi-resolution model and using standard formats of input files.

6.5 Case: A Digital Twin for SMEs

Uhlemann et al. (2017) present a concept for the realization of a Digital Twin of the production system within SMEs. Their concept is feasible by assuring sufficient data quality with minimized investment costs, and without compromising the advantages of the Digital Twin and of the CPPS. Their concept contains the proposal for database structure and guidelines for the implementation of the Digital Twin in production systems in SMEs. The further concept of the Digital Twin for a production process enables a coupling of the production system with its digital equivalent as a base for an optimization with a minimized delay between the time of data acquisition and the creation of the Digital Twin. This allows the construction of a cyber-physical production system, opening up powerful applications. To ensure a maximum concordance of the cyber-physical process with its real-life model, a multimodal data acquisition and evaluation has to be conducted.

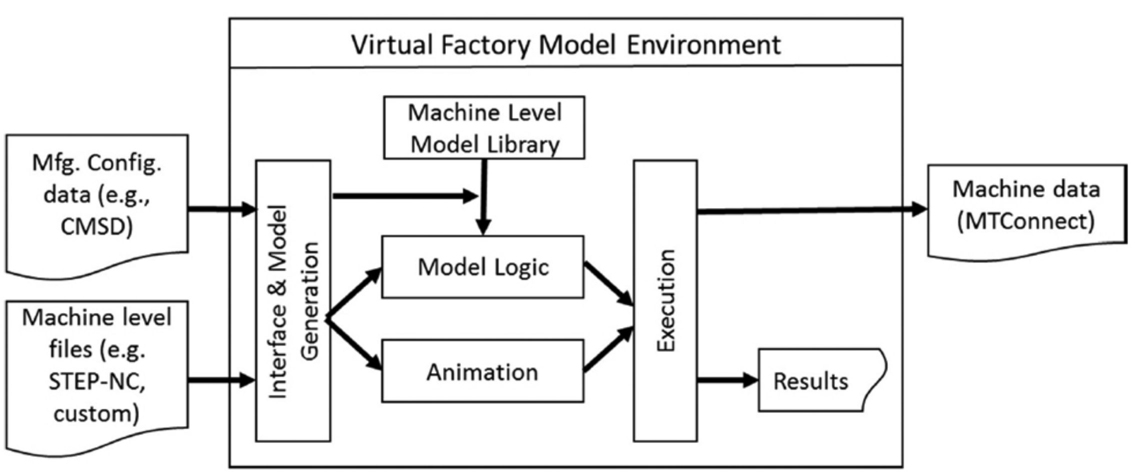

Figure 5: Standard data format based modelling automation system schematic (Jain & Lechevalier, 2016)

6.5.1 Problem description

In recent years, Industry 4.0 is one of the most prevalent subjects in production engineering. However, methods of Industry 4.0 are currently still under-represented within manufacturing operations. Authors furthermore describe the following difficulties in the course of the realization of the Digital Twin as an essential precondition of a CPPS (Uhlemann, Lehmann, & Steinhilper, 2017):

- manual acquisition of motion data is widely used, though in conflict with necessary real-time availability,
- manual acquisition of motion data snapshots limits the potential of simulation,
- combined with decentralized data acquisition, a central information system is required ,
- in-house implementation of Industry 4.0 concepts is frequently insufficient,
- slow standardization of data acquisition in productions systems hinders agile and adaptable system implementations,
- standardization of data acquisitions has not yet been achieved,
- high costs for new IT-environments inhibit the application of vertical Industry 4.0,
- coupling of simulation and optimization is not sufficiently ensured to take full advantage of near real-time models, and
- data security concerns.

The acquisition of motion data combined with data on employee activity as well as position and use of production machines forms a great potential for the realization of a CPPS. Especially in SMEs, which generally have a low degree of automation, existing time-dependent position data sources and databases are not sufficient. A comprehensive image of the production system can only be achieved if additional information of movements of employees and means of production are considered. A comprehensive image of the reality within a production system therefore can only be achieved through a multi-modal data acquisition, similarly to the procedures in modern self-driving automobiles. (Uhlemann, Lehmann, & Steinhilper, 2017)

6.5.2 Results

As the database of production data in SME is extremely heterogeneous and its quality regularly insufficient for the realization of the Digital Twin, the authors (Uhlemann, Lehmann, & Steinhilper, 2017) introduce sensor based tracking and machine vision for manufacturing process data acquisition. Sensor-based tracking provides information regarding routes and position of production employees and routes and position of large and highly mobile production devices, e.g. forklifts. The required technologies, i.e. sensor-based tracking systems and extensive program libraries for the machine vision implementation are commercially available, and therefore the implementation of the proposed concept is feasible. Sensor-based tracking is to provide information regarding routes and position of production employees and routes and position of large and highly mobile production devices, e.g. forklifts, while the image recognition enables detection and identification of types of products at the production and smaller machines.

Authors (Uhlemann, Lehmann, & Steinhilper, 2017) propose the next step as the development of a virtual production system, which generates data following the real production system with the two implemented data acquisition technologies. Based upon this, the data layer and the information and optimization section are constructed and verified trough testing. In the last step, the data acquisition hardware is implemented into a real model process and linked with the data layer. This forms the final and major step within the realization of the CPPS in SME as part of the presented concept. The schematic of the proposed Digital Twin concept is shown in Figure 6.

The described concept is novel in comparison to approaches prevalent in large enterprises, which focus on full automation. Automated gathering of machine data is not considered, as the low degree of digitalisation of manufacturing in SMEs data does not allow it. Furthermore, the collection of detailed machine data is not required with the presented concept. The innovative aspect of the concept is in the integration of well adopted and commercially available components, which are already available as isolated solutions. (Uhlemann, Lehmann, & Steinhilper, 2017)

7 Conclusion

7.1 Lessons learned

In this chapter we summarize the main conclusions and lessons learned from the presented multiple-case study. From the examined cases we can conclude, that while the new simulation modelling paradigm and the Digital Twin concept are being adopted by large and small companies, there are significant differences in problems that they face, and the methodologies and technologies they use to overcome the issues. The large players in airspace (Thiers, Graunke, & Christian, 2016) and automotive industries (Kirchhof, 2016) are concerned with the development of standardized methodologies and architectures that would allow integration within their R&D processes and existing ERP and MES solutions, and the purchase or development of automation technologies is not presented as problem, probably due to large available resources, the SMEs are more focused on using economical, off-the-shelf simulation modelling tools (e.g. Anylogic) and commercially available sensors to build proprietary automation

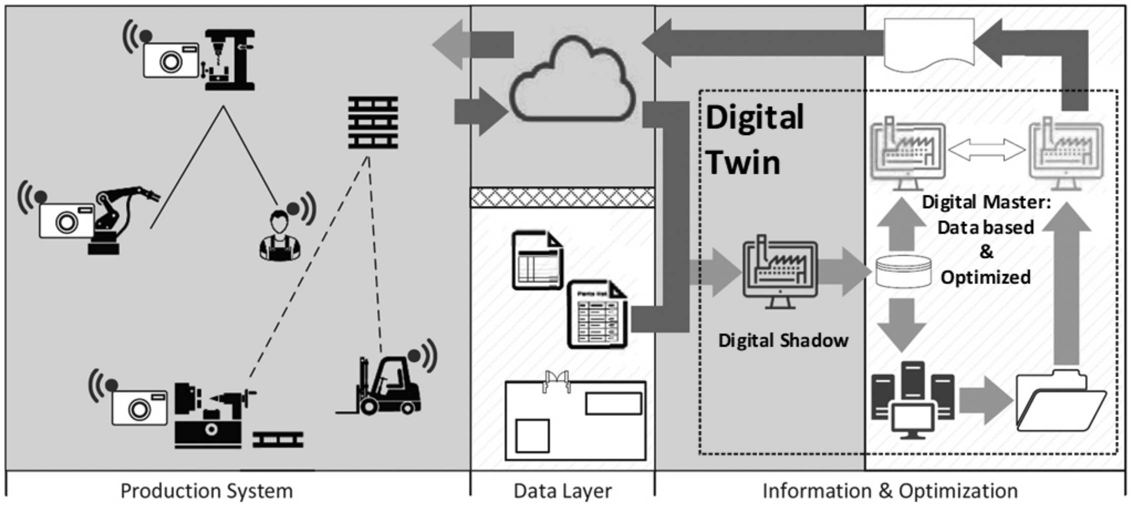

Figure 6: Concept of the CPPS through the Digital Twin in SMEs - adapted from (Uhlemann, Lehmann, & Steinhilper, 2017)

solutions, which would allow them to implement selected Industry 4.0 concepts, in order to remain a competitive supplier to their (larger) business partners.

Even when companies are not consciously implementing the Industry 4.0 paradigm, the pressure from their competitors or partners will require them to do so. The motivation for using the new simulation modelling paradigm concepts such as online automated modelling and database integration can originate from the demands of modelling a modern, diversified manufacturing process. In (Rodič & Kanduč, 2015), data based automated model building was the only option to construct the model of the manufacturing process for any given set of orders in an acceptable amount of time. On the other hand, even the largest companies like Boeing are stimulated by the promise of large-scale cost reduction and design process acceleration to invest in development of new methodologies allowing automation of simulation modelling and customization of products early in the product lifecycle (Thiers, Graunke, & Christian, 2016). Automotive industry is known as an early adopter of Industry 4.0 concepts, however many aspects like ERP and MES integration still lack standardization (Kirchhof, 2016).

7.2 Discussion

Currently, methods of Industry 4.0 are under-represented within manufacturing operations. This is, on one side, based on non-uniform definitions of Industry 4.0, an issue that current publications counteract against. On the other side, common difficulties as non-existing standards, uncertainties regarding the economic benefits while facing the requirement of sometimes considerable investments. Within a 2015 German Mechanical Engineering Industry Association (VDMA) survey, only 10% of those surveyed stated to have implemented comprehensive acquisition of process and machine data. Only a third applied the gained data in a feedback based production control system. Especially the low degree of automation in SMEs reveals a great requirement for alternative approaches for the realization of CPPS. (Uhlemann, Lehmann, & Steinhilper, 2017)

The research presented in this paper includes novel solutions, that allow researchers and engineers to develop solutions that automate the model generation and solution seeking aspects of simulation based decision support and engineering systems. Presented methodologies and solution allow the automation of general purpose / off-the-shelf simulation modelling tools by using ERP/MES data and standards, and the development of Industry 4.0 automation solutions using the Digital Twin concept with widely available sensor technologies. Design-to-production transition is a complex business process, and the described research results supports that process by enabling designers to appreciate production consequences of design decisions much earlier in a program's design cycle than is possible today (Thiers, Graunke, & Christian, 2016).

An unanswered challenge for the multi-level modelling is model validation, which can prove to be a challenge for automatically built models, especially for multi-level models. Each simulation model has to be validated carefully including the impact of intrinsic and extrinsic uncertainties. All the physics-based process models have to be validated against real machine processes and their ranges of applicability defined. A one level of such a model depends on the outputs of another, the multi-level model results in stacking of validity uncertainties across the multiple levels. The impact of stacking of uncertainties needs to be understood and quantified before the virtual factory and other multi-resolution models can be used to support decision making in industry. (Jain & Lechevalier, 2016)

The adoption of new simulation modelling paradigm in research environment requires closer cooperation with industry partners, and diversification of knowledge of researchers, in order to build integrated, multi-level models of systems. As shown by the presented cases, lack of tools is not a problem, as the current generation of general purpose simulation modelling tools offer sufficient integration options. Furthermore, a number of solutions have been developed for automatic generation of simulation models corresponding to manufacturing systems, with a good overview of solutions presented in Barlas and Heavey (2016). As the multi-level modelling requires the integration of model built using different methodologies and tools, the Industry 4.0 and Digital Twin concept present researchers with a new motivation for closer cooperation and transfer of knowledge between research groups and institutes.

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Industrija 4.0 in nova paradigma simulacije in modeliranja

Ozadje in namen: Namen tega prispevka je predstaviti vpliv Industrije 4.0 na razvoj nove paradigme modeliranja in simulacije, ki jo pooseblja koncept »Digital Twin«, in preučiti razširjanje nove paradigme v okviru študije več primerov raziskav in razvoja, ki vključujejo akademsko in industrijsko panogo.
Zasnova: V prvem delu predstavimo paradigmo Industrija 4.0 in njeno ozadje, trenutno stanje razvoja in njen vpliv na razvoj nove paradigme modeliranja in simulacije. Nadalje predstavimo metodologijo študije primerov in več primerov raziskav in razvoja, ki vključujejo avtomatizirano modeliranje industrijskih procesov, predstavljenih v novejših znanstvenih publikacijah in zaključimo s predstavitvijo ugotovitev naše študije.
Rezultati: Predstavimo raziskovalne probleme in glavne rezultate petih posameznih primerov implementacije nove paradigme modeliranja in simulacije. Naša glavna ugotovitev je, da medtem ko tako velika kot mala podjetja sledijo novi paradigmi modeliranja in simulacije, obstajajo velike razlike med njimi, in sicer pri težavah, s katerimi se soočajo, ter metodologiji in tehnologiji, ki ju uporabljajo za premagovanje teh težav.
Zaključek: Čeprav obravnavani primeri kažejo, da industrija in znanstvena skupnost sprejemata novo paradigmo modeliranja in simulacije, njeno uveljavljanje v akademskem okolju zahteva tesno sodelovanje z industrijskimi partnerji in diverzifikacijo znanja raziskovalcev, da bi lahko razvijali integrirane, večplastne modele kiber-fizičnih sistemov. Kot je razvidno iz predstavljenih primerov, pomanjkanje orodij ni problem, saj že sedanja generacija splošnih simulacijskih orodij ponuja ustrezne možnosti integracije.

Ključne besede: *simulacija in modeliranje; avtomatizirano modeliranje; Industrija 4.0; »Digital Twin«; MSP; študija primerov*

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Systems Approach to Tourism: A Methodology for Defining Complex Tourism System

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Background and Purpose: The complexity of the tourism system, as well as modelling in a frame of system dynamics, will be discussed in this paper. The phaenomenon of tourism, which possesses the typical properties of global and local organisations, will be presented as an open complex system with all its elements, and an optimal methodology to explain the relations among them. The approach we want to present is due to its transparency an excellent tool for searching systems solutions and serves also as a strategic decision-making assessment. We will present systems complexity and develop three models of a complex tourism system: the first one will present tourism as an open complex system with its elements, which operate inside of a tourism market area. The elements of this system present subsystems, which relations and interdependencies will be explained with two models: causal-loop diagram and a simulation model in frame of systems dynamics.
Design/methodology/approach: Systems methodology will be shown as the appropriate one, when we discuss complex systems challenges. For illustration, systems approach and systems methodology will be applied to tourism models. With building a qualitative causal-loop diagram we will describe the tourism system complexity in forms of system's elements relations. Mutual influences among the elements will be presented with positive and negative loops, which forms circles of reinforcement and balance. This will help us to discuss the problem categorically. The final model will follow the causal-loop diagram. This will be a simulation model in a frame of system dynamics as an illustration of the discussed methodology.
Results: The methodology offers the solution of effective and holistic promotion of complex tourism system transformation, which has the potential to go beyond the myth of sustainable tourism and create significant shifts in the approach and acting of the participants (elements of the system) involved. Systems approach brings to tourism and the society, in general, broader dimensions of thinking, the awareness interdependency, interconnectivity, and responsibility for the behaviour of a system, which can be observed by feedback loops.
Conclusions: Findings about meaningfulness of systems thinking presented in the paper, are rarely presented to tourism society systemically and with the aim of designing sustainable complex tourism system. They show new approach, systems awareness and teaches thinking "out of the box". Consequently, the sustainable behaviour is achieved: tourism supply and demand meet on responsible base and they connect to responsible stakeholders.

Keywords: *systems approach; complexity; tourism system; modelling; system dynamics*

1 Introduction

The system was an axiom for a whole composed from parts in human philosophical history and ancient civilisations (Mayan civilisation lived according to systems principles). Contemporary systems theory has been recognized as an important part of world science and research when biologist Ludwig von Bertalanffy published his book on General System Theory (Bertalanffy, 1952). Systems theory was adopted by many scientists from other fields of science than biology (Boulding, 1956). As a methodology for complex phenomena research, nowadays systems theory plays an important role in different fields of scientific

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research. The systems we research can be simple, complicated or complex. Simple systems are linear and have predictable interactions, consist only of few components, are repeatable and decomposable, Complicated systems have many components, separated cause and effect over time and space. They have something in common with simple systems: they are also repeatable, decomposable but also analysable (Baggio, 2008). Complex systems do not have predictable reactions, cannot be decomposed, they have nonlinear interactions, high sensitivity to initial conditions, they are dynamic, adaptable to the environment and produce emergent structures and behaviours, and can become chaotic. They are usually understood intuitively, as a phenomenon consisting of a large number of elements, which "nest" in each other. The word "complex" is used only to point out the fact that the problem treated here cannot be expressed only in hard (quantitative) relations and that most relevant values are qualitative (Jere Lazanski, Kljajić, 2006).

The complex system is a system of the systems, which exchange energy and information with their environment while in transit, inflected by internal and external influences. Simple and complicated systems are hard systems (technical), whereas soft systems (organisations) are complex. Tourism systems are soft, organisational systems and among its subsystems e.g. supply, demand, intermediaries, tourists, information, as well as psychological, social, material, financial, and energetic relations exist. They are goal oriented systems and their development depends on interactions that have among themselves, activities, and behaviour.

Following Einstein's thought on a problem, which can only be solved from the higher level of consciousness and not from the same that created a problem, we can say that, complex systems have complex problems and only appropriate methodology can solve these problems. Methodology for complex systems problem solving was mentioned in the past in many works such as: *Viable Systems* (Beer, 1959), *Industrial Dynamics* (Forester, 1961) *The Tree of Knowledge* (Maturana and Varela, 1973), *Living Systems* (Miller, 1978), *Anticipatory Systems* (Rosen, 1985), *The Fifth Discipline: The Art and Practice of the Learning Organization* (Senge, 1994), *Business Dynamics: Systems Thinking and modelling for a Complex World* (Sterman 2000), *Systems Engineering: A 21st Century Systems Methodology* (Hitchins, 2007), *Thinking in Systems: A Primer* (Meadows, 2008), as well as others.

Critical thinking, soft analysis and dialectical theory of system were described in (Roosenhead, 1989 and Mulej 1992). Systems methodology used for solving tourism problems has been discussed in many articles in the last twenty years as well as in last years (Buchta and Dolničar, 2003, Lagiewski, 2005, Jere Jakulin and Kljajić, 2006, Jere Jakulin, 2016). When we talk about a tourism system, we cannot avoid complexity. So, the complexity will also be discussed and described together with its symptoms. To properly describe a complex tourism system, we will create three models. A model of an open complex tourism system, which will serve as a base of causal loop diagram (CLD) or so called qualitative diagram, which is an aid for discussing problem categorically. Finally, we will build a simulation model in a frame of systems dynamics (SD), which is a quantitative complement to causal loop diagram. The methodology will show its appropriateness for complex tourism system strategy planning and problem solving.

2 Systems Complexity

Like all systems, the complex system is an interlocking structure of feedback loops. This loop structure surrounds all decisions public or private, conscious or unconscious. The processes of man and nature, of psychology and physics, of medicine and engineering all fall within this structure. (Jay W. Forrester)

Complexity has been discussed in several scientific areas. Complexity theory in social sciences was discussed in (McMaster, 1996, Stacey, 1996, Rosenhead, 1989a, 1998). In a complex system, the interaction among components of the system, and the interaction between the system and its environment, are of such a nature that the system as a whole cannot be fully understood simply by analysing its components (Cilliers, 1999). Systems nest in each other, which represent elements of a larger system being systems themselves. Complex systems are affected by the environment. At the same time, they affect the same environment, which means that they are dynamic and change over time. Their behaviour is sometimes predictable and sometimes cannot be predicted. They change in a regular manner, e.g. solar system, and other systems lack the stability e.g. a tourist in the middle of the airport strike, the impact with an air transport, which stops due to the strike. Symptoms of complexity which can be noticed in a system were defined by Baggio (Baggio, 2008) and Cilliers (Cilliers, 1998).

Table 1 shows symptoms of complexity as Baggio and Cilliers approached them. Non-determinism says that it is impossible to anticipate precisely the behaviour of a complex (adaptive) systems because the behaviour depends strongly on the initial conditions is and appears to be extremely sensitive; the only predictions that can be made are probabilistic. Positive and negative feedback loops influence the overall behaviour of the system. Distributed natured represent a distributed system where many properties and functions cannot be precisely localized. Next, the system evolves, increasing its complexity up to the next self-organization process. One effect of such a characteristic is the capability to show a good degree of robustness to external (or internal) shocks. At the critical points of instability, the system will reorganize through feedback mechanisms. The self-similarity is evidence of possible

Table 1: Symptoms of a complexity (Source: Jere Jakulin, 2017)

Cilliers	Baggio
A large number of elements form the system	Nondeterminism
Interactions among the elements are nonlinear and usually have a somewhat short range	Presence of feedback cycles
There are loops in the interactions	Distributed nature
Complex systems are usually open and their state is far from equilibrium	Emergence and self-organization
Complex systems have a history, the "future" behaviour depends on the past one	Self-similarity
Each element reacts only to information that is available to it locally.	Limited decomposability.

internal complex dynamics of a system. The system considered will look like itself on a different scale, if made smaller or magnified in a suitable way. The last symptom of complexity is limited decomposability, which tells that it is impossible to study the properties of a dynamic structure by decomposing it into functionally stable parts (Jere Jakulin, 2017). Cilliers describes even more symptoms such as history

3 Complex Tourism System

It is always possible to break up a complicated system into separate entities and study them individually, being sure that the final object will be the (linear) composition of them (Procaccia, 1988).

If we talk about technical systems that are composed of many elements, we talk about complicated systems. Talking about the tourism system we must have in mind interactions of all elements in the tourism market: tourism supply and demand, intermediaries, tourism support institutions, transit regions, tourist flows, and environment influences. To maintain sustainability of complex tourism system or developed tourism areas the tourism policymakers must take fast and integrated decisions. Figure 1 represents tourism as a complex system from a system's points of view. Boundaries in real tourism system are permeable. We can say that complex tourism system is an open system. This openness is shown in Fig. 1 by dashed lines, and it means that the behaviour of the tourism system can be understood only in the context of its environment (Gharajedaghi, 2006).

Internal elements of the system are tourism market area, tourism demand and supply, supporting institutions, intermediaries, tourists' flows. The environment, which influences the tourism system as a whole at once as the tourism system influences the environment, presents the external part of the system. Figure 1 holds basic elements of a tourism system and is a support for building causal loop diagram (CLD), which in continuation describes mode of relationships among elements of the tourism system.

4 Qualitative Modelling with Causal Loop Diagram (CLD)

I suggest that complex systems can be modelled. The models could be computationally implemented, and may lead to machines that can perform more complex tasks. The models themselves, however, will have to be at least as complex as the systems they model, and may therefore not result in any simplification of our understanding of the system itself. (Cilliers, 1999)

Building of a tourism system qualitative model requires some procedure, knowledge, to identify the elements of the systems and theory to find the relationship between the elements. We can also say that, modelling represents the activity to describe one's experiences by using one of the existing languages in the framework of a certain theory. Tourism has seen only a very few attempts at using modelling techniques in simulating the behaviour (Walker, et al.1998) of a tourism system or in supporting strategic management decisions (Buchta & Dolnicar, 2003).

Models built by Butler (1980) and modified (Hall & Butler, 1995; Lagiewski, 2005; McKercher, 2005; Russell, 2005), are able to give a valuable description of a tourism system and are useful for managing its development. Let us explain the modelling process of a tourism systems with a triplet subject, object and model. Subject is the observer (decision-maker), object is a tourism system and model is a graphic representation of a real object (Jere Jakulin, Kljajić, 2006). For modelling, we must see the tourism system

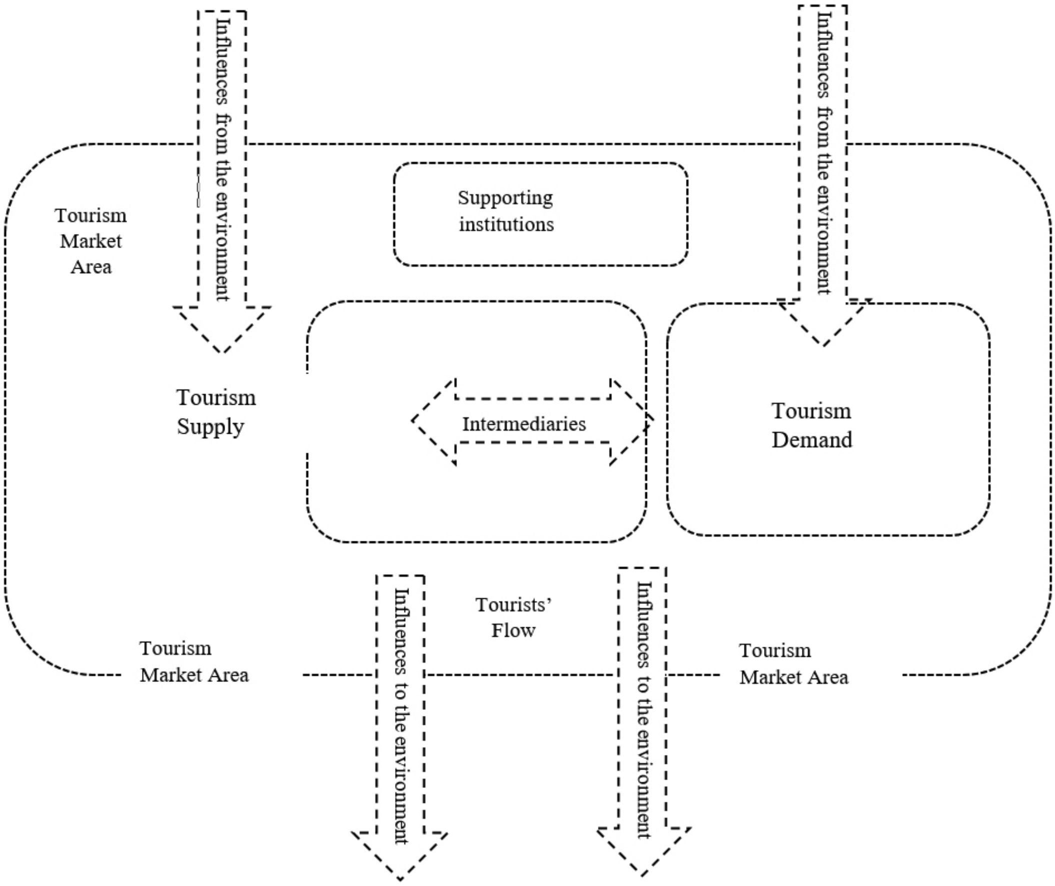

Figure 1: The Complex Tourism system (Source: author)

from the general point of view. It can be defined by a set:

$TS = (E, R)$ (1)

where $e_i \in E$, $i = 1, 2,..n$ represents the set of elements and $R \subseteq E \times E$ the relation between elements. In this way, our experiences also become accessible to others: they may be proven, confirmed, rejected, broadened or generalized (Jere Jakulin, Kljajić, 2006). This paradigm can be stated with a triplet (*TO*, *TS*, *TM)*. *TS* represents the real object (tourism system), original, independent from the observer, while *TO* represents the researcher (subject) or an observer with his knowledge, and *TM* the tourism model of the object. Their relations in the process of analysing are shown in Figure 2.

Figure 2 presents relations of the tourism decision-maker, tourism system and tourism model or so called TD-TS-TM triad. The *TD* →*TS* → *TM* relationship presents an active relation of the tourism decision-maker in the phase of the tourism system's cognition. The TM →*TS* → *TD* relation the process of learning and generalization (Kljajić, 1998). The importance of creating a model lies in a team of experts, which represent the TS entity or so called tourism decision-makers. They are a part of the tourism business process and have different tasks: the technical authority, which orders a project (tourism authority), the political authority which approves or rejects a project (a local government), the system analyst who develops the project and the stakeholders (local interest groups). The tourism expert group works on ideas and scenarios which go through modelling process. Actual performances of the system are compared in order to adapt the strategy according to changes in the environment. Results are continuously mediated to the expert group, providing an informational feedback loop in the learning process, which has a significant, impact on the decision process (Jere Jakulin, 2006).

Qualitative modelling is possible as soon as we agree on the criteria, which we consider to be important for the system. Fig. 3 represents a tourism system model and an influence diagram of a simulation model, which is built after the tourism decision-makers unite their knowledge. The positive signs (+) at the arrowheads indicate that the effect is positively related to the cause (Sterman, 2000).

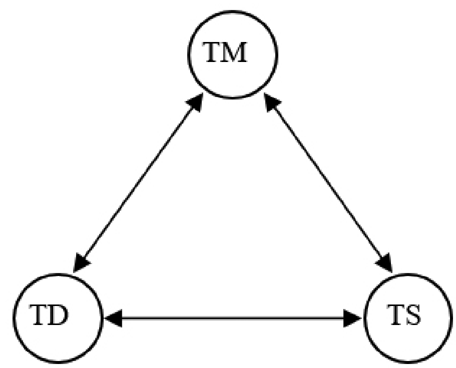

Figure 2: TD-TS-TM relations in the process of analysing (Source: author)

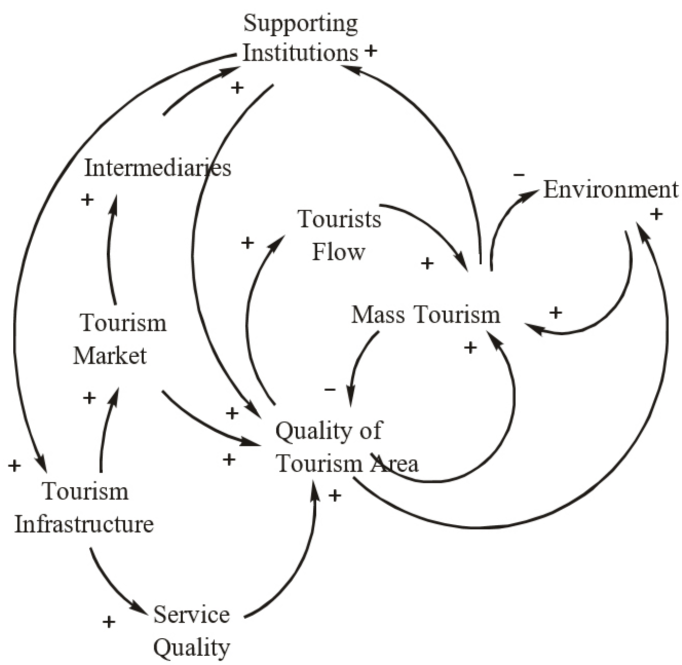

Figure 3: Causal loop diagram (CLD) of interdependent tourism system elements (Adapted and modified from Jere Jakulin & Kljajić, 2006)

The entities connected with + signs represent reinforcement cycles. Since no real entity can grow forever we must take into concern the limits of growth. These limits are created by negative feedback (-). We describe the relations among entities as follows: Supporting institutions (state administration, ministries, government positively (+) influence tourism infrastructure, which influences (+) the tourism market, and tourism market positively influences the growth of intermediaries (+) and intermediaries influence (+) supporting institutions. The described connections represent the circle of reinforcement. Every reinforced complex system needs its regulation in a form of balancing loop (-) and balancing circle. The balancing circles in Fig.3 between quality of a tourism are, which influences positively (+) the number of tourist and mass tourism and mass tourism influences (-) quality of tourism area. Another circle of balance is presented by the environment which influences the number of tourists (+) as mass tourism, and mass tourism influences ecologically the environment (-). Another reinforcement circle we can see among the entities with positive feedbacks (+) hence supporting institutions, tourism infrastructure, tourism market, intermediaries, which conclude the loop with supporting institutions. We can say that elements of a tourism market mentioned above, represent a set of entities and the directed branch represents the flow between entities. In other words, Fig. 3

represents the directed graph of the system. On the outline, one can find the polarity of the causal loop and estimate the qualitative trend of the system behaviour. For example, and quality of tourism area loop represents negative feedback and the regulation of quality. This means that desired quality of tourism area depends on quality of tourism service and tourists flow (number of tourists) are functions of strategic are planning. The tourism market's growth is proportional to quality of service, but quality of service is dependent on infrastructure investment, which is a function of the difference between the target state and current state of the system. This loop is the basis for all other loops in the system, most of which are positive loops. In the example, similarities among different methods of operating complex systems can easily be seen in the cognitive graph, the semantic graph or influence diagrams (Jere Jakulin, Kljajić, 2006). If the above entities are considered as a Level (Stocks) in the Dynamic (Forrester, 1994) and the directed branch as a flow between Levels, one can derive a difference equation for the computer simulation.

The next diagram shows the structure of a tourism model. From this diagram, one can derive the dynamic equations, which are necessary for a computer simulation (Jere Jakulin, Kljajić, 2006). The entities are not quantitatively evaluated, since there is much work to do with analysing the details of a model. This is only an answer and a presentation of possible results.

5 Modelling in Frame of System Dynamics (SD)

All systems, no matter how complex, consist of networks of positive and negative feedbacks, and all dynamics arise from the interaction of these loops with one another. (John Sterman)

The theory of nonlinear dynamics is a base on which system dynamics models rest on. To understand system dynamics as a rigorous method we must consider it as a set of conceptual tools that enable us to understand the structure and dynamics of complex systems. It enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations (Sterman, 2000). Modelling in frame of system dynamics is slightly different in the graphic presentation of the elements and their relationships, from causal loop diagram modelling. Models are essentially simple and serve as a tool for systemic – strategic planning. Methods of modelling, which have been developed for mathematical modelling of real systems were motivated by the problem itself and the researcher in that field (SD, compartment model, block diagram, etc.). The system structure in SD consists of level elements representing state variables of the rate elements, representing the flow and the auxiliary elements connected in the flow diagram. The diagram is sufficiently abstract to allow a qualitative and quantitative analysis of the system functioning through feedback loops. As soon as one becomes satisfied with the "picture" of the model, he will proceed by writing equations of the simulation model. In our opinion, SD suggested by Forrester (1961) has some semantic advantage for users less experienced with formal methods. In a practice closely related to the SD methodology, some authors use a causal loop diagram or influence diagram (Sterman, 2000). In this case, the influence loop diagram precedes the SD stock and flow diagram because the former is more abstract while the second is more convenient for computer programming. Stocks and flows, along with feedback, are the two central concepts of dynamic systems theory. Stocks are accumulations. They characterize the state of the system and generate the information upon which decisions and actions are based. Stocks give systems inertia and provide them with memory. Stocks create delays by accumulating the difference between the inflow to a process and its outflow. By decoupling rates of flow, stocks are the source of disequilibrium dynamics in systems.

Figure 4 represent a SD model as a model, which upgrades CLD model. It shows a system dynamics model depicting the interaction among dependence on tourism market, quality of the environment, service quality, mass tourism (number of tourists), supporting institutions, and investments into infrastructure. The model is composed of stocks (rectangles), flows (inflows are represented by arrow pointing into the stock and outflows by arrows pointing out of the stock), valves which control the flows, and clouds, which represent the sources and sinks of the flows. A source represents the stock from which a flow originating outside the boundary of the model arises; sinks represent the stocks into which flows leaving the model boundary drain. Sources and sinks are assumed to have infinite capacity and can never constrain the flows they support (Sterman, 2000). The purpose of the simulation model is to help managers and decision-makers, who influences the tourism complex system understanding the basics of systems methodology and, in particular, the financial implications of various decisions. Through the process of modelling and model building they recognise the values of their decisions without having additional costs, which is not a case in real life if systems approach is not recognised as an official tool for decision-making and strategic planning.

6 Conclusions

In the paper, we discussed systems methodology, which we applied to the research area of tourism.

