Using business process simulation approaches for business process identification and analyses: the case of manufacturing, operational decision support, and supply chain

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Naložba v vašo prihodnost
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»Operacijo delno financira Evropska unija in sicer iz Evropskega sklada za regionalni razvoj. Operacija se izvaja v okviru Operativnega programa krepitve regionalnih razvojnih potencialov za obdobje 2007-2013, 1. razvojne prioritete: Konkurenčnost podjetij in raziskovalna odličnost, prednostne usmeritve 1.1: Izboljšanje konkurenčnih sposobnosti podjetij in raziskovalna odličnost.«

“The operation is partially financed by the European Union, mostly from the European Regional Development Fund. Operation is performed in the context of the Operational program for the strengthening regional development potentials for the period 2007-2013, 1st development priorities: Competitiveness of the companies and research excellence, priority aim 1.1: Improvement of the competitive capabilities of the companies and research excellence.”

Table of contents

1 Business Process Management

The technical innovations of the industrial revolution lead to significant increasment of productivity an consecuently to improvements in the organization of work, and the usage of information technology. As a result, the complexiy of business processes has increased mainly due to the fact that it heavily relys on information systems which may even span multiple organizations. Moreover, the intensified globalisation, has emphasised the importance of effective management of an organisation's business processes.

These two factors have led to rise in frequency of goods ordered, brought greater need for fast information transfer and quick decision making, need to adapt to change in demand, have increased the number of international competitors, and created demands for shorter cycle times [1]. All these aspects have challenged the profitability and the survival of big and small companies. Moreover, BPM is seen as a competitive edge for the organizations, as with it they can determine and exhibit their maturity level [2].

There are several definitions of BPM, one of which suggests that "BPM is a discipline that combines knowledge from information technology and knowledge from management sciences and applies this to operational business processes" [3], [4]. BPM is a comprehensive discipline that includes methods, techniques, and tools to support the design, enactment, management, and analysis of operational business processes, thus is frequently defined as an "extension of classical Workflow Management approaches and systems" [5]. Several specification and modeling languages and tools have been proposed to be used in BPM, from which the BPMN (Business Process Model and Notation) language has become the 'de facto' standard language to represent business processes. Nevertheless, other languages such as UML Activity Diagrams have also been used for modeling business processes [6], [7].

This work builds upon the work done by [8]. Business process management is a chalenging and complex task. According to [8] a process model, which represents a true reflection of the business process discussed, is essential for carrying out business process management and consequently successful development of information system. Business process management (BPM) as a field of study and research deals with the one constant – that is ever changing environment. BMP further encaptulates changes dealing with an organization's formal structures described in process models with the aim to enable organization's improvements that result in more competitive, efficient and consequently successful organization. There are many methods and techniques which cover the field of business process modelling [8].

2 Business process and business process identification

Business processes are different processes conducted within various types of organizations whose purpose is creating outputs that are produced to serve customers' needs [8]. Such management of business processes requires a process-oriented organization. However, there are still many traditionally structured organizations dealing with a lot of bureaucracy and overstaffing with employees for different and mainly useless purposes.

A process-oriented organization manages and evaluates its activities from the customer's perspective, which requires following the flow of work procedures and their accomplishment throughout different functional areas of the company or organization [8].

In any organization two types of processes exist; these are core and support processes. [9] defined these processes as follow:

- The core processes are the operational processes of the business and result in the production of the outputs that are required by the external customer; and
- The support processes are those that enable the core processes to exist.

[10] identified three types of process: core, support, and management.

- Core processes concentrate on satisfying external customers;
- Support processes concentrate on satisfying internal customers; and
- Management processes concern themselves with managing the core processes or the support processes, or they concern themselves with planning at the business level.

The literature offers various definitions of a meaning of a business process. It is defined [11] as: "A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer". [9] defined a business process as: "A flow of work passing from one person to the next, and for larger processes probably from one department to the next". The process is comprehended as a transformation of inputs to outputs [12]. [13] and [14] stress the lack of a single unified or standardised comprehension of a business process; consequently they offer an in-depth revision of available understandings. Additionally, equally important definitions can be further found in [15]; [16]; [17]; [18]; [18]; [19] as well as in [20], where a process, major process, subprocess, activity, and task are explained:

- A process is a logical, related, sequential (connected) set of activities that takes an input from a supplier, adds value to it, and produces an output to a customer;
- A major process is one that usually involves more than one function within the organizational structure, and its operation has a significant impact on the way the organization functions;
- A subprocess is a portion of a major process that accomplishes a specific objective in support of the major process;

- Activities are things that go on within a process or subprocess; they are usually performed by units of one (one person or one department);
- Tasks are individual elements and/or subsets of an activity; tasks relate to how an item performs a specific assignment.

The definitions made by [20] are important because they determine an easy and practical specification for a major process by saying: "When a major process is too complex to be flowcharted at the activity level, it is often divided into subprocesses". Additonally, [20] define a differentiation between an activity and a task by emphasizing that an activity is performed by units of one, which means that an activity includes a few tightly related tasks, whereas a task is an elementary work. We may imagine an activity is a group of instructions and a single instruction is a task [8]. On the other hand, [21] identified business process from the outside-in perspective meaning that a true process comprises all the things we do to provide someone who cares with what they expect to receive. [21] continued that a true process starts with the first event that initiates a course of actions and is not complete until the last aspect of the final outcome is satisfied from the point of view of the stakeholder, who initiated the first event or triggered it. The process is characterized by the following:

- Inputs of all types, such as raw materials, information, knowledge, commitments, and status are transformed into outputs and results;
- Transformation occurs according to process guidance, such as policies, standards, procedures, rules, and individual knowledge; and
- Reusable resources are employed to enable the change to happen, such as facilities, equipment, technologies, and people [8].

The processes that occur in a company, together with the activities that constitute them are what makes the core of the business. Before we continue towards a broader overview of BPS, we need define “business processes” and subsequently define process modeling and the approaches to it.

There is no clear and agreed definition of a “business process” that literature agrees on[1]. However, all definitions in some way recognise them as flow that transforms the inputs into outputs/results/value added. Adapting the processes according to the needs and goals of the company, happens over time involves changes in people, activities and technology. The literature has identified a multitude of approaches, methodologies, and techniques that has been used to support the reengineering of the activities in a company. However, as the process of reeingineering happens over time, this dynamic flow has been found to be best modeled with the method of simulation. As all of the ways that people can interact of with processes and technology may result in an infinite number of possible scenarios and outcomes, these are rather difficult to

[1] See [71] for overview of different existing definitions about process

predict and evaluate using widely popular static process modelling methods. In this chapter we will focus on the simulation as a modeling method and will provide the reader with a general overview of the most widely used approaches, tools, the benefits of their use and the drawbacks and challenges.

2.1 Business process management approaches

Globalisation and international presence of companies has presented them with pressures to minimize the time it takes to service customers, minimize the time to develop new products, fulfil demand and strengthen their competitiveness. Hence, the ability to quickly evaluate alternatives becomes an important advantage in a competitive company. The most cost effective, accurate, and rapid evaluation of alternatives is provided by computer simulations of the one company's internal processes. By modeling them and providing a visualization of their flow, and exploring how they might behave in different scenarios, computer simulations are an invaluable tool for decision making.