We presented complex tourism system with its internal elements: tourism market where meet the demand and supply, intermediaries, supporting institutions and tourists flow. We showed interrelations and role of a triplet tourism system, tourism decision-maker(s) and tourism model. We

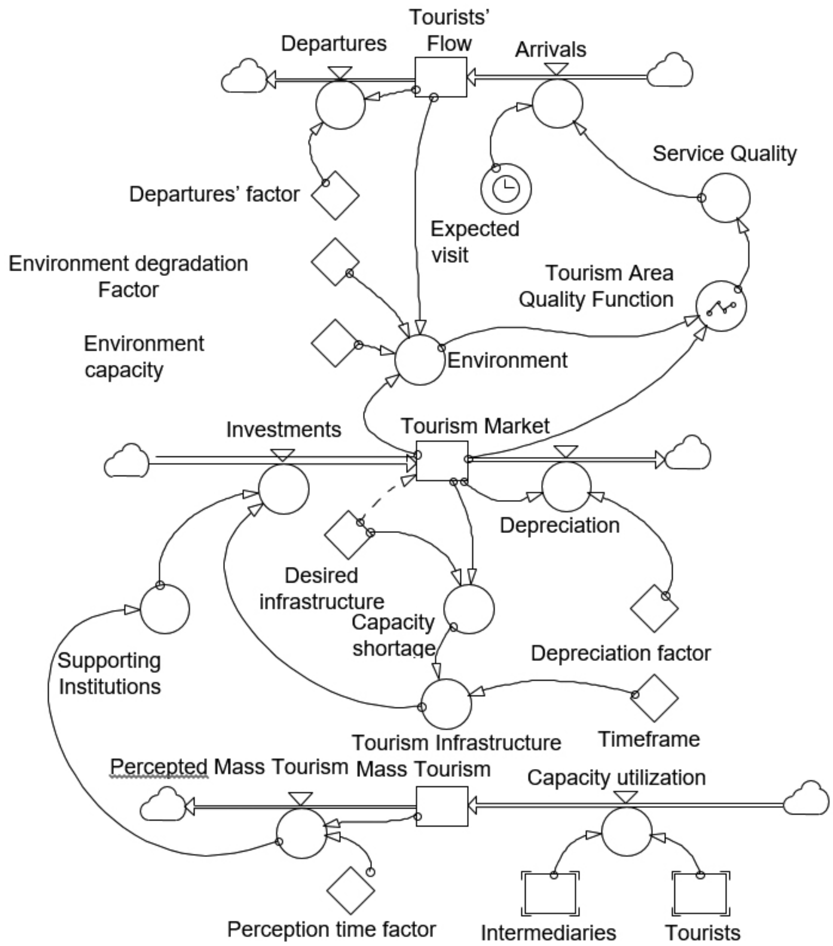

Figure 4: A simplified simulation model of complex tourism system (Adapted and modified from: Jere Jakulin & Kljajić, 2006)

treated tourism system as an object, whose relationship to a tourism decision-maker (subject, observer) explains a tourism model. As soon as tourism decision-makers as observers of a tourism system, find consensus of their tourism and modelling knowledge, they can build the qualitative CLD model of a tourism system, which serves as a model of strategic planning in tourism. The causal-loop model is followed by a system dynamic model, which is actually a simulation model. There is a difference between CLD and SD model. System dynamic model has different quantity of parameters than causal-loop diagram. It also needs concrete data for simulation, which are gathered in system dynamics. The availability of statistical data is very important. It is the essence for strategic planning and modelling of a complex tourism system since the model must represent a strategic planned reality. We can also suggest that the appropriate statistical data should be used, social and political environment and their feedback mechanisms, must be considered as well as an incorporation of work practice parameters. For a simulation model we have built, some of the data could be found and gathered in a statistical office as well as within tourism subsystems' decision-makers. Equipped with qualitative and quantitative data the system dynamics model proves that SD methodology offers new opportunities for solving virtual problems in complex systems modelling. We can conclude that the advantage of systems approach and complex system modelling lies in a fact that they are an experimental confirmation of those hypotheses, which compose the approach and modelling theory.

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Sistemski pristop k turizmu: metodologija za definiranje kompleksnega turističnega sistema

Ozadje in namen: Namen članka je obravnava kompleksnega turističnega sistema kot tudi sistemsko modeliranje in modeliranje v okviru sistemske dinamike. Pojav turizma, ki poseduje tipične lastnosti globalnih in lokalnih organizacij bo predstavljen kot odprt kompleksni sistem z vsem svojimi elementi in preko optimalne metodologije za razlago odnosov med njimi. Zaradi svoje transparentnosti je pristop, ki ga želimo predstaviti odlično orodje pri iskanju sistemskih rešitev, hkrati pa služi kot pripomoček za strateško odločanje. Predstavili bomo sistemsko kompleksnost in razvili tri modele kompleksnega turističnega sistema: prvi model bo predstavil turizem kot odprt kompleksni turistični sistem z vsemi elementi, ki delujejo znotraj sistema turističnega trga. Elementi kompleksnega turističnega sistema predstavljajo podsisteme, katerih medsebojne odnose in medsebojne odvisnosti bomo pojasnili preko dveh modelov: vzročno-zančnega diagrama ter simulacijskega modela v okviru sistemske dinamike.
Oblikovanje/metodologija/pristop: Sistemska metodologija bo predstavljena kot metodologija primerna za obravnavo izzivov kompleksnih sistemov. Za ilustracijo bosta sistemski pristop in metodologija uporabljena pri turističnih modelih. Z gradnjo kvalitativnega vzročno-zančnega diagrama bomo opisali kompleksnost turističnega sistema v obliki odnosov med elementi sistema. Medsebojni učinki elementov prikazani s pozitivnimi in negativnimi povratnimi zankami, ki tvorijo kroge krepitve in regulacije. To nam bo pomagalo razpravljati o problemu kategorično. Končni model bo sledil vzročno- zančnemu. To bo simulacijski model v okviru sistemske dinamike kot ilustracija obravnavane metodologije.
Rezultati: Metodologija ponuja rešitev učinkovite in celostne promocije transformacije kompleksnega turističnega sistema, ki ima potencial preseči mit trajnostnega turizma in ustvariti preskok s pristopom in delovanjem vseh udeležencev (elementov sistema). Sistemski pristop prinaša turizmu in družbi na splošno, širše dimenzije razmišljanja, zavest o medsebojni odvisnosti, povezanosti in odgovornosti za obnašanje sistema, ki ga lahko opazujemo preko njegovih povratnih zank.
Zaključki: Spoznanja o vrednosti in uporabnosti sistemskega načina razmišljanja, ki ga predstavljamo v članku, so v turističnem okolju redko predstavljena celostno in z namenom prikaza oblikovanja kompleksnega turističnega sistema. Prikazujejo nov pristop, sistemsko zavest in učijo razmišljanje »izven škatle«. Posledično s tem dosežemo trajnostno obnašanje znotraj kompleksnega turističnega sistema: turistični trg se s svojimi elementi srečuje na osnovi sistemske odgovornosti in povezuje z odgovornimi deležniki znotraj sistema in v njegovem okolju.

Ključne besede: *sistemski pristop; kompleksnost; turizem; turistični sistem; modeliranje sistemska dinamika*

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Organizational Learning Supported by Machine Learning Models Coupled with General Explanation Methods: A Case of B2B Sales Forecasting

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Background and Purpose: The process of business to business (B2B) sales forecasting is a complex decision-making process. There are many approaches to support this process, but mainly it is still based on the subjective judgment of a decision-maker. The problem of B2B sales forecasting can be modeled as a classification problem. However, top performing machine learning (ML) models are black boxes and do not support transparent reasoning. The purpose of this research is to develop an organizational model using ML model coupled with general explanation methods. The goal is to support the decision-maker in the process of B2B sales forecasting.
Design/Methodology/Approach: Participatory approach of action design research was used to promote acceptance of the model among users. ML model was built following CRISP-DM methodology and utilizes R software environment.
Results: ML model was developed in several design cycles involving users. It was evaluated in the company for several months. Results suggest that based on the explanations of the ML model predictions the users' forecasts improved. Furthermore, when the users embrace the proposed ML model and its explanations, they change their initial beliefs, make more accurate B2B sales predictions and detect other features of the process, not included in the ML model.
Conclusions: The proposed model promotes understanding, foster debate and validation of existing beliefs, and thus contributes to single and double-loop learning. Active participation of the users in the process of development, validation, and implementation has shown to be beneficial in creating trust and promotes acceptance in practice.

Keywords: *decision support; organizational learning; machine learning; explanations; B2B sales forecasting*

1 Introduction

Business-to-Business (B2B) sales forecasting is a complex (inter)organizational process that is tightly related to decision making. The dynamic environment (economic and political), multi-stage sales processes, multiple participants with possibly conflicting interests (sellers, buyers), and multiple interrelated attributes all contribute to the complexity of the process. B2B sales forecasts serve as the basis for managerial decisions that result in resource

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allocation. Implications of incorrect forecasting can lead to non-optimal decisions and consequently to a waste of resources.

Forecasting of the sales outcomes is a well-researched subject, especially in the context of time series. Although there is a vast body of literature and technological advancement on the topic of forecasting (Fildes, Goodwin and Lawrence, 2006; McCarthy, Davis Golicic and Mentzer, 2006; Armstrong, Green and Graefe, 2015), there is a weak evidence on successful business implementations. Decision-makers remain skeptical about recommendations offered by forecasting support systems (FSS) and rather rely on applying their own mental models (Goodwin, Fildes, Lawrence and Stephens, 2011)the resulting forecasts are often 'sub-optimal' because many judgmental adjustments are made when they are not required. An experiment was used to investigate whether restrictiveness or guidance in a support system leads to more effective use of judgment. Users received statistical forecasts of the demand for products that were subject to promotions. In the restrictiveness mode small judgmental adjustments to these forecasts were prohibited (research indicates that these waste effort and may damage accuracy. Mental models are reflected as deeply rooted assumptions and generalizations that influence the way individuals act and are often unconsciously reflected in behavior that limits the organization's development capabilities. If an organization wants to improve its efficiency (i.e. decreasing the gap between the forecasts and realization), it needs to reflect upon those anchored mental models.

Organizational learning thus represents a constant effort to create organizational knowledge, which according to Senge (1990) consists of team learning, personal mastery, mental models, building a common vision, and systemic reflection as an all-inclusive, fifth discipline. Furthermore, it refers to organizations' ability to adapt effectively to changes in its environment. In an analogy to individual learning, it can be described as an alteration of the behavior based on an individual/group experience (Škraba et al., 2007) or a process of detection and correction of errors (Argyris and Schön, 1996). In contrast to individual learning, the organizational learning is more complex since it is not only a sum of individual learning but an exchange of individual models, beliefs, and behaviors. When it is based on a feedback, and individuals and groups change their mental models (beliefs and behaviors), we speak about double-loop learning. It can occur on an individual level, but it is rarely observed outside an organizational setting (Kljajić Borštnar et al., 2011).

The two types of learning were defined by Argyris and Schön (1996). A problem solving oriented single-loop learning is often efficiently supported by a "black-box" models ("know-how"). Double-loop learning assumes critical reflection that leads to an understanding of a system ("know-why"). Understanding why complex (inter) organizational systems operate in a certain way, helps in identifying changes in the environment and reacting to them, effectively supporting organizational learning. Transparent models thus create the basis for double loop learning and promote organizational learning (Größler, 2000; Flesichmann and Wallace, 2005). However, many models, including top performing machine learning (ML) models, are black boxes and cannot support such learning.

The learning process should provide sufficient knowledge for effective decision-making (Škraba et al., 2007), while feedback is the key part of the learning process (Kuchinke, 2000). Simon (1960) proposed the model of the decision process, which consists of three basic phases: intelligence, design, and choice among options. The first phase deals with the identification of the problem and the collection of data they describe. The design phase deals with the preparation and design of different decision options, which are then evaluated in accordance with the set criteria in the third phase with the goal of choosing the best option.

In this paper, we focus on all three Simons' (1960) decision-making phases, especially focusing on organizational aspects and people-related evaluation. The novel use of general explanation methodology applied to business (B2B) sales forecasting process was introduced in Bohanec et al. (2017a) in the context of a decision-making framework with double-loop learning (Bohanec et al., 2017b). Analysis of the proposed organizational model and its implementation as a part of research design is discussed in this paper. Our hypothesis is that it is possible to use interpretable machine-learning models to support both single and double-loop learning, and at the same time foster acceptance by involving users. As a consequence sellers and companies make fewer mistakes in sales forecasting.

The proposed model will, through a combination of machine learning methods, knowledge and practice of experts, surpass the shortcomings of partial approaches and make the decision-making process transparent and consequently comprehensible to the participants. By making forecasting support systems models transparent, the users are encouraged to reflect not only on the outcomes but also on the reasons for the specific outcome. In this way individuals' and organizations' mental models are tested and the underlying model can improve (Grossler, Maier and Milling, 2000; Senge and Sterman, 1992), thus the gap between the forecasts and actual outcomes can be reduced. Furthermore, the machine learning model, built on a small set of features and supported by visualizations to support the reflection of a decision-makers, addresses important limitations of human decision-makers (Simon, 1991; Sterman, 1994and states the requirements for successful learning. The feedback loop (FL; Kljajić Borštnar, Kljajić, Škraba, Kofjač and Rajkovič, 2011) and helps building trust (Fleischmann and Wallace, 2005).

The rest of the paper is organized as follows. Section

2 gives an overview of related work. Section 3 describes research approach, which is interconnected with companies' organizational process. In Section 4 we introduce an explanatory toy example. Analysis of an implementation in a company is presented in Section 5. Conclusions are put forward in Section 6.

2 Related work

Many techniques and solutions support forecasting of sales result - both for the business to consumer (B2C) and B2B segments. They can be grouped as quantitative (relying on data collected over longer period of time) and qualitative, based on judgment, intuition and informed opinions (and inherently subjective) (Davis and Mentzer, 2007; Kerkkänen and Huiskonen, 2007; Ingram, LaForge, Avila, Schwepker and Williams, 2012; Armstrong and Green, 2014). If a company has a large number of stored transactions, it is possible to use probability estimation techniques based on the development of opportunity, i.e. Sales funnel (Lodato, 2006; Duran, 2008; Söhnchen and Albers, 2010). Such an approach less applicable where there are fewer sales opportunities. In this case, the importance of sales forecasts for a company is all the more important as it could get either no sale closed or get all sales closed (even the unexpected cases). Additionally, the size of the opportunity also matters, since the company needs to allocate its resources (Duran, 2008).

A survey of the leading companies in various industries has shown that companies relying on data-driven decision-making (DDDM) achieve better results (Provost and Fawcett, 2013). On average, the top one-third DDDM companies from their industry are on average 5% more productive and 6% more profitable compared to their competition (Brynjolfsson, Hitt and Kim, 2011; McAfee and Brynjolfsson, 2012).

However, research on a development of sales forecasting (McCarthy, Davis, Golicic and Mentzer, 2006) showed that the knowledge of forecasting techniques from both categories, quantitative and qualitative, is declining. Similarly, the review of sales forecasting (Armstrong, Green and Graefe, 2015) showed that forecasting practice had seen little improvement, despite major advances in forecasting methods and development of sophisticated statistical procedures. Other researchers note a negligible positive effect of forecasting techniques, which is a result of decision makers' doubts about their reliability and comprehensibility (Lawrence, Goodwin, O'Connor and Önkal, 2006). In practice, managements easily and quickly decide qualitatively, in its own discretion, based on experience, knowledge and mental models of individuals. The reasons for weak user acceptance are generally low trust in technology, doubts about the quality of data and the doubts about the benefit of such recommendation systems. This is especially true in domains where process data cannot be easily measured, like for example in B2B business sales.

In contrast to the B2B domain, the B2C domain receives more attention in the academic literature (Lilien, 2016). In B2C, large amounts of data are generated from user behavior. In contrast, in B2B sales process data are interpreted and collected by the sales experts. Subjective interpretations of the process' features decrease confidence in data quality. On the other hand, it enables organizations to capture »soft« features of the sales process (i.e. expectations of the client about the offered solution), which is a good starting point for describing preferences and sales processes with qualitative attributes that describe the state of opportunity (Söhnchen and Albers, 2010; Monat, 2011).

B2B sales acquisition applications of ML have been discussed in (Yan et al., 2015; D'Haen and Van der Poel, 2013). Yan et al. (2015) explicated that ML methods outperform subjective judgment. Furthermore, when sellers were provided with scorings for their resource allocation decision, their results improved, indicating the regenerative effect between prediction and action. An iterative three-phased automated ML model for identifying promissing clients (sales opportunities) in a B2B environment was proposed by D'Haen and Van der Poel (2013). They emphasize the importance of documenting the decisions made, steps taken, etc., to incrementally improve client acquisition. We address feedback issues with explanations of predictions. A comprehensive review of the literature on B2B sales leads explicates that there is little research, lack of rigor (theoretical grounding or validation) and no corroborative data (Monat, 2011) on this subject.

A review of 52 articles addressing the application of ML in Decision Support Systems (DSS) between 1993 and 2013, suggests that ML usefulness depends on the task, the phase of decision-making and applied technologies (Merkert, Mueller and Hubl, 2015). Furthermore, these researchers found that ML methods (i.e. support vector machines and neural networks) are used mostly in the first two phases of the decision-making process, intelligence and design, as described by Simon (1960), while the third phase, choice, is less supported. We address the identified gap by using ADR approach, which includes all three phases in an organizational context.

In many classification problems, users are concerned with more than predictive performance, and in decision support, the interpretability of prediction models is of great importance. In order to apply prediction models, users have to trust them first and models' transparency is a crucial step in ensuring the trust. As many comparative studies show, complex models, like random forests, boosting, and support vector machine, achieve significantly better predictive performance than simple interpretable models such as decision trees, Naive Bayes, or decision rules (Caruana and Niculescu-Mizil, 2006). Unfortunately, complex models are also difficult to interpret. This can be alleviated either by sacrificing some prediction performance and selection of transparent model or by using an explanation method that improves the interpretability of complex models, like the general explanation methodology that can be applied to any classification or regression model (Robnik-Šikonja and Kononenko, 2008; Štrumbelj, Kononenko and Robnik-Šikonja, 2009).

The present paper builds on our previous work, where we proposed a novel use of general explanation methodology inside an intelligent system in a real-world case of B2B sales forecasting (Bohanec et al., 2017a). We first assembled a set of attributes from academic literature (Bohanec, Kljajić Borštnar and Robnik-Šikonja, 2015a), developed an optimization process to define the minimum sized data set (Bohanec, Kljajić Borštnar and Robnik-Šikonja, 2016b) and built machine learning model (Bohanec et al., 2017a). The ML model, enhanced with the general explanation methods, was applied in a real-world B2B process so that users could validate their assumptions with the presented explanations and test their hypotheses using the presented what-if parallel graph representation. The results demonstrate effectiveness and usability of the methodology. A significant advantage of the presented method is the possibility to evaluate seller's actions and to outline general recommendations for sales strategy. The results on the use of the framework were discussed in (Bohanec et al., 2017b). The results suggest that the provided ML model explanations efficiently support business decision makers, reduce forecasting error for new sales opportunities, and facilitate discussion about the context of opportunities in the sales team. In this paper we focus on the organizational context. We analyze the evidences of single and double-loop learning occurring in the process of model building and use.

3 Methodology

Our research idea is grounded in the Design Science Research paradigm (Hevner, March, Park and Ram, 2004), which deals with the development of IT artifacts. Due to weak user acceptance of the developed IT artifacts, the participatory research design was employed. Action Design Research (ADR) is a participatory design, which combines action research (Avison and Fitzgerald, 2006) with design science research (Hevner et al., 2004). Here users and researchers cooperate in the development of the solution in an organizational context/setting (Sein, Henfridsson, Purao, Rossi and Lindgren, 2011). By involving users, the acceptance of the developed IT artifact is addressed at the same time.

The ADR methodology has four stages, each supporting certain key principles as shown in Figure 1. In our context, ADR results in an organizational artifact, represented by the comprehensible explanations of top-performing black-box ML models supporting decision-making in B2B sales forecasting. The artifact is bound by the context of the organization. Different organizations require re-conceptualization of learning from the specific solution (as presented in this paper) into knowledge needed to create other instances of solutions (i.e. B2B sales forecasting decision-making process in another organization).

The four ADR stages with their application as defined by Sein et al. (2011) are as follows:

1. Problem formulation, which is triggered by a problem perceived in practice or anticipated by researchers.
2. Building, intervention, and evaluation builds upon problem framing and theoretical premises from Stage 1.
3. Reflection and learning enable the move from the conceptual solution for a particular instance to a more general solution. This stage runs in parallel with Stages 1 and 2, recognizing that the research process involves more than problem-solving.
4. Formalization of learning formalizes the learning from the ADR project into general solution concepts for a class of field problems.

3.1 CRISP DM

Cross industry standard process for data mining (CRISP-DM) phases are presented in Figure 1. We shortly describe the methodology through its use in the context of our ADR based approach.

In the first phase, Business understanding, the team identified a problem, set up goals and expectations. In the second phase, data were exported from the existing customer relationship management system (CRM), followed by preliminary analysis and data-driven problem understanding. Since standard CRM attributes showed to have little predictive value, the ADR team selected 23 attributes describing the specific context of the participating company from the list of attributes identified in the literature review. In the Data preparation phase, the selected attributes were added to the companies' CRM. The Modeling phase is comprised of the model building based on the collected data (selected attributes) from sales history. Prediction models were built and discussed with the ADR team in order to identify outliers, check data quality (Bohanec et al., 2015b), and foster critical reflection on the predictions and thus sales forecasting process (Figure 2). This fostered user acceptance of the models and the whole process. We used several software packages to build and present ML models, e.g., Orange, WEKA, and R. Once the consensus on data quality and presentation format was achieved among ADR team, we compared different ML methods (random forest, naive Bayes classificatory, decision trees, artificial neural nets, and support vector machines). Besides the classification accuracy (CA) measure, we observed also the ROC curve (AUC measure). ML models explanations were generated by IME and EXPLAIN methods (Bohanec et al., 2017a).

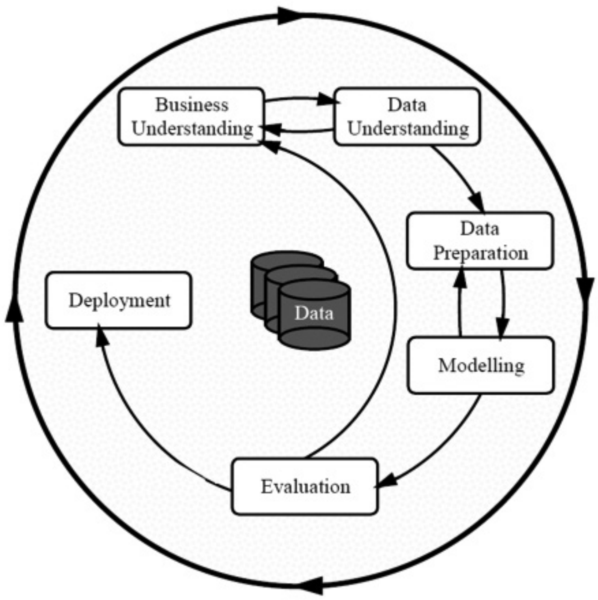


Figure 1: CRISP-DM methodology (Wirth and Hipp, 2000)

In the Evaluation phase, the final artifact was presented to the larger group of users (in the participating company) in a form of a workshop. The ML model predictions were interpreted on new sales opportunities. Users identified some erroneous data and the cycle was rerun.

Once the ADR team was satisfied with the model, the deployment phase followed. The model was used in the monthly forecasting process for several consecutive months. Every month the users and external consultant, using the ML model coupled with explanations, produced the sales outcome predictions. The users were presented with the results of ML model predictions and predictions of the consultant (using the ML model and explanations). This resulted in revised forecast of users. At the end of each month, the predictions and actual outcomes were analyzed.

Figure 2 presents the proposed research framework, which is grounded in ADR methodology and consists of several design cycles (following CRISP-DM methodology), in which business users together with researchers define the problem, build an ML model, use the model in an organizational decision-making process, and use new insights to update the model. Figure 2 depicts single loop learning (supported by the ML model), and double-loop learning (supported by the ML model, enhanced with explanations).

4 Introduction to general explanation methodology with examples

We use two general explanation methods IME and EXPLAIN (Robnik-Šikonja and Kononenko, 2008; Štrumbelj et al., 2009). These two methods explain model's predictions as contributions of individual attributes. The explanations are based on the structure of the model and visualize the context of individual opportunities.

In general, prediction explanations can be divided into two levels - domain level and model level explanations. The domain level explanations would show a true causality between dependent and independent variables, and can only be achieved for artificially constructed problems, where relations between variables and distribution probabilities of outcomes are known. In real world problems, these relations are not known and only the built model can be used to explain the causalities (model level explanations). The model level explanation transparently presents the prediction process with a particular ML model, which is trained from examples described by the attributes. The research on artificial problems shows that models with better predictive capacity allow better explanation (Štrumbelj et al., 2009).

From the model, we can get explanations of individual cases or the explanation of the whole model. The whole model explanations average the explanations of training set examples. They display the impact of the attributes as a whole as well the influence of individual values of attributes in the model. Since individual values of attributes affect different outcomes differently, each outcome

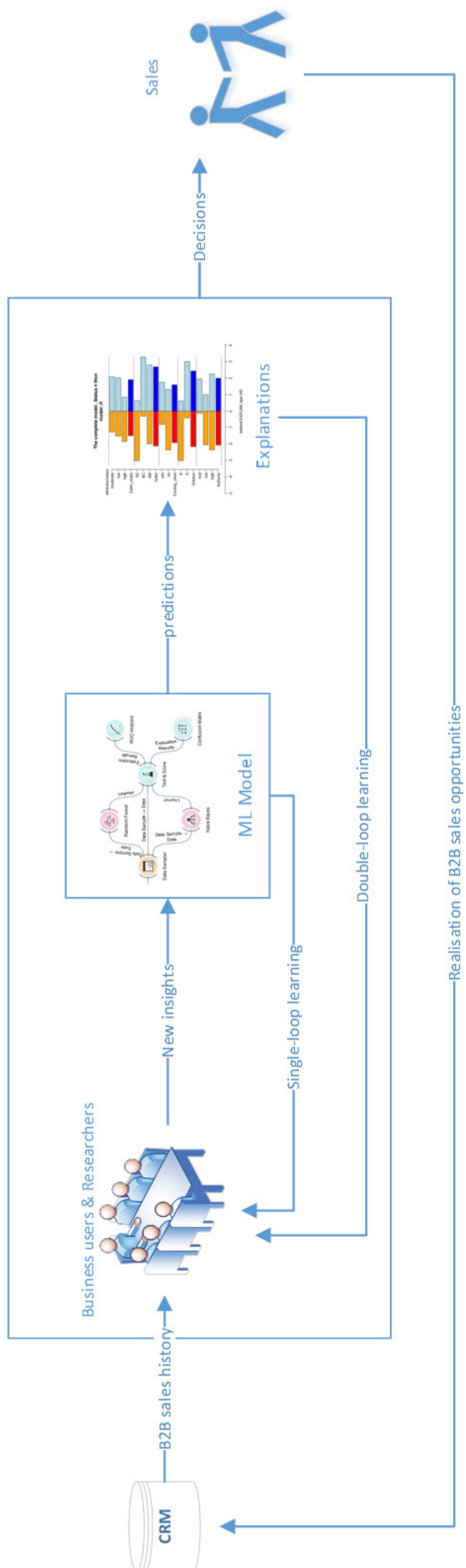


Figure 2: Proposed organizational learning based on ML model, enhanced with explanation methods

(i.e. class in ML terminology) has to be taken into account separately. The EXPLAIN method observes changes of one variable at a time. In case there are strong redundancies between the input variables (i.e. disjunctive relationship with the class), we can get unrealistic assessments of contributions. The IME method samples contributions of groups of input variables and thereby avoids the problem of redundancy but is more time-consuming. In practice, we test the performance of both methods and if they produce similar results, we use the faster EXPLAIN method, otherwise, we have to use the IME method.

We present a simple, toy example to introduce the use of the proposed explanation methodology applied to B2B sales problem. The data set contains a basic description of B2B sales events of a fictional company. The practice shows that simpler visualizations achieve better acceptance and foster trust at the beginning of learning.

We assume that our fictional company offers two complex solutions, A and B, on a B2B market. Their key customers are business managers and a certain level of sales complexity is expected (e.g., several units with competing priorities at client side). The company has grown on the success of their initial Solution A, however recently Solution B was added to the sales portfolio to open new sales opportunities. Preferably, the company offers the Solution B to existing clients, a practice called cross-selling. The sales personnel tries to pursue sales deals in which they can offer complex solutions together with the company's deployment consultants. Their previous experience shows that for a successful sale, the sales team should attempt to engage senior business leaders at prospects, with the authority to secure the budget and participate in the definition of requirements. The data for the fictional company is described in Table 1.

For example, the attribute *Authority* represents the authority level of a key contact at the prospect. It has three values with the following meaning: "high" (e.g., a person can secure the funding), "moderate" (e.g., a person influences the project specification, but lacks budget), and "low" (e.g., a person just collects information and has no power to make important decisions). The toy example fictional data set consists of 100 instances. We randomly take 80 percent of the instances as a training set and the remaining 20 percent as a testing set. To build a classifier, we use the ensemble learning method Random Forest (RF) (Breiman, 2001). The RF model is passed as the input to the EXPLAIN or IME explanation methods. Figure 3 introduces an example of an explanation for a specific case (the sales opportunity named instance 14), where the sale was discussed with the high-level manager at a new prospect, the *Seller* AM offered the *Solution* A and was experiencing high complexity in the sales effort.

The left-hand side of Figure 3 outlines the attributes, with the specific values for the selected instance on the right-hand side. For this instance, the probability returned by the model for the outcome *Status* ="Won" is 0.74, and "Won" is the true outcome of this instance. The impact of attributes on the outcome is expressed as the weight of evidence (WE) and shown as horizontal bars. The length of the bars corresponds to the impact of the attribute values on the outcome predicted by the model. Right-hand bars show positive impacts on the selected outcome (*Status*="Won" in this case, see the header of the figure), and left-hand sidebars correspond to negative impacts. The thinner bars (light gray bars) above the explanation bars (dark gray) indicate average impacts (obtained from training instances) for particular attribute values.

For the given instance 14 in Figure 3, we can observe that *Solution*="A", *Authority*="high" and *Sales_cmplx*="high" are in favor of closing the deal. The attribute *Existing_client*="no" is not supportive of a positive outcome. For the attribute *Seller* with a value AM, there is no bar present, exposing the role of AM as completely neutral in the context of this instance. The thinner bars show that on average both positive and negative impacts of these values are observed, with different intensities. The average value for the attribute *Solution* with value A is the most biased towards a positive outcome. This is in-line with our toy

Table 1: Data for the fictional company (Bohanec et al., 2017a)

Attribute	Description	t
Authority	Authority level at a client side.	low (24), mid (37), high (39)
Solution	Which solution was offered?	A(51), B(49)
Existing_client	Selling to existing client?	no(47), yes(53)
Seller	Seller name (abbreviation).	RZ(35), BC(29), AM(36)
Sales_complexity	Complexity of sales process.	low(31), moderate(53), high(16)
Status	An outcome of sales opportunity.	lost(45), won(55)

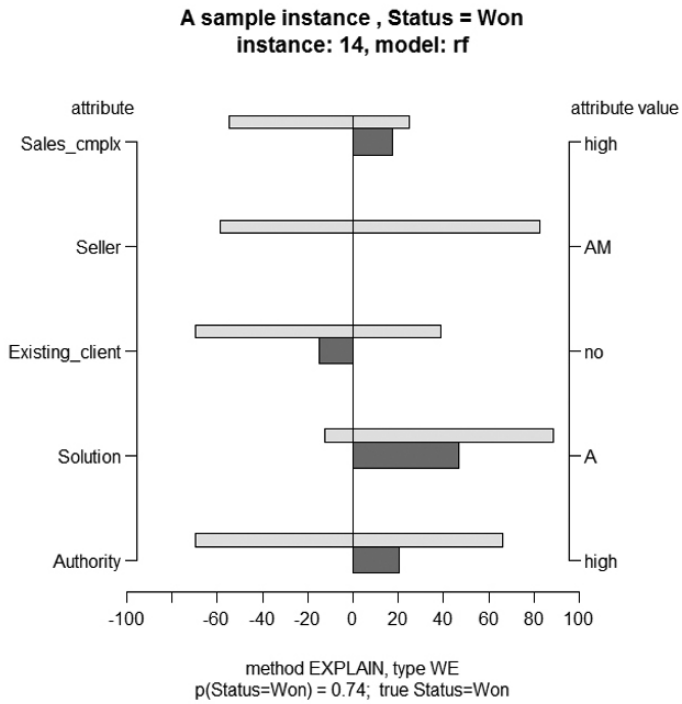


Figure 3: Explanation for a specific case (the sales opportunity named instance 14)

scenario where the Solution A is a flagship product selling very well.

To understand the problem on the level of the model, all explanations for the training data are combined. Visualization of the complete model showing all attributes and their values (separated by dashed lines) is shown in Figure 4.

From Figure 4 we can observe that the impact indicators for attributes (dark gray bars) spread across the horizontal axis, which indicates that both positive and negative impacts are possible for each attribute. Dark gray bars representing attributes are weighted averages of the impact of their values that are shown above them. For each attribute value (light gray bar), an average negative and positive impact are presented. Specific attribute values often contain more focused information than the whole attribute. For example, moderate sales complexity or dealing with mid-level managers indicate a stronger tendency towards positive outcome than towards negative outcome. The value "yes" for the attribute *Existing_client* has a prevailing positive impact on the positive outcome, but the value "no" can also have a positive impact. Note the scale of the horizontal axis in Figure 3 and 4. While on Figure 4 original values of WE are shown, we normalized the sum of contributions to 100 in Figure 3. Such normalization can be useful if we compare several decision models or if we want to assess the impact of attributes in terms of percentages.

As indicated in (Robnik-Šikonja and Kononenko, 2008), the method EXPLAIN is fast but does not capture the disjunctive and redundant interactions among attributes. To indicate these effects, Figure 5a utilizes the method IME (calculation takes somewhat longer) for a visualization of the whole model. A comparison with Figure 4 shows certain differences, therefore, we will subsequently use the IME method for the toy example. When users want to focus their analysis on a particular subset of attributes, they can single them out. For example, Figure 5b only presents attributes *Sales_cmplx* and Authority in the model view.

The explanation follows the underlying model; therefore if the model is wrong for a particular testing instance, the visualizations will reflect that. For example, Figure 6 shows the instance 9, where the RF model estimates that the probability of successful closure is 0.41 (which is less than the threshold 0.50, indicating the outcome "Lost"). However, this instance was actually "Won".

In practice, sellers are interested in explanations of forecasts for new (open) cases, for which the outcome is still unknown. Figure 7a visualizes an explanation of such a case. The initially predicted probability of successful sale is 0.49.

The explanation reveals a positive influence of the fact that the sale is discussed with an existing client, also the impacts of attributes *Sales_complexity* and *Authority* are positive. The *Seller* RZ (thin bar indicates his low sales performance) has a negative impact. The fact that the Solu-

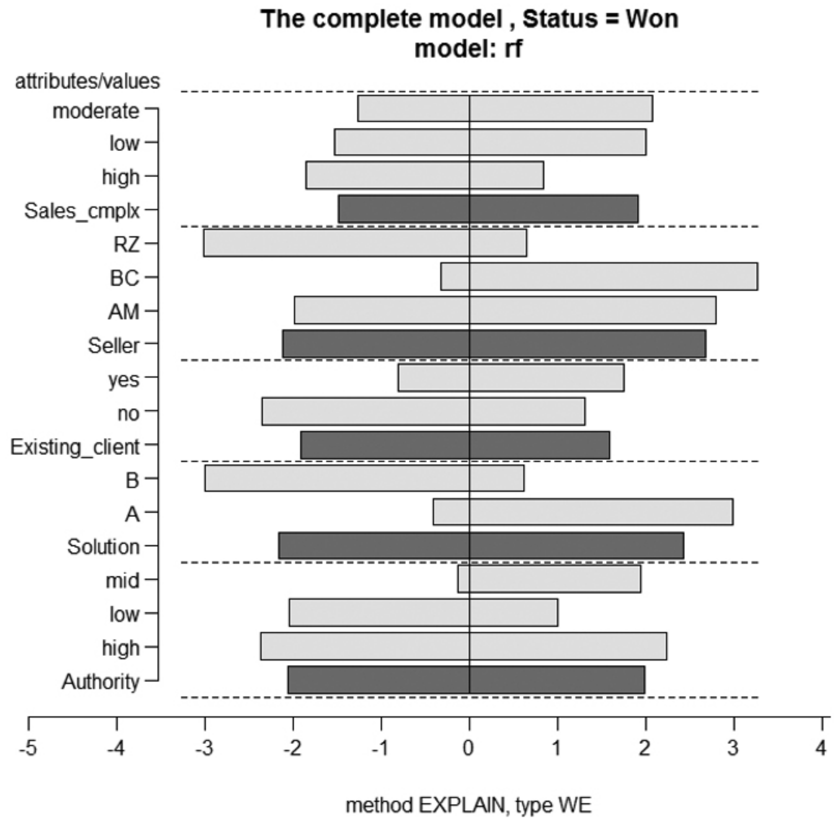


Figure 4: Visualization of the complete model, method EXPLAIN

tion B is offered shows a clear tendency toward the negative outcome.

As this sales opportunity is critical for the company, increasing the chances for a positive outcome is paramount. The low predicted probability triggers a discussion about the actions needed to enhance the likelihood of winning the contract. Unfortunately, not a lot of attributes can be influenced by the company as they are controlled by the prospect (e.g., *Authority* =”mid” cannot be changed). They consider the effect on the outcome a change of seller from “RZ” to “AM” would cause, with all other attribute values left the same. Figure 7b shows the implications of this change. The likelihood of winning the deal rises to 0.85. The explanation bars indicate strong positive influences of all attribute values but *Solution*, which follows our intuition given that, Solution B is a new offering.

By introduction of explanation methodology in a decision-making process, users are supported in transparent reasoning. This provides evidence for informed decisions and challenges prior assumptions.

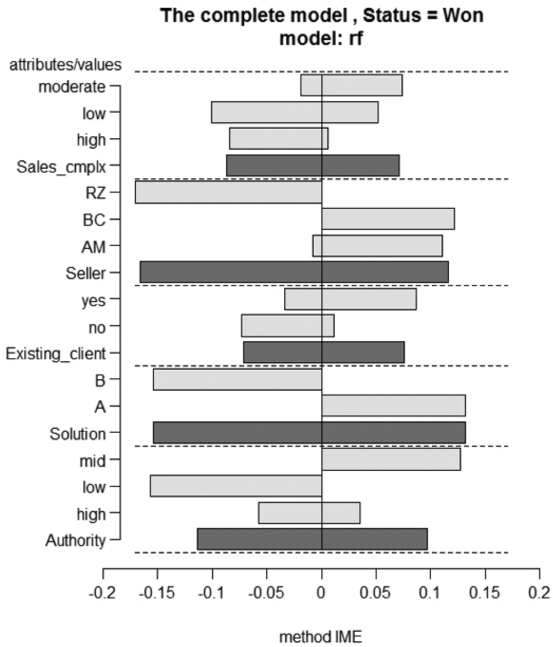
5 Results and discussion

The process of model building and some examples of the model use on a real company data are described in this section. In contrast to toy example, described in Section 4, we wanted to explicate the complexity of the real life application. Further, we analyze the effects of implementation of the model in the company over the observed 16 months.

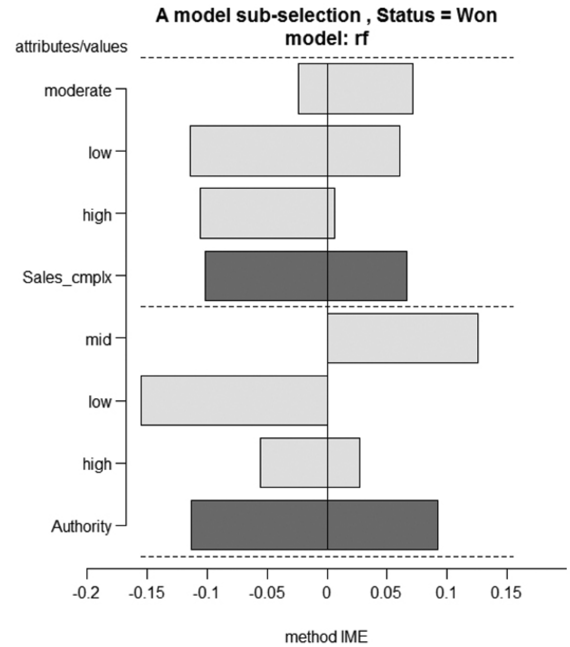
5.1 Features

A sample of the final set of attributes which is an input to the ML scheme for a real-world case study is presented in Table 1. The complete list is described in Bohanec et al (2017a, 2017b). A detailed description of attributes identification, analysis of attributes importance, and final attribute selection can be found in (Bohanec et al., 2015a, 2015b; Bohanec et al., 2016a, 2016b).

The data set was developed in the course of several months (Bohanec, 2016). It consists of 448 instances described by 22 attributes and one class attribute (the outcome of the sales opportunity: won, lost). There are 51% instances of the class »won«, and 49% with the class »Lost«. Data set is publicly available (Bohanec, 2016) to



a)



b)

Figure 5: a) Method IME model explanations, b) drilling into attributes to visualize attributes of interest

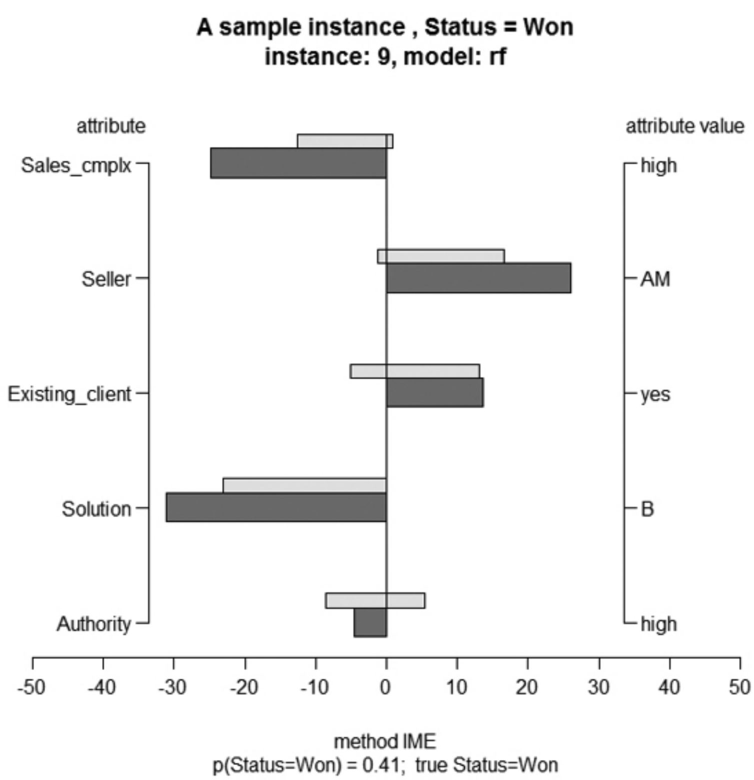


Figure 6: An example of the wrong prediction

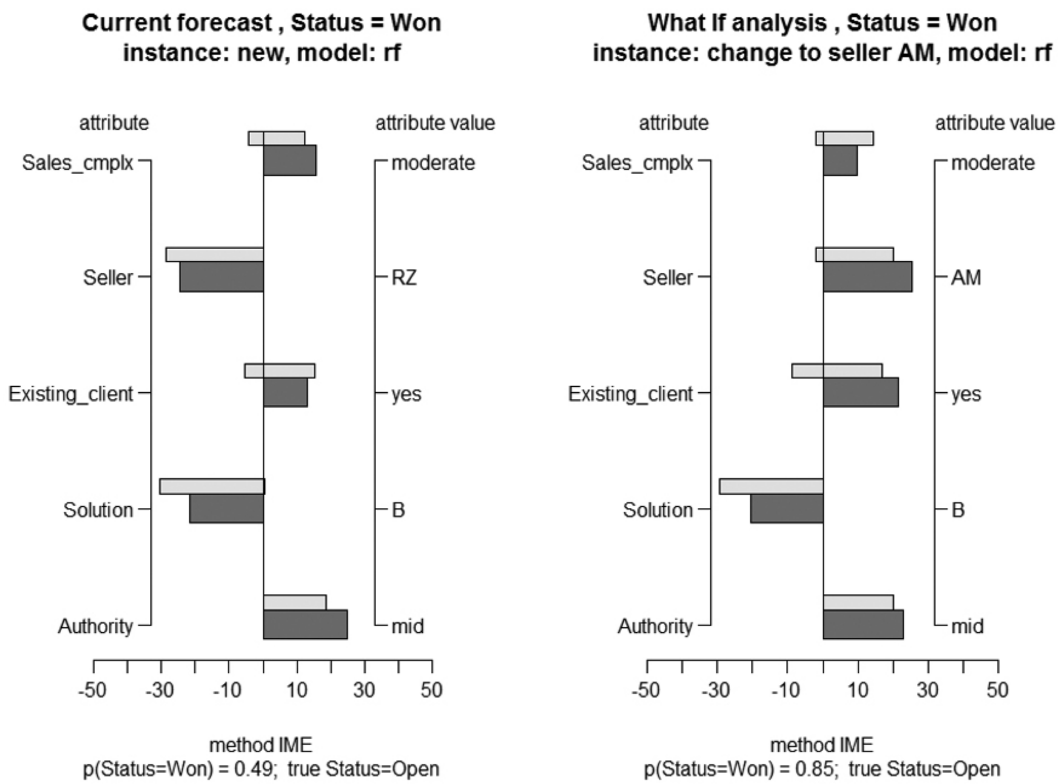


Figure 7: a) explanation of a prediction a new sales opportunity, and b) "what-if" analysis for the new sales opportunity

reduce the gap in the field of B2B research data (Lilien, 2016).

5.2 Building an ML model

The process of ML model building, presented in Figure 1, is in itself a circular process, where users (B2B sales experts) contribute input data for classification model building, examine the results of the model with explanation methods and evaluate the proposed decisions. In this process, new insights are generated and fed back into the system (the group uses new insights in the second cycle of model building, examines the updated model etc.). The process of model building and usage is contributing to better understanding of the model and B2B sales forecasting process, and thus to acceptance of the model.

Table 2 contains several classification algorithms and their performances, measured with the classification accuracy and ROC. The data set was divided into a training set (80% of cases used for training) and testing set (20% of cases used for evaluation). The process of classifier training is repeated 30 times to increase stability and reliability of the performance estimation. Average results of this experiment, along with standard deviation values, are presented in Table 2. We evaluated the performance of random forest (RF), Naive Bayes (NB), decision tree (DT), neural nets (NN) and support machine vectors (SVM) method. The RF algorithm performed best in two different experiment settings (Bohanec et al., 2017a, 2017b).

5.3 Model use in the company

The presented approach enables explanation of predictions and other analyses, for example, »what-if« analysis and exploration of how individual attributes influence the possibilities of closing a deal with a new client (presented in Section 4 with the toy example).

An example of visualization of the model built on the data from a real world company is presented in Figure 8. Figure 8a shows all attributes with their values for a new sales opportunity. For more clear visualization, it is preferable to concentrate only on the most impactful attributes. Users can limit the threshold of attribute impact shown on the graph and in the same time test the implication of changes for a particular attribute(s) of interest. Figure 8b shows the predicted impact of getting confirmation about the budget (*Budget*="Yes") and formal purchase process (*Purchase_dept* = "Yes"). In Figure 8b, only the values higher than the threshold for WE=1 are shown. This improves graph readability and supports discussion focused

Table 1: Sample of the final list of attributes describing our B2B sales process

Attribute	Description	Values
Authority	Authority level at a client side.	low, mid, high
Product	Offered product.	e.g. A, B, C, etc.
Seller	Seller's name.	Seller's name.
Competitors	Do we have competitors?	no, yes, unknown
Client	Type of a client.	new, current, past
…	…	…
Attention to client	Attention to a client.	first deal, normal, etc.
Status	An outcome of sales opportunity.	lost, won

Table 2: Average results of 30 repetitions of classification models training (Bohanec et al., 2017a)

Classification method	CA average	CA std.dev.	AUC average	AUC std.dev.
RF	0.782	0.045	0.853	0.034
NB	0.777	0.036	0.835	0.040
DT	0.742	0.040	0.764	0.039
SVM	0.567	0.259	0.589	0.325
NN	0.702	0.051	0.702	0.051

on the most impactful attributes.

The participating company was interested in improving the efficiency of acquisition of new customers. In order to adapt the presented methodology, we adjusted the data set to contain only instances relevant to the context of the question. This means that only instances with the value of attribute *Client* = "New" were extracted from the database (in our case, there were 158 matching records). As shown in Figure 9, the company shall focus on attracting prospects to attend sales events and on opportunities to collaborate with other companies. The performance of different products varies significantly.

5.4 Analysis of the implementation of the model in the company

For several months, the participating company used the proposed solution in the forecasting process of B2B sales prediction. The process started at the beginning of each month after the management together with the sellers (users) predicted which opportunities would be successfully completed by the end of the month. The forecasts were recorded in the CRM system, thus creating baseline sales forecasts. At that moment, the data were forwarded to an external consultant (researcher) who applied ML model and generated predictions together with their explanations. Based on that, the external consultant prepared his sales predictions. The predictions of "consultant + ML prediction" were passed back to the company together with explanations for each sales opportunity. The sellers were encouraged to reconsider their initial forecast. Challenged by nonmatching outcomes or large differences in predicted probabilities they sometimes changed their initial forecasts, which resulted in revised forecast.

The users took some time to embrace the proposed model into their regular monthly forecasting process. Figure 9 shows that in the last few months the users changed their initial forecasts based on the ML model predictions and surpassed the performance of "consultant + ML model predictions". This supports our initial hypothesis that users (domain experts) can use the proposed model (ML model predictions with explanations) to reflect upon the B2B sales forecasting process and learn from it on an individual, as well as on the group level. Double loop learning is explicated by the revision of the users' beliefs and mental models. In this way, the process of model building and usage is contributing to improved understanding of the model and the B2B sales forecasting process and thus acceptance of the model. Furthermore, they can identify slippage of a sales opportunity, which is an opportunity that will not be closed within that month but will slip into the following months. The current ML model cannot predict these slippages.

We calculated the accuracy of the forecasts. Figure 9

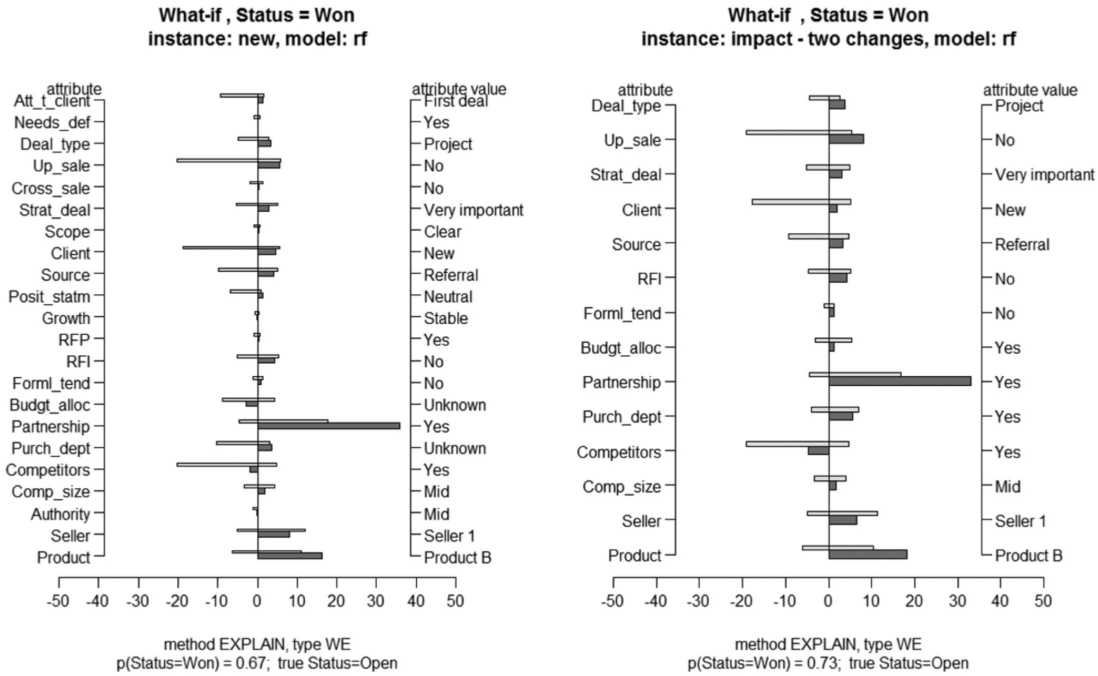


Figure 8: a) All attributes with their values for a new sales opportunity, b) analyzing impact after changing certain values of attributes (using the threshold of 1 to reduce complexity of visualization)

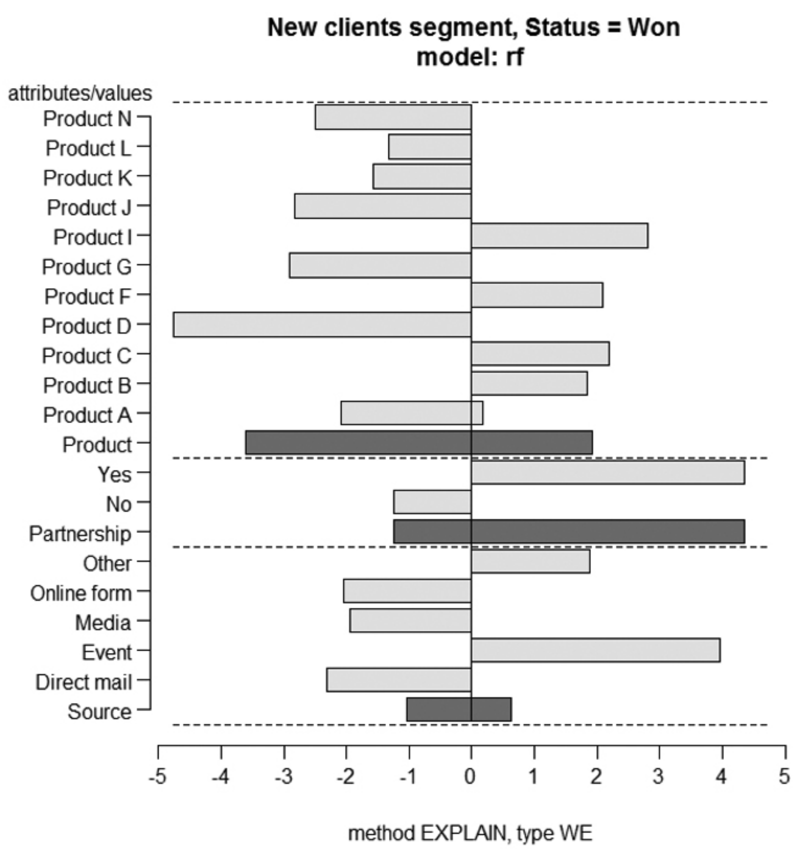


Fig 9: Drill into analysis for a specific business question

shows the results for a period between March 2016 and June 2017. The lines in Figure 9 represent the accuracy for the following types of forecasts:

- The initial forecast (double line) - the accuracy of the sellers at the beginning of the month.
- Consultant + ML model prediction (dot with dashed line) - The accuracy of the external consultant using the model and its explanations.
- An updated forecast (dashed line) - the performance of company using feedback with explanations of individual forecasts.
- Time lag (dotted line) – the percentage of slippages, (opportunities that were not decided in the current month) i.e. the opportunity has shifted.

As an example, we take the month March 2017. Only 17% of initial predictions were correct at the end of the month. An external consultant who took into account the ML model predictions along with the explanations achieved far better precision (43%). After the company reviewed the forecasts of the external consultant and explanation according to the developed ML model, their prediction accuracy rose to 65% for the observed month.

The implementation of the model allows for higher accuracy of the forecast compared to the company's baseline forecasts. By comparing the initial predictions with the updated ones (based on the proposed model), the users can recognize overly optimistic predictions, which are not supported by the data, and review their understanding. In all months, a large percentage of delayed opportunities exist (shown by the dotted line), reflecting too optimistic initial predictions of the users at the beginning of a month. In the future, this problem could be addressed by including additional attributes that will reflect too optimistic forecasting opportunities.

For the most of the observed months in Figure 9, the revised company forecasts (dashed line) are outperforming the external consultants' forecasts (dot with dashed line). This is in line with the intuition that an internal team in the company can better evaluate the context of opportunities than the external consultant. We notice a significant change in behavior as a consequence of individual/group exposure to a specific experience (Kljajić Borštnar et al., 2011). The results show that double-loop learning helps to establish new mental models (which are reflected in revised forecasts) and repeal existing ones (changes in initial forecasts). This is confirmed by improvements in prediction accuracies of the revised forecasts compared to the initial ones.

6 Conclusions

In this paper, we addressed the problem of weak performance in judgmental B2B forecasting. We chose the action design research approach to develop an ML model, coupled by general explanation methods (IME, EXPLAIN), and introduce it into the organizational process. In this way, we involved users in all stages of model development, testing, and use.

In the proposed process, we first identified the problem and described it with a minimum set of features (attributes). Since the existing data from the company CRM were of little value, this phase consumed a lot of time and effort. When we agreed upon the attributes, the company started to collect the data and we built the data set and used it to train the ML prediction model. Based on the CA and AUC performance measures, we selected Random forest as the most appropriate method. Users reported their B2B sales

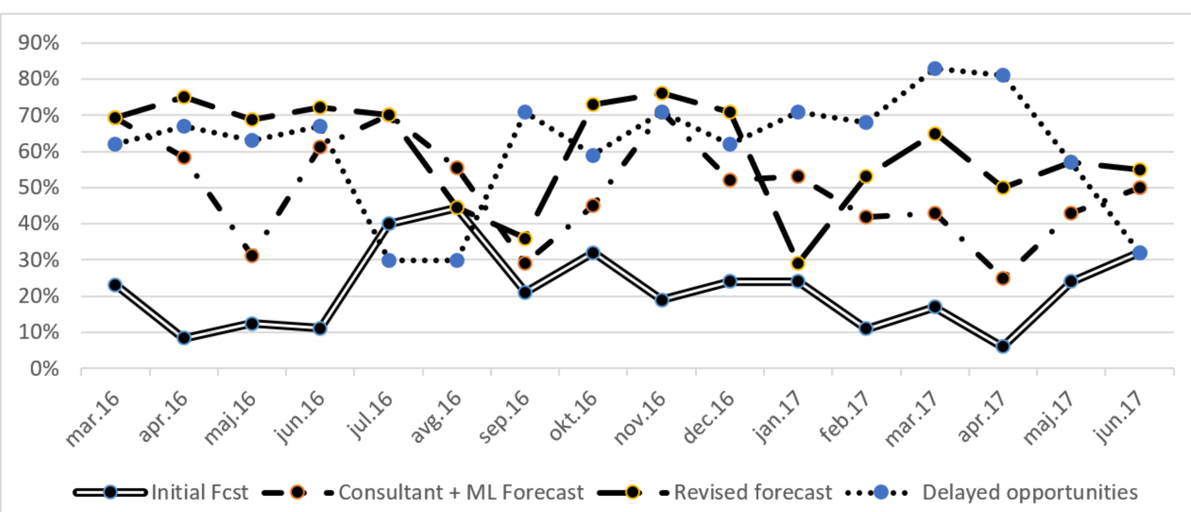


Figure 10: Comparison of prediction accuracy of the users, ML model + consultant and users + ML model

forecasts monthly and compared them to the ML model forecasts and the forecasts made by the external consultant, using ML model with explanations for every sales opportunity. We evaluated the forecasts to actual outcomes the next month and repeated the activities.

In the observed period, it was evident that the users were too optimistic in predicting outcomes of sales opportunities. Interestingly, the external consultant, using the ML model predictions with explanations, frequently achieved better results compared to users' initial forecasts. In most months, the revised forecasts of the users outperformed the forecasts of the ML model and of the external consultant, reflecting their better understanding of the total context of their business. This is in line with the intuition that internal teams in a company can better evaluate the context of opportunities compared to external consultants. The double loop learning is explicated by the revision of users' beliefs and mental models. We recognize a significant change in behavior due to individual/group exposure to a specific experience (Kljajić Borštnar et al., 2011). The results show that double-loop learning helps to establish new mental models (which are reflected in revised forecasts) and repeal existing ones (change in initial forecast). This is also corroborated by the data since the accuracy of the revised forecasts is better than the initial ones (Figure 9).

There are several limitations to this approach. First, the ML model is built upon data, collected by the users, and it reflects users' misperceptions (as evident from Figure 9). We addressed this problem to some extent by standardizing understanding of each attribute and its values. Furthermore, it is evident that the users are over-optimistic in predicting sales outcomes, resulting in several slippages. When confronted with ML model predictions, coupled with explanations, the users can identify slippage of a sales opportunity (the opportunity that will not be closed within a current month but will slip into the following months). The ML model in the current state cannot predict slippages.

Business environments are changing fast, which affects changing of modeled concepts (known as concept drift). It is important for the users to continuously reflect upon the predictions and their explanations in order to detect those changes and identify the need for additional attributes to be taken into account.

Finally, we recommend to actively support users in the phases of selection of attributes, the definition of their values, and implementation of data collection in the organizations' information system. It is important to regularly re-evaluate the values describing open sales opportunities. This can contribute to reduced noise in the data, improved accuracy of models, and builds trust in the model. An important lesson of this research is that neither ML models nor human decision-makers alone can successfully address the problem of B2B sales predictions. However, human decision-makers supported by the ML models enhanced by explanations can surpass the limitations of human rationality.

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Organizacijsko učenje, podprto z modeli strojnega učenja in splošnimi metodami razlage: Primer napovedovanja prodaje na medorganizacijskem trgu

Ozadje in namen: Napovedovanje prodaje na medorganizacijskem trgu je kompleksen odločitveni proces. Čeprav obstaja več pristopov in orodij za podporo temu procesu, se odločevalci v praksi še vedno zanašajo na subjektivno presojo. Problem je možno modelirati kot klasifikacijski problem, vendar pa so zmogljivi modeli strojnega učenja črne škatle, ki ne podpirajo transparentne razlage. Namen raziskave je predstaviti organizacijsko-informacijski model, ki temelji na modelu strojnega učenja, razširjenega s splošnimi metodami razlage, s ciljem podpore odločevalcem v procesu napovedovanja prodaje na medorganizacijskem trgu.
Načrt/metodologija/pristop: Uporabili smo pristop akcijskega načrtovanja, ki z vključevanjem uporabnikov v proces raziskovanja, spodbuja sprejetost modela med uporabniki. Pri razvoju modela strojnega učenja smo sledili metodologiji CRISP-DM ter uporabili programsko okolje R.
Rezultati: Model strojnega učenja smo skupaj z uporabniki razvijali v več ciklih. Model smo ovrednotili z večmesečno uporabo v sodelujočem podjetju. Rezultati kažejo, da so uporabniki izboljšali napovedi prodaje, ko so uporabljali model strojnega učenja, opremljenega z razlago napovedi. Ko so začeli zaupati v model, so na podlagi napovedi in razlag spremenili svoja prepričanja, izdelali natančnejše napovedi in prepoznali lastnosti procesa, ki ga model strojnega učenja ne vključuje.
Zaključki: Predlagani pristop podpira razumevanje, spodbuja diskusijo in validacijo obstoječih prepričanj ter na ta način prispeva k učenju z enojno in dvojno zanko. Aktivno sodelovanje uporabnikov v procesu razvoja, validacije in implementacije je prispevalo k zaupanju in s tem k sprejetosti modela v praksi.

***Ključne besede:** podpora odločanju; organizacijsko učenje; strojno učenje; razlaga napovedi; napoved prodaje na medorganizacijskem trgu*

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Validation of Agent-based Approach for Simulating the Conversion to Organic Farming

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Background and Purpose: The purpose of this study is to describe the principles of the development of parallel system-dynamics and agent-based models of organic farming for the case of Slovenia. The advantage of agent-based modeling is demonstrated by including geospatial information as an agent attribute. The models were compared by the validation, confirming the appropriate level of similarity.
Design/Methodology/Approach: Both system-dynamics and agent-based modeling approaches were applied. Statistical methods were used in the validation.
Results: The results of the validation confirm the appropriateness of the proposed agent-based model. Introducing additional attributes into the agent-based model provides an important advantage over the system-dynamics model, which serves as the paradigmatic example.
Conclusion: A thorough validation and comparison of the results of the system-dynamics and agent-based models indicates the proper approach to combining the methodologies. This approach is promising, because it enables the modeling of the entire agricultural sector, taking each particular farm into account.

Keywords: *agent-based models; organic farming; system dynamics; validation; multimethod simulation*

1 Introduction

Organic farming has been declared the most viable farming system in terms of sustainability (Rozman et al., 2013) and has been modeled by various approaches (Rozman et al., 2015). The system-dynamics (SD) methodology has been applied by Shi and Gill (2005) for the modeling of ecological agriculture development for Jinshan County (China) and by Rozman et al. (2013) for the modeling the development of organic agriculture in Slovenia. Agent-based modeling (ABM) has emerged as an alternative approach that has become possible with the increased computing power of personal computers. Agent-based modeling is the computational study of social agents as evolving systems of autonomous, interacting agents from the complex adaptive system perspective. ABM researchers are interested in how macro phenomena emerge from micro-level behavior among a heterogeneous set of interacting agents (Holland, 1992).

By using ABM as computational laboratories, one may test in a systematic way different hypotheses related to attributes of the agents, their behavioral rules, the types of interactions, and their effect on stylized macro-level facts of the system (Jansen, 2005). In designing an ABM, the modeler takes a "bottom-up" approach by considering the relevant actors and decisions at the micro level that may produce an observable macro phenomenon (e.g., a system-level outcome). Therefore, the use of ABM to improve our understanding or support the rigorous analysis of potential outcomes of that system (e.g., scenario and policy analysis) requires that ABMs have credible and defensible representations of micro-processes. This require-

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ment raises important questions about available empirical approaches for capturing micro processes and their relative merits (Robinson et al., 2007). Gaube et al. (2009) used ABM in combination with stock-and-flow models for participative analysis of land-use systems in Reichraming (Austria). In this light, Deffuant et al. (2002) presented agent-based simulation of organic-farming conversion in Allier département, where they combined mixed-methods research with integrated ABM to explain land change and economic decision-making in the United States and Mexico.

In this paper, we present the development of an agent-based model for conversion to organic farming and compare it to an SD conversion model. The model will consider only the structure of information spread, i.e. market absorption. We have developed a parallel model, in which the main parameters are set once, and both models apply them. The main topic of the present study is therefore the validation of the proposed ABM model of market absorption. It is important to provide such parallels and validate them, because the library of system dynamics is large, and a methodology for straightforward conversion would be convenient.

2 Methodology: System-dynamics Modeling and Agent-based Modeling

In a previous study (Rozman et al., 2013), we developed a model of organic-farming transition based on SD. Methodologically, SD, ABM and DES (Kljajić et al., 2000) converge as one can observe on the following example. The development of an organic-farming model according to the principles of SD was described in detail in Rozman et al. (2013).

To model the market-absorption process, the following equations can be used to express the two main states:

$$P(t) = P(0) - \int_0^t kC(s)ds \quad (1)$$

$$C(t) = C(0) + \int_0^t kC(s)ds \quad (2)$$

where P is potential customers, C is customers, k is concentration of potential customers expressed as $k = P(t)/a$, where a is the size of the potential market, i.e., the number of potential customers, with initial conditions $C(0) = 1$ and $P(0) = a - C(0)$ (Rahmandad & Sterman, 2012). This definition of the model is sufficient for the SD case and is well worked out (Sterman, 2000).

The development of the agent-based model is illustrated in Figure 1, where the information-spread process is considered, which is the basis for the model of organic-farming transition. To begin, we assume that there is only one organic farm in the system (1), which is represented by a red square. If the social factor is set at 3, this farm communicates in one time step with three others (2), which are represented as yellow. One out of the three farm owners who were informed about organic farming

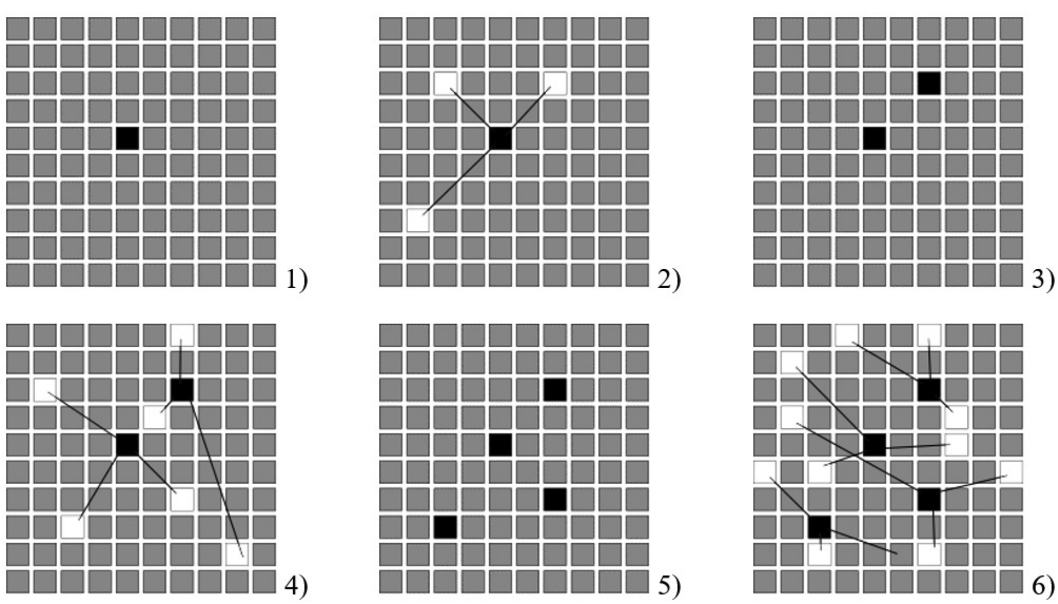

Figure 1: Information spread in an agent-based form

decides to make a transition and is represented by a new red square (3). In the next time step (4), there are two organic farms, each of which communicates with three other, conventional farms. Out of the six newly informed farm owners, represented by yellow, two decide to convert to organic farming. Therefore, four farms have converted (5). The process continues in a similar manner; an increasing number of farm owners are informed (6).

The aforementioned process could be modelled by ABM, which has two states: “Conventional Farm” and “Organic Farm.” Figure 2 shows SD and agent-based models of information spread, which influences the transition from conventional to organic farming in parallel. Both models were implemented with AnyLogic software. The left-hand portion of Figure 2 shows the SD model. This is a structure of market absorption in which the transition from conventional farms to organic farms is considered. Two level elements represent the number of each. The transition is determined by the contact rate and the conversion probability. These parameters represent the main influence on the rate of the transition. At the same time, the agent-based approach is modeled runs in parallel; it is shown in the right-hand portion of Figure 2. The model is based on the Bass diffusion agent-based model. As in the SD model, the state chart consists of two states: “Conventional Farm” and “Organic Farm.” A transition from conventional to organic farm occurs when “Conventional Farm” receives the message “Convert.” This is done in a random manner, which is coded as follows: “sendToRandom(“Convert”);”. The message is conveyed when the contact between two farmers is made and the information about organic farming is exchanged. In our case, the SD and agent-based models are interconnected, and the rate of communication is determined by the set Social Factor and Coefficient of Transition. The code that determines the ABM Contact Rate is coded as follows: “main.ContactRate*main.ConversionProbability”.