In recent years, understanding and analyzing the functioning of an organization from the business process view point became widely accepted and adopted compared to the functional understanding of the organization [8]. The foundation stones were the publicationof two papers by Hammer "Reengineering Work: Don't Automate, Obliterate" and by Davenport and Short "The New Industrial Engineering: Information Technology and Business Process Redesign" in 1990. Since then the field of business processes has evolved grately through a generation of new ideas, approaches, techniques, and methods; all with the aim to result in organization's more successful and efficient behavior. This field has advanced rapidly since 1990 and simultaneously with this advancement a number of well-known approaches were developed for use in solving process improvement problems, such as business process reengineering or innovation, business process improvement or redesign, and business process management [8]. They all deal with identifying the possibilities that would result in more successful organization.

2.1.1 Business process reengineering and improvement

Business process reengineering was defined in [22] focusing on the differatiation between efficiency defined as "doing things right" and effectiveness defined as "doing the right things".

[20] also developed important definitions of efficiency and effectiveness stating that

- "Efficiency is a measurement of how well a process uses its resources", and this includes resources such as people, time, space, and equipment;
- "Effectiveness is the degree to which an item provides the right output at the right place, at the right time, at the right price".

Among mentioned approaches, business process reengineering is the most radical approach. It starts with creation of a business process from scratch by using the company's strategic goals as foundations to develop new business processes suitable for the implementation of these goals [8]. Consequently, some literature also defines it as business process innovation. According to [8], this name indicates that this approach depends on the reengineering team who should be very knowledgeable and experienced in order to work as an innovative group capable of creating new ideas on how to develop breakthrough business processes. Organizations should implement this approach when business process functioning is time- inefficient as well as incorporate many redundancies. Some literature recommends that implementing this approach should begin with designing a new business process, whereas others such as [8] recommend that understanding and analyzing the existing business process is a very important concept and should be used as the starting point for building a new business process. In [18] the authors provided a definition of business process reengineering as: "The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed". [9] defined business process reengineering as: "BPR is the creation of entirely new and more effective business processes, without regard for what has gone before". Concerning business process reengineering [20] mention in their book the following interesting conclusions, which could be beneficial:

- Process reengineering, when applied correctly, reduces cost and cycle time between 60-90% and error rates between 40-70%;
- Process reengineering is the correct answer for 5-20% of the major processes within an organization;
- The process reengineering approach provides the biggest improvement but is the most costly and time consuming approach;
- Process reengineering is associated with the highest degree of risk;
- It includes organizational restructuring and can be very disruptive to the organization.

There is a vast literature concerning redesign of business processes ([18]; [23]; [24]) and simulation of business processes ([25]; [26]) (for more see [27]).

Redesign of a business process can be executed:

- based on process documentation (top-down) or
- based on process data (bottom-up).

The latter approach focusses on identifying performance issues of the actual process and potential improvements based on available process data. *Process models* can be obtained using automatic discovery of information from *event logs*, which is called *process mining.* The discovered models can be used as a feedback tool that helps auditing, analyzing and improving already enacted business processes. For an extensive overview about process mining, see [5].

Redesigning business processes focusses on specific redesign objectives, which can be expressed by selecting the appropriate performance criteria. The performance criteria define how the business process is assessed. Based on this performance assessment, the proposed redesign will be created.

Redesign goals can range from incremental to radical change. According to [18] in Business *Process Re-engineering (BPR)* the central topic is improving the management of processes. According to [28], "BPR is driven by a business vision which implies specific business objectives such as Cost Reduction, Time Reduction, Output Quality Improvement, Quality of Work Life, Learning and Empowerment. For [29], BPR is used to improve the performance of organisations as measured by cost, cycle time, service and quality. [30] emphasised on the customer point of view as the BPR goal, namely the focus on improving product distribution and delivery performance to the customer.

The focus of BPR may concern different aspects: product standardisation, tasks design, routing, prioritising, information exchange, work allocation, IT support, process information, production control, and management style (van Hee & Reijers, 2000). Consequently, Key Performance Indicators (KPIs) such as service time (total time spent on case), waiting time (total idle time of the case), resource utilisation, number of errors, etc., must be measured [31].

[20] suggested implementing business process reengineering as follows:

a) Big picture analysis: The team should study the organization's mission and strategy. In addition, the team must understand the present situation and future goals of the organization, how the new process could support the organization's future needs, and what changes the new process should provide to achieve the organization's business goals.
b) Theory of ones: After the big picture is completed, the reengineering team begins dealing with defining the business process starting from its input, continuing with defining each piece of work carried out within the process, and completing it with the process's output.
c) Process simulation: After completing the process design theoretically, the team starts developing its simulation model, which is then tested and its functioning evaluated. Testing the process's simulation model continues until the team is satisfied with it.
d) Process modeling: When the newly designed process meets the vision statement and the process model is put into reality by verifying the details at a pilot location or a small part of the organization, then completing the process implementation is continued in the whole organization.

According to [19] business process improvement is an alternative approach to business process reengineering as is focused on improving the functioning of existing business processes by identifying ways to increase business process performance, quality, and lowering their cost. The improvement team tries to understand the business processes selected one by one [8], by:

- Firstly, carefully identifying and analyzing its functioning and organization and
- Secondly, trying to find solutions to the problems and obstacles discovered that obstruct the expected functioning of the process analyzed.

[20] give the following very important conclusions about using the improvement approach:

- it is applied to processes that are working with fair success to well;
- it will reduce cost, cycle time, and error rates between 30-60%;
- it is the correct approach to use with approximately 70-90% of major business processes; and
- it is the right approach if improving the process performance by 30-60% would give the organization a competitive advantage.

The same authors suggested a list of tools or steps to be applied in order to carry out the approach, such as bureaucracy elimination, value-added analysis, duplication elimination, simplification methods, cycle time reduction, error proofing, process upgrading, simple language, standardization, supplier partnership and automation, mechanization, and information technology [8]. [19] published important conclusions of a comparison analysis between the approaches of business process improvement and innovation (business process reengineering), which could be very useful for students and practitioners. In the following some of them are listed:

- Process innovation means performing a work activity in a radically new way;
- Process innovation has the following characteristics such as
    - implements radical changes
    - starts from the beginning
    - is carried out one-time
    - requires a long-time
    - has high risk
    - cultural/structural changes are included;
- Process improvement involves performing the same business process with slightly increased efficiency or effectiveness;
- Process improvement has the following characteristics:
    - implements incremental changes
    - starts with the existing process
    - is curried out one-time/continuous
    - requires a short period of time
    - has moderate risk
    - cultural changes are included [19].

It must be emphasized that after carrying out the improvement of a certain business process, the company may expect that the process concerned gains a number of different advantages concerning its performance, cost, and quality in comparison with other competitive business processes [8]. However, these improvements have time limitations as other organizations on the market are improving their functioning as well.In order for business process improvement to be successful, it requires a real support by the management at the highest level of the organization should be provided, the needed resources should be available to the improvement approach, and an improvement plan should be prepared and implemented in order to ensure that the implementation of a continuous process improvement plan is going on constantly throughout the organization [8]. [20] mentioned that continuous business process improvement should result in a 10-15% yearly ongoing improvement in the process. Business process management is widely researched by many very good and contemporary books which contribute an important role in introducing the approach successfully from different points of view as "Business Process Management: Concepts, Languages, Architecture", published by Weske in 2007 [4]. According to [8] business process management approach could be understood as the continued development of the two previously introduced approaches and is based on new ideas, which combine possibilities for optimization of business processes with the use of contemporary information technology in order to create a new and an as effective and efficient environment as possible to implement the business process analyzed. To understand properly the meaning of business process management, let us present definitions given by [4] for the business process, business process management, and business process management system.