Additionally, to leverage the power of ABM, we determine the geographic location of each farm in Slovenia as well as observe the regional distribution of organic farms. This is important for strategic regional planning and other strategic purposes, such as marketing and food processing. For each particular farm, the geolocation was determined and the data was stored in the text file. Initialization of the agents was performed according to the Java programming language code shown in Figure 3, which reads 2,060 posi-

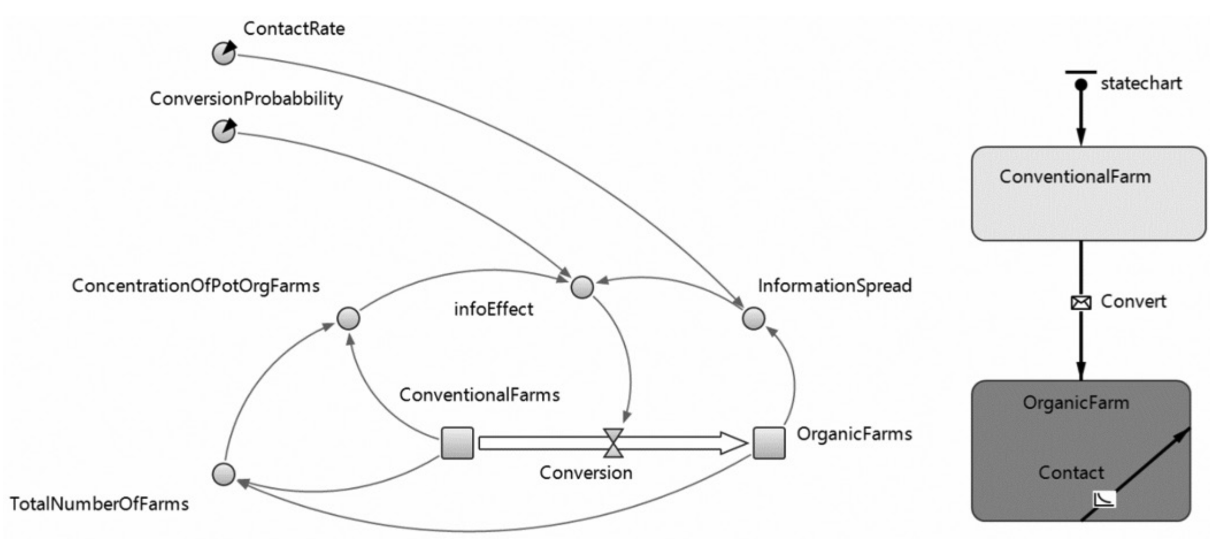

Figure 2: Agent-based model of transition to organic farming; model of information spread

```
for (int i = 0; i < 2060; i++){
        Farm p = add_people();
        p.jumpTo(file.readDouble(), file.readDouble());
        p.oval.setFillColor(gray);
}
deliverToRandomAgentInside("Convert");
```

Figure 3: Initialization code for determination of geospatial agent position; the position of each farm is read from the text file

tions of organic farms from the data file at startup.

The ABM approach is promising because it can model an entire agricultural sector in detail, taking each particular farm into account. At the beginning, one initializes the particular number of agents, in our case 2,060, because this is the number of potential farms for transition. This was the initial situation when the organic-farming policy was implemented. Initially, all the agents are represented by gray, because all the farms are conventional. During the simulation, agents transform from conventional to organic farms; in the graphical view, such agents turn from gray to green (Rozman et al., 2011). This view is extremely important for observation of the concentration of organic or conventional farms in a specific geographic region. The graphical view also contains a graph, where a comparison of the cumulative number of organic farms of the ABM and the ASD model over time is shown.

One can conclude, that an important advantage of the proposed agent-based model is precisely the geographical location of farms. Clearly, the SD model could not provide the user with geolocation information or with any other potential information about the farm. As an example, in our case, the ABM approach shows a high concentration of organic farming in Primorska region, providing decision makers with new information right away. The ABM approach makes it easy to observe the dynamics of the conversion process, which is an important advantage, especially with regard to the concertation of farms in a specific area.

3 Results

The results presented here are twofold. First, we compare the responses of the SD and agent-based models in parallel, and second, we validate the agent-based model, which is done by comparing the results of the two models. Figure 4 shows the results of one simulation run; on the left-hand side, the number of organic farms is shown, whereas the right-hand side presents the conversion rate (farms/month). In both cases, the x-axis represents the time in months. One can observe the difference in response, which is expected, because the agent-based model (red line) depends on probability, whereas the SD model (blue line) is deterministic.

To validate the results from the agent-based model, thorough validation was performed. The SD and the agent-

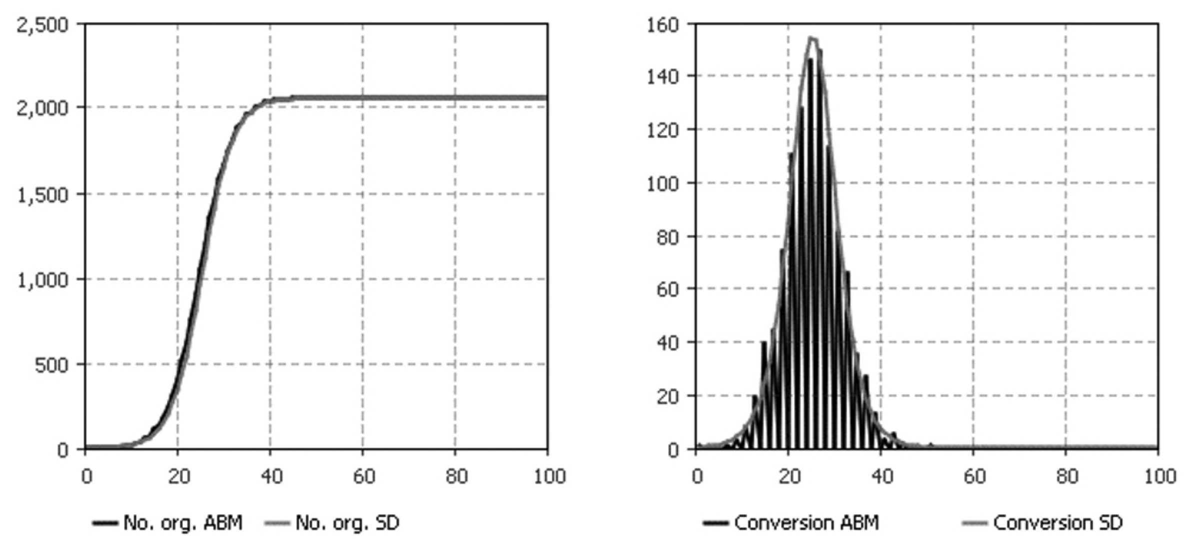

Figure 4: Comparison of the responses of the system-dynamics model (gray line) and agent-based model (black line). Left: cumulative number of organic farms, Right: conversion rate (farms/month). In both cases, x-axis represents the time in months

Table 1: Simulation scenarios and the parameters' values

Scenario	Contact Rate	Conversion Probability
SC1	1	0.1
SC2	2	0.1
SC3	3	0.1
SC4	1	0.3

based models were compared in different scenarios by setting different values for the model parameters defined in Table 1. Here, we change the Contact Rate and Conversion Probability which determine the behavior of both models. The Contact Rate represents the intensity of the organic-farming-initiative spread, whereas the Conversion Probability represents the degree to which the farmers actually intend to perform the transition from conventional to organic farming.

For each of the defined scenarios, five simulation runs were conducted to obtain the averages of the agent-based model. As noted, ABM has a probabilistic character; therefore, certain statistical postprocessing tasks should be completed, an undertaking that inevitably accompanies multiple simulation runs. To illustrate the results, Figure 5 shows five simulation runs for scenario SC1. The graph shows the dynamics of the conversion rate over time. Results are stochastic, giving slightly different responses each time, but the overall response has a distinct characteristic: the conversion rate is low at the beginning, but it gradually increases and, in the end, gradually decreases as the number of organic farms saturates towards their maximum capacity of 2060 farms.

To perform the validation for n data points, the following measures, expressed in Eqs. 3–9, were computed to compare the results of the SD and agent-based models: determination coefficient r^2, mean absolute percent error (MAPE), mean square error (MSE), root mean square error (RMSE), correction (bias) component of the MSE U^M, variation component of the MSE U^S, and covariation component of the MSE U^C (Oliva, 1995). For all scenarios, n is set to 101 (initial time step plus 100 months).

$$r^2 = \left(\frac{\frac{1}{n}\sum_{t=1}^{n} S_t A_t - \overline{S}\,\overline{A}}{S_S S_A} \right)^2 \quad (3)$$

$$MAPE = \frac{1}{n}\sum_{t=1}^{n} \left| \frac{S_t - A_t}{A_t} \right| \quad (4)$$

$$MSE = \frac{1}{n}\sum_{t=1}^{n} \left(S_t - A_t \right)^2 \quad (5)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n} \left(S_t - A_t \right)^2} \quad (6)$$

$$U^M = \frac{\left(\overline{S} - \overline{A} \right)^2}{MSE} \quad (7)$$

$$U^S = \frac{\left(S_S - S_A \right)^2}{MSE} \quad (8)$$

$$U^C = \frac{2\left(1 - r\right) S_S S_A}{MSE} \quad (9)$$

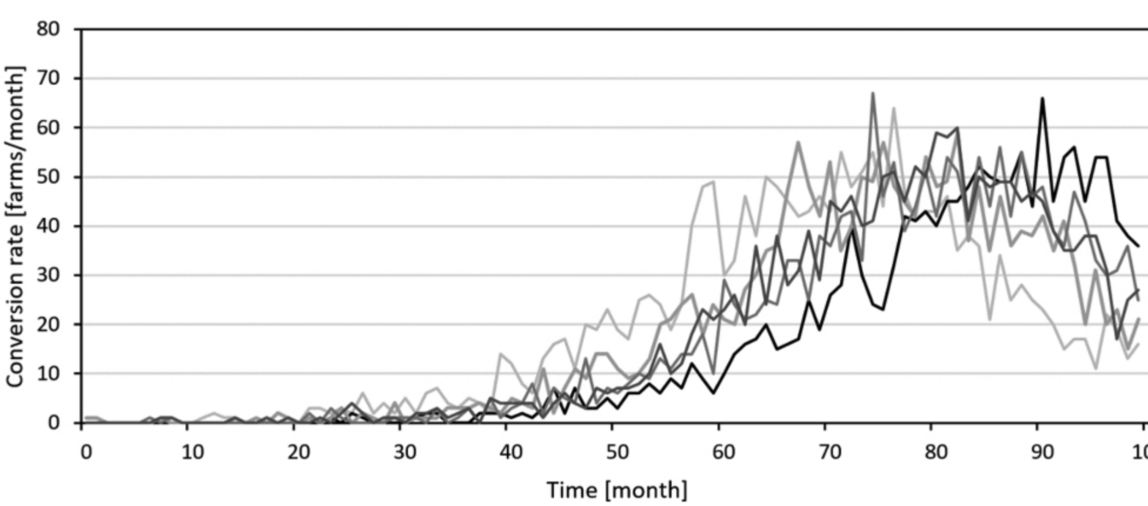

Figure 5: Example of five runs (different gray lines) of the agent-based model for scenario SC 1

where S_t and A_t represent the number of farms in the SD and agent-based models at time *t*, respectively. $\overline{S}$ and $\overline{A}$ represent the mean of the time series of the SD and agent-based models, respectively, and S_S and S_A represent their respective standard deviations.

Table 2 shows the results of five simulation runs of the model for Scenario 1 with the parameters Contact Rate and Conversion Probability set to 1 and 0.1, respectively. There are five columns representing the values of validation statistical measures. The last column shows the average value of measures. In this case, we can observe an r^2 value of 0.982, which indicates a high correlation between the models. MAPE is below 1%. U^M has the highest value, indicating that deviation from average is most influential. A low value of U^S indicates that deviation is more in tune with SD results and an even better result is provided with covariation U^C. Similar results can be found in Table 3, Table 4 and Table 5 for scenarios 2, 3 and 4, respectively.

By examining several parameter combinations and thorough validation with the statistical measures, we find that the lowest r^2 value is 0.957 and the highest MAPE value is 0.34%, across all scenarios. From these results, we can conclude that the SD and agent-based models can be treated as equal and that the agent-based model could be used in further development of organic farming modeling. The validation results by themselves define the general approach to ABM validation when transitioning from SD.

4 Conclusions

The process of transition from conventional to organic farming is complex, incorporating different entities, relations, and regional specifics. The previously applied SD approach to organic farming modeling (Rozman et al., 2013) has been improved by the application of the ABM approach, which enables us to develop models with greater accuracy. It is our intention to model each particular farm in Slovenia as an agent with its unique characteristics. The present study represents an important intermediate step in our effort; it clearly outlines the similarities in SD and ABM methodology, and its results demonstrate that the ABM approach is suitable for the challenging modeling task.

The SD and ABM methodologies are quite different. The ABM is less pre-prepared, because the variety of agents' interactions and attributes is much richer than in the SD approach. To develop adequate models, it is important to be well acquainted with basic principles of ABM. For the SD modeler, it is important to have a good "Rosetta stone" in order to correctly transcribe the main SD principles into the language of ABM. The future of modeling will certainly be in hybrid or multidomain (multimethod) modeling, in which SD, ABM, and discrete-event simulation are integrated. In our case, the advantage of the ABM approach is demonstrated by incorporating the geographical information system component, declaring the geographical location of each farm and revealing important geospatial information about the regional concentration of farms. Therefore, there are many reasons to transform models to ABM in addition to the increased computer power that has enabled the development of relatively large ABM models.

It is important to validate rigorously in the carving of the SD–ABM Rosetta stone, because the ABM models may be quite complex from the programming point of view and, on the other side, SD models are very well validated.

We believe our contribution to this important topic will help modelers further develop good SD–ABM relationships and merge the approaches appropriately.

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Table 2: Validation of Scenario 1 (Contact Rate is 1 and Conversion Probability is 0.1)

Measure	Run 1	Run 2	Run 3	Run 4	Run 5	Average
r^2	0.989	0.946	0.999	0.986	0.990	0.982
MAPE	0.388	0.572	0.177	0.327	0.235	0.340
MSE	15465.886	92841.638	1876.977	23250.744	14744.608	29635.971
RMSE	124.362	304.699	43.324	152.482	121.427	149.259
U^M	0.527	0.465	0.499	0.492	0.487	0.494
U^S	0.158	0.365	0.289	0.295	0.251	0.272
U^C	0.315	0.170	0.212	0.213	0.262	0.234

Table 3: Validation of Scenario 2 (Contact Rate is 2 and Conversion Probability is 0.1)

Measure	Run 1	Run 2	Run 3	Run 4	Run 5	Average
r^2	0.989	0.988	0.969	0.932	0.985	0.972
MAPE	0.388	0.128	0.449	0.312	0.179	0.291
MSE	15465.886	14046.094	35657.427	83490.845	17970.980	33326.246
RMSE	124.362	118.516	188.832	288.948	134.056	170.943
U^M	0.527	0.282	0.306	0.316	0.310	0.348
U^S	0.158	0.012	0.031	0.007	0.008	0.043
U^C	0.315	0.706	0.663	0.677	0.682	0.608

Table 4: Validation of Scenario 3 (Contact Rate is 3 and Conversion Probability is 0.1)

Measure	Run 1	Run 2	Run 3	Run 4	Run 5	Average
r^2	0.990	0.922	0.984	0.910	0.979	0.957
MAPE	0.222	0.737	0.138	0.254	0.124	0.295
MSE	8984.011	68848.186	14833.077	91788.603	19841.957	40859.167
RMSE	94.784	262.389	121.791	302.966	140.861	184.558
U^M	0.218	0.204	0.193	0.210	0.198	0.204
U^S	0.095	0.102	0.061	0.056	0.059	0.075
U^C	0.688	0.694	0.746	0.734	0.743	0.721

Table 5: Validation of Scenario 4 (Contact Rate is 1 and Conversion Probability is 0.3)

Measure	Run 1	Run 2	Run 3	Run 4	Run 5	Average
r^2	1.000	0.987	0.996	1.000	0.997	0.996
MAPE	0.035	0.199	0.073	0.110	0.068	0.097
MSE	38.488	11932.703	3669.380	278.900	2225.930	3629.080
RMSE	6.204	109.237	60.575	16.700	47.180	47.979
U^M	0.004	0.204	0.175	0.213	0.200	0.159
U^S	0.204	0.093	0.069	0.035	0.028	0.086
U^C	0.792	0.704	0.756	0.751	0.772	0.755

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Validacija agentnega pristopa pri simulaciji prehoda na ekološko kmetijstvo

Ozadje in namen: Namen pričujoče raziskave je opisati razvoj paralelnega modela, razvitega po principih Sistemske Dinamike in Agentnega modeliranja. Model je razvit za potrebe simulacije prehoda k ekološkemu kmetijstvu na področju Slovenije. Prednost agentnega modeliranja je bila prikazana z vključitvijo geografske informacije kot agentnega atributa. Izvedena je bila primerjava modelov. S pomočjo validacije je bila potrjena visoka stopnja podobnosti izhodnih rezultatov ter primernost pristopa.
Oblikovanje/metodologija/pristop: Uporabljeni so bili principi modeliranja Sistemske Dinamike in agentnega modeliranja. Pri izvedbi validacije so bile uporabljene statistične metode.
Rezultati: Rezultati validacije so potrdili primernost razvitega agentnega modela. Možnost dodajanja novih atributov v agentnem modelu zagotavlja pomembno prednost pred modeliranjem po principih sistemske dinamike, in hkrati predstavlja paradigmatski primer.
Zaključek: Z izvedenim postopkom validacije in primerjavo modela razvitega po principih Sistemske Dinamike in agentnega modeliranja smo potrdili ustreznost razvitih struktur. Predlagani pristop pretvorbe modelov izkazuje ustrezen potencial za nadaljnje delo pri razvoju modela, kjer obravnavamo vsako posamezno kmetijo kot agenta z večjim naborom atributov.

***Ključne besede**: agentno modeliranje; ekološko kmetijstvo; sistemska dinamika; validacija; multimetodna simulacija*

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Financial System and Agricultural Growth in Ukraine*

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Background/Purpose: An effective financial system should increase the efficiency of economic activities. This study provides evidence regarding the importance of financial development for agricultural growth in Ukraine.
Methodology: We used non-integrated and integral indicators, time series and regression analysis to investigate the link between the financial development and agricultural growth.
Results: The results based on integral indicators shows that the financial development does not affect agricultural growth in Ukraine. The study based on non-integrated indicators, which characterizes various aspects of the financial system's banking component and agricultural growth, provided a significant link between the financial system and agriculture growth. The regression models revealed if bank deposits to GDP (%) increases the value added per worker in agriculture increases exponentially. The results of the study indicate that, agriculture is more sensitive to lending changes than the vast majority of other sectors of the economy. The increasing lending of one UAH (Ukrainian hryvnia) resulted in retail turnover growth of 1.62 UAH, while agricultural gross output, growth was UAH 5.06.
Conclusion: Our results reveal a positive relationship between financial system's banking component and agriculture growth in Ukraine. The results indicate the necessity for continued research into further developing universal methodological approaches of appraising the nexus of the financial system's banking component on agriculture growth in general as well separate farm groups. The results of our study has important implications on policy making authorities efforts to stimulate agricultural growth by improving the efficiency of the financial system's banking component.

Keywords: *Agricultural growth; the integral indicator of the agricultural growth; the integral indicator of the financial development; time series analysis; regression analysis; financial system*

1 Introduction

Agriculture is considered the main driver of the Ukrainian economy due to its availability of natural factors of production (soil fertility, favorable climatic conditions, etc.). Thereby, agriculture can provide technological, investment and socio-economic recovery in the country. The importance of agriculture is evidenced by the following data: the share of agriculture in the gross domestic product (GDP) of Ukraine is about 14%, of the country's exports - more than 20% of the total volume. However, according to experts (EFSE, 2012, OECD, 2012), one of the main factors hindering the formation of effective agriculture in Ukraine is the existence of significant restrictions on access to financing for agricultural producers.

However, in existing Ukrainian research, the importance of the financial system for the development of agriculture is intuitively implied but not supported by good factual scientific evidence. Ukrainian research says that the agriculture growth is slowed down without financial development. However, there are several objections against this statement:

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- For countries with a high proportion of agriculture, agriculture itself is the driver of growth for other sectors and the economy as a whole; therefore, the agricultural growth affects the financial system and not vice versa;
- In developed industrial and post-industrial economies, the development of the financial system can be carried out regardless of the development of agriculture. The growth of lending in the economy as a whole may be accompanied by a decrease in the volume of lending to agriculture because of the processes of redistribution of credit resources between sectors.
- The implementation of large-scale financial support for agricultural producers and rural areas using non-bank instruments significantly reduces the dependence of agriculture on bank lending.

Therefore, we decided to investigate how the financial system affects agriculture in Ukraine. In the literature, we can find numerous studies that explored the link between financial development and economic growth, but only a few studies deal with the impact of the financial system on agriculture. The purpose of this paper is to identify the importance of financial development for agricultural growth in Ukraine.

What were the trends in the development of agriculture and the financial system of Ukraine? Which indicators, integral or non-integrated are better suited to answer the questions concerning the impact of the financial system on agriculture?

2 Literature review

When reviewing the literature, we found many studies conducted with the link between financial development and economic growth. Scholars have seriously explored this topic for only the last 20 years. The first attempt to define the relationship between financial development and economic growth was made by Goldsmith (1969). Using cross-country data, Goldsmith found evidence of a positive trend of the ratio of financial institutions' assets to GDP for 35 countries over 1860-1963 (Goldsmith, 1969). Later many authors have extended this line of inquiry and have confirmed Goldsmith's findings. They have applied a variety of approaches to study the relationship between financial development and economic growth. Mostly scientists have used three approaches for the investigation of the finance-growth nexus: cross sectional analysis (or cross-country analysis), a time-series approach, panel data methods (a combination of both techniques). Cross sectional analysis has been used by, King and Levine (1993), Levine and Zervos (1998), Beck et al. (2000), Levine (2002), Rajan and and Zingales (2003). Time-series techniques have been explored by researchers Demetriades and Hussein (1996), Shan and Morris (2002), and Ghirmay (2004). Furthermore, panel data methods have been discussed in recent literature Edison et al. (2002), Manning (2003).

Each of these approaches has made useful contributions to the investigation of the relationship between finance and economic growth. However, as Schmidt emphasized in his work (Schmidt et al, 2006), all approaches suffer from some important limitations which do not allow us to take all the results at face value. The general problem of all empirical studies is that, to examine the relationship between financial development and growth, one has to define appropriate measures of financial development. Researchers came up with various definitions and measures. Some studies use the size of the banking sector typically measured by the deposit liabilities to GDP or bank claims on the private sector to GDP, others use the size of the stock markets, defined as market capitalization to GDP or total value of domestic equities traded on the stock exchanges to GDP. However, these measures have been criticized by others (Schmidt et al, 2006).

The literature review revealed the existence of studies that focus on the relation between the financial system and agriculture. Researchers from developing countries of India, Iran, Indonesia, Pakistan etc., have mostly studied this topic. They used different methods and they tried to answer the question does the financial system affect the agriculture growth in the country. For example, Yazdani (2008) probed co-integration and causal relationship between financial development, capital stock, real interest rate, international trade and agriculture growth in the Iranian economy. The vector autoregressive model (VAR) was used in modelling multivariate relationships. Their findings confirmed that variables are co-integrated for long run association. Causality analysis revealed that financial development affects agriculture growth. However, there exists only a unidirectional causality from GDP growth to financial development.

Sharif et al. (2009) continued the research about the link between financial development and agricultural growth in Iran. They used research methodology which was based on both survey and description methods. The study showed that financial market plays very important role in developing agricultural sector in Iran. As well, the results also indicated that Iranian financial markets are needed financial reforms to improve the performance of the financial sector.

Anthony (2010) explored the role of agriculture credit, interest rate and exchange rate for the Nigerian economy. Using the historical simulation, the results indicated that agriculture credit improves the efficiency of the agriculture sector and the agriculture sector promotes economic growth. The study suggests that governing bodies should prioritize agriculture and launch a comprehensive macroeconomic policy to stimulate the agriculture sector.

Hye and Wizarat (2011) examined the effect of financial liberation on agriculture growth by employing Cobb-Douglas function in Pakistan using the ARDL bounds testing approach to cointegration. Their results showed that financial liberalization has contributed to improve the performance of agriculture sector in long-and-short runs. A rise in interest rate reduces the growth of agriculture by increasing the cost of production. Capital and the labor force also play roles in enhancing the efficiency of the agriculture sector.

Shahbaz et al. (2013) investigates the relationship between financial development and agriculture growth in Pakistan economy using the Cobb-Douglas function. Their results revealed that financial development has a positive effect on agricultural growth. This implies that financial development plays a significant role in expanding agricultural growth and production.

Yazdi and Khanalizadeh (2014) examine the causal relationship between the dynamic financial development, economic growth and instability in Iran using annual time series covering the period of 1970-2011. The results of the model suggest that there is bidirectional causality between agricultural economic growth and financial development.

For developed EU countries, and Japan, with existing high state financial support, the impact of the financial system on agriculture is not the challenge for the research.

The above research in developing countries showed that researchers used various techniques with varying degrees of complexity. However we didn't find any research there is using some integral indicators for exploring nexus between financial development and agricultural growth. As well, the results of research indicated that financial development has a positive impact on the agricultural growth of these countries.

3 Methodology

The most common (traditional) approach to assessing the impact of one research object (phenomenon or process) on the development of another object is based on an analysis of the interdependence of the indicators characterizing both of these objects. This interdependence could be analyzed using different methodological approaches, the most available being the following:

1. Time series analysis.
2. Regression analysis.

These two methodological approaches were chosen to assess the impact of financial development on agriculture in Ukraine from 2004 to 2013.

In a situation where the objects being studied are complex systems (from the point of view of system theory), the analysis of interdependence may involve the use of integral indicators that generalize the characteristics of individual elements of these systems. Since this is the case in this study, it is necessary to determine the relevant integral indicators.

One of main problems of creation of integral indicator of the financial development and agricultural growth is the impossibility of a completely objective assessment of both these phenomena. The financial system and agriculture are so complicated that any scholar's attempt of simulation and evaluation could not provide the absolute face value. Moreover, it is not possible to make adequate assessments, because the objects of assessment are complicated and there is lack of generally accepted objective criteria of valid estimates for these objects.

The last statement asserts the impossibility of creating a complicated model of finance-growth nexus estimation, which consist of wide database and many indicators and requires using complex mathematical methods. However, it is unacceptable to provide an over-simplified evaluation, leading to simple generalizations and subjective expert assessments of certain aspects of the finance-growth nexus and contradicts the principles of scientific knowledge.

In our opinion, the best option for solving methodological problems of evaluation of the finance-growth nexus is compliance of the concept of "moderate middle way", which provides[1]:

- using publicly available statistical data – quantitative objective indicators calculated using generally accepted methods and openly published on the Internet;
- maximum avoidance of subjective assessments and indicators that are characterized by uncertainty regarding the methods of collection or calculation;
- using the mathematical approaches of the average level of complexity and using average dimension data sets. However, data sets must be sufficient to identify the main statistical regularities on base of regression analysis;
- visualization of assessment results.

We suggest using the principles of concept of "moderate middle way", which is mentioned above, to build the simplified model of integral indicator of level development, which is associated with generalization of the three type's indicators: 1) scale (extensity development); 2) resources; 3) efficiency. The composition of these indicators is illustrated in the Table 1. These indicators are calculated according to the methodology of the World Bank and is available at its website (World Bank 2016a, 2016b).

We divide the financial system into two components – banking sector and financial markets. We propose to call the model of the integral indicator of the relative level of the financial development as «3+3», which allows simplicity and affordability, but quite adequate, provide a comparative analysis of financial system of individual countries

1 A more detailed explanation of the concept of "moderate middle way" is in Wasilewski at el (2015).

and identify their type (bank-based or market-based)[2].

We offer to consider the significance of each indicator as equal. It avoids result distortion, associated with subjective judgments, regarding the ranking of each indicator.

The integral indicator of level development is calculated as an area of the geometric figure (triangle is for economic and agricultural growth, hexagon – for financial system), with the tops in a coordinate system of 3 or 6 axes. Each axis corresponds to one of the indicators listed in the Table 1. On each of the three or six axes, we plot the relative values, which are defined as a share of the maximum (or reference) value of the indicator.

The integral indicator of the financial development level as an area of the hexagon can be calculated by the formula:

$$II_{FS} = \frac{1}{2} \times [(I_1 \times I_2) + (I_2 \times I_3) + ... + (I_6 \times I_1)] \times \sin 60^\circ \quad (1)$$

where II_{FS} – the integral indicator of the financial development level;

I_1, I_2, ...I_6 – relative values of indicators used in the model "3 + 3" (6 indicators): I_1, I_2, I_3 – relative values of banking sector indicators, I_4, I_5, I_6 – relative values of the financial market indicators (see table 1).

The integral indicator of the economic growth level as an area of the triangle can be calculated by the formula:

$$II_{EG} = \frac{1}{2} \times [(I_1 \times I_2) + (I_2 \times I_3) + (I_3 \times I_1)] \times \sin 120^\circ \quad (2)$$

where II_{EG} – the integral indicator of the economic growth level;

I_1, I_2, I_3 – relative values of indicators of scale, resources and efficiency.

The integral indicator of the agricultural growth is calculated as well as the integral indicator of the economic growth level by the formula 2 using three indicators according to the table 1.

The integral indicator describes the relative development level and it cannot be calculated only for one country for one year without comparison with another country or establishing reference values or time-series data[3].

4 Results

If the level of the financial system significantly affects agricultural growth, then, obviously, we should observe a significant statistical relationship between the relevant integral indicators. However, the conducted research has revealed that the relationships between the integral indicators of the financial system and agriculture in Ukraine for 2004-2013 are not observed (see Figure 1).

Consistent statistical patterns between integral indicators of financial development and agricultural growth are absent, but a strong relationship between the integral indicator of financial development and economic growth is present. In this case, we can assume that agriculture should be viewed as one of those industries, for which the complex impact of the financial system does not have significant value.

In general, the relatively stable development of Ukrainian agriculture took place with turbulent financial system and economic development processes in the background (Figure 2).

The study reveals a strong statistical relationship between integral indicator of financial development (taken with 1 year in advance) and the integral indicator of economic growth of Ukraine (Figure 3), despite the fact that any similar interdependencies with integral indicator of agricultural growth were not observed.

Absence of a relationship between two integral indicators in Figure 1 does not give any reasons to conclude that the development of financial system does not influence the development of agriculture in Ukraine. Important relations may exist between indicators characterizing separate aspects of financial system and agricultural growth.

Despite the relatively small number of observations (only 8 values), the regression model is statistically significant and adequate. This confirms the following: 1) the significant value of the coefficient of determination (R-squared) in Figure 3; 2) p-values for the slope coefficient and the constant in the equation – 0.0011 and 0.0044, respectively; 3) the residuals show a random character; 4) heteroskedastic effect is not observed.

Taking into consideration only the financial system's banking component as the most significant one (as many researchers assume) for small and medium agricultural producers, and analyzing the correlation between its integral indicator and separate indicators of agricultural growth, we identify certain statistical dependencies (Table 2).

Most notably, in the Table 2 we can observe a strong negative correlation between the development of the financial system's banking component and value added in agriculture (% of GDP). Regression models (Figure 4) illustrate the identified dependencies.

In Ukraine, the relationship between the developments of the banking component and value added per worker in agriculture is very weak. This fact, combined with the existence of an inverse relationship between the development of the banking component and value added in agriculture (Figure 4), can be evidence to the following: agriculture in Ukraine should be viewed as an industry for which the complex influence of the banking component of the financial system is insignificant or negative.

2 A more detailed explanation of the model "3+3" is in Oliynyk at al (2015).

3The more detail explanation of the concept of "moderate middle way" is Wasilewski at el (2015).

Table 1: The indicators of the simplified model of the integral indicator
Source: own development based on data (World Bank 2016a, 2016b).

The integral indicator	Components of integral indicator		
	Scale (extensity development)	**The resources**	**The efficiency**
1. Financial development:			
banking sector	Commercial bank branches (per 100,000 adults)	Bank deposits to GDP (%)	Domestic credit to private sector by banks (% of GDP)
financial markets	Listed domestic companies (per 1,000,000 adults)	Market capitalization of listed companies (% of GDP)	Stocks traded, total value (% of GDP)
2. Economic growth	Employment to population ratio, 15+, total (%) (modeled ILO estimate)	Gross capital formation (% of GDP)	GDP per capita (current US$)
3. Agricultural growth	Arable land (hectares per person)	Agriculture, value added (% of GDP)	Agriculture value added per worker (constant 2005 US$)

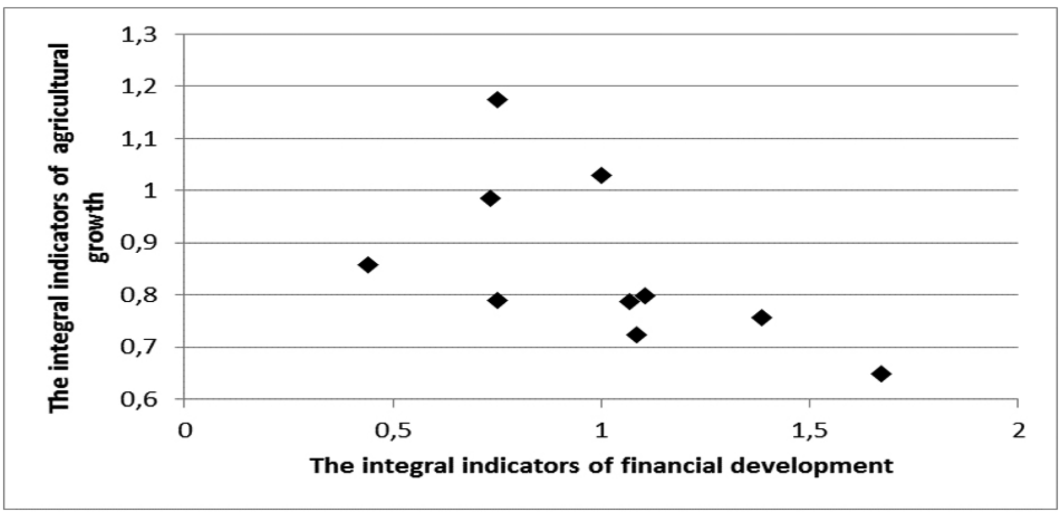


Figure 1: The interdependence between the integral indicators of financial development and agricultural growth in Ukraine, 2004 – 2013
Source: author calculations based on data (World Bank 2016a, 2016b).

5 Discussion

The obtained results of the analysis of empirical data are debatable, therefore they are subject to verification and confirmation. Thus, we attempted to check two assumptions based on statistical data of the National bank of Ukraine.

The first assumption: the presence of the above mentioned inverse correlation is the result of the fact that the Ukrainian agriculture is less dependent on bank credit compared to other sectors of the economy. According to this assumption, the development of Ukraine's banking component leads to increases in the value added of other economic sectors resulting in the decrease of agricultures share of the GDP.