- Business process: A business process consists of a set of activities that are performed in coordination in an organizational and technical environment. These activities jointly realize a business goal. Each business process is enacted by a single organization, but it may interact with business processes performed by other organizations.
- Business process management: Business process management includes concepts, methods, and techniques to support the design, administration, configuration, enactment, and analysis of business processes.
- Business process management system: A business process management system is a generic software system that is driven by explicit process representations to coordinate the enactment of business processes.

Business process management is defined by Khan [32] in his book "Business Process Management" as: "Business process management is the discipline of modeling, automating, managing and optimizing business processes throughout their lifecycle to increase profitability".

2.2 Business process modelling and business process modeling techniques

As previously mentioned, literature widely covers the fields of business process as well as process modeling as both fields have been gaining recognition and acceptance. [33] have conducted a comparative study that closely examined 25 methodologies, 72 techniques and 102 tools. Furthermore, business process modelling is one of the requirements of the ISO 9000 international standard for quality management and assurance [10], as well as being one of the key questions when implementing the majority of information systems such as workflow management systems, enterprise resource planning and e-business [8]. Additionally fields such as business process renovation are centred around business process as a starting piont in the analysis of the organisation.

The difference between the two was deifned by [8] as a model is an abstraction of the usually complex functioning of a real system that preserves all the characteristics of the system, ensuring that the model reflects the true behavior of the original system whereas a process model is usually a diagram that depicts of a group of activities that are connected sequentially as predecessor(s) to successor(s) by their outputs and inputs, and organized in a number of paths in order to describe a certain functioning within an organization.

Authors in [4] gave the following interesting definition: "A business process model consists of a set of activity models and execution constraints between them. A business process instance represents a concrete case in the operational business of a company, consisting of activity instances. Each business process model acts as a blueprint for a set of business process instances, and each activity model acts as a blueprint for a set of activity instances".

Business process model is required as it is a starting point to enable various simuation scenarious to be tested out rather than doing it on real-life business process. Such testing is necessary to identify problems and obstacles existing within the process in order to find solutions to improve it [8].

According to [34], it is the business processes that are the key element when integrating an enterprise. Furthermore, conceptual modelling of business processes is deployed on a large-scale to facilitate the development of software that supports the business processes, and to permit the analysis and re-engineering or improvement of them [35]. Furthermore, a process is defined as structured, measured sets of activities designed to produce a specified output for a particular customer or market [19]. Hence, a process converts inputs by summing their value through various activities into outputs [8]. A business process is defined by Hammer [36] as a collection of activities that takes one or more kinds of input and creates an output that is of a value to the customer. However, Aguilar-Saven [35] stressed that a business process is related to the enterprise, as it defines the way in which the goals of the enterprise are achieved as the input and output, and the entry and exit points determine the process boundaries within which the relationship between the process and its environment is created through the inputs and outputs. Besides the inputs and outputs, the process architecture also includes four other main features: the flow units, the network of activities and buffers, the resources, and the information structure [37]. The flow units are the temporary entities that flow through diverse activities in order to exit as a completed output [8]. A process is described by Laguna and Marklund [12] as a network of activities and buffers through which the flow units have to pass in order to be transformed from inputs to outputs. To sufficiently define a process, firstly the process activities need to be identified, and then the sequence order of the identified activities needs to be established [8]. Resources are origins of supply, material assets required to activate process activities and are consequently twofold; capital assets and labour [12]. The information structure, finally, is of key importance in the process of information gathering and implementation.

The field of business process modelling is still evolving ([38]; [39]; etc.), and from the static view of business-functional organisational structure till present time, business processes have developed to offer a dynamic overview of an organisation. This is achieved with identification of activities that coevolve through time and create value. To acquire such an overview, groups of dependent activities are identified, which overlap the borders of traditional functional organisation, evolve through time and consequently add value to consumers. Such overview of the business processes has many benefite, including better understanding of customers' demands and desires of the consumers rather than spending time dealing with internal matters such as organisational structure or business rules [39].

Creating a process model starts with mapping of the business processes. Other steps in the process modeling are process discovery, process simulation, process analysis and process improvement or reengineering. Although a holistic business process modeling exercise would cover all these steps in some depth, analysts have found that even a partial modeling exercise that involves a subset of these steps is a good start and yields significant benefits.

As mentioned above, the key step in understanding and redesigning the activities that a typical company employs to achieve its business goals is business process modeling. BPS has multiple benefits to companies and organisations. These include, but are not limited to aligning operations with business strategy, improving process communication, increasing control and consistency, improving operational efficiencies, obtaining competitive advantage.

A *process model* provides an analytical framework for describing the activities and their relationships in detail. It extends the concept of business process reengineering by providing a quantitative predictive capability. A process model codifies the process and provides a common understanding of how a current or future system behaves.

A process model, when simulated, mimics the real-life or hypothetical operations of the business in order to predict their performance under different circumstances and/or improve them. By visualising the workflow dynamics i.e.

across time, the simulation software keeps track of statistics about elements of the model and on the basis of the output data the performance of a process can be evaluated.

2.2.1 Quality of process models for successful simulation

Business process models (or process models for short) are required as a basis for knowledge transfer, quality purposes, regulations, communication between internal and external collaborative partners, and documentation in general [40]. With the help of simulation, these models can provide the most accurate and insightful means to analyse and predict the performance measures of business processes. Given the important part modelling plays in a success of a company, it is important that it is done right. The quality of business process models will impact on the quality of (the design of) information systems and on envisaged business process improvements as the use of incorrect modeling and analysis procedures which can result in erroneous results.

A corroboration to this serve the research done by Rosemann ([41], [42]), where he lists 23 pitfalls based on his observations of business process modelling projects. This list reveals challenges faced by many modellers related to the quality[2] of the process model. More precisely, the author points out the risk of "getting lost in detail" when modeling and trying to capture all possible scenarios rather than the relevant ones. Another caveat in process modeling suggested by Tumay [43] is the use of incorrect analysis procedures which can result in flawed results. A modeller needs to bear in mind that different types of processes call for different modeling, specifically tailored to the process, the simulation procedure, and analysis considerations. In this respect, Tumay [43] suggests categorisation of the business processes into four major categories (which not necessarily capture all types of existing business processes):

1. Project-based processes,
2. Production-based processes,
3. Distribution-based processes,
4. Customer service based processes.

In Table 1 the four major categories of business process are compared on the basis of model elements and selected examples.

Category	Model elements	Examples
Project-based processes	Entities	proposal, report
	Resources	consultants, workers
	Activities	design, testing, review
	Workflow	parallel flow, feedback loops
Production-based processes	Entities	orders, electronic forms

[2] For an overview on studies on business process modeling quality refer to [110].

	Resources	equipment, staff
	Activities	batching, assembly, inspection
	Workflow	sequential flow, feedback loops
Distribution-based processes	Entities	people, loads
	Resources	trucks, rail cars, planes
	Activities	load, move, unload
	Workflow	alternative routes, looping
Customer service-based processes	Entities	customers, patients
	Resources	service representative, nurse
	Activities	take order, service, assist
	Workflow	based on customer type or state

Source: [43]

Process modeling is as much art as science. While sophisticated computer-based analysis tools make the job faster, it requires experience and judgment to translate a real-world system into a compact yet unambiguous process model description. The trick is to capture just the right amount of detail so that the generated performance measures provide a reasonable approximation to real-world behaviour. Only in this way can you be assured that your processes will be truly improved.

2.2.2 Modeling technigues

As stated earlier, successful business process modelling depends on the appropriate selection of available modelling methods, techniques or process flow analyses. There are many techniques or analyses used in this field, such as general process charts, process activity charts, flowcharts, dataflow diagrams, quality function deployment (QFD), the integrated definition of function modelling (IDEF), coloured petri-nets, object-oriented methods, seven management and planning tools and so forth. There have also been attempts to classify business process modelling practice and the research in this area is threefold. The first group of studies compares various stages of process modelling with tools and techniques used by some of the leading companies around the world. Elzinga et al. [44] developed a general methodology by studying tools and techniques and classifying them according to their suitability for each phase of the methodology. Kettinger et al. [33] conducted a comparitive study that closely examined 25 methodologies, 72 techniques and 102 tools. Willcocks and Smith [45] looked at various unsuccessful modelling attempts which failed due to the use of partial approaches in the analysis stage. Consequently, they recommend a completely multidisciplinary approach that includes technological, sociological, cultural and political elements.

The second group of studies deals with the deployment of existing techniques for business process modelling. Johansson et al. [29] conducted and offered a short overview of different techniques for process mapping that has sources in process management, process modelling and simulation, and systems engineering. Miers [46] similarly compared various techniques such as flowcharts, action workflow diagrams, data flow diagrams, etc. and their usability with business process modelling. Busby and Williams [47] studied values and limitations of process modelling using the IDEF0 technique for manufacturing a company case-study. They concluded that even though the models present current activities and alternative scenarios, they have serious limitations such as not enabling quantitative assessments, are subjective, present data mechanically, and their maintenance is relatively demanding. Hence, the literature suggests that one unique technique for the use in business process modelling does not exist, which is why practice is mainly to use the toolkit approach when modelling that enables the use of different techniques based on the data available for model development and regarding the purpose of modelling [48]. The third group studies and compares various tools for business process modelling. Classe [49] examined 19 tools and through case-studies demonstrated tools deployment in seven companies; as a conclusion she identified the following elements that influete the use of tools – goal of the project, scope and purpose of changes, possibility of IT deployment, organisational culture, etc. Similar research has been conducted by [50], [51], and [52].

The following techniques are briefly described. The general process chart produces a table where the rows list the analysed activities and the columns contain information about the current process, the redesigned process and the difference between the two. Within each column, there are three categories of queried information – the number of activities, total time of each activity and the percentage of the time this activity requires in regard to the overall process time. Such an analysis enables the modeller to identify major problems within the process but only monitors the frequency of each activity and the time it takes, and does not provide the sequence of activities. The process is improved when the redesigned process contains more value-adding activities; that is achieved by decreasing of number of non-value adding activities in the current process. The process activity chart complements the general process chart by providing details to gain an understanding of the sequence of activities in the process [12]. On the downside, process activity charts sum the average time of the activities and are impractical when illustrating several alternatives, as each alternative requires its own chart. DataFlow Diagrams are Yourdon's technique [53]. A data flow diagram (DFD) illustrates the flow of information through various places and therefore provides the organisation of data from the beginning. The relationship shown by a DFD is between the process, data stores, the users and the external environment. A DFD is able to describe what a process will do rather than how it will be done [35] and, at the same time, enables a hierarchical view providing the required details. Dataflow diagrams as simple, easy to comprehend and easy to improve, as they are intended for communication between the modeller and the users.

Such documents show the relationships among all components of the system specification (or detailed user requirements), including system outputs, data definitions, system inputs (or transactions), and process specifications (or business rules)[3]. The starting points of dataflow diagrams are the context (level 0 or top-level) diagrams that illustrate the whole systems as one process, and the connections among the system and its environment (users and external entities) are also shown. Context diagrams are built with the purpose of defining the extent of the analysed system, as well as to provide a framework for the subsequent diagrams. The subsequent diagram (level 1 or system diagram) shows the breakdown for all major functions within the system and is used as a basis for further analysis.

The QFD technique is a set of powerful product development tools that were developed in Japan to transfer the concepts of quality control from the manufacturing process into the new product development process The QFD technique uses the "Voice of the Customer" that represents consumer statements regarding market demand and transferring them into a "House of the Customer" – a matrix that integrates document information, observations and conclusions. According to the literature, the QFD technique, if deployed properly, decreases marketing time, designs adjustments as well as costs, increases quality and consequently enables the organisation to acquire the ability to provide better customer satisfaction. The IDEF is a family of methods that supports a paradigm capable of addressing the modelling needs of the enterprise and its building areas. IDEF was created for use within the United States Air Force with the purpose of enabling identification of required information by process modelling and includes 16 methods (IDEF0, IDEF1, IDEF1X, IDEF2,. . . IDEF14). The methods represent different types of modelling; for example, IDEF0 presents function modelling, IDEF1 information modelling, IDEF1X data modelling, IDEF2 simulation model design, IDEF3 process description capture, etc. IDEF methods are used to create graphical representations of various systems, analyse the model, create a model of a desired version of the system, and to aid in the transition from one to the other. The IDEF0 method is a method designed to model the decisions, actions, and activities of an organisation or system and is founded on a graphical language called structured analysis and design technique (SADT). The system of coloured petri-nets is a graphically-oriented language for design, specification, simulation and verification of systems [35] where symbols vary by colours. Some of the advantages of using coloured petri-nets are as follows: they are very general and can be used to describe a large variety of different systems; have very few, but powerful, primitives; have an explicit description of both states and actions; offer hierarchical descriptions; can be extended with a time concept; offer interactive simulations where the results are presented directly on the CPN diagram; have a number of formal analysis methods by which the properties of CP-nets can be proved, etc. Coloured petri-nets

[3] www.idinews.com/life-cycle/dataflow.html

enable four types of analyses, which are interactive simulation, automatic simulation, occurrence graphs and place invariants.

Besides, six sigma and its QFD technique, others are widely used, such as the seven management and planning tools. They are used in leading organisations throughout the world as a set of team-based tools for making better decisions and implementing them with greater success. The seven tools can, if deployed effectively, enable an organisation to manage assessments as well as decision-making, and when used interchangeably, according to affinity consulting, provide a powerful answer to the way in which teams can respond effectively to issues that can at times seem confusing and chaotic; and include the affinity diagram, the tree diagram, the inter-relationship diagraph, the matrix diagram, prioritization matrices, the process decision programme chart (PDPC) and the activity network diagram.