But this assumption is not confirmed (see Table 3). Comparison of lending volumes and amounts of economic activity at current prices revealed that the volume of agricultural production is more sensitive to lending changes than the volume of other sectors and the economy as a whole (Table 3).

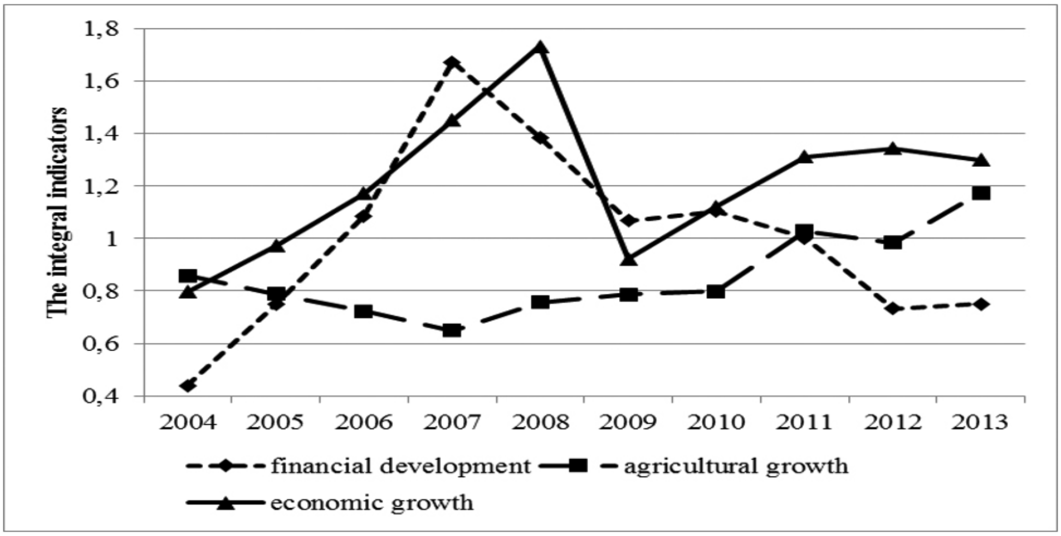


Figure 2. The trend of integral indicators of financial development, economic and agricultural growth in Ukraine, 2004 – 2013
Source: author calculations based on data (World Bank 2016a, 2016b).

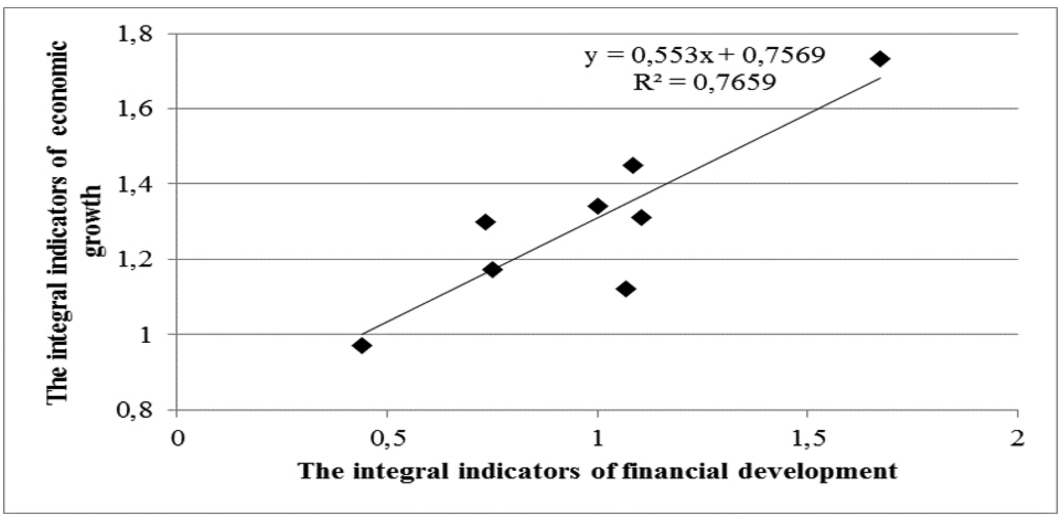


*Figure 3. The regression model describing interdependence between the integral indicators of financial development (for the previous year) and economic growth in Ukraine**
Source: author calculations based on data (World Bank 2016b).
**The values of integral indicators of the financial development are for 2004-2012, data of 2008 is excluded; the values of integral indicators of the economic growth are for 2005-2013, data of 2009 is excluded*

Particularly, in trade (it was a driver of economic growth in Ukraine during the study period), increasing lending of one UAH (Ukrainian hryvnia) resulted in retail turnover growth of 1.62 UAH, while agricultural gross output, growth was UAH 5.06. Comparing agriculture and the economy as a whole identified that agriculture is four times more sensitive to changes in lending.

The research revealed if bank lending increases the gross output of agriculture increases exponentially but nominal GDP growth slows down (see Figure 5, 6). Similarly, the retail trade turnover growth slows down in the case of increasing bank lending.

Revealed patterns not only deny the first assumption, but also illustrate the importance of bank lending for the development of Ukrainian agriculture; it is of even higher significance than for most other sectors and for the economy as a whole.

The second assumption: the inversely proportional

Table 2: Correlation coefficients between integral indicator of the financial system's banking component and separate indicators of agricultural growth in Ukraine, 2004-2013
Source: author calculations based on data (World Bank 2016a, 2016b).

The indicator of agricultural growth	Correlation coefficients with integral indicator of the banking component of financial system
Arable land (hectares per person)	0,450
Agriculture, value added (% of GDP)	**-0,843**
Agriculture value added per worker (constant 2005 US$)	0,212

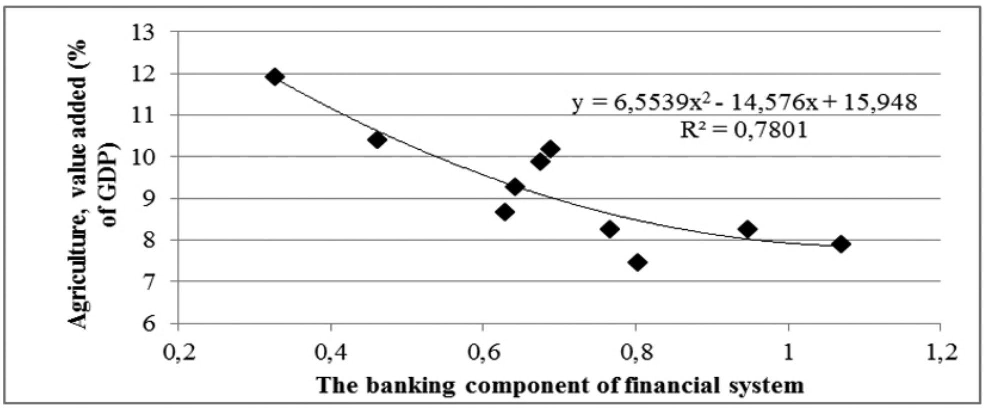


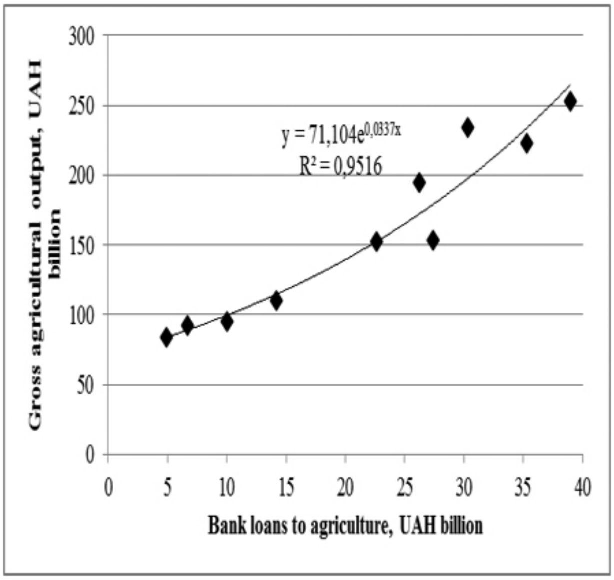
Figure 4: Regression model that describes the relationship between integral indicator of the banking component of financial system and agriculture, value added (% of GDP) in Ukraine 2004 – 2013
Source: author calculations based on data (World Bank 2016a, 2016b).

Table 3: Simple linear regression model parameters describing the relationship between the volume of lending and the volume of economic activity at current prices in Ukraine in 2004-2013
Source: author calculations based on data (World Bank 2016a, 2016b; NBU 2015).

Industry	The indicator of the economic activity	Parameters		R-squared values
		slope coefficient	constant	
Agriculture	Gross output	5.061	49.617	0.9224
Trade	Retail turnover	1.619	29.481	0.9616
Economy as a whole	GDP	1.265	265.5	0.9037

relationship between the development of the bank component and the indicator "agriculture, value added (% of GDP)" in Ukraine relates to the fact, that the indicator "Domestic credit to private sector by banks (% of GDP)" changes inadequately when elasticity of GDP according to the bank loans is greater than one. In this case, the banking sector development, accompanied by growth in lending to the real sector, leads to relatively higher GDP growth, as a result the domestic credit to private sector by banks (% of GDP) decreases.

The second assumption is confirmed by the analysis of the interdependence between the volume of bank credits at current prices and nominal GDP in Ukraine for 2004-2013. It showed that increasing in lending is accompanied by relatively higher GDP growth (as shown in Table 3, lending increasing of one UAH was accompanied by GDP growth of 1.265 UAH). Thus, the existence of the inversely proportional relationship between the integral indicator of the bank component and agriculture, value added (% of GDP) in Ukraine does not evidence the negative financial devel-



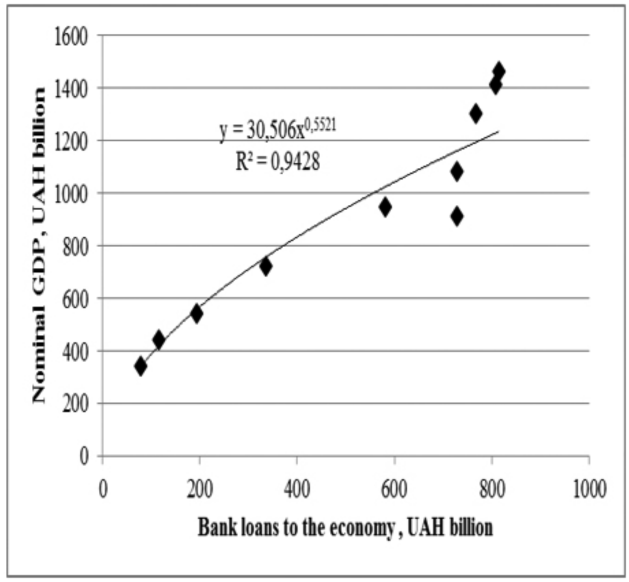
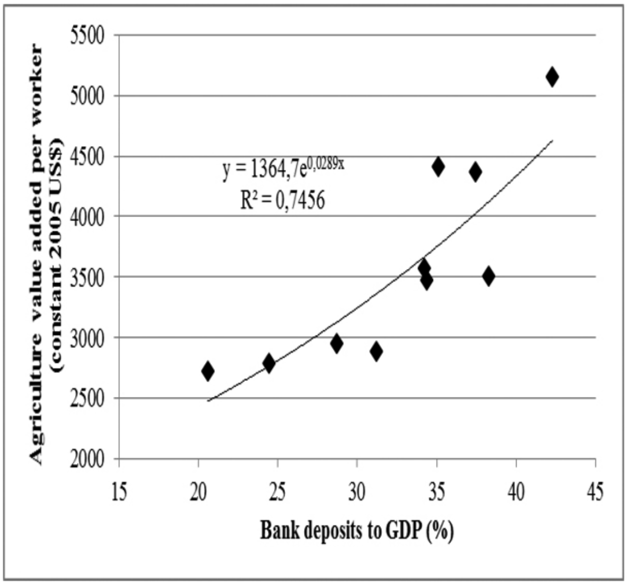


Figure 5 (left): Regression model that describes the relationship between the volume of bank loans to agriculture and the gross agricultural output in Ukraine, 2004 – 2013 (at current prices)
Source: author calculations based on data (World Bank 2016a; NBU 2015)

Figure 6 (right): Regression model that describes the relationship between the volume of bank loans to the economy and nominal GDP in Ukraine, 2004 – 2013 (at current prices)
Source: author calculations based on data (NBU 2015).



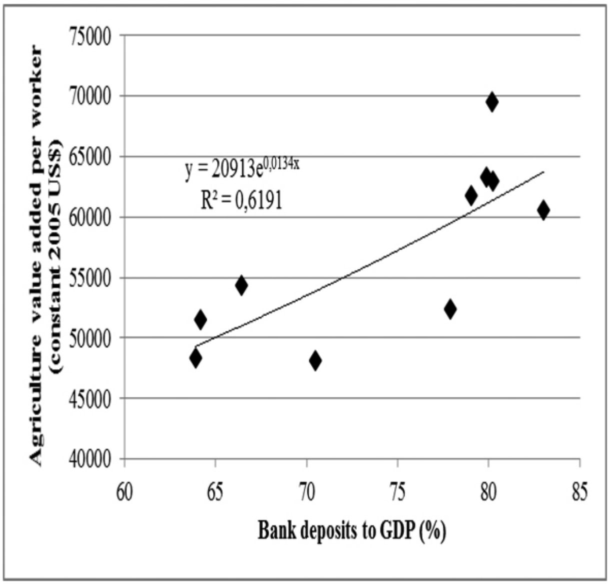


Figure 7 (left): Regression model that describes the relationship between bank deposits to GDP (%) and Agriculture value added per worker (constant 2005 US$) in Ukraine, 2004 – 2013
Source: author calculations based on data (World Bank 2016a; NBU 2016).

Figure 8 (right): Regression model that describes the relationship between bank deposits to GDP (%) and Agriculture value added per worker (constant 2005 US$) in USA, 2004 - 2013
Source: author calculations based on data (World Bank 2016a; FRS 2015).

opment impact on agriculture.

The importance of financial development (particularly its banking component) for agriculture of Ukraine is confirmed by the regression model that describes the relationship between bank deposits to GDP (%) and value added per worker in agriculture (constant 2005 US $) – see Figure 7. This model provides an exponential growth rate of value added per worker in agriculture, which may indicate the existence of substantial potential for increasing agriculture productivity, reached by the stimulation of financial development through increasing its resource base. It should be noted that the positive relationship between bank deposits to GDP (%) and value added per worker in agriculture (constant 2005 US $) for 2004-2013 was also observed in the US (Figure 8) and in many other countries with developed agriculture.

The market component of the financial system, unlike the banking component, was characterized by the absence of significant statistical dependence of certain aspects of agricultural growth of Ukraine, taking into consideration the integral indicator as well as its separate components.

6 Conclusion

Depending on what indicators used integral or non-integrated, we obtained different results on how financial development affects agriculture growth. The results based on integral indicators showed that the financial development does not affect agricultural growth in Ukraine. The study based on non-integrated indicators, which characterizes various aspects of the financial system's banking component and agricultural development, provided a significant link between financial system and agriculture growth. The regression models revealed if bank deposits to GDP (%) increases the value added per worker in agriculture increases exponentially.

We found that the indicator "domestic credit to private sector by banks (% of GDP)", which characterized the efficiency of the banking sector, showed specific dynamics in Ukraine. It means when the monetary amount of loans was increased the level of indicator was decreasing over 2004-2013. The reason was the high dependency of the Ukrainian economy on bank lending, which was reflected in the high elasticity of GDP to changing in lending. The specific dynamics of indicator "domestic credit to private sector by banks (% of GDP)" is one of the reasons for the absence of a statistical dependence between the integral indicators of financial development and agricultural growth. The results of the study indicate that, agriculture is more sensitive to lending changes than the vast majority of other sectors of the economy. The increasing lending of one UAH resulted in retail turnover growth of 1.62 UAH, while agricultural gross output growth was UAH 5.06.

However, our study has several limitations. First, the results obtained are relevant only for Ukraine. From a scientific viewpoint, it is worth exploring the patterns that are inherent to all agrarian countries. Secondly, the study did not take into account significant differences in the activity of certain groups of agricultural producers in Ukraine. In particular, we can assume that financial development has a different impact on the activities of small and large farms.

We found arguments that indicated a positive relationship between the financial system's banking component and agriculture growth but have not completely proven this dependency. It requires developing universal methodological approaches of appraising the nexus of the financial system's banking component on agriculture growth in general as well separate farm groups for agrarian countries with bank-based financial systems. These universal methodological approaches will help to create the applied techniques for identification how the new loan programs and new financial models affect agricultural growth. The absence of these methodological approaches negatively affects the value of any future research based on empirical data.

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Finančni sistem in rast kmetijstva v Ukrajini

Ozadje / Namen: Pričakovati je da učinkovit finančni sistem poveča učinkovitost gospodarskih dejavnosti. Ta študija proučuje pomen finančnega razvoja za rast kmetijstva v Ukrajini.
Metodologija: Uporabili smo neintegrirane in integrirane kazalnike, časovne vrste in regresijsko analizo, da bi raziskali povezavo med finančnim razvojem in kmetijsko rastjo.
Rezultati: Rezultati, ki temeljijo na integriranih kazalnikih, kažejo, da finančni razvoj ne vpliva na rast kmetijstva v Ukrajini. Študija, ki temelji na neintegriranih kazalnikih, ki označujejo različne vidike bančnega komponente finančnega sistema in kmetijsko rast, je ugotovila pomembno povezavo med finančnim sistemom in rastjo kmetijstva. Regresijski modeli so pokazali: če bančne vloge v (% BDP) eksponentno povečujejo dodano vrednost na delavca v kmetijstvu. Rezultati študije kažejo, da je kmetijstvo bolj občutljivo na spremembe pogojev kreditiranja kot velika večina drugih sektorjev gospodarstva. Povečanje posojil za eno UAH (ukrajinsko grivno) je povečalo rast prodaje na drobno 1.62 UAH, medtem ko se je v kmetijstvu bruto proizvodnja povečala za 5.06 UAH.
Zaključek: Naši rezultati kažejo na pozitivno povezavo med bančnimi komponentami finančnega sistema in rastjo kmetijstva v Ukrajini. Rezultati kažejo na potrebo po nadaljnjih raziskavah, predvsem nadaljnjem razvijanju univerzalnih metodoloških pristopov ocenjevanja povezanosti bančne komponente finančnega sistema in rasti kmetijstva na splošno, pa tudi ločenih skupin kmetijskih gospodarstev. Rezultati naše raziskave imajo pomembne posledice za prizadevanja organov za oblikovanje politik, da spodbujajo rast kmetijstva z izboljšanjem učinkovitosti bančnega in finančnega sistema.

Ključne besede: *rast kmetijstva; Integralni kazalnik kmetijske rasti; Integralni kazalnik finančnega položaja, Razvoj; Analiza časovnih vrst; Regresijska analiza; Finančni sistem*

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The Importance of Business Model Factors for Cloud Computing Adoption: Role of Previous Experiences

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Background and Purpose: Bringing several opportunities for more effective and efficient IT governance and service exploitation, cloud computing is expected to impact the European and global economies significantly. Market data show that despite many advantages and promised benefits the adoption of cloud computing is not as fast and widespread as foreseen. This situation shows the need for further exploration of the potentials of cloud computing and its implementation on the market. The purpose of this research was to identify individual business model factors with the highest impact on cloud computing adoption. In addition, the aim was to identify the differences in opinion regarding the importance of business model factors on cloud computing adoption according to companies' previous experiences with cloud computing services.
Methodology: Based on literature review, prior research results, and interviews with cloud computing providers and users, a research model was developed. Statistical analysis focused on identification of factors' importance on cloud computing adoption and differences in opinions according to respondents' previous experiences with cloud computing services. The study was done among 80 companies and five major cloud computing providers in Slovenia.
Results: The research results reveal statistically significant differences in opinions on the importance of cloud computing business model factors according to respondents' previous experiences with cloud computing services. The results can provide orientation for redesign or innovation of existing business models towards the creation of a customer-oriented business model for the more successful exploitation of cloud computing services and business opportunities. For potential users, the findings represent guidelines for the successful adoption of cloud computing services.
Conclusions: In our research, the investigated business model factors could be classified into so-called "business model organizational factors", as they primarily need to be considered by cloud service providers when defining or innovating their business models. For future research, the model should also include the impact of environmental factors, such as Competition, Business Partners, Legislation, Economic Situation, in order to investigate their impact on cloud adoption.

Keywords: *Cloud Computing adoption; SaaS; IaaS; Paas; Business model factors*

1 Introduction

More than five decades of research and development activities in virtualization, distributed computing, networks, and software solutions and services enables the implementation of current cloud computing services and facilities. Nowadays, cloud computing is defined as the provisioning of ubiquitous, on-demand available, dynamically scalable, virtualized IT services and facilities to the customer based on the minimum intervention of the provider (Marston, Li,

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Bandyopadhyay and Ghalsasi, 2011). With its characteristics of service orientation, flexibility, resource sharing, elasticity, virtualization, and charging according to service usage, cloud computing offers significant changes in traditional IT implementation and governance and results in optimization and cost reduction (Chebrolu, 2011).

According to IDC InfoBrief report (2015), approximately four of ten organizations have already adopted public or private cloud services, with the primary goals of increased efficiency and decreased costs. In 2017, cloud adoption impact is also expected to result in the strategic allocation of IT budgets at the higher level and increased revenue. According to the same study (IDC InfoBrief, 2015), over 50 per cent of organizations' IT spending is expected to be for third platform technologies, solutions, and services, built on the technology pillars of mobile computing, cloud services, big data and analytics, and social networking, rising to over 60 per cent by 2020. According to IDC Research (IDC Research, 2015), IaaS spending, in particular, is expected to grow at a compound annual growth rate (CAGR) of 15.1% and is expected to reach $53.1 billion by 2019. The total global cloud computing market is expected to grow from $40.7 billion in 2011 to $241 billion in 2020. According to Gartner (Gartner Inc, 2016), by 2020, a corporate "no cloud" policy will be as rare as a "no internet" policy is today.

Cloud computing is, therefore, expected to impact the European and global economies significantly, especially the ICT industry and other industries, in terms of the potential benefits of cloud computing usage through re-energized productivity, efficiency, and competitiveness. According to Eurostat (2016), 19% of EU-28 companies used cloud computing in 2015, mostly for hosting their e-mail systems and storing files in electronic form. Almost half of those companies used advanced cloud services relating to financial and accounting software applications, customer relationship management or to the use of computing power to run business applications. According to the results of the same study, significant differences can be observed across countries. For example: in Finland, Iceland, Italy, Sweden, and Denmark, the cloud computing service adoption rate is over 30%. In contrast, the rate in Hungary, Bulgaria, Greece, Poland, Latvia, and Romania was below 10% (Eurostat, 2016).

The data show that despite many advantages and promised benefits, resulting mainly in more effective and efficient IT governance and service offerings in companies, the adoption of cloud computing is not as fast and widespread as foreseen. This situation demonstrates the need for further exploration of cloud computing potentials and its implementation on the market. While companies adopting cloud computing services aim to achieve maximum business value from the services, providers face the challenge of providing efficient and attractive business models for achieving competitive advantages on the market.

The situation calls for further action. Cloud computing providers need to re-evaluate and redesign their current business models to accelerate cloud computing adoption. They need to position themselves in the market, recognize potential networks, partnerships and understand adoption factors that need to be taken into consideration when addressing current and potential users. It is important to understand what the customers' needs are, what their requirements are, what they prefer, refuse, and what their fears related to cloud computing adoption are. To assure success and long-term development in the cloud computing market, it is also important to consider interactions of the identified factors.

To address the above-presented challenges, we conducted a study focused on the evaluation of business model factors of cloud computing providers. The study was done in Slovenia. The aim of the study was twofold. First, we identified cloud computing business model factors and developed a research model, consisting of 40 factors, classified into eight factor groups. Factors and factor groups were identified from prior research and interviews with cloud computing providers and users. Second, the defined business model factors were estimated to have an impact on cloud computing adoption in companies. In particular, we were interested in the factors' importance and the differences in opinion according to respondents' previous experiences with cloud computing services. It is expected that understanding of cloud computing business model factors and their importance for its adoption will contribute to the development of more efficient cloud computing business models tailored to the customers (users) expectations. In addition, results of the study will contribute to higher levels of awareness of companies considering cloud computing adoption and faster adoption rate. The study was done among 80 companies and five major cloud computing providers in Slovenia.

The paper is organized as follows. After the introduction, a literature review is given, which is followed by introduction of methodology. The next chapter presents the research results. The paper ends with discussion and conclusions.

2 Literature review

The American National Institute of Standards and Technology (Badger et al., 2011) classify cloud computing services according to their key features and implementation model as follows: software solutions as a service, platform as a service, and infrastructure as a service. For value maximization of cloud service delivery to end users, it is necessary to understand the business aspects of cloud computing (Marston et all, 2011). There have been several studies (Tweel, 2012; Chebrolu, 2011; Low, Chen, and Wu, 2011; Benlian, Hess, and Buxmann, 2009; Chen, Shiue, and Shih, 2011, Watson, 2010) conducted related to the impact of cloud computing adoption factors and research models based on different technology adoption theories, such as: Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTUAT), Task/Technology Fit Theory (TTF), Technology Organization Environment Model Factors (TOE), and others. Previous research models revealed some individual factors that were included in our study. However, according to our evidence, no comprehensive research model of cloud computing business model factors providing a comprehensive overview of the importance and correlation of these factors to cloud computing adoption exists.

In this chapter, we present a literature review of cloud computing adoption factors and business models. The presented research results have served as a basis for initial research model of business model factor design.

2.1 Cloud computing adoption factors

The literature review of factors impacting cloud computing adoption has revealed the following research models, suggesting some of the factors that could be classified as business model factors (Bogataj and Pucihar, 2012):

Technology Acceptance Model factors impacting cloud computing adoption

Watson (2010) investigated factors impacting the adoption of cloud computing by decision-making managers. The purpose of his research was to evaluate the factors impacting the adoption of cloud computing as a part of their strategic information technology planning. The impact of the following factors to cloud computing adoption was investigated: Cost-effectiveness, the Need for Cloud Computing Services, Perceived Cloud Computing Reliability, and Cloud Computing Service Security and Effectiveness. The study results show a strong positive correlation between each of these four independent variables to cloud computing adoption. These findings are also interesting for our research as the model comprises some factors (Reliability, Security) that can also be classified as business model factors.

Low et al. (2011) investigated important factors affecting SaaS adoption. His explorative model integrates the Technology Acceptance Model (TAM) related theories with additional imperative constructs: Marketing Efforts, Security, Trust, Environmental Factors, Perceived Usefulness, and Attitude Towards Technological Innovations. These findings are also interesting for our research because this model comprises some of the factors that can also be classified as business model factors. The study results show that Marketing Efforts have a positive effect on Social Influence as well as on Perceived Ease of Use, Perceived Usefulness, Security, and Trust.

Factors impacting cloud computing adoption - combination of different adoption theories

Benlian et al. (2009) investigated the factors impacting SaaS adoption. The introduced research model is based on the combination of Transaction Cost Theory, the Resource-Based View, and the Theory of Planned Behaviour. The study results revealed that decision patterns about SaaS adoption differ across application types. Social Influence, Attitude Toward SaaS Adoption, Adoption Uncertainty, and Strategic Value turned out to be the strongest and most consistent drivers across all application types. Furthermore, the study results show that Firm Size does not matter in SaaS adoption, since large companies and small- and medium-sized (SMEs) companies had similar adoption rates.

Low et al. (2011) investigated the impact of technological, organizational and environmental factors to cloud computing adoption in the high-tech industry. Their explorative model investigates the impact of the following factors on cloud computing adoption: Relative Service Advantage, Service Complexity, Service Connectivity, Management Support, Company Size, Technology Readiness, Competitive Pressure, Trading Partner Pressure. The results demonstrate the statistically significant impact of the following factors: Relative Service advantage, Management Support, Company Size, Competitive Pressure, and Trading Partner Pressure. In contrast, the results show no significant impact of Service Complexity and Service Connectivity to cloud computing adoption. Furthermore, Tweel (2012) introduced a research model by utilizing factors from Innovation Diffusion Theory, Institutional Theory, and Technology-Organization-Environment Frameworks in order to examine the relationship of the factors in adopting cloud computing. The study demonstrates the statistically significant positive impact of Relative Advantage, Compatibility, and Top Management Support to cloud computing adoption. The results show statistically significant positive correlation between all investigated factors in the research model, except Company Size.

Borgman et al. (2013) presented a research model conceptualizing the link between the TOE Framework and the Decision of Organizations to Adopt Cloud Computing, as well as the moderating effect of IT Governance Structures and Processes on these relationships. The results show that a high Perceived Relative Advantage of cloud computing, a high level of Top Management Support and High Competition Intensity are positively linked to the decision for cloud computing adoption. Moreover, according to the research results of Lumsden and Gutierrez (2013), Compatibility and Relative Advantage are the most essential components impacting cloud computing adoption. According to the same research (Lumsden and Gutierrez, 2013), in the organizational group of factors, Top Management Support is most critical for the adoption of cloud computing.

Gangwar et al. (2015) presented a research model integrating TAM factors and TOE Model factors. The study identified that Relative Advantage, Compatibility, Complexity, Organizational Readiness, Top Management Commitment, and Training and Education as relevant variables for affecting cloud computing adoption, using Perceived Ease of Use and Perceived Usefulness as mediating variables. Furthermore, Competitive Pressure and Trading Partner Support were found to directly affect cloud computing adoption intentions. The findings of this research are also interesting for our research as the model comprises some of the factors (Complexity, Compatibility) that can also be classified under the umbrella of business model factors.

Task-Technology Fit and Information Systems Effectiveness model factors impacting SaaS adoption

Chen et al. (2011) investigated SaaS adoption through TTF. Their explorative model investigates the impact of Technology Characteristics, Task Characteristics, Individual Abilities to Adoption Intention, Relation Consideration, and Benefit Consideration. The results show that Technology Characteristics. Task Characteristics and Individual Abilities can influence the degree of TTF positively. The higher the degree of TTF is, the higher the intention to adopt SaaS is.

Chebrolu (2011) was assessing the correlation of Strategic Alignment, Information Technology Effectiveness and Cloud Computing Adoption in IT companies. The study findings show a very strong statistically significant correlation between Cloud Computing Adoption and Information Technology Effectiveness. In contrast, the correlation between Cloud Computing Adoption and Strategic Alignment was not recognized as statistically significant.

Table 1 and Table 2 present summaries of previous research findings of related research studies, investigating the impact of strategic, economic, social factors, UTAUT, TTF, and TAM factors on cloud computing adoption.

2.2 Business models and business model factors

Many authors (Timmers, 1998; Afuah and Tucci, 2001; Petrovic, Kittl, and Teksten, 2001; Hedman and Kalling, 2003; Rappa, 2010; Osterwalder and Pigneur, 2005, 2009, 2010; Amit and Zott, 2001; Gordijn, Akkermans, and van Vliet, 2000) provide definitions of the business models, business model frameworks and ontologies. For example, Timmers (1998) defines “business model” as an architecture and presentation of a) information and service/product flows, including a description of business actors and their roles, b) potential advantages for individual business actors, c) sources of revenue. Gordijn et al. (2000) define “business models” as descriptions of what the business is about and explanations of “who provides services or products of value to whom, and what he expects in return”.

Lambert and Davison (2012) provide an overview of research on business models for the period of 1996-2010. Their findings contribute to the definition of business model elements and concepts. The following findings are relevant for our study: Rappa (2010) defines the business model as the method of doing business by which a company can generate revenue. Amit in Zott (2001) define “business models” as descriptions of value creation steps, aiming at finalizing different transactions. In general, the business model can be defined as the logic of an organization that reflects its business strategy (Johansson, Malmstrom, Chroneer, Styven, Engstrom, and Kåreborn, 2012). In business model definition, it is also important to include the company’s ecosystem (Pucihar, Lenart, Kljajić, Marolt, and Maletič, 2016).

Osterwalder and Pigneur (2009, 2010) define “business model” as follows: “a business model describes the rationale of how an organization creates, delivers and captures value”. They introduce the business model canvas, which is nowadays a popular strategic tool that enables practitioners to design business models in a creative way. The canvas tool is a comprehensive conceptual model with various design variables in different domains. In this context, a business model is defined as a presentation of a) Values offered by the organization to one or more customer segments, b) Organizational business framework and partner network aiming at producing, marketing, delivering created values and profit generation. The concept also considers the following elements: a) Customer Relationship Management, b) Partner Network, c) Revenue Generation, d) Price Mechanisms (Osterwalder and Pigneur, 2009).

The STOF Business Model Framework (Bouwman, De Vos, and Haakre, 2008) elaborates ways of dealing with design issues and success factors for business models. The method describes the interdependencies between the four core domains: Service, Technology, Organization, and Finance. It provides a detailed description of each domain and the interdependencies of critical design issues of each domain and between domains (Bouwman, De Reuver, Solaimani, and Daas, 2012).

A comprehensive overview of business model definitions also results from the 5th Framework Programme research project E-Factors: A Thematic Network and E-Business Models. According to their definition, a business model concept is structured of following groups of elements: a) Technical and Technology, b) Organizational, c) Industrial d) Individual, e) Social (E-Factors consortium, 2003).

The previous overview of research on business model definitions is not exhaustive. Nevertheless, it offers a comprehensive outline of business model elements and business model design methods. Business models should evolve through time and vary regarding product or service life cycle and its level of adoption in the market (De Reuver, 2007).

Table 1: Summary of previous research results – impact of strategic, economic and social factors to cloud computing adoption

Author	Factor / Factor group	Findings
Gangwar et al.	• Technological (Relative Advantage, Compatibility, Complexity) • Organizational (Readiness, Top management commitment, Training and Education) • Environment (Competitive Pressure, Trading Partner Support) • Others (Perceived Ease of Use, Perceived Usefulness)	• Statistically significant, positive impact of the following variables: Perceived Ease of Use and Perceived Usefulness as mediating variables to cloud computing adoption: Relative Advantage, Compatibility, Complexity, Organizational Readiness, Top management Commitment, and Training and Education • Competitive Pressure and Trading Partner Support were found to directly affect cloud computing adoption intentions.
Borgman et al.	• Technological (Relative Advantage, Complexity Compatibility) • Organizational (Top Management Support, Firm Size, IT expertise of Business Users) • Environmental context (competitive and regulatory environment) • IT Governance Structures • IT Governance Process	• Positive impact of a high perceived Relative Advantage of cloud computing, a high level of Top Management Support and a high Competition Intensity are positively linked to the decision for cloud computing adoption.
Lumsden and Gutierrez	• Technology (Relative Advantage, Complexity, Compatibility) • Organization (Top Management Support, Firm size, Technology Readiness) • Environment (Competitive Pressure, Trading Partners Pressure)	• Statistically significant positive impact of the following variables to cloud computing adoption: Compatibility and Relative Advantage, Top Management Support.
Tweel	• Relative Advantage • Compatibility • Company Size • Company Organizational Readiness • Top Management Support • Skimming • Environmental Factors (Legislation, social Norms, Expectations, Skimming).	• Statistically significant, positive correlation of all investigated factors of introduced model, except with Company Size. • The most important factors impacting cloud computing adoption: Compatibility, Top Management Support, Relative Advantage.
Chebrolu	• Company Strategic Alignment • Modularity, Connectivity, Compatibility of Services • Information Technology Effectiveness.	• Statistically significant, positive correlation of Information Technology Effectiveness and cloud computing.
Low et al.	• Relative Service advantage • Service Complexity • Service Connectivity • Management Support • Company Size • Technology Readiness • Competitive Pressure • Trading Partner Pressure.	• Statistically significant, positive correlation of all investigated factors • Statistically significant, positive impact of almost all factors to cloud computing adoption, except Service complexity and Service Connectivity.
Benlian et al.	• Business and Technological Uncertainty of Service Adoption • Unique Service Value • Strategic Service Value • Ability for Service Replacement • Individual attitude And Behaviour	• Statistically significant, positive correlation of Individual Attitude and Adoption Rate • Statistically significant, negative correlation of Strategic Service Value and Adoption Rate and Unique Service Value and Adoption rate.