According to [35] object-oriented methods might be defined as methods to model and programme a process described as objects, which are transformed by the activities along the process. The basis presented by an object includes its attributes as well as its operations (behaviour). From the variety of available object-oriented methods, brief descriptions of UML and TAD methodology follow. UML (unified modelling language) is a general-purpose visual modelling language that is used to specify, visualize, construct, and document the artefacts of a software system [54]. There are several different types of UML diagrams, such as use-case, sequence, collaboration, activity, class, package, and other diagrams. The activity diagram is a flowchart, which is used to describe a use-case or to model a process by presenting its activities in a determined sequence order. A flowchart is supported by different software packages, such as iGrafx, for modelling business processes. The sequence diagram is used by UML and for the purpose of this paper is mentioned only briefly. The diagram develops a model that presents how objects (identified in use-cases) communicate amongst each other and various others users in time. Hence, the sequence diagrams show the sequence of messages between the elements of the system, as well as between the objects and the system's elements in regard to time.

TAD (Tabular Application Development) methodology is used to carry out business process management [8]. The methodology consists of the following five phases: Process Identification, Process Modeling, Process Improvement and Innovation, System Development, and System Maintenance. The first phase of TAD methodology deals with the problem of identifying an organization's business processes, starting with a set of core processes that are essential for the functioning of the organization. The second phase of TAD methodology is called Process Modeling and deals with developing a process model for the business processes identified in the previous phase using the Activity Table technique. The third phase of TAD methodology deals with business process improvement and innovation and consists of four subphases, which are "as-is" process model analysis, "to-be" process model creation, "to-be" process model analysis, and process simulation. The fourth phase of TAD methodology deals with the development of a process management system that implements the "to-be" process model created in the previous phase. The fifth phase of TAD methodology deals with controlling the functioning of the improved business process and the process management system [55], [56].

Phalp in [57] suggested that there is a need for different notational approaches, for different modelling purposes and audiences. The pragmatic approaches use diagrammatic techniques, and are suitable for the development of software for business process support, as the user simply observes the model and does not interact with it. On the other hand, business process analysis and re-engineering require more than just observation. Qualitative analysis is insufficient, as the dynamic and functional side play an important part. The user, besides observing, requires the ability to interact and analyse various states of the model. Hence, the usability of business processes is threefold (as stated in [35]): to learn about the process, to make decisions on the process, or to develop business process software.

The above given discussion shows that the methods and techniques of business process modelling could be divided into two groups; the diagrammatic and the tabular methods. The aim of this paper is to choose and discuss a technique from each of the two mentioned groups and then to make a comparative analysis of the two techniques. The flowchart and the activity table are chosen as representatives of the diagrammatic and tabular techniques, respectively.

A lowchart was chosen for discussion as a representative of diagrammatic techniques because it is a simple diagram and is used to model business processes in software packages such as iGrafx. In addition to process modelling, iGrafx also enables us to perform simulation of the modelled processes. The flowchart technique defines a flowchart as a formalised graphical representation of a program logic sequence, work or manufacturing process, organisation chart, or similar formalised structure [58].

A flowchart is commonly used to show the flow of a process from its start to its end. It usually consists of different symbols connected by lines, arranged in such a way to lead us through a series of steps in the correct sequence order.

Process flow is traced by following the connecting lines between the symbols

drawn. These symbols include: start and end, activity, input and output, decision, and department. A flowchart begins with a starting point and finishes with an ending point. The terminus symbol is commonly used in flowcharting to designate the beginning and the end.

An activity is represented by a rectangle and means an elementary task. The path by which processes flow through the diagram consists of connecting lines between activities. A set of activities could be contained by a container called a department. An input is indicated by an arrow, which enters an activity. An output is shown by an arrow, which leaves an activity. An arrow connects one activity to another, showing the movement of the diagram. A decision specifies alternative paths based on some Boolean expression and is shown by a diamond. There can be only one path to a decision, but there can be many output paths [59]. A decision is a point at which the process flow can take one of several possible paths based on a defined criterion. To model a task performed simultaneously by different departments or to model parallel activities, we define different outputs from an activity as split outputs. A split is made by defining multiple paths from a single activity to a set of activities.

After a parallel task has been performed, outputs of those activities which performed the parallel task could be modelled to enter a single activity; this is called a joint input. According to Aguilar-Saven [35] flowcharts are built to offer an enhanced comprehension of the processes, which is a requirement for process improvement. The flexibility of the flowchart technique is argued by many to be its advantage as it allows each modeller to unite various pieces of the process together to gain the overall picture as he/she feels they fit best. On the other hand, some argue that the technique is too flexible, describing large models without illustrating the hierarchy of different layers.

3 Using simulation as an approach for business process management

A simulation in its basic connotation represents an imitation i.e. a model that imitates a real-world process or system in a given period of time. According to Peček [60] simulation is a methodology whose scope goes beyond the mere support for the organization's operations and into the scope of the strategic planning and its management. The simulation model that is being developed in the process thoroughly investigates the behavior of the system in the observed period, and it usually assumes the form of assumptions [61] that pertain to the way the system operates. These assumptions can be expressed with mathematical, logical, and/or symbolic relations between the entities or the objects of the system at study. Once the simulation model is developed and evaluated it allows the implementation of various what-if questions concerning the functioning of the real system. The simulation of the potential changes to the system or the processes allows prediction of their impact on the performance of the system performance without inflicting modifications on the real system.

Simulation involves the development of descriptive computer models of a system and exercising those models to predict the operational performance of the underlying system being modelled [62]. Simulation is the method of developing and experimenting with computer – based models of operations, such as construction processes, to analyse and evaluate the behaviours of a system [63].

Once the simulation model has been developed to represent a system or a process, the company would need to find a tool that would produce high quality solutions. Although the steps in business process simulation (BPS) be the same irrespective of the simulation tool used, each simulation tool will have a different applicability. Most systems can be viewed as discrete event systems (DES) and include for example manufacturing systems, business processes, supply chains, etc. For each of these systems, there are different simulation tools applicable to them. In continuation we provide an overview of the steps of business process simulation and different tools by steps and activities.

3.1 Simulation application guidelines

The growing availability of customized simulation languages, the development of the information technology, as well as the development of the simulation methodologies, has led to wider application of the simulations in the fields of operations research and systems analysis. There are numerous applications of simulation, and according to Naylor et al. [64] and [65] they can be summarized as follows.

- Simulation enables the study of the internal relations of the complex systems or subsystems within a complex system;
- Informational and organizational changes as well as changes in the environment can be simulated in order to observe the effects of these changes on the system;
- The process of developing a simulation model is a learning exercise, that serves as a ground for proposing improvements to the current system;
- By modifying the inputs and observing the changes in the output, simulation reveals the importance of separate variables and their correlations;
- Simulation examines the potential outcomes of new strategies before their actual implementation;
- Simulation can also be used for verification of the analytical solutions;
- The simulation models that are designed for learning enable costless learning that does not disrupt the actual processes or workplace.

Banks in Gibson [66], on the other hand, indicate ten instances when simulation is not the most suitable choice:

- When the problem can be solved with the help of logical reasoning;
- When the problem can be solved analytically;
- When it is easier to perform the actual experiment;
- When the cost of simulation is higher than pay off that simulation brings;
- When there are no available resources (time included);
- When data for the evaluation of the results of the simulation is not available;
- When managers have unrealistic expectations from the simulation as a tool;

- When the operation of the system is too complex or can not be defined.