Table 2: Summary of previous research results – impact of TAM, UTAU, and TTF factors on cloud computing adoption

Author	Factor / Factor group	Findings
Chen et al.	• Technology Characteristics • Task Characteristics • Individual Abilities to Adoption Intention • Relation Consideration • Benefit Consideration	• Statistically significant, positive impact on Relation Consideration and Technology Characteristics to cloud computing adoption.
Wu	• Marketing Effort • Environmental Factors • Perceived Usefulness • Attitude Towards Technological Innovations • Security and Trust • TAM theory factors	• Statistically significant, positive correlation of the following factor groups: • Marketing Effort and Security and Trust • Attitude towards Technological Innovations and TAM theory factors • Perceived Usefulness and Attitude Towards Technological innovations.
Watson	• Perceived cost effectiveness • Perceived need for service adoption • Perceived service security • Perceived service reliability	• Statistically significant, positive correlation of all investigated factors and cloud computing adoption.

Rapid development and ever-changing and competitive environments demand continuous evaluations, adjustments, and development of business models in order to remain competitive over time and sustain future growth (Amit and Zott, 2012; Teece, 2010; Zott, 2009). Furthermore, business model innovation is becoming an essential and continuous activity for the companies to survive and thrive in today's global competitive markets (Hanelt, Hildebrandt and Polier, 2015).

3 Methodology

In this chapter, we present the research model, research questions and hypotheses, and data collection method.

3.1 Research model

The research framework used in our research was derived from prior research results and is based on two holistic frameworks: Osterwalder's (2004) business model framework and the framework designed in the research project E-Factors: A Thematic Network and E-Business Models (E-Factors consortium, 2003). The preliminary research model consists of the following business model pillars: Provider's Capability for Cloud Computing, Value Proposition, Customer Relationship Management, Revenues, and Costs. Each of the four pillars in the research model consists of several groups, for which several business model factors have been identified. For the purpose of initial research model evaluation, we conducted interviews with five major cloud computing providers and five cloud computing users in Slovenia. The detailed research model is presented in Figure 1. Further in this chapter, we describe the model in detail (Bogataj and Pucihar, 2012; Bogataj and Pucihar, 2013; Bogataj Habjan and Pucihar, 2017).

Provider's Capability for Cloud Computing

The Provider's Capability for Cloud Computing pillar consists of two groups of factors: Collaboration with Partners and Provider's Tangible Assets. Both groups consist of several factors related to provider's capability for service and value delivery:

Collaboration with Partners

- Co-branding or linked branding is considered to be a strategy of the joint presentation of two or more independent brands within one service (Erevelles, Stevenson, and Srinivasan, 2008).
- Collaboration among Partners is considered to be the level of arrangement to cooperate among partners in their network.
- Dispute Resolution Mechanisms with partners are considered to be the definition of potential problem-solving means among partners in the cloud provider's partner network.
- Partner Network Size is considered to be the number of cloud providers included in a partner network.

Provider's Tangible Assets

- The Financial Resources of the provider are considered to the availability of the provider's financial resources, proving the capability for execution of business and development investments in order to ensure service quality.

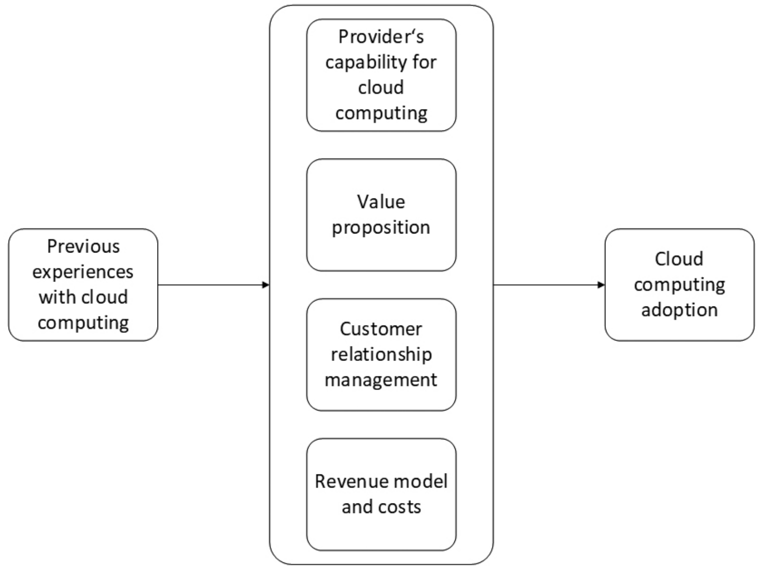

Figure 1: Introduced research model – Provider's business model pillars (Adapted from Osterwalder, E-Factors Consortium and interview results) (Bogataj and Pucihar, 2013)

- Provider's Technology and equipment are considered to be ICT availability (Hardware, Software Solutions, Telecommunication Equipment, and Services) for offering cloud computing services.

Provider's Intangible Assets
- The Provider's Reputation is considered to be its corporative reputation.
- References and Recommendations are considered to be the range of recommendations of satisfied customers, expressing positive collaborative experiences with the cloud computing provider. They support potential new users in selecting a specific service provider or selecting a specific cloud computing service.
- Knowledge and Experiences are considered to be a set of data and provider's behaviour, acquired through education and work.

Value Proposition

The Value Proposition pillar covers all aspects related to the product/services of the company: in our case, cloud computing services. This pillar is also related to the manner in which providers differentiates their service offering from their competitors. For the purpose of our research, value proposition pillar consists of two factor groups: service value for customers, and orientation of services to target customers.

Service Value for Customers
- Economic Value of the Service/cost savings is considered to be a recognized service value that can be expressed monetarily or from the aspect of cost reduction (i.e. investment, maintenance, better efficiency in source exploitation, etc.).
- Usability is defined as the level of service conformity to the needs, desires, and demands of customers.
- Flexibility is defined as the level of service conformity in regard to customer's needs.
- Trademark is defined as the label or combination of labels, established for representing a cloud computing provider or its service.
- Added Value is defined as a standard upgrade of cloud computing service.
- Connectivity/Interoperability is defined as the ability to use the same service through different service providers of cloud computing services.
- Customer Support is defined as the level of customer assistance for using cloud computing services.

Orientation of Services to Target Customers
The focus of cloud computing service by individual segments of target customers in the research is defined according to the activity area and size of the target customer, as well as according to the complexity of their processes and their geographic activity.

Customer Relationship Management

The Customer Relationship Management pillar is related to providers' activities towards their customers. In our research, this pillar consists of two groups of factors: marketing and trust-building mechanisms:

Marketing
A group of factors, defined as the usage of different marketing channels to offer cloud computing services: Internet and Social Media, Events (conferences, workshops, etc.), Direct Marketing, Use of Partners' Marketing Channels, Publications.

Trust-Building Mechanisms
- User Authentication or Access Control is a basic starting element for secure service provisioning.
- System Security is considered to be the ability of cloud service providers to prevent access to network and data to unauthorized users, with suitable tools and technologies (i.e. firewall, virtual private networks, use of safer protocols, advanced encryption techniques, etc.).
- Service Quality is not exclusively limited to performance, but it can also be defined with other characteristics, such as security, availability, upgrade possibility, etc.
- Service and System Availability are defined in close relation to their reliability.
- Service Recovery Procedures are considered to be the definition of recovery/restoration process after service malfunction (due to hacking, loss of power, or an accident).

Revenue Model and Costs

In our research, the business model pillar of Revenue Model and Costs defines the revenue model and costs structure for value creation. The logic of revenue generation is an indicator of business results and organizational success (Sainio and Marjakoski, 2009). For the purpose of our research, we define the following factors in these groups:

Revenue Model
- Service Billing Pay Per Use is defined as a means of charging that is based on the number of transactions, used disk space, recorded use of other resources, etc.
- Service Billing Pay Per Service is defined as the means of charging in regard to service use.
- Service Billing Based on Market Price is defined as the means of charging for the service based on supply and demand.
- Service Billing Based on Target Customers is defined in the research as means of charging for the service according to customer type, their characteristics, abilities, and willingness to pay for the service.

Costs
- Provider's Hardware Costs are defined as the costs of hardware equipment necessary to provide cloud computing services: servers, computers, processors, hard disks, etc.
- Provider's Software Costs are defined as service provider costs of application servers, operating systems, software solutions for virtualization and other software solutions providing cloud computing infrastructure, platforms, and services (Li, Liu, Qui, and Wang, 2009).
- Human Resources Costs of the Provider are defined as costs which occur due to service provisioning and maintenance, technical assistance, ensuring system security, etc. (Li, Liu, Qui, and Wang, 2009). The above-stated costs originate mostly from the salaries of employees.
- Outsourcing Costs of the provider, defined in the research as costs that occur because of the need to involve external services, equipment, and infrastructure when providing cloud computing service. This includes costs for providing security, service restoration, additional technical expertise, etc.
- Collaboration Costs With Other Cloud Computing Providers are defined as costs that occur in business cooperation among service providers.
- Network Costs are defined as the costs of network devices and network equipment, as well as the direct costs of energy for network activity.

Figure 2 presents the initial research model in detail.

3.2 Research questions and hypothesis

Based on the introduced research model, the aim of the research was to address the following research question:

Q1: What are the differences in opinion about the importance of business model factors on cloud computing adoption according to previous cloud computing experiences?

Based on the research question, we developed the following hypothesis:

H01 There are no significant differences in opinion about the importance of business model factors on cloud computing adoption according to previous cloud computing experiences.

3.3 Data collection

The importance of the factors and their impact on cloud computing adoption was investigated by a survey conducted among 80 companies in Slovenia, which was conducted using the questionnaire, which was designed based on

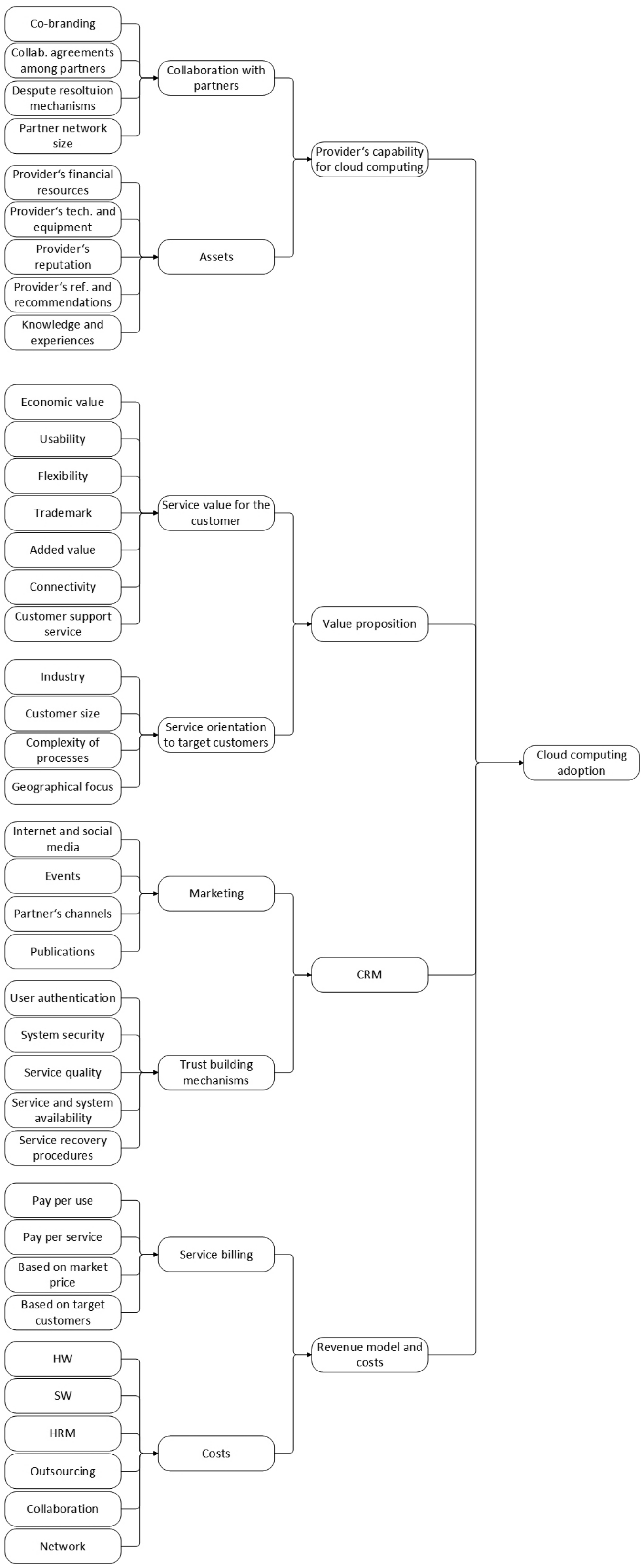

Figure 2: Initial research model for investigation of business model factors for cloud computing adoption

initial research model. The questionnaire was tested with 10 participants (six representatives of cloud computing providers and four representatives of cloud computing end users).

The questionnaire was structured in the following question groups:

- Data on respondents (field of work, experiences) and companies (role, size, main activity area, number of employees in ICT, previous investments in ICT, etc.)
- Opinion on cloud computing business model factors' importance for cloud computing adoption (introduced 40 factors) for each service type (SaaS, PaaS, IaaS). A five-point Likert scale was used from "1" meaning not important at all to "5" meaning very important.
- Experiences with cloud computing adoption (SaaS, PaaS, IaaS).

Managers and IT managers of 900 companies (300 randomly selected large companies, 300 medium-sized companies, 300 small companies) were invited to participate in the survey. In total, 80 responses were valid for further statistical analysis.

4 Research results

Most of the surveyed companies, 42% (n = 34) can be categorized as medium-sized companies; 35% (n = 28) of the sample were smaller (micro and small) companies. Large companies represent 23% (n = 18) of the sample.

A total of 32.89% of companies have already had previous experiences with cloud computing services. Table 3 (below) presents the proportion of responses according to previous cloud computing experiences.

Model Reliability and Validity

The reliability and validity of the structural model were tested with Cronbach alpha and the average variance (AVE). The model consists of nine combined variables. Table 6 (below) presents the AVE and Cronbach alpha values. Confirmation of the reliability and validity of the structural model allowed the continuation of the analysis.

Impact of business model factors on cloud computing adoption

Based on the statistical analysis results, it can be con-

Table 3: Respondents according to previous cloud computing experiences by service type

Experiences with cloud computing services	Frequency	%
Experiences with SaaS	25	32.89%
Experiences with PaaS	25	32.89%
Experiences with IaaS	16	21.05%

Table 4: AVE and Cronbach alpha values

Business model pillar	Business model factor group	AVE	Cronbach alpha
	Y – Cloud Computing Adoption	0.726	0.811
Value Proposition	D1.1 – Service Value for Customers	0.729	0.982
	D1.2 – Service Orientation Towards Target Customers	0.896	0.989
Providers Capability for Cloud Computing	D2.1 – Collaboration with Partners	0.755	0.971
	D2.2 – Assets	0.758	0.978
Customer Relationship Management	D3.1 – Marketing	0.690	0.960
	D3.2 – Trust-Building Mechanisms	0.750	0.980
Revenue Model and Costs	D4.1 – Revenue Model	0.754	0.971
	D4.2 – Costs	0.590	0.925

cluded that there is no statistically significant impact of the analysed business model factors on cloud computing adoption.

Nevertheless, slope coefficient values and t-statistics also reveal some business model factors with moderate or strong impact on cloud computing adoption, by service type. Based on slope coefficient values and t-statistics, in the Value Proposition business model factor group, Service Added Value and Service Usability can be recognized as having the highest (although not statistically significant at p=0.05) impact on all cloud computing service types. Furthermore, in the business model factor group of Collaboration with Business Partners, Collaboration Agreement Among Partners can also be identified as having the highest (although not statistically significant at p=0.05) impact on all cloud computing service types. In the business model factor group of Revenue Model, the factor Service Billing Based on Target Customers can be recognized as having the highest (although not statistically significant at p=0.05) impact on all cloud computing service types.

Table 5 (below) presents business model factors with positive slope coefficients and their statistical importance to cloud adoption by service type (SaaS, PaaS, IaaS).

Differences in opinion on importance of business model factors impacting cloud computing adoption according to previous experiences with cloud computing

Table 6 (below), titled "Differences in opinion on importance of business model factors impacting cloud computing adoption according to previous experiences with SaaS", presents statistically significant differences in opinion on the importance of business model factors among companies with previous SaaS experiences (e.g. implemented ERP, CRM as a Service, Document Management System as a Service, etc.) and companies without previous SaaS experiences.

We can claim that companies with previous SaaS experiences estimate the following factors as more important in comparison to companies without previous experiences with SaaS: Service Usability, Customer Support Services, Co-Branding User Authentication, and Service Recovery Procedures in case of detected problems. In contrast, we can claim that companies without previous experiences with SaaS (specifically experiences with customer relationship management services) view the following factors as more important in comparison to companies with such experience: User Authenticity and Service Quality as more important compared to companies with such experience.

Table 7 "Differences in opinion on the importance of business model factors impacting cloud computing adoption according to previous experiences with PaaS" (below) presents statistically significant differences in opinion about business model factors' importance on cloud computing adoption. The differences are presented among companies with previous experiences with PaaS and the companies without previous such experiences. We can claim that companies without previous experiences with PaaS recognize in Table 7 (below) "presented business model factors to be more important for cloud computing adoption in comparison to companies with previous such experiences.

Table 8 "Differences in opinion on the importance of factors according to experience with the service type, Infrastructure as a service" presents statistically significant differences in opinion about business model factors' importance on cloud computing adoption. The differences are presented among companies with previous experiences with IaaS and those without such experiences. We can claim that companies without previous experiences with IaaS recognize almost all factors (except Service Billing Based on Service Usage) in Table 9 (below) as more important for cloud computing adoption in comparison to companies with previous experiences with IaaS.

Based on the results, hypothesis H01, stating there are no significant differences in opinion about the importance of business model factors to cloud computing adoption among the companies with previous cloud experiences and the companies without previous cloud computing experiences, has been rejected.

5 Discussion and conclusions

5.1 Discussion of research results

Our study was aimed at identifying business model factors with the highest impact on cloud computing adoption. In particular, we were interested in identifying the differences in opinion regarding factors' importance according to respondents' previous experiences with cloud computing services (SaaS, PaaS, IaaS). For those purposes, we developed a research model consisting of 40 cloud computing business model factors, placed into eight factor groups. The research model was built upon prior research and adapted from Osterwalder's business model framework (Osterwalder, 2004) and the E-Factors research project (E-Factors consortium, 2003). The initial research model was evaluated and adapted based on interviews with five major cloud providers and five cloud computing users. Furthermore, a survey was conducted among 80 companies in Slovenia, which represented an 8.89 per cent response rate. The initial sample size was 900 randomly selected companies.

Business model factors' importance

First, based on the statistical analysis results, it can be concluded that there is no statistically significant impact of the analysed business model factors on cloud computing adoption. Nevertheless, slope coefficient values and t-statistics reveal some business model factors with moderate or strong impact on cloud computing adoption, by service

Table 5: Business model factors with positive slope coefficients and their statistical importance to cloud adoption – by service type

Business model pillar	Business model factor group	Business model factor	Slope coeffi-cient	t-statistics
Value Proposition	D1.1 Value Proposition	Customer Support Service → SaaS	5.5764	0.737
		Customer Support Service → PaaS	4.5745	0.5218
		Service Added Value → SaaS	2.0215	0.2754
		Service Added Value → PaaS	0.6933	0.1058
		Service Added Value → IaaS	3.4923	0.4442
		Service Usability → SaaS	1.8263	0.2158
		Service Usability → PaaS	1.4948	0.2041
		Service Usability → IaaS	1.3551	0.1152
		Service Connectivity → SaaS	0.1723	0.0193
		Service Connectivity → IaaS	1.5868	0.1097
		Service Economic Value → IaaS	3.3911	0.4897
	D1.2 Service Orientation Towards Target Customers	Based on Industry → SaaS	1.688	0.2466
		Based on Customer Size → SaaS	0.554	0.0434
		Based on Customer Size → PaaS	6.3405	0.4501
		Based on Customer Size → IaaS	16.6395	1.1293
		Based on Geographical Focus → PaaS	2.5631	0.3609
		Based on Geographical Focus → IaaS	4.7213	0.701
Provider's Capability for Cloud Computing	D2.1 Collaboration with Business Partners	Collaboration Agreement Among Partners → SaaS	6.8348	1.1638
		Collaboration Agreement Among Partners → PaaS	0.0801	0.0245
		Collaboration Agreement Among Partners → IaaS	0.4	0.1051
		Co-Branding → SaaS	2.3194	0.4075
		Co-Branding → PaaS	4.8125	0.7936
		Dispute Resolution Mechanisms → PaaS	0.3704	0.0553
		Size of the Partners' Network	6.5178	0.7411
	D2.2 Assets	Provider's Technology & Equipment → SaaS	6.0943	0.9282
		Provider's Reputation → SaaS	2.4508	0.3933
		Provider's Reputation → PaaS	3.1992	0.4155
		Provider's Financial Resources → SaaS	1.4277	0.2541
		Provider's Financial Resources → IaaS	1.4128	0.1187
		Provider's References and Recommendations → PaaS	1.4149	0.2757
		Provider's References and Recommendations → IaaS	0.5752	0.0567

Table 5: Business model factors with positive slope coefficients and their statistical importance to cloud adoption – by service type (continued)

Customer Relationship Management	D3.1 Marketing	Partner's Channels → SaaS	3.3262	0.478
		Internet and Social Networks → IaaS	2.6258	0.4777
		Publications → PaaS	15.6806	1.193
	D3.2 Trust-Building Mechanisms	System Security → SaaS	2.8447	0.3455
		User Authentication → SaaS	4.2828	0.7241
		Service Quality → PaaS	4.544	0.3811
		Service Quality → IaaS	1.6883	0.1477
		Service and System Availability → SaaS	1.6711	0.2187
		Service and System Availability → IaaS	1.0593	0.1046
		Changing the Provider Trust-Building Mechanism → SaaS	0.8035	0.1419
		Changing the Provider Trust-Building Mechanism → PaaS	3.6428	0.526
		Service Recovery Procedures → IaaS	1.4396	0.075
Revenue model & Costs	D4.1 Revenue model	Service Billing Pay Per Use → SaaS	5.0161	0.6061
		Service Billing Pay Per Use → PaaS	3.1423	0.4053
		Service Billing Pay Per Use → IaaS	4.2671	0.475
		Service Billing Based on Target Customers → SaaS	1.1348	0.1308
		Service Billing Based on Target Customers → PaaS	2.5428	0.1746
		Service Billing Based on Target Customers → IaaS	4.5038	0.3307
		Service Billing Based on Market Value → PaaS	0.6273	0.0904
	D4.3 Costs	HW Costs → SaaS	1.552	0.3636
		HW Costs → IaaS	0.6253	0.1803
		Human Resources' Costs → IaaS	0.4338	0.1324
		Outsourcing Costs → SaaS	0.7145	0.1919
		Outsourcing Costs → PaaS	2.4583	0.4665
		Outsourcing Costs → IaaS	2.2053	0.803
		Collaboration Costs → SaaS	0.385	0.056
		Network Costs → SaaS	0.1903	0.0273
		Network Costs → PaaS	0.2483	0.0141
		Network Costs → IaaS	1.3417	0.2266
R^2 = 0,412 – SaaS, R^2 = 0,4474 – PaaS, R^2 = 0,439 - IaaS				

Table 6: Difference in opinion on importance of business model factors impacting cloud computing adoption according to previous experiences with SaaS

Business model factor group	Business model factor	Independent variable	t	p	M1	M2
Service Value for Customers	Service Usability	Document management	-2.15	0.045	4.27	4.89
Service Value for Customers	Customer Support Services	ERP	-2.58	0.018	4.20	4.89
Collaboration with Partners	Co-Branding	ERP	-2.09	0.049	2.87	3.78
Assets	Knowledge and Experiences	Customer relationship management	2.886	0.011	4.82	3.92
Marketing	Internet and Social Media	Group work	2.243	0.035	4.45	3.23
Trust-Building Mechanisms	User Authentication	Customer relationship management	3.000	0.007	4.75	4.00
Trust-Building Mechanisms	User Authentication	Document management	-2.35	0.028	4.13	4.78
Trust-Building Mechanisms	Service Quality	Customer relationship management	2.165	0.049	4.92	4.33
Trust-Building Mechanisms	Service Recovery Procedures	Document management	-2.22	0.038	4.40	4.89
Legend: M1 – average on factor importance / companies without previous SaaS experiences, M2 – average on factor importance / companies with previous SaaS experiences, t- value, p – statistical significance						

Table 7: Differences in opinion on importance of business model factors according to previous experiences with PaaS

Business model factor group	Business model factor	Independent variable	t	p	M1	M2
Service Value for Customers	Service Added Value	Software Development	2.515	0.029	4.00	2.25
Service Value for Customers	Customer Support Services	Data Warehousing	2.206	0.052	5.00	4.45
Service Orientation to Target Customers	Based on Customer Process Complexity	Software Development	3.245	0.008	4.11	2.00
Collaboration with Partners	Defined Collaboration with Partners	Data Warehousing	4.977	0.000	5.00	3.69
Collaboration with Partners	Dispute Resolution Mechanisms	Data Warehousing	4.168	0.002	5.00	3.92
Assets	Provider's References & Recommendations	Memory Capacity	3.237	0.008	4.83	3.14
Assets	Provider's Knowledge and Experiences	Software Development	2.892	0.014	4.78	3.40
		Migration of Software Solutions	2.854	0.015	4.70	3.25
Marketing	Partners' Marketing Channels	Software Development	2.286	0.052	3.89	3.00
Revenue Model	Service Billing Based on Service Usage	Data Warehousing	2.93	0.014	5.00	4.08
Legend: M1 – average on factor importance / companies without previous PaaS experiences, M2 – average on factor importance / companies with previous PaaS experiences, t- value, p – statistical significance companies with previous SaaS experiences, t- value, p – statistical significance						

Table 8: Differences in opinion on importance of business model factors according to experience with service type, IaaS

Business model factor group	Business model factor	Independent variable	t	p	M1	M2
Service Value for Customers	Service Flexibility	IaaS - Server Capacity	2.689	0.03	5.00	4.30
		IaaS - Network Equipment	2.505	0.03	4.75	3.75
Service Value for Customers	Customer Support Services	IaaS - Memory Capacity	2.535	0.030	4.67	3.67
Service Orientation to Target Customers	Based on customers˙ company size	IaaS - Network Equipment	2.449	0.03	4.13	2.25
Service Orientation to Target Customers	Based on customer process complexity	IaaS - Network Equipment	2.736	0.02	4.25	2.25
Service Orientation to Target Customers	Based on customers˙ geographical location	IaaS - Network Equipment	2.736	0.02	4.25	2.25
Collaboration with Partners	Collaboration with partners	IaaS - Network Equipment	2.616	0.02	4.11	2.80
Assets	Provider's Technology & Equipment	IaaS - Server Capacity	2.283	0.05	5.00	4.36
Assets	Provider's References & Recommendations	IaaS - Server Capacity	2.39	0.04	5.00	4.27
Revenue Model	Service billing based on service usage	IaaS – Network Equipment	-2.26	0.05	4.00	4.83
Legend: M1 – average on factor importance / companies without previous IaaS experiences, M2 – average on factor importance / companies with previous IaaS experiences, t- value, p – statistical significance						

type. Based on slope coefficient values and t-statistics, in the Value Proposition business model factor group, Service Added Value and Service Usability can be recognized as having the highest (although not statistically significant at p=0.05) impact on all cloud computing service types. Furthermore, in the business model factor group of Collaboration with Business Partners, Collaboration Agreement Among Partners can also be identified as having the highest (although not statistically significant at p=0.05) impact on all cloud computing service types. In the business model factor group of Revenue Model, the factor Service Billing Based on Target Customers can be recognized as having the highest (although not statistically significant at p=0.05) impact on all cloud computing service types.

Differences in opinions

The research results reveal statistically significant differences in opinions. We can assert that companies with previous SaaS experiences estimate the following factors as more important compared to companies without previous experiences with SaaS: Service Usability, Customer Support Services, Co-branding, User Authentication, and Service Recovery Procedures in the case of detected problems. In contrast, we can assert that companies without previous experiences with SaaS (specifically experiences with Customer Relationship Management Services) consider the following factors to be more important in comparison to companies with such experience: User Authenticity and Service Quality.

Furthermore, companies without previous PaaS experiences declare the following factors to be more important to cloud computing adoption in comparison to companies with previous PaaS experiences: Service Added Value, Customer Support Services. Service Orientation to Target Customers Based on Customers' Process Complexity, Dispute Resolution Mechanisms, References & Recommendations, Knowledge & Experiences, Partners˙ Marketing Channels, and Service Billing Based on Service Usage.

Companies without previous experiences with IaaS recognize the following business model factors as more important for cloud computing adoption in comparison to the companies with previous experiences with IaaS: Service Flexibility, Customer Support Services, Service Orientation to Target Customers Based On Customers' Size, Service Orientation To Target Customers Based on Customers' Process Complexity, Service Orientation To Target Customers Based on Customers' Geographical Location, Collaboration With Partners, Technology & Equipment, and References & Recommendations.

5.2 Implications for practice

The results of our research also have implications for practitioners. They can provide orientation for the innovation of existing business models towards the creation of a customer-oriented business model for the more successful exploitation of cloud computing services and business opportunities. For potential users, the findings may represent guidelines for the successful introduction and adoption of cloud computing services.

The research model presents a comprehensive consideration of the impact of business model factors on cloud computing adoption. Besides identifying business model factor groups and individual factors having the highest impact on cloud computing adoption, it also addresses the differences in opinion resulting from previous experiences with cloud computing services. Furthermore, end users should consider these factors with special consideration when defining service level agreements with providers and deciding about cloud computing service adoption.

It is understandable that cloud computing business models will be changing and evolving over time, adapting to market requirements, technological development, environment/social needs, and legislation. However, the results of this study show which factors of business models are considered to be more sensitive and important when companies consider cloud computing adoption. This can help providers to rethink, redesign, or re-market their current business models and tailor them according to the needs of different customer segments.

5.3 Limitations and future research recommendations

Findings of this study should also be interpreted considering its limitations.

The analysis shows a low proportion of explained variance in the model (it can be argued that cloud computing adoption is impacted by many other factors. not included in our structural model). Due to this result, future research should further investigate individual business model factors or their grouping into new factor groups. The research should thus focus on the definition of research models with a higher proportion of explained variance.

The response rate in our study was 8.88%. For further research, an increase in the rate of participating companies is recommended. As the study has been done in Slovenia, research should be expanded to other geographical areas.

Further investigation is also recommended to address public institutions, as well as investigating potential models of cloud computing adoption (public cloud, private cloud, hybrid cloud, etc.).

With the aim of in-depth understanding of the impacts of business model factors, deepening the investigation of each group of respondents (users/providers) is suggested. In this direction, it would be interesting to investigate and compare the characteristics of users and providers. Potential differences could also be investigated from the perspective of organizational structure, strategic alignment, the role of ICT, etc.

In our research investigated business model factors could be classified into so-called "business model organizational factors", as they primarily need to be considered by cloud service providers when defining or innovating business models. For future research, the model should also include the impact of environmental factors, such as Competition, Business partners, Legislation, Economic Situation, in order to investigate their impact on cloud adoption.

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Pomen dejavnikov poslovnega modela za uvedbo računalništva v oblaku: vloga predhodnih izkušenj

Izhodišča: Računalništvo v oblaku prinaša številne priložnosti za učinkovitejše upravljanje IT in izrabo IT storitev, zato v prihodnjih letih pričakujemo njegov pomemben vpliv na tržišču. Podatki o trenutni uporabi računalništva v oblaku na tržišču kažejo, da kljub prednostim in priložnostim računalništvo v oblaku še ni razširjeno kot je bilo pričakovano. Omenjena situacija nakazuje potrebo po nadaljnjem raziskovanju potenciala za uvedbo računalništva v oblaku. Namen raziskave je bilo identificirati posamezne dejavnike poslovnega modela računalništva v oblaku, ki imajo največji vpliv na njegovo uvedbo v organizacijah. Poleg tega, smo v raziskavi želeli identificirati razlike v mnenjih o pomembnosti posameznih dejavnikov poslovnega modela računalništva v oblaku glede na predhodne izkušnje organizacij.
Metodologija: Na podlagi pregleda literature, predhodnih raziskav in intervjujev s ponudniki in uporabniki računalništva v oblaku smo oblikovali raziskovalni model. Statistične analize so bile usmerjene na identificiranje pomembnosti dejavnikov za uvedbo računalništva v oblaku in razlike v mnenjih glede na predhodne izkušnje uporabnikov. V raziskavi je sodelovalo 80 organizacij in 5 največjih ponudnikov računalništva v oblaku v Sloveniji.
Rezultati: Rezultati raziskave so pokazali statistično pomembne razlike v mnenjih o pomembnostih dejavnikov poslovnega modela računalništva v oblaku glede na predhodne izkušnje organizacij. Rezultati raziskave predstavljajo usmeritve za preoblikovanje ali inoviranje obstoječih poslovnih modelov ponudnikov računalništva v oblaku. Na podlagi tega lahko ponudniki oblikujejo poslovne modele računalništva v oblaku, ki bodo prilagojeni potrebam strank ter s tem omogočili učinkovitejšo izrabo storitev računalništva v oblaku in odpiranje novih poslovnih priložnosti. Za potencialne uporabnike, rezultati raziskave predstavljajo usmeritve za učinkovitejšo uvedbo storitev računalništva v oblaku.
Zaključek: Dejavniki poslovnega modela, obravnavani v tej raziskavi, spadajo v tako imenovano skupino organizacijskih dejavnikov. Ponudniki računalništva v oblaku jih upoštevajo pri preoblikovanju ali inoviranju poslovnih modelov. V prihodnjih raziskavah bi bilo smiselno vključiti tudi dejavnike, ki se nanašajo na poslovno okolje ponudnikov kot na primer konkurenca, poslovni partnerji, pravni vidiki in tržne razmere ter proučiti tudi njihov vpliv na uvedbo računalništva v oblaku.

Ključne besede: *računalništvo v oblaku; uvedba; SaaS; IaaS; Paas; poslovni model; dejavniki*

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Homecare Service Providers as an Organizational Form of Support for the Elderly: Establishment and Planning of Optimal Capacity

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Background and Purpose: Different studies have highlighted health care allocation problems in Slovenia that indicate the increased need for homecare services for the elderly. It was also found that Slovenian municipalities differ dramatically in the availability of elder care services. A number of older people with diverse unmet needs for care remains. Therefore, the need for the establishment of an additional type of formal homecare services for the elderly exists.
Design/Methodology/Approach: Although many positive effects of home elder care against institutional care are stressed in the literature, the results of many studies performed in recent years have indicated that accessibility of homecare for elderly in Slovenia remains scarce, and it is not equally accessible throughout the country. To mitigate this problem, a new organizational form called "elder homecare service provider" is indicated. The aim of the provider is to offer a variety of different services for the elderly (e.g. homemaking, social networking, transfer services, basic life needs, basic health services, etc.). The establishment of such an organization needs to be designed carefuly, while the unique characteristics and specific needs of the target population must be addressed to optimize desired outcomes.
Results: The aim of the paper is to provide fundamental guidelines for the establishment of elder homecare service provider. All essential characteristics of such an organization are defined. To ensure an appropriate level of service quality, the primarly focus is oriented towards the planning of personnel team capacity. For this purpose, the service provider was described using the stochastic queueing model, which enables service capacity optimization considering different performance measures. The usefulness of the model was illustrated with a numerical example, which has shown that the results obtained provide valuable information for decision support.
Conclusion: The establishment of a homecare service provider network would have many positive effects on society in general. The quality of the everyday life of the elderly is expected to be improved considerably, particularly in the rural areas where a lack of institutional care support is reported. Guidelines proposed in the paper together with the quantitave model for planning of its optimal capacity provide useful information, which are especially relevant in the preliminary phase of the establishment of service providers.