There are many advantages to simulation. Pedgen, Shannon and Sadowski [67] credit its application with the following:

- New procedures, decisions, information flows, etc. can be developed and evaluated without disturbing the functioning of the current real system and its operations;
- New equipment, products' form, transportation systems, etc. can be tested without actual employment of resources for their testing;
- Assumptions regarding causes of particular events can be tested and their applicability and feasibility;
- The simulation time can shorten or stretch the actual interval of the observed system;
- Simulation provides insight in the interactions between variables;
- Simulation provides insight on the impact of individual variables on the successful implementation of the system;
- Simulation enables the identification of bottlenecks i.e. the places in the model where there are implementation delays;
- Simulation contributes to better understand of the system functioning;
- Simulation seeks answers to what-if questions.

The same authors also emphasise the following drawbacks of simulation:

- Building the simulation model requires special training. It is an art that is acquired with time and experience.
- Simulation reports results are difficult to interpret. Since most simulation tools are based on random variables, which are results of random input elements, it is difficult to determine whether the observed behavior of the system is a result of the actual relationships between the variables or it is a result of chance.
- Simulation modeling and analysis can be time consuming and expensive. The limited resources involved in modeling and analysis can may result in designing inadequate model or analysis.
- Simulation is used when an analytical solution is possible, or even preferable
- Banks et al. [61] provide the following arguments to support the above mentioned drawbacks:
- Simulation software vendors are actively developing tools that already contain partial or complete models that require only input data.
- Many simulation software vendors in their various tools implement diffeent analysis of the output data.
- The rapid development in the field of simulations provides for faster implementation of the different simulation scenarios. This is due to the developments in both, computer hardware, as well simulation tools.

3.2 System simulation

3.2.1 Business systems

A business system has two parts – static part and a dynamic one. The dynamic part of a business system are the business processes (and activities), which were introduced in Section 2.3. The static aspect of a business system, on the other habd, involves the organizational structures within which business processes are conducted, the various business, and information objects etc.

Each business system, together with its two aspects, generates economic benefit and value added. Key in the analysing and modeling a business system is defining the system limits. A business system that is to be modeled can span an entire organization. In this case, we talk about an organization model.

3.2.2. Business process simulation

According to Greasley and Barlow [68] business processes simulation involves application of models that study the behavior of systems, identify their optimal operation, and seek the optimal organization. Banks et al. [61] define the system as a group of objects that are linked together in order to achieve a defined objective. Concurrently, it is also true that the changes in the system environment influence the system itself [69]. Therefore it is important that in the process of system modeling the boundaries of the system are determined by which the system is separated from its environment. These boundaries are defined depending on the purpose of the modeling and can vary from a model to model.

Table 2 shows lists examples of systems and their elements, such as entities, attributes, activities, events, and system variables. Banks et al. [61] defined the system elements as follows:

- An entity is an object of interest within the system;
- An attribute is a property of the entity;
- The activity is an event in a certain time period, whose duration is determined by the onset of the event;
- The state of the system is defined as a collection of variables that designate the system at any time;
- An event is defined as the momentary phenomenon that can change the state of the observed system.

Table 2. Examples of systems and their components

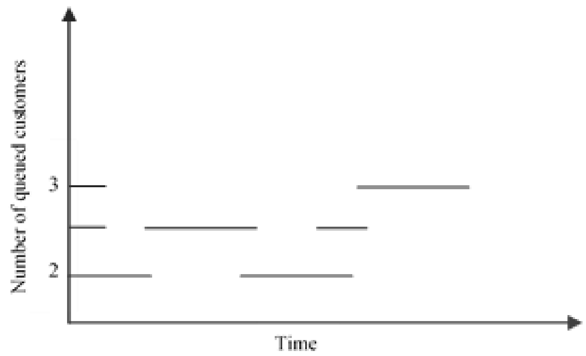
System	Entities	Attributes	Activities	Events	State variables
Bank system	Clients	Checking account balance	Depositing money	Arriving, leaving	Number of available clerks, num-

System	Entities	Attributes	Activities	Events	State variables
					ber of queued customers
Railway system	Travellers		Travelling	Arrival, departure	Number of travellers on the station, number of travellers on board

Source: [61]

The systems can discrete or continuous. According to Law and Kelton [70] there are almost no systems that are in practice only discreet or only continuous, but in most cases it is possible that the predominant characteristic of the system can be determined. The *discrete system* is a system whose variables change only at discrete points in time, as shown in Figure 1. The figure shows the change in the number of clients that occur at discrete points in time.

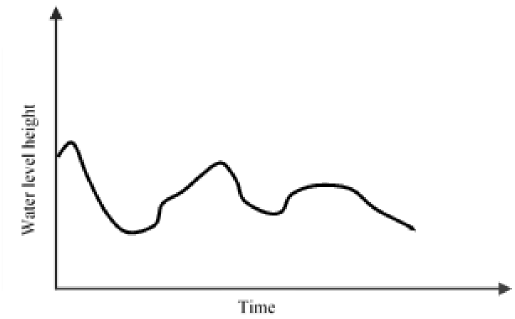
Figure 1. Change in the number of clients



Source: [61]

Continuous system, on the other hand, is a system in which the variables are changing in a continuous manner within a time interval. Figure 2 shows a continuous movement of the system variables in the case of changes in the dam level.

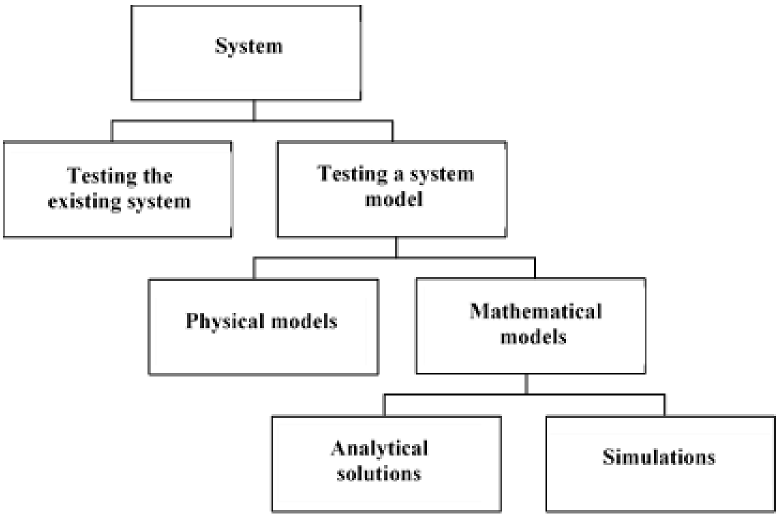
Figure 2. Changes in dam level



3.2.3 System model – definition

According to Banks et al. [61], a representation of the system whose purpose is its examination is what represents the system model. It is a conceptual model that describes and represents a realistic system in an abstract way. In building the model, it is necessary to take into account only those elements which are directly related to the studied problem. These elements are the building blocks of the model, which is simplified representation of the system. It is important that the model is a faithfully and detailed representation of the system, because that will guarantee results that are applicable to the real system.

Figure 3. Process testing methods



Source: [60]

A model can be mathematical or physical. Mathematical models use symbolic notation and mathematical equations to represent the system. The simulation model is a special type of mathematical system model. Other classifications of simulation models include: static or dynamic models, deterministic or stochastic, and continuous or discrete simulation models. The **static simulation model** represents the system at a particular point of time. The **dynamic** one, on the other hand, captures the changes of the system. The simulation model whose input variables are not random is classified as **deterministic**. Deterministic models have a known set of inputs, which allow production of a determined set of outputs. The stochastic simulation model, on the other hand, contains one or more random input variables, which in turn lead to the production of random outputs of the system.