Keywords: *elderly; service provider; performance measures; capacity planning; cost optimization; queueing theory*

1 Introduction

Population ageing is characterized by a rise in the share of the elderly population, resulting from longer life expectancy and declining fertility rates. On average, across OECD countries, the share of the population aged over 65 has increased from less than 9% in 1960 to 15% in 2010 and is expected to nearly double in the next four decades to reach 27% in 2050 (OECD, 2013). Moreover, the proportion of individuals aged 80 and more is expected to almost

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triple, from 4% in 2004 to 11.4% in 2050 (OECD, 2013). Eurostat data also indicate that in 2011 26.6% of the population aged between 65 and 74 as well as 35.4% of the population aged 75 and over reported strong limitations in activities of daily living, while about 6.7% of them are reported to receive long-term care (LTC) (EU-SILC survey as cited in Hlebec et al., 2016a).

Since population ageing has significant effects on European societies, the problem of elder care has attracted many authors. For example, in the ENEPRI[1] report, the organization and provision of LTC for the elderly population in 21 Member States of the European Union was investigated (Riedel and Kraus, 2011). In their study, Bolin et al. (2008) analysed whether informal care,[2] provided by family members, and formal care[3] are substitutes or complements, and whether this relationship differs across Europe. The authors determined that informal and formal homecare are substitutes, while informal care is a complement to doctor and hospital visits. Furthermore, Gannon and Davin (2010) studied the use of formal and informal care services among older people in Ireland and France. Their results highlighted some health care allocation problems which indicate the increased need of homecare services for dependent elderly people. Several studies have also proved that health-care costs rise as the proportion of elderly increase (see e.g. Rechel et al., 2009).

Results of the studies performed in Slovenia show that the situation is quite similar as in other parts of Europe. The main available LTC services in Slovenia can be divided into institutional care, homecare, and social services (Prevolnik Rupel et al., 2010). Results of the case study Genet et al. (2013) revealed that institutional care was more prevalent among Slovenes than homecare was. The reason lies in the accessibility of homecare, which was scarce (only 1.7% of people 65+ received social homecare in 2009), it covered only 20 hours per week, and it was not equally accessible throughout the country. However, due to population ageing, the demand for LTC is growing and cannot be met by providers of formal services. Therefore, the need for performing informal services is increasing. The results of the recent study by Hlebec et al. (2016b) showed that the role of home elder care has enlarged. The authors have proclaimed informal care to be the most wide-spread form of care for the older people in Slovenia. In contrast, another study by Hlebec et al. (2016a) revealed that, despite the efforts toward care for dependent elderly in Slovenia, there are still a proportion of older people with several needs for care, which are being unmet. Furthermore, the research by Hlebec et al. (2014) showed that municipalities in Slovenia differ dramatically in the availability of care for the older people. Some offer only a poor quality of care (mainly smaller rural municipalities), while others provide higher quality of care and a strong combination of both institutional and homecare.

Since the capacities of formal institutions providing elder care services are limited, the Slovenian strategy of LTC from 2010 is oriented towards homecare while institutional care should be provided only in the case when the care is so demanding or costly that the provision of it at home is impossible. Such orientation has human, moral, and economic advantages. Prevolnik Rupel et al. (2010) reported that living at home strongly impacts the quality of life and the success of care, as well as its costs, which are lower in a case of cooperation of family and friends of the elderly. The authors also stress many benefits of home elder care (formal or informal) against institutional care. For example, the study of Bolin et al. (2008) has shown that informal homecare reduces the risk of depression in the elderly and that formal homecare increases their general mental health. Therefore, this is probably one of the main reasons why many older people prefer to grow old in the privacy of their homes rather than in an institution like a home for the elderly (Riedel & Kraus, 2011).

According to the statements listed above, we can conclude that in Slovenia exists a considerable need for the establishment of a new type of formal organization providing homecare services adjusted especially for elderly people. In this context, we present the concept of elderly homecare service provider, which can offer a variety of different services (e.g. homemaking, social networking, transfer services, basic life needs, basic health services, etc.) at the homes of the elderly. Such an organization would be especially worthwhile in the rural areas, where the support of institutional care is often insufficient.

The institute of formal home-healthcare services is not something entirely new in Slovenia. One of the most frequently used approaches is "home nursing" which is organized as an independent organizational unit within primary health care institutions. The provider of home nursing care is a nurse, who is employed within the primary health care institution, where all the services provided are 100% paid for by the Health Insurance Institute of Slovenia (Prevol-

1 European Network of Economic Policy Research Institutes

2 The "textbook" definition of informal care is "a nonmarket composite commodity consisting of heterogeneous parts produced by one or more members of the social environment of the care recipient as a result of the care demands of the care recipient." Simply put, informal care is unpaid care provided by family, friends, and volunteers based on a complex social relationship between the carer and the supported person (IFA, 2014)).

3 Formal care refers to paid care services by a healthcare institution or individual for a person in need. Formal care is available in most countries privately and publicly although public formal care is significantly more limited than private options. It is widely recognized that formal care is often a last case resort which is only chosen by family members or friends who can no longer provide the necessary care to their loved one (IFA, 2014).

nik Rupel et al., 2010). Since the empirical results (Prevolnik Rupel et al., 2010) proved that home nursing is well-accepted among the elderly population (the number of persons aged 60 and over who need home nursing care is increasing), the idea is to establish a service provider who would offer wider assortment of services, but the services would be strictly oriented to the elderly population who still live in their homes. In our opinion, such a new approach can result in many positive effects on society as a whole. In addition to the already mentioned positive effects on quality of everyday life, such institutions can also relieve the burden on institutional facilities such as homes for elderly or nursing homes and hospitals (Hlebec, 2014). Moreover, the elderly homecare service provider can aid the busy family members who must take care to their older relatives. Finally, such solutions represent an excellent opportunity for youth employment, either in the form of business marketing opportunities, public-private partnerships or social entrepreneurship.

Although some experiences in providing formal home-healthcare services exist, the establishment of an elderly homecare service provider requires an elaborate approach. Such an organization needs to be designed carefuly, and the unique characteristics and specific needs of the target population must be addressed in order to optimize desired outcomes. The aim of this paper is to provide fundamental guidelines for the establishment an elderly homecare service provider. All key organizational characteristics which have to be taken into account before a new service is launched on the market are defined. To ensure an appropriate level of service quality, the focus is oriented towards the planning of personnel team capacities. For this purpose, we developed a model based on a queuing theory approach, and illustrate its usefulness with a numerical example. The model enables the calculation of different performance measures of the elderly homecare service provider, such as traffic intensity, the probability that a customer who enters the service provider cannot be served immediately but must wait for the service, expected number of waiting customers, expected waiting time, etc. Such measures are worthwhile especially in the preliminary phase of a service provider establishment, and represent useful information for decision making to ensure an appropriate level of service quality under minimal operating costs.

Results of a literature review about homecare, provided by Basher et al. (2012), indicated that the majority of the literature work in this area is about assignment and routing problems, while the issues like resource dimensioning, homecare modelling, and districting problems are less frequently treated. From a methodological point of view, our contribution attempts to fill this gap by modelling an elderly homecare service provider with a stochastic queuing model.

The paper is organized as follows: in the second section, we have examined theoretical aspects of main organizational characteristics of an elderly homecare service provider. These characteristics must be considered in the preliminary phase of the establishment of an elderly homecare service provider. Furthermore, we provide a stochastic queuing model for the planning of optimal capacity of the personnel team. The model enables the calculation of various performance measures that provide valuable information for decision support as well as cost optimization. The usefulness of the model is illustrated with a numerical example. Finally, the main conclusions are discussed, and the directions for future research are indicated.

2 Organizational characteristics of the elderly homecare service provider

Successfully introducing new products or services into the market is vital to the long-term growth of a company (Kotler, & Keller, 2006). Before a new service is launched, providers create programs to maximize the chance of success. This is often a challenging managerial decision because, in order to set the appropriate pricing levels as well as advertising and promotion budgets, providers must have reliable estimates for to respond to different levels of organizational characteristics (Luan, & Sudhir, 2010). The distinctive nature of service performances requires strategic elements, such as service elements, price, promotion, and people (Lovelock, & Wright, 2002, Ambler, 2003; Farris et al. 2010; Lehmann, & Reibstein, 2006). Kajonius (2016) for example defines the social service structure as all factors affecting the conditions of caregiving, such as budget resources, staff training, reward systems, payment methods, facilities, and equipment.

Services are generally associated with the everyday needs and desires of people. A service is an act or performance offered by one party to another (Lovelock, & Wright, 2002). Several studies to assess perceived service quality have been performed in the healthcare industry. Some have been done regarding public healthcare (Aagja, & Garg, 2010, Camilleri, & O'Callaghan, 1998) while others address private healthcare (Camilleri, & O'Callaghan, 1998). The fact is that specific needs emerge daily and are associated with basic necessities of life. In contrast, there are also occasional needs that do not need to be satisfied daily. Most importantly, the range of services must be taken as understanding the needs and desires of elderly people. The expanded range can follow in consensus and according to the agreement with the individual.

Any service or product manufacturing is inevitably linked to the **cost component**. Price and other user outlays cover the expenditures of money, time, and effort that customers incur in purchasing and consuming services (Lovelock, & Wright, 2002). The LTC expenses are divided into public and private expenditures, and expenditures for health and social LTC. Almost 80% of all expenditures for long-term social and health care are public expenditures (Prevolnik Rupel et al., 2010). In defining the pricing policy of the elderly homecare service provider, we are faced with price differentiation, which requires a more sophisticated analysis of defining service prices given the degree of scarcity of financial resources. We argue that service is not simply a market-based approach to provide services in the direction of profits, but is accompanied with a wider social responsibility, we steer toward the consistency of setting cost carriers to the interests of local communities or states. For such services, either a public-private partnership or the preparation of subsidies for vulnerable groups is considered.

Communication is both a competence that all service providers must master and an opportunity to bring out a word about them to the right place. Communication through promotion and education means all communication activities and incentives designed to build customer preference for a specific service or service provider (Lovelock, & Wright, 2010). Because television is the most accessible technology for elderly, it can be an important technological device to serve this population segment, through features such as distance helping, support of services that promote social interaction on collective viewing, provision of medical information, or information dissemination about public services (Telmo et al., 2016). The basic promotional web is associated with the selection of a suitable location (the market, shopping centres, spas, hospitals, hotels for elderly people) and with all the tools that the marketing communication provides: advertising (e.g. web portals such as med.over.net, 24ur.com, siol.net, newsletters of pensioners' organizations, advertisements in local newspapers, etc.), sales promotion (e.g. by preparing favourable offers for certain seasonal chores), direct marketing (e.g. through catalogues that are sent to the personal address of potential users), personal sales (e.g. the establishment of personal communication and presentation of the services), and public relations (e.g. with an independent advertisement about the service provider in the already mentioned advertising media). Equally important are the tangible elements of the communication, such as a recognizable logo of the service provider, car equipment, uniforms, etc. Several studies indicate that Internet and telecommunication technologies and infrastructures may contribute significantly to the performance of health care systems (Smits, & Janssen, 2008; Babulak, 2006). The existence of a network of health care, social care, and professional service providers, working articulately with an underlying effective management and intermediation service, based on an electronic marketplace for health and social care services, can be a powerful tool and result in effective and efficient service to people with special needs and to the population in general (Cruz-Cunha et al., 2012).

Employees involved in service production are a distinctive element within the organization (Lovelock, & Wright, 2010). The key elements of **professionalism and personal qualities assessment of service providers** are clearly competences. In the context of providing services to the elderly, we assume that the main competences are linked to communication skills, social sensitivity, work versatility, integrity, ethics, and morals, flexibility, language literacy, body language, computer literacy, and ingenuity. There is a multitude of human resource practices that have been shown to have a positive correlation with business performance (Kesti, 2012). The status and role of human resource managers in the field of strategic management are closely related to its importance for human resources in terms of success and competitiveness of the organization. With the growing importance of intangible assets for the organization, the impact of strategic human resource management arises. This factor determines the significance of the human resource role in the organization. This fact reflects the human capital theory, according to which the costs associated with the procedures and processes in human resources should be viewed as an investment that will generate income in the future (Becker et al. 2001).

3 Planning of service provider capacity

The performance of any healthcare system is measured by its capacity and waiting cost optimization. In general, the healthcare system works as a queuing system in which patients (i.e. customers) arrive, wait for services, obtain service, and then depart. Potential disparity between customers' demand for a service and the system capacity available to meet that demand usually results in delays, which leads to higher cost of system operation and consequently to the dissatisfaction of customers. To improve the effectiveness of such a system a queueing theory approach (Beichelt, 2006; Hudoklin Božič, 2003) can be applied, and provide useful information to enhance decision making. The comprehensive overview of contributions and applications of queueing theory in the field of healthcare is provided by Fomundam, & Herrmann (2007) or Singh (2006).

Considering an elderly homecare service provider, we can ascertain that the situation is quite similar to that of other healthcare or social systems. The primary objective of an elderly homecare service provider (in the following text "service provider") management is to organize activities in such way to ensure an appropriate level of service quality while the operating costs remain manageable. This raises questions such as:

- What is the maximal number of customers (i.e. elderly individuals) that the personnel team of the service provider is able to serve if we want to ensure that the offered services will satisfy the acceptable quality

level (i.e. response times and consequently waiting times are not too long; fraction of customers who cannot be served immediately and need to wait for the service is not too high, etc.)?
- What is the minimal service capacity (i.e. expense of the personnel team, number of servers) if the service provider wants to supply an elderly population of a given size?
- What level of service capacity should be offered to ensure the total costs of the service provider operation are minimal?

In the next section, we present a stochastic queueing model whose application to a real situation can provide precise answers to similar questions. The usefulness of the model is illustrated by a hypothetical numerical example.

3.1 Model assumptions

We based our model on the following assumptions:
- the customers' requests to the service provider arrive according to a Poisson process with rate α,
- the service provider personnel team employ *r* workers (i.e. servers) who fulfil the customers' requests,
- the service times of any server are independent exponentially distributed random variables with parameter 1/σ,
- the service rate is independent of the queue length; servers do not go faster because the line is longer,
- the population of customers of the service provider is limited to *k* customers; there are no other limits to the number of the queue,
- the customer who enter the service provider earlier is served earlier (i.e. FIFO discipline); there are no priority classifications for any arrival.

Considering these assumptions, the service provider can be described by the queueing model of type "M/M/r - finite number of customers" (Hudoklin Božič, 2003).

3.2 Service provider performance measures

Applying the queuing theory approach the following quantitative characteristics (i.e. performance measures) of the service provider can be calculated:

Traffic intensity: $$\rho = \frac{\alpha}{r\sigma} \quad (1)$$

The value ρ is usually called a utilization factor, and represents a fraction of time the servers are busy.

Probability that there are exactly *i* customers at the service provider (i.e. in the system), *i*=1..*k*:

$$p_i = \frac{1}{S}\frac{k!(r\rho)^i}{(k-1)!i!}, \quad 0 \le i \le r \quad (2)$$

$$p_i = \frac{1}{S}\frac{r^r k!\rho^i}{r!(k-i)!}, \quad r \le i \le k \quad (3)$$

The value *i* includes the customers currently being served, as well as the customers in the queue who wait for the service.

Probability that a customer who enter the service provider cannot be served immediately, but has to wait for the service:

$$p_{\grave{e}} = \sum_{i=r}^{k} p_i = 1 - \sum_{i=0}^{r-1} p_i \quad (4)$$

Since $p_{\grave{e}}$ represent the fraction of customers, who cannot be served immediately, $1 - p_{\grave{e}}$ is the fraction of customers who can be served immediately, without waiting.

Expected number of customers at the service provider (i.e. in the system[4]):

$$E(N) = \sum_{i=0}^{k} i p_i \quad (5)$$

Expected number of waiting customers (i.e. the length of the queue):

$$E(N_q) = \sum_{i=r}^{k} (i-r)\, p_i \quad (6)$$

Expected waiting time (i.e. time a customer spends in the queue before service begins):

$$E(W_q) = \frac{E(N_q)\left(\frac{1}{\alpha} + \frac{1}{\sigma}\right)}{k - E(N_q)} \quad (7)$$

Expected total waiting time (i.e. total time a customer spends at the service provider, including service and waiting time):

4 Number of customers in the system includes the customers being served as well as the customers waiting for the service.

$$E(W) = E(W_q) + \frac{1}{\sigma} \qquad (8)$$

The symbol S in equations (2), (3) and (4) denotes the sum, which can be calculated as follows:

$$S = \sum_{j=0}^{r-1} \frac{k!(r\rho)^j}{(k-j)!\,j!} + \sum_{j=r}^{k} \frac{r^r k!\rho^j}{r!(k-j)!} \qquad (9)$$

The measures (2) to (8) can be used as optimization criteria in defining the desired or acceptable level of service quality. The optimization criteria can be defined as follows:

- probability of a certain number of customers at the service provider should not exceed a predetermined value,
- fraction of customers who cannot be served immediately should not exceed a predetermined value,
- expected number of customers at the service provider or the expected number of waiting customers should not exceed a predetermined value,
- expected total waiting time or expected waiting time in the queue should not exceed a predetermined value.

Using iteration, we can always determine maximal number k of customers or minimal number r of servers to fulfil the chosen optimization criterion that ensures effective operation of the service provider.

3.3 Cost optimization

The goal of cost optimization is to determine such a service level which minimizes the total costs of service provider operation (see Figure 1). It can be seen from Figure 1 that the total costs of service provider operation consist of the service costs and the waiting costs.

The expected total costs of service provider operation *E(TC)* per time unit can therefore be calculated as the sum of the expected service costs *E(SC)* per time unit and the expected waiting costs *E(WC)* per time unit:

$$E(TC) = E(SC) + E(WC) = rC_s + E(N_q)C_w \qquad (10)$$

where C_S represents the cost per time unit of each server, while C_W denotes the opportunity cost per time unit of waiting by customers. Using iteration, we can always determine the number of servers r, which ensures the minimal value of *E(TC)*.

3.4 Numerical example

The usefulness of our model will be demonstrated with a hypothetical example. Since all the data, used in the example were adopted from the actual case studies of Smolej et al. (2008) as cited in Prevolnik Rupel et al. (2010) and Genet et al. (2013), we think that these results are sufficient to prove the applicability of the model.

Consider a service provider with a personnel team of three employees. We assume that on average one customer per hour calls or visits the service provider, and the expected service time is 30 minutes. We want to answer the following questions:

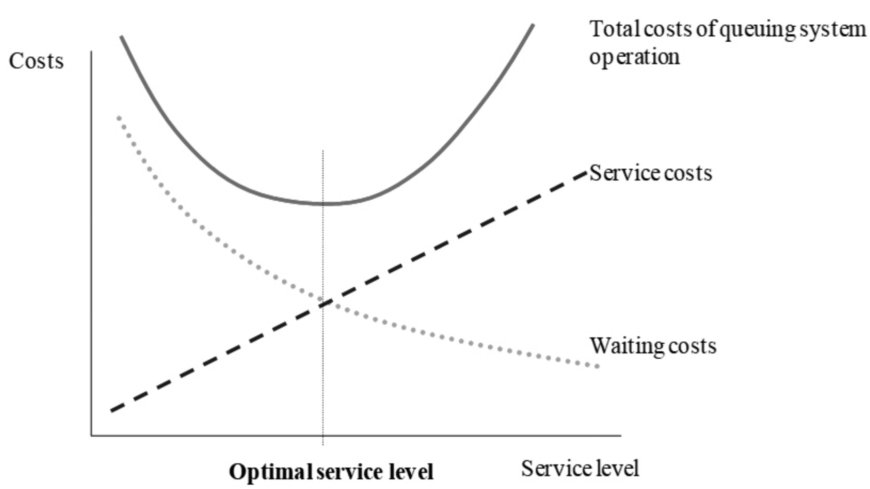

Figure 1: Costs of queueing system operation (Brezavšček, & Baggia, 2014)

The service provider supplies 15 customers. What are the performance measures of the system?

Considering α = 1/*h* , σ = 2/*h* , *r* = 3 and *k* = 15 , and using the equations (1) – (9) we calculate:

Traffic intensity: $\rho = 0,167$

Fraction of customers who cannot be served immediately and need to wait to be served:

$$p_{\check{c}} = 1 - (p_0 + p_1 + p_2) = 0.994 = 99.4\%$$

Expected number of customers at the service provider:

$$E(N) = 9.02$$

Expected number of waiting customers:

$$E(N_q) = 6.03$$

Expected total waiting time:

$$E(W) = 1.51h = 90.6min$$

Expected waiting time in the queue:

$$E(W_q) = 1.01h = 60.6min$$

The results show that under given circumstances the service provider does not ensure the acceptable level of service quality. Almost all the customers have to wait for the service, while the expected waiting time is quite long (more than 1 hour). To prevent the dissatisfaction of customers, such a system needs improvements.

How will the performance measures change if the service provider employs another worker?

We repeat the calculation considerin α = 1/*h* , σ = 2/*h* , *k* = 15 and *r* = 4.We obtain:

Traffic intensity: $\rho = 0.125$

Fraction of customers who cannot be served immediately and need to wait to be served:

$$p_{\check{c}} = 1 - (p_0 + p_1 + p_2 + p_3) = 0.919 = 91.9\%$$

Expected number of customers at the service provider:

$$E(N) = 7.24$$

Expected number of waiting customers:

$$E(N_q) = 3.36$$

Expected total waiting time:

$$E(W) = 0.93h = 55.8min$$

Expected waiting time in the queue:

$$E(W_q) = 0.43h = 25.8min$$

It is evident that employment of additional staff results in considerable improvement of all the measures of the service provider. However, we are not sure whether we achieved an optimal level of service that meets the needs of customers and, with that, contributed to their satisfaction. We can further deepen the analysis and adapt the operation of the provider to specific and pre-set requirements.

What is the maximal number of customers can the personnel team of four workers supply if we want to ensure that at least 15% of customers entering the service provider will be served immediately, meaning that at most 85% of them need to wait to be served?

Mathematical formulation of the optimization criterion can be written as follows: $p_{\check{c}} \leq 0.85$. Taking into account that α = 1/*h* , σ = 2/*h* and *r* = 4 we select the initial value of *k*, and according the equations (4), (2), (3) and (9) calculate the characteristics of the service provider under consideration. Using iteration, we then determine the maximal value of *k* to fulfil the stated optimization criterion. The results are:

k = 12 => $p_{\check{c}}$ = 0.721 => The optimization criterion is fulfilled, *k* can be increased.

k = 13 => $p_{\check{c}}$ = 0.805 => The optimization criterion is fulfilled, *k* can be increased.

k = 14 => $p_{\check{c}}$ = 0.87 => The optimization criterion is not fulfilled, 14 customers are too many.

From the obtained results, we can conclude that if we want to fulfil the stated optimization criterion (at least 15% of customers of the service provider should be served immediately; at most 85% of them needs to wait to be served), the service provider with four employees can supply at most 13 customers.

Suppose that the number of customers suddenly increases from 15 to 20. What is the minimal number of employees needed to ensure that the expected waiting time will not exceed 20 minutes?

The optimization criterion can be written as: $E(Wq) \leq 20$ min = 0.33*h*.

Taking into account that α = 1/*h* , σ = 2/*h* and *k* = 20 we select the initial value of *r*, and according the equations (8) and (9) calculate the characteristics of the service provider under consideration. Using iteration, we then determine the minimal value of *r* to fulfil the stated optimization criterion. The results are:

$$r = 6 \Rightarrow E(W_q) = 0.25h = 15min$$

The optimization criterion is fulfilled, *r* can be decreased.

$$r = 5 \Rightarrow E(W_q) = 0,523h = 31.38min$$

The optimization criterion is fulfilled, *r* can be decreased.

$$r = 4 \Rightarrow E(W_q) = 1h = 60min$$

The optimization criterion is not fulfilled, 4 servers are not enough.

If we want to fulfil the optimization criterion (i.e. the service provider who supply 20 customers should ensure that the expected waiting time will not exceed 20 minutes), the personnel team should employ at least five workers.

Suppose that C_s = €/h6.50 and C_w = €/h4,30. How many employees should the service provider who supplies 15 customers employ if we want to ensure that the expected total costs of provider operation per time unit are minimal?

Considering $\alpha = 1/h$, $\sigma = 2/h$ and $k = 15$, and using the equation (6) we can determine the value *r* which ensures the minimum of the cost function (10). Results are given in Table 1 and Figure 2. It can be seen that under given conditions the expected total costs of service provider operation are minimal when the provider employs five servers.

4 Discussion and conclusion

The aging population is currently one of the main issues facing international healthcare systems. A recognized fact is that with advancing age, the rates of developing health problems and chronic disease will increase and the demand for healthcare resources will escalate. Consequently, this will impact the healthcare institutions and LTC facilities (Lovell, 2006). All countries in Europe are experiencing an ageing of their populations, and this trend is projected to continue. This process is often regarded as a primary cause of upward pressure on healthcare costs.

The growth of population aging is also reported for Slovenia. This raises many fundamental questions for policy makers; therefore, much more activity from the state, local communities, relatives and the rest of the social environment is needed. In the ENEPRI research report (Prevolnik Rupel et al., 2010), actions focused on the improvement of elder care system in Slovenia are described. For example, in 2004 different forms of homecare started to

Table 1: Summary of cost optimization of service provider operation

R	**2**	**3**	**4**	**5**	**6**
$E(SC)$	13	19.5	26	32.5	39
$E(N_q)$	9.00	6.03	3.36	1.53	0.59
$E(WC)$	38.70	25.91	14.44	6.57	2.53
$E(TC)$	**51.70**	**45.41**	**40.44**	**39.07**	**41.53**

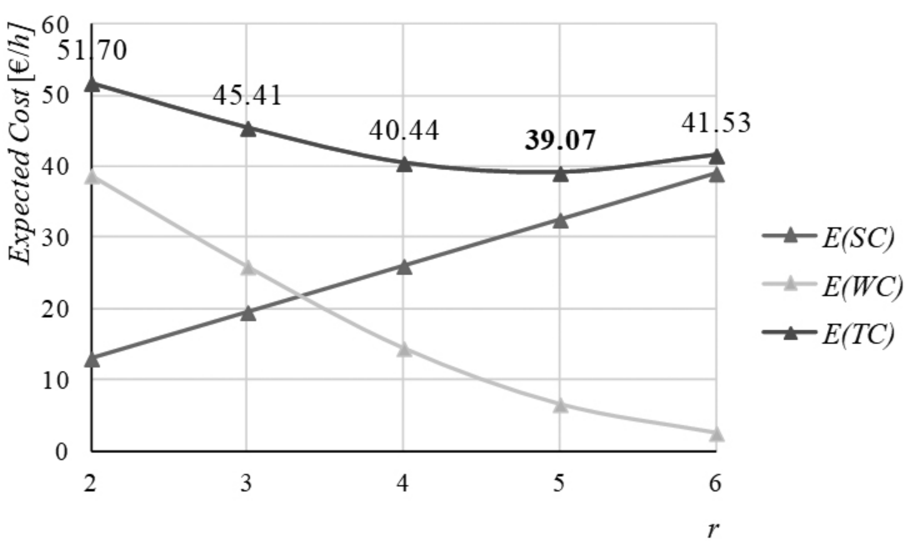

Figure 2: Expected cost of service provider operation

develop, offered by homes for the elderly, centres for social work, and different voluntary institutions and organizations. Unfortunately, the connection among providers of different kinds of services is weak, which lowers the efficiency of the service. There are also distinct differences in the accessibility of services for persons in the institutional care and persons in homecare as well as high regional differences in the availability of these services. Furthermore, the estimated number of people with severe unmet needs suggests that there are significant opportunities for social policy changes and development of new public and private services for older people in need, as well as for the integration of fragmented LTC (Hlebec, 2016a). These statements confirm the ascertainment that there exists a need for development of additional type of the formal homecare services for the elderly in Slovenia.

In this paper, a new type of formal organizational form of homecare services for elderly people has been examined. All essential characteristics of such an organization, which have to be considered during the establishment of a service provider, have been defined. The focus of our study was oriented towards planning of optimal capacities of personnel team to ensure an appropriate level of service quality. For this purpose, we developed a model based on a queuing theory approach. Using the model, different performance measures of the service provider are calculated. Furthermore, the optimal service capacity is determined, which minimizes the total cost of service provider operation. The usefulness of the model was illustrated by a numerical example. Results obtained proved that such an analysis provides valuable information for decision making, which is valuable, especially in the preliminary phase of service provider establishment. Economic analysis helps the management of service provider to make a trade-off between the increased costs of providing a higher service level and the decreased waiting costs of customers derived from providing that service.

In that development of the model, we identified two important features that we attempted to follow:

- The model should reflect the random nature of elderly (customers) requests as well as random nature of service times.
- The model should be sufficiently simple to be useful in practice.

We found the queueing models to be the natural candidate in view of both features. We note that detailed simulation models may also capture the stochastic nature, but due to the limited availability of data and process information, we opted for simple models that reflect the key characteristics of the elder care delivery process. Such models demonstrate the key principles for supporting staffing decisions on a strategic or tactical level and are sufficiently simple to implement (van Eden et al., 2016).

We assume a simple M/M/r model, which anticipates that both the interarrival and the service times may be well approximated by an exponential distribution. While the assumption of exponentially distributed interarrival times is quite justified, such conclusions for care delivery durations are less affirmative. This is also the main limitation of our study. To prove this assumption, empirical data on the actual care delivery process would be necessary. Moreover, the time needed for the traveling of care workers to customers should also be considered.

In our opinion, the development of a formal homecare service provider network would have many positive effects on society as a whole. First, we expect a great positive impact on the quality of elderly life, especially in the rural areas where a lack of institutional care support exists. Since the idea is based on the market fundamentals, it can represent an opportunity to reduce the existing share of unemployed young people. The idea is also in accordance with Slovenian LTC strategy, which defines that the LTC of the future is to be oriented towards homecare (Prevolnik Rupel et al., 2010).

Despite the fact that long-term elder care will become increasingly necessary in the next decades, the body of operations research (OR) literature directed on this topic remains quite limited (van Eden et al., 2016). We agree with the authors who have challenged the researchers in the field of OR to put more emphasis on research on long-term elder care. They emphasized that finding usable data will be an important first step for future research in this promising field, as reliable and valid information is scarce and seldom collected. Nevertheless, the most important challenge for future research will be to not overemphasize the importance of efficiency because the needs and preferences of the elderly customers should always be kept in mind when researching this area.

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Socialni servis kot organizacijska oblika podpore starostnikom na domu: vzpostavitev in planiranje kapacitet

Uvod. Staranje populacije ima pomembne učinke na evropsko družbo. Z naraščanjem deleža ostarelih naraščajo stroški zdravstvene oskrbe kakor tudi potreba po storitvah dolgotrajne oskrbe. Ker z razpoložljivimi kapacitetami formalne oskrbe ni mogoče zadostiti vsem zahtevam starostnikov, je zaznati povečano potrebo po storitvah oskrbe na domu. Rezultati nekaterih raziskav, izvedenih v Sloveniji, nakazujejo na neenakomerno geografsko razporeditev ponudbe formalne oskrbe za starostnike ter izkazujejo velike razlike med posameznimi občinami. Kljub razmeroma zadovoljivemu stanju na nekaterih bolj razvitih območjih smo predvsem na podeželskih predelih še vedno priča precejšnjemu deležu starostnikov, katerih potrebe po oskrbi niso zadovoljene. Slednje utemeljuje potrebo po vzpostavitvi dodatnih storitev formalne oskrbe za starostnike na njihovih domovih.

Metode. Čeprav strokovnjaki poudarjajo številne prednosti, ki jih jima oskrba starostnikov na domu v primerjavi z formalno obliko oskrbe, rezultati več študij dokazujejo, da je stopnja oskrbe slovenskih starostnikov na njihovih domovih nezadovoljiva in neenakomerno porazdeljena po državi. Za omilitev tega problema predstavljamo v prispevku novo organizacijsko obliko formalne oskrbe za starostnike na domu, imenovano socialni servis. Poleg enostavnih zdravstvenih storitev, bi socialni servis lahko pokrival širok spekter storitev, prilagojenim starostnikom, od pomoči v gospodinjstvu, socialnih, transportnih storitev, ipd. Vzpostavitev take organizacije mora biti skrbno načrtovana in premišljena, saj je potrebno, če želimo zagotoviti željene učinke, upoštevati specifične značilnosti in potrebe ciljne populacije.

Rezultati. Cilj prispevka je podati temeljne smernice, ki jih je potrebno upoštevati pri ustanavljanju socialnega servisa. Definirane so vse pomembne organizacijske karakteristike, ki jim mora socialni servis zadoščati. Za zagotovitev ustreznega nivoja kakovosti nudenih storitev je ključna aktivnost planiranje optimalnih kapacitet osebja. V ta namen smo socialni servis obravnavali kot sistem množične strežbe. Razvili smo model, ki omogoča planiranje kapacitet osebja socialnega servisa upoštevaje različne parametre učinkovitosti. Uporabnost modela smo ponazorili s hipotetičnim numeričnim primerom. Ugotovili smo, da dobljeni rezultati predstavljajo koristno informacijo za odločanje predvsem v preliminarni fazi načrtovanja in vzpostavitve socialnega servisa.

Diskusija in zaključek. Po našem mnenju bi imela vzpostavitev mreže socialnih servisov številne pozitivne učinke. Nedvomno bi taka storitev pozitivno vplivala na kakovost vsakdanjega življenja starostnikov, predvsem na področjih, kjer je zaznati primanjkljaj obstoječe infrastrukture formalne oskrbe. Socialni servis lahko predstavlja atraktivno zaposlitveno priložnost za populacijo mladih brezposelnih. Poleg tega je ideja v skladu s slovensko strategijo dolgotrajne oskrbe, ki je usmerjena k povečanju oskrbe starostnikov na domu. Smernice, ki smo jih oblikovali v prispevku, skupaj s kvantitativnim modelom za planiranje optimalnih kapacitet zagotavljajo dobre temelje za vzpostavitev učinkovitega socialnega servisa.

Ključne besede: *starostniki; socialni servis; planiranje kapacitet; optimizacija stroškov; teorija množične strežbe*

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An Overview of Image Analysis Algorithms for License Plate Recognition

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Background and purpose: We explore the problem of License Plate Recognition (LPR) to highlight a number of algorithms that can be used in image analysis problems. In management support systems using image object recognition, the intelligence resides in the statistical algorithms that can be used in various LPR steps. We describe a number of solutions, from the initial thresholding step to localization and recognition of image elements. The objective of this paper is to present a number of probabilistic approaches in LPR steps, then combine these approaches together in one system. Most LPR approaches used deterministic models that are sensitive to many uncontrolled issues like illumination, distance of vehicles from camera, processing noise etc. The essence of our approaches resides in the statistical algorithms that can accurately localize and recognize license plate.
Design/Methodology/Approach: We introduce simple and inexpensive methods to solve relatively important problems, using probabilistic approaches. In these approaches, we describe a number of statistical solutions, from the initial thresholding step to localization and recognition of image elements. In the localization step, we use frequency plate signals from the images which we analyze through the Discrete Fourier Transform. Also, a probabilistic model is adopted in the recognition of plate characters. Finally, we show how to combine results from bilingual license plates like Saudi Arabia plates.
Results: The algorithms provide the effectiveness for an ever-prevalent form of vehicles, building and properties management. The result shows the advantage of using the probabilistic approached in all LPR steps. The averaged classification rates when using local dataset reached 79.13%.
Conclusion: An improvement of recognition rate can be achieved when there are two source of information especially of license plates that have two independent texts.