Figure 3 shows the approaches of the testing of the processes. The testing can be done on the existing system, which is not recommended and can be costly, or it can be done on the system model. The latter can be carried out as shown, with physical models (a prototype), and a limited production of the good, or with mathematical models. The mathematical models can be **analytical** or simulation models. Analytical models provide accurate information about the behavior of the system and examples of these models include Petri nets, operational research, etc. The **simulation** models, on the other hand, allow observation of the behaviour of the system behavior under a variety of simulation scenarios.

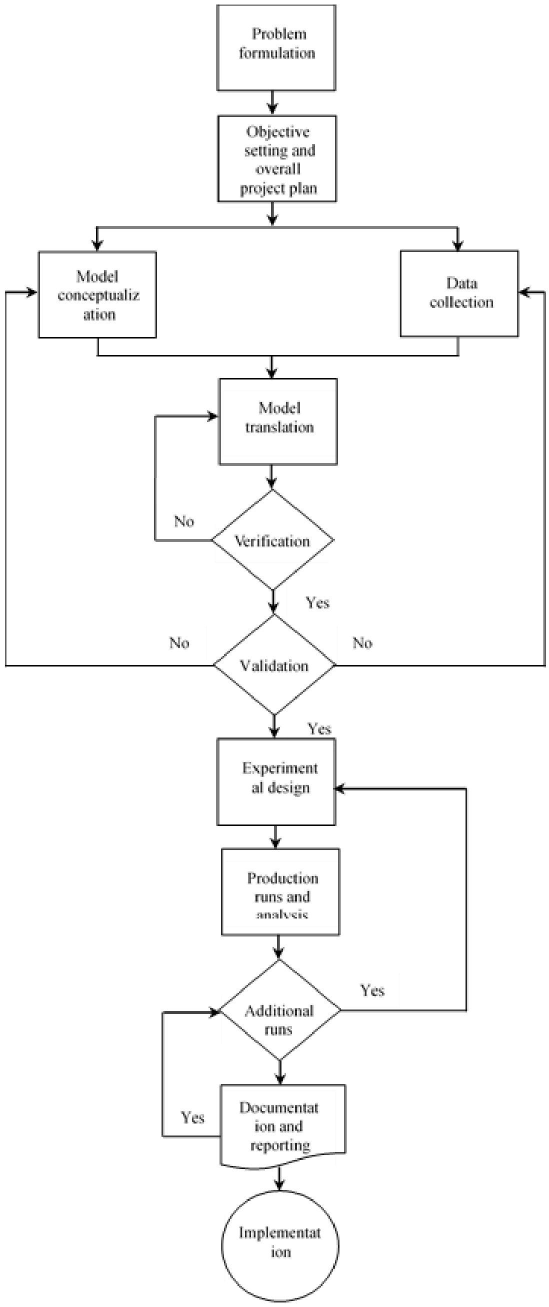
The simulation model is run on the basis of a determined set of input elements and characteristics during which its behaviour is observed. After a number of iterations with different inputs and characteristics, the different scenarios are evaluated. The best solution is then proposed for implementation in the real system.

Different authors propose different classification of the elements in creating the flow of business process simulaiton (see for example [71], [61], and [72]). The following steps for building a system model have been put forth by Banks et al. [61] (Figure 4).

Problem identification and formulation. A successful research starts out with proper identification of the problem at hand. If the problem is defined by the organistaion's management, it is important that the analyst has a clear understanding of it. In the case where the problem is identified by the analyst, it is important that it is clear and approved by the management.

Objective setting and overall project plan. The objectives dictate the questions that should be answered by the simulation. Of key importance in this step is determining whether the methodological approach is appropriate for solving the problem at hand and whether the simulation objectives are clearly set. In the case where the simulation is the appropriate way to resolve the problem, the general project plan needs to also include alternative scenarios as well as methods for evaluation of their effectiveness. Additionally, the plan needs to predict the necessary resources (number of people involved, cost of implementation, number of days required for the completion of each phase) and the expected results.

Figure 4. Steps of the simulation study



Source: [61]

Model conceptualization. Conceptualization is dependent on several factors: (i) the ability to identify the underlying characteristics of the problem, (ii) the choices made, (iii) the modification of the basic assumptions about the system, and (iv) the possibility to extend of the model. Thus, Banks et al. [61] suggest that it is better to start by creating a simple model and then proceed towards more complex versions of the model.

Data collection. Shannon [73] argues that there is a consistent link between model design and data collection. By changing the complexity of the model one can also change the data that are required by the model. Data collection is time-consuming and takes a large part of the total time of the project, so it makes sense to start by collecting as early as possible.

Model translation. Most models that represent real systems require appropriate methods of data storage and IT support, so that the model can be expressed in an acceptable format. This can be done using simulation languages, which offer support and flexibility, such is GPSS/HTM, or customised simulation software, which can significantly reduce the development time of the model, such are, for example, Arena®, AutoModTM, CSIM, ExtendTM, Micro Saint, WITNESSTM, iGrafx, etc.

Model verification. In this step, the input elements i.e. events, logical connections, etc., are verified whether they are correctly presented and defined within the set simulation language or tools. With that, the model is verified whether it is ready for computer processing.

Model validation. The model is validated when it is established that it accurately represents the real system. The conclusion is based on the iterative comparison of the model behaviour and the behaviour of the real system, and the subsequent inclusion of the observed differences in the model.

Experimental design. The alternative simulation scenarios needs to be defined upfront. Often, the choice of alternative scenarios is a subject of previously concluded and analysed simulations.

Production runs and analysis. The product tests and analysis are used to assess the scenarios of the simulated system.

Additional runs. Based on the analyses of conducted tests, the analyst decides whether the model need additional testing. In the case the need for additional tests is identified, new alternative scenarios are set.

Documentation and reporting. There are two types of documentation, program documentation, and a progress report. The program documentation is important for reproduction of the process and is especially helpful to the analysts conducting the simulation. Likewise, regular progress reports are also important, as they represent 'written history of the project simulation' [74]. Progress reports contain chronological data, decision made at every step, and results.

Implementation. The success of the implementation is highly dependent on two factors, and namely the successful completion of the previous phases, and the analyst’s capability to successfully incorporate the end user in the simulation. If the end user is constantly involved in the implementation and understands the model and its outputs, then the probability of successful implementation of much larger [75].

Figure 4 depicts the twelve steps which the authors divided into four phases. The first phase includes steps 1 and 2, the formulation of the problem and establishing objectives and general project plan and represents a period of discovery or orientation. At this stage the problem is only generally defined, the objectives will go through a number of revisions, and the project plan will also go through certain modification.

Stage 2 consists of model conceptualization and data collection, which together with model verification, and validation are in constant relation. The inclusion of end-user model in phase 2 is indispensable and has a decisive impact on the successful implementation of the model.

Phase 3 deals with the implementation of the model and includes the steps of experimental design, Production runs and analysis, and additional runs. The essence of this phase is to identify precise alternative scenarios.

Phase 4 aspires for flawless model implementation and is constituted from the steps program documentation and progress report. The critical step of the entire process is step 7, or the validation step, since an incorrect model will lead to biased results, which implemented could significantly cost the end-user.