Keywords: *Image Analysis; Probabilistic Modeling; Signal Processing; License Plate Recognition*

1 Introduction

Image processing transforms information from the real world into image data represented by matrices. The manipulation of these real valued matrices requires mathematical and statistical solutions in order to locate objects in the images. Optical character recognition (OCR) is the technology of identifying written or printed text that are included in images using image-processing algorithms. OCR is a well-explored problem. It has been used and commercialized in many applications that include LPR, libraries, banks, converting document into text searchable document in scanner and sorting mail in post offices. Some of our solutions apply in such contexts.

Many around the world contributed to research in license plate recognition. LPR systems are in use in several countries, and Britain has an extensive ANPR (Automatic

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Number Plate Recognition) CCTV network. Such achievements took many years of research. However, the problem remains difficult to solve perfectly. For example, in many countries the law still requires the plate number of an infringing car to be recognized visually. This reliability issue keeps the LPR problem an active research topic. LPR uses video captured images to automatically identify vehicles through their license plate. LPR finds applications in theft prevention, parking lot management, hotels and property management, traffic laws enforcement, border control etc. There are other methods to identify cars such as transponders, bar-coded labels and radio-frequency tags. License plate reading remains however the way a vehicle is identified. LPR attempts to make the reading automatic by processing sets of images captured by cameras. There are three steps in the process; detecting a vehicle, triggering the captures of images related to that vehicle and treating those images for recognition of the characters in the license plate. The capture of the images, their transfer in digital form to a processor and the coordination of all tasks in a LPR system is a feasible engineering problem. The processing of images for recognition is where research starts. LPR has three main parts; localization of license plate from image, segmentation of characters from localized license plate region and recognition of those characters. These steps are performed automatically by software and require algorithms.

1.1 License Plate Localization

Plate localization is the first step in LPR. It aims to locate the license plate of the vehicle in an image. A variety of approaches have been proposed to localize a license plate in captured video images (Al-Hmouz and Aboura, 2014). Some of the existing methods are morphological operations, edge detection, corner detection, sliding concentric windows (Anagnostopoulos et al., 2006), fuzzy logic (Chang et al., 2006), Hough transform (Duc et al.,2005), neural networks (Kim et al. 2000), Fourier transform (Acosta, 2004), adaptive boosting (AdaBoost) algorithm (Dlagnekov, 2004). Al-Hmouz and Aboura (2014) introduce a new approach of plate localization using a statistical analysis of Discrete Fourier Transform of the plate signal. The plate signal is represented by five statistics: strength of the signal, normalized maximum amplitude, frequency of maximum amplitude, frequency center and frequency spread. Combining with the color-based histogram thresholding (Aboura, 2008), the method achieves 97.27% accuracy using plate signals from binary images.

1.2 License Plate Segmentation

The second task in LPR is to extract the characters from the localized license plate region. The most common method is the projection method. First, the image is thresholded, reduced from a color or gray-scale image to a black and white (background/foreground) image. The projection method then counts the number of foreground pixels vertically and horizontally in the license plate area to separate and extract the characters. Other methods and variants include, thin window scanning, local vector quantization, scale shape analysis, Laplacian transform, Hough transform and Markov Random fields. The final task in LPR is the recognition of characters. An optical character recognition algorithm is used to recognize characters in the image. A series of approaches were developed. The most common ones are the correlation-based template matching and neural networks. Other methods are feature based, use pattern mapping or are based on the Hausdorff distance. Binary classifiers are used as well as the Hidden Markov model and probabilistic modeling. All three steps in LPR rely on thresholding or binarization of the original image. A common approach is the well cited Otsu method (Otsu, 1979). The Otsu method performs rather poorly in LPR if applied to the whole image. The resulting binary image often doesn't show the license plate characters as foreground. In Aboura (2008), this topic is discussed and a new thresholding method is introduced. It is used in the approaches described in this article.

1.3 License Plate Recognition

The final task in LPR is the recognition of characters. The extraction of characters results in a number of selected regions in the image. These regions contain the characters of the license plate and are processed for recognition by what is referred to as an Optical Character Recognition (OCR) algorithm. While OCR applies in LPR, it is a field that has a much wider stage of applications. OCR dates back to 1929 and is a method designed to translate automatically images of handwritten or typewritten text. There are of-the-shelves software packages that can translate a faxed page of text or an image that contains text. However, these OCR commercial packages do not yield good results in the case of LPR. A series of approaches were developed to recognize license plate characters. The most common OCR approaches used in LPR are the correlation-based template matching and neural networks. Other methods are feature based, use pattern mapping or are based on the Hausdorff distance. Binary classifiers are also used as well as the Hidden Markov model (Aboura and Al-Hmouz, 2007). Neural networks (NN) haven been applied successfully in many prediction, classification and recognition problems. In LPR, they are used to localize the license plate in the image and to recognize the extracted characters of the plate. A Neural network is an artificial network made up of sets of interconnected nodes called neurons. In its simple form, the feed forward structure used in LPR, there is a set of input nodes, for example the features and attributes of the image being processed (Figure 1), that are connected through a network of nodes, hidden layers, to a set of output nodes, the classes to which the image belongs.

Template Matching is the other approach most used in character recognition in LPR. It is a technique in image analysis for scanning an image template until part of it matches an image at hand. There are many variants in the application of template matching to character recognition. In its simplest form, the image in its binary form (Figure 1) is compared with same size parts of the template image using a suitable metric. The metric can be the Euclidian distance or a correlation measure between the pixels of the image and the template. For example, the cross correlation, a statistical measure used by Horowitz (1957) and Pratt (1974) for image recognition, can be a metric for template matching. The template matching approach is combined with other methods in character recognition. However, it remains a method based on the minimization of a distance between two images and can prove to be inefficient in practice.

The objective of this paper is to present a number of probabilistic approaches in LPR steps, then combine these approaches together in one system. Most LPR approaches used deterministic models that are sensitive to many uncontrolled issues like illumination, distance of vehicles from camera, processing noise etc. The essence of our approaches reside in the statistical algorithms that can accurately localize and recognize license plate.

The structure of the paper is as follows, first we show the probabilistic approaches that investigate the localization and recognition phases in LPR systems. In section 3, we show the results of the presented approaches. Followed by discussion in section 4. Finally, the paper ends with conclusions in section 5.

2 Research Methods in Probabilistic Image Analysis

In this section, we review some of the statistical and signal processing methods that address the localization and character recognition problems discussed in the introduction. We also point to the global thresholding method used in the methodology.

2.1 Localization using the Discrete Fourier Transform signal

A variety of approaches have been proposed to localize a license plate in captured video images. Al-Hmouz and Aboura (2014) introduce a new approach of plate localization using a statistical analysis of Discrete Fourier Transform of the plate signal. The plate signal is represented by five statistics: strength of the signal, normalized maximum amplitude, frequency of maximum amplitude, frequency center and frequency spread. The idea is that license plate numbers show frequencies that lead themselves to a spectral analysis through the Fourier transform. Al-Hmouz and Aboura (2014) introduce a formal statistical analysis of the Fourier transform data from a systematic scanning of the image. The authors use the Hysteresis thresholding (Canny, 1986) over scanned regions of the image to obtain a clear signal. They improve the speed of the methodology and its accuracy by thresholding the whole image using the binarization approach of Aboura (2008). The behavior of the power spectrum of the scanned region shows a significant increase in magnitude at some frequencies for scanned regions that contain the license plate or parts of it. This is due to the periodicity in the signal generated by

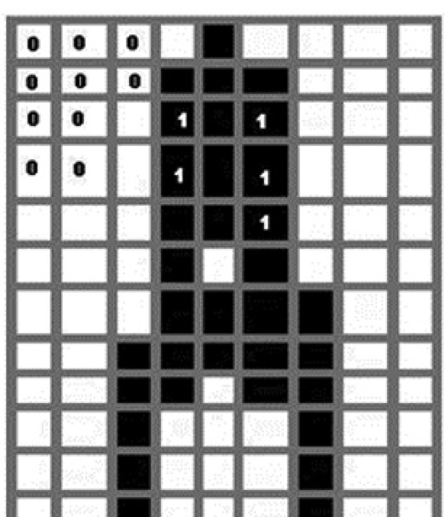

Figure 1: Binary image with foreground pixel =1 and background pixel = 0

the characters of the license plate. A set of 5000 images was used as historical data. The images were taken at a parking lot entrance. Each image was visually inspected for the existence of a car in it. For the image signal, the five statistics were considered and used in a statistical model. A Bayesian analysis delivered high probability candidate regions in the image. To locate the license plate in one of the candidate regions, another probabilistic method was used that yielded the achieved accuracy.

2.2 Probabilistic Optical Character Recognition

The LPR optical character recognition is the problem where uncertainty prevails as to what class an input image belongs to. Given that it is a stochastic problem, one expects probability answers, if one adheres to the principle that probability is the only coherent way to address uncertainty (Lindley, 1987). Despite some attempts, such as the probabilistic transition trees (Eichelberger and Najarian, 2006), the only noticeable probability based research direction is that of the probabilistic neural networks, for example (Anagnostopoulos, Anagnostopoulos, Loumos and Kayafas, 2006). The probabilistic neural network (PNN) was developed by Donald Specht (1988) and provides a solution to classification problems using Bayesian classifiers and the Parzen Estimators. It is a class of neural networks which combine statistical pattern recognition and feed-forward neural networks technology. It is characterized as having very fast training times and it produces outputs with Bayes posterior probabilities. PNNs are very effective for pattern recognition. However, the LPR character recognition problem is a simple OCR problem and can be addressed by a full probabilistic approach such as the one we present. To solve the problem probabilistically is to treat features or statistics from the input image, using a probability model. The input character image to the OCR module is usually a binary image such as the one in Figure 1. The historical data of extracted characters is made of two sets; training data and validation data. These are images of license plate characters that have been extracted from images of vehicles using the first two steps LPR. They are binary images that have been cleaned, cropped and normalized (Figure 2). The characters are visually inspected one by one and classified in the 36 possible classes {A,B,C, ..., X,Y,Z,0,1, ...,8,9}. Each set of characters is then split into a training set and a validation set.

Examples of statistics of an extracted character are the fill percentage and the projected foreground. The fill percentage is the proportion of foreground pixels in the binary

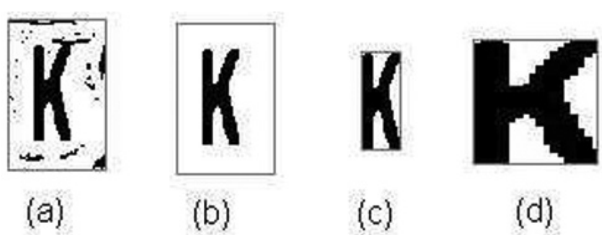

Figure 2: Extracted character (a), cleaned (b), cropped (c) and normalized (d)

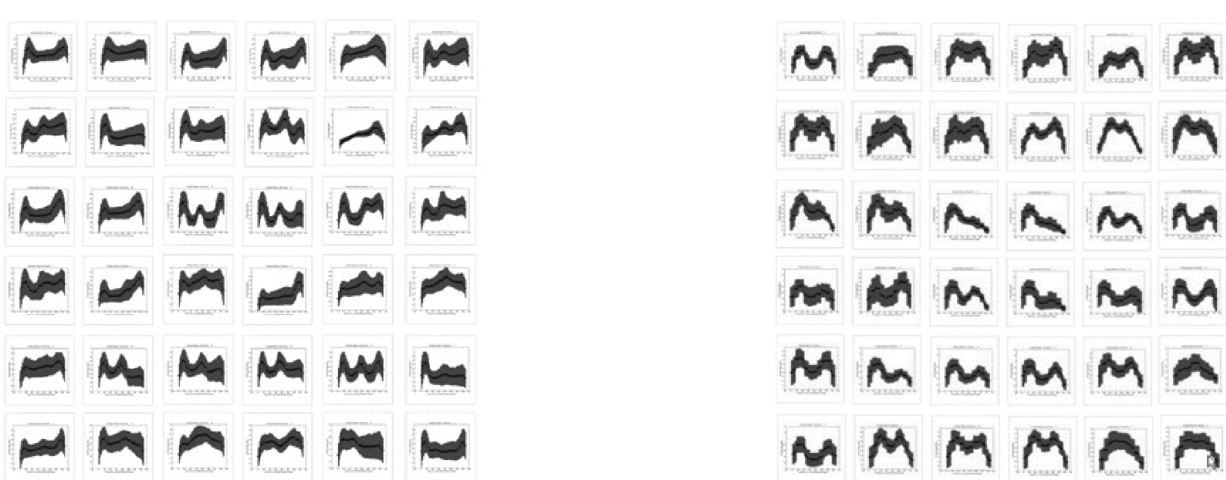

Figure 3: Historical means of projected foreground for the 36 characters

image. If F is the matrix of the digitized binary image, then the fill percentage is $\sum_x \sum_y F(x,y) / (N_x N_y)$, where N_x and N_y are the height and width of the image in pixels. The projected foreground is the normalized projection of the foreground on the x and y axes of the image $\sum_y F(x,y) / N_y$, $x = 1, \ldots, N_x$ and $\sum_x F(x,y) / N_x$, $y = 1, \ldots, N_y$ respectively. These statistics seem to provide distinguishing information, as seen in Figure 3 where the mean of these statistics is plotted within one standard deviation. We used the minimization of squared errors to attempt to recognize the characters using the normalized projection foreground:

$$Minimize_{(C=A,B,\ldots,X,Y,Z,0,1,\ldots,8,9)}$$

$$\sum_x \left(\sum_y F(x,y) / N_y - \mu_x^C\right)^2 + \sum_y \left(\sum_x F(x,y) / N_x - \mu_y^C\right)^2$$

where μ_x^C and μ_y^C, $C=A,B,\ldots,X,Y,Z,0,1,\ldots,8,9,$ are the historical means from the training set. The approach failed to return a good recognition. In an attempt to remedy, the projected foreground was augmented with the distance of the pixels to the side of the image, thus incorporating the information about the locations of the foreground pixels. The minimum squared errors method failed again, an indication that these features of the image do not offer enough information to fully distinguish among the characters.

In general, let Z be the random variable that represents the statistical feature of a character image. For example, Z can be the fill percentage seen above. Note that Z need not, and often isn't univariate. The probabilistic approach starts by building a probability model for that feature in the form of $Prob(Z|C), C = A,B,\ldots,9$. For each image in the training set, the value of Z is computed. Data analysis tools are used, along with any engineering/prior knowledge to arrive at the probability model $Prob(Z|C)$. Seen as a function of the event C, that is the character is C, the probability model $Prob(Z|C)$ is known as the likelihood function $L(C) = Prob(Z|C)$. This likelihood function is at the heart of the probabilistic approach. If this model is built properly and the statistical feature Z offers enough information about the character's class, the probabilistic approach will be effective. Given a likelihood model, the probabilistic approach proceeds as follows. Let z be the value of Z for an image being analyzed. Then the probability that the character is C, given the data z is

$$Prob(C|Z = z) = \frac{Prob(Z = z|C)Prob(C)}{\sum_{S=A}^{S=9} Prob(Z = z|S)\, Prob(S)}$$

for $C = A,B,\ldots,9$. $Prob(C)$ is the model built with any prior knowledge about what C might be. It is called the prior distribution.

$$\delta = \sum_{S=A}^{S=9} Prob(Z = z|S)\, Prob(S)$$

is a normalizing constant. $Prob(C|Z=z)$ is the posterior distribution of C. The solution is given in the selected character $\hat{C}$, mode of the posterior distribution,

$$Prob(\hat{C}|Z = z) = Max_{C=A,B,\ldots,9}\, Prob(C|Z = z).$$

If there is no prior knowledge as to what C might be, then the discrete uniform distribution is used where $\text{Prob}(C) = 1/36$ for $C = A, B, \ldots, 9$. This probabilistic approach is often referred to as a Bayesian approach. A non-Bayesian approach would simply maximize the likelihood function, ignoring the prior component, and select $\hat{C}$ such that

$$Prob\left(\hat{C}\middle|Z = z\right) = Max_{C=A,B,\ldots,9}\, Prob(Z = z|C)$$

As one can see, both these statistical approaches rely on the likelihood function. These simple operations are at the heart of many probabilistic predictions, classifications and inferences. While seemingly simple in principle, their success depends on the proper selection of the random variable Z and the probability model $Prob(Z|C)$.

In our search for a statistic Z, we arrived at the conclusion that the values of the pixels in the binary image hold all the information needed to recognize the character in an image that has been cleaned, cropped and normalized. We defined Z as the multidimensional vector of the values of all the pixels in the image. Each of these values is either 0 or 1, the input image being binary. For each pixel, we applied the Bernoulli probability model $\theta_i^{(Zi} (1 - \theta_i)^{1-Zi}$, Z_i being the value of Z at pixel i. Making the assumption of conditional independence of the pixel values given an image, we construct the likelihood function

$$L(C) = Prob(Z|C) = \prod_{i=1}^{|Z|} \theta_i^{Z_i}(1-\theta_i)^{1-Z_i}$$

where $|Z|$ is the cardinal, or vector size, of Z. To estimate the proportion θ_i for pixel i, a number of approaches are available. But given that the sizes of the historical sets are relatively large, in the order of 200 images per character $C = A,B,\ldots,X,Y,Z,0,1,\ldots,8,9,$ the estimates converge to the average

$$\hat{\theta}_i = \sum_{j=1}^{N_C} x_{i,j}/N_C$$

where N_c is the size of the training set for character C, and $x_{ij} = \{0 \text{ or } 1\}$ is the value of pixel i for image j of the training set. This is done for each character C. For simplicity of exposition, we used θ_i when in fact it is a $\theta_i(C)$ that differs for each C. From a computational point of view, the assessment of the likelihood parameters is very simple. For each character C, all the image matrices of the training set are added, then divided by the size of the set N_c, automatically providing a matrix of estimates

$$[\hat{\theta}_i]_{i=1}^{|Z|}$$

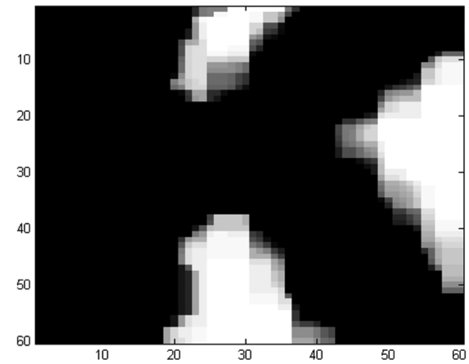

Figure: 4 Likelihood image of character K

This is a simple operation, inexpensive computationally, that replaces the training of a neural network. It needs to be done only once, and the estimates matrices are used subsequently to recognize the characters.

Figure 4 shows the matrix

$$[\hat{\theta}_i]_{i=1}^{|Z|}$$

for character K. Each value of the pixel *i* of the image in Figure 4 is the estimate $0 \leq \theta_i \leq 1$ for character K. It is the estimate of the parameter of the Bernoulli model for pixel *i*, for character K. In essence, this method builds a likelihood function value for each character *C*, that results from a matrix, where the values of 1 signify that the corresponding pixels are always present in the foreground of *C* (in black in Figure 4), the values 0 mean that the corresponding pixels are always background in *C* (in white in Figure 4), and the values in between correspond to pixels *i* that are present in *C* with a positive probability θ_i. One observes that the K in the image is not a perfect one, due precisely to statistical variation. In addition, the colors of the image do not show all the nuances in the values. But the matrix

$$[\hat{\theta}_i]_{i=1}^{|Z|}$$

is computed with double precision accuracy and provides accurate estimates of the probabilities of the foreground existence.

Once the likelihood function is constructed, it is used to recognize characters in a simple operation. Let *z* be the realization of the statistic *Z* for a binary image that has received similar cleaning, cropping and resizing as have the images of the training set. Then

$$Prob(C|z) = \frac{Prob(z|C)Prob(C)}{\sum_{S=A}^{S=9} Prob(z|S)\, Prob(S)}$$

where

$$Prob(z|C) = \prod_{i=1}^{|Z|} \hat{\theta}_i^{z_i}(1-\hat{\theta}_i)^{1-z_i},$$

noting that the appropriate θ_i correspond to a given *C*. This posterior probability distribution ranks the characters *A,B,...,X,Y,Z,0,1,...,8,9* for their likelihood of being the character in the image being treated. This method provides a full probabilistic approach. One introduces prior knowledge in the Bayesian analysis above in the form of *Prob(C)* for each character *C* . Such knowledge can vary from country to country for example, where the position of a character in the license plate may indicate whether it is a letter or a number, for example. If such knowledge does not exist, or is hard to embody in a formal model, then the characters are declared to be equally probable a priori, letting *Prob(C) = 1/36* in this case. To further improve the speed and increase the accuracy, we note that maximizing the product of two bounded positive values is equivalent to maximizing their sum. Therefore we implemented the following

$$Max_{C=A,B,\dots,9}\, f(C) = \sum_{i=1}^{|Z|}\{\hat{\theta}_i^{z_i}+(1-\hat{\theta}_i)^{1-z_i}\}$$

where *f(C)* is the score function defined by the sum. This method yielded excellent results.

2.3 Global Thresholding

Al-Hmouz and Aboura (2014) used a global thresholding method to improve significantly the performance of a signal processing localization algorithm. This is in contrast to most methods that use a local thresholding approach in view of the fact that global thresholding is hard to perform adequately. The global thresholding method of Aboura (2008) was effective in highlighting the signal of the license plate (Figure 5). A more effective global thresholding method experimented with consisted of the color-based method of Aboura (2008) coupled with a range of techniques including clustering. In a striking result, all but the characters of the license plate remained as foreground in the thresholded image. Such an approach would eliminate the need for a localization algorithm and facilitate greatly the recognition of the characters. In most cases, only some of the characters or part of remained as foreground. This still reduces considerably the localization of the license plate. This research was not completed and is a future direction of work.

3 Research Results

3.1 Object Localization in Image

In Al-Hmouz and Aboura (2014), a statistical localization approach of Discrete Fourier Transform and five statistics of the plate signal is used to extract the license plate in LPR system. The approach yielded 99% of license plates were among few candidate regions and the overall performance was 97.27% for local data set and 88.1% for public data set. The method is considered computationally complex compared to other methods in the literature. However, the processing time can be reduced to competitive values (150 ms) considering less number of sliding window locations by increasing the step size of the sliding window and ignoring places where license plates do not exist such as image sides. Methods such as CCA and edge detection could be used in improving robustness after the plate candidate regions have been determined. In the future, information about license plate images which are not localized will be studied through suitable models.

3.2 Probabilistic Optical Character Recognition

The LPR optical character recognition falls within the realm of pattern recognition. While such problems often require sophisticated approaches due to the large number of patterns, known and unforeseen ones, making it hard to use parsimonious probability models, the recognition problem in LPR is much simpler. We introduced a simple, and very inexpensive method to solve a relatively important problem, using a full probabilistic approach. As most methods in this category, the approach failed to distinguish as such fully between some characters like 2 and Z, 5 and S, 1 and I, B and 8, and O,0,D and Q. However, using the same logic and applying it exclusively to parts of the image, we reach a 97% reliability. In Figure 6, we show how 2 and Z are distinguished by focusing the probabilistic OCR algorithm in the areas of the boxes. The likelihood of the pixels in those areas has already been computed, and it is applied to the image that was initially recognized either as a 2 or a Z. Similarly, Figure 7 shows how the remaining confusions are dealt with. This added step is a refinement equivalent to moving a magnifier glass, in the form of the probabilistic OCR algorithm, to parts of the image. Although the likelihood function is the same, the scoring changes and the choice is between two, or four, rather than 36 candidates.

The algorithm was tested on a large validation set, of the order of a couple of hundreds of images per character. Table I shows the reliability per character, summing up to an overall 0.9705 reliability. One could possibly conduct comparison tests with other methods. But as it is often the case in LPR problems, the scenarios and setups that provide sources of data vary dramatically, making it hard to compare universally. We used two sources of data; images

Figure 5: Image thresholded using global thresholding method

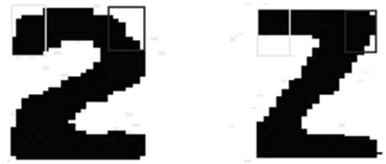

Figure 6: Probabilistic OCR applied to eliminate Confusions

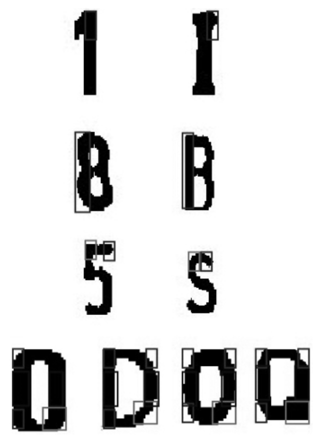

Figure 7: Refinement of the Probabilistic OCR

taken live from a LPR system setup in a parking lot entrance, and images taken from the entrance of the parking lot of the university. The lighting conditions and the positioning of the cameras differed between the two locations. In addition, two slightly different character segmentation methods were used in each case. The tests conducted performed well on both types of data mixed together, as indicated in table I.

3.3 Global Thresholding

A global thresholding method for the automatic license plate recognition is introduced that makes use of the colour information in the image through a probabilistic model. LPR still finds it difficult to apply global binarisation whereby a single threshold value for the entire image is calculated. Local thresholding methods are preferred, but their efficiency comes at a cost. Reported work is often focused on one of the three LPR steps, and thresholding is assumed effective. Thresholding a range of images in an automatic fashion is not a trivial task. Aboura (2008) introduces the concept of a statistically determined global threshold for LPR images that is shown to be effective on a large data set. Although the approach is enveloped in a linear regression model, it is the way information from the image is selected and introduced in the explanatory variables that leads to the reliable results. The reported methodology proposes a model that can be used in conjunction with other methods to result in automated systems.

4 Discussion

All the previous approaches adopted probabilistic models in LPR steps. Each approach improved the recognition rate for the plate with regard to localization recognition rate and character recognition rate. Using both approaches in LPR system yielded an average recognition rate that reaches up to 97.13%. As mentioned earlier, the confusion between some characters (refer to figure 6 and 7) might have the major drawback of this algorithms. However, this problem will not have an effect on bilingual plates in which two independent texts are appeared in the plates.

In some non-English speaking countries like Saudi Arabia, license plate appears in English and Arabic text (Figure 8). Arabic letters are associated with their corresponding English letters. This can be considered as two source of information available for character recognition. In this case, the probabilities of Arabic and English characters can be combined in character recognition phase. The posterior of each Arabic characters is fused with its associated English characters. The prevailing character probabilities after fusion will be considered as the final recognition. The flow chart of license plate recognition for bilingual plates is show in Figure 9.

Table 1: OCR Reliability Results

Character	Reliability	Character	Reliability
A	0.9888	S	0.9385
B	0.9259	T	0.9828
C	0.9841	U	1.0000
D	0.9552	V	0.9306
E	0.9359	W	0.9898
F	1.0000	X	1.0000
G	0.9608	Y	1.0000
H	1.0000	Z	0.9722
I	0.9500	0	0.8636
J	1.0000	1	0.8864
K	1.0000	2	1.0000
L	1.0000	3	0.9649
M	1.0000	4	0.9899
N	0.9529	5	0.9623
O	0.9630	6	0.9756

Figure 8: Saudi Arabia license plate examples

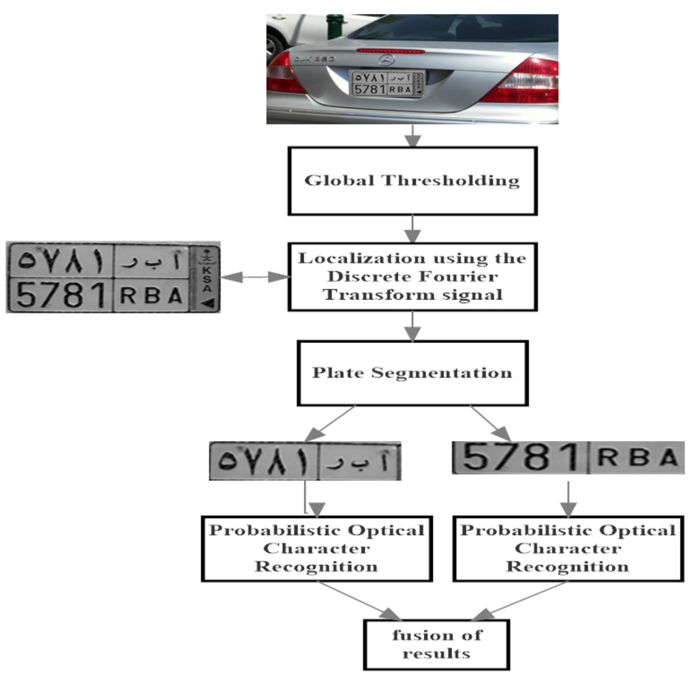

Figure 9: Bilingual plate (Arabic English) processing steps

5 Conclusions

In this paper, we described a number of solutions that can be used in recognition systems for decision support. These algorithms are effective alongside the application of global thresholding and other techniques that uses frequency of signals from the images by means of the Discrete Fourier Transform. This paper presented a probabilistic character recognition approach. The likelihood functions were formed using the Bernoulli model for each pixel value and the posterior probabilities of characters were obtained by fusing the probabilities of pixel value in each location. In making the assumption of independence between pixels of the image in the construction of the likelihood function, we in fact constructed a Naïve Bayes solution. The results showed an impressive recognition rate of average (97.13%) when using the previous approaches. Also an improvement of recognition rate can be achieved when there two source of information especially of license plates that have two independent texts. For further study, fusion process at pixel level for bilingual plates can investigated.

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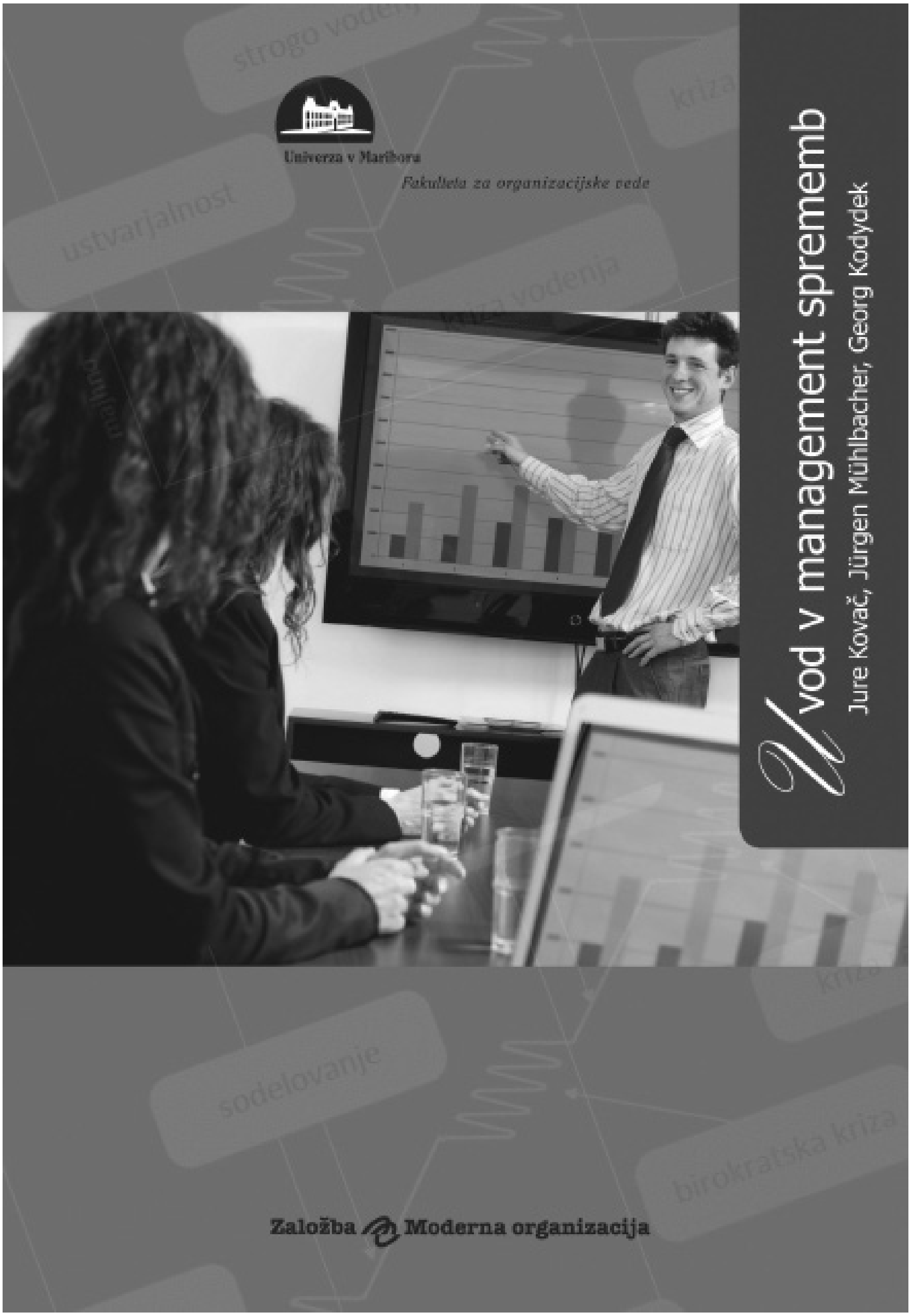
Pregled algoritmov za analizo slike za prepoznavanje registrske tablice

Ozadje in namen: V članku raziskujemo problem prepoznavanja registrskih tablic (LPR), in podamo pregled številnih algoritmov, ki jih lahko uporabimo pri problemih analize slik. V sistemih za podporo vodenju, ki uporabljajo za prepoznavanje slikovnih objektov, je inteligenca vgrajena v statistične algoritme, ki jih je mogoče uporabiti v različnih korakih razpoznavanja. Opisujemo več rešitev, od začetnega koraka do lokalizacije in prepoznavanja slikovnih elementov. Cilj tega prispevka je predstaviti več verjetnostnih pristopov v korakih razpoznavanja, nato pa združiti te pristope v en sistem. Večina pristopov uporablja deterministične modele, ki so občutljivi na številne nenadzorovane vplive, kot so osvetlitev, razdalja vozila do kamere, šum pri procesiranju itd. Bistvo naših pristopov je v statističnih algoritmih, ki lahko natančno lokalizirajo in prepoznajo registrsko tablico.
Oblikovanje / metodologija / pristop: Predstavimo enostavne in poceni metode za reševanje relativno pomembnih problemov z uporabo verjetnostnih pristopov. Pri teh pristopih opisujemo številne statistične rešitve od stopnje začetnega praga do lokalizacije in prepoznavanja slikovnih elementov. V koraku lokalizacije uporabljamo frekvenčne signale iz slik registrskih tablic, ki jih analiziramo z uporabo diskretne Fourier-jeve transformacije. Pri prepoznavanju znakov na tablicah smo uporabili tudi verjetnostni model. Na koncu prikazujemo, kako združiti rezultate iz dvojezičnih tablic, kot so na primer tablice Saudove Arabije.
Rezultati: Algoritmi so učinkoviti pri razpoznavanju znakov na vozilih, v stavbah in drugod. Rezultat kaže prednost uporabe verjetnostnega pristopa v vseh korakih razpoznavanja registrskih tablic. Povprečne stopnje uspešnega razpoznavanja pri uporabi lokalnega nabora podatkov so dosegle 79,13%.
Zaključek: Izboljšanje stopnje razpoznavanja je mogoče doseči, če obstajata dva vira informacij, še posebej na registrskih tablicah, na katerih sta dve neodvisni besedili.

Ključne besede: *analiza slike; verjetnostno modeliranje; obdelava signalov; prepoznavanje registrske tablice*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