Modelling and simulation are two prominent methods and tools increasingly used in enterprise engineering and organisational modelling. They yield invaluable benefit for modern enterprises in addressing a variety of challenges they are facing when designing new processes or systems, redesigning existing processes, or seeking improvements for which different options need to be compared both quantitatively and qualitatively.

4 BPS approaches - an overview

4.1 Fields

This chapter provides information of the needs for discrete event simulation in the fields of operations management [76], business process management [77], operational decision support [78], healthcare decision making processes [79], [80], [81], simulation as a tool for redesign of BP [27], for manufacturing and business analysis [82], [83], [84], [85]. In addition, we discuss some well-known tools for simulation of BP, such as ARENA, CPN, FLOWer, FileNet [72].

1. **Operations management** is a discipline that deals with analysis and improvement of BP both in services and in manufacturing. Its main goals are to increase productivity and responsiveness, to provide more choices to the customs and deliver higher quality standards. To

achieve these goals, the practitioner has to perform process analysis, define the bottlenecks of the involved processes in the manufacturing, define the flow rates and inventory levels and so on. In order to provide solutions to the defined problems, operations management makes use of optimization and simulation techniques [76].

2. **Business process management**, as a field in operations management, represents the processes in the companies in a form of workflows on top of which designs its goals: improvement of corporate performance by managing and optimizing a company's business processes [1]. Simulation is widely used in the field of business process management as an analytical and optimization tool [77].

3. In BPM, decision making (DM) is performed in three levels: strategic, tactic and **operational decision making**, based on the type of information and their aggregation. While strategic and tactic DM relate to setting the goals and frameworks of the businesses, the operational DM relate to daily operations of an organization. As such the decisions on this level can easily lead to ineffective organizations. To avoid such scenarios, decision on this levels are supported with modeling and simulation tools that can simulate different scenarios given the current state of the organization. In particular, modeling and simulation, which are the two most widely used technique in the field of operations management, allow decision makers to concentrate on the relevant variables and form decisions that will be reflected in optimal or near optimal performances of the daily activities [86].

4. Discrete event simulation (DES) is a generally accepted tool in management decision making, as the overwhelming literature on the subject proves [79]. More specifically its use in providing efficient and effective healthcare services [87]. The challenge that this approach tries to address is the predicting of waiting time (during the patient trajectory diagnosis-therapy-care), which can be highly volatile due to the large variability that exist between patients care needs, even for patients with a similar pathology. The main reasons for using DES **for healthcare decision making** can be found in [80], [81]. DES is used very often for healthcare decision making. For example, it I used for Stroke patient management [79], and for simulation to estimation the capacity of a stroke unit for a Dutch hospital [88]. Additionally, a petri net approach has been used to simulate the stroke unit care flow [89]. Simulation of the patient care system is reported in [90]. A modeling framework that combines Markov models with DES is applied for stroke patient flow modelling [91]. DES is used for simulating the flow of tissue plasminogen activator (tPA) patients, a patient group with other care needs than the ischemic stroke patients [92], etc.

5. In **manufacturing and business analysis,** the review literature suggests three general classes of application of DES techniques: manufacturing system design, manufacturing system operation, and simulation language/package development from 1969 to 2014 [84], [83]. The usage of different simulation techniques are vastly covered in some fields such as manufacturing system design and operation, [84]. Additionally, there are attempts for implementation of graphical simulation model to advance the field of virtual manufacturing (VM) which represents a successful tool in today`s manufacturing and marketing [82].

6. In order to be competitive on the market, organizations are faced with the problem of adjusting their business processes in line with the changing environment. The change of one component of the process leads to adjustments to the whole system, hence to the problem of redesign. DES is a primarily used tool in the redesign of BP. A **business process redesign** (BPR) is a technical and socio-cultural challenge [93], [94], [95]. To conducting BPR, a framework for BPR implementation has been developed [96] in order to define best BPR practices. The BPR framework presents different views that we should consider, when implementing BPR. It is relevant because it separates components (participants, information, and technology) of the business process. Authors in [97] defined four dimensions that are influenced by the BPR implementation: time, cost, quality and flexibility. These four dimensions should ideally change in order to decrease time and costs, and increases quality and flexibility, but in fact, they may be operational in different way.

7. The primary task in BPR is to develop a new process design that improves current process plan. It is very powerful way to boost performance of business processes. In order to reach desired improvement one has to define a framework that would support process designer to choose most appropriate best practice, when optimizing existing process through BPR. The aim of the framework is to not only list best practices, but also classify them. One possible framework that is defined by [98], consists of several linked elements: customers, products, operation view, behavior view, organization structure, organization population information, technology and external environment. The BPR community approves such framework and finds customers, products and information in the most interesting framework aspects, with focus on customer, product and information.

   In addition BPR provides the following benefits: a possibility of prediction of future performance of BP [27], the newly developed models can be used for auditing, analyzing and improving the current BP. The methodology that implement both simulations and redesigned has been applied to the following fields according to [27]: in a private company for redesign a BP involved in booking a gas capacity; in a public organization responsible for collecting fines, including the entire flow of activities from initial regulation to payment; and redesigning a Web-based decision support system (DSS) that supports agricultural users.

4.1.1 Tools for BPS

The current algorithms for BPS require an order set of actions to perform the simulations. Regardless of the ordered steps for simulations, each simulation tool usually leads to a priory determined applicability. In literature, one can define more that hundreds of simulation tool. Here we categorise them into three general categories, a classification taken from [72]:

- Business process modelling tools. The tools in this category are developed to describe and analyze business processes. Some of the most frequently used tools that belong here are Petri Nets (Protos) and ARIS Toolset, which is a tool based on Event-driven Process Chains.
- Business process management tools. The tools here are regarded as successors of Workflow Management systems. Most commonly used tools are FLOWer and FileNet.
- General purpose simulation tools. Simulation tools may be tailored towards athe required domain or to be developed for general simulation purposes. An example of tools that belong to this category are ARENA (used in manufacturing, distribution, processes, logistics, etc.), iGrafx, SIMUL8 and CPN Tools.

4.2 Benefits

The benefits of using DES can be found in all categories mentioned earlier.

For example, the research reveals us the trend of most published topics in **operations management** by 1970s is scheduling. However, in the mid 1980s capacity planning and cellular manufacturing have become more significant from perspective of empirical simulation research [76]. By merging design information, historic information and state information, it is possible to construct a model, based on real, accurate behavior. Simulation modification allows us to investigate various what-if scenarios. BPS build with tools like: YAWL, CPN tools, ProM and ProMimport, supports most of desired aspects. Benefits of DES for BP in **Process mining** are due to possibilities to analyze BPM in terms of time, costs and resources [77]. In addition BPS has the ability to perform stochastic, as well as quantitative modelling [78], [99] thus providing **operational decision support**.

In [79] one can find the benefits of using DES for **healthcare business processes**. The main benefit is that unlike traditional optimization models (such as queuing theory), DES been shown to be able to provide insight into the impact of operational changes. Such examples are: concerning available scanner capacity, or determining the timing of the patient's trajectory in a hospital unit. The application of DES has lead to lower average queue waiting times, and to lower total number of requested scans and as a consequence queue waiting times [79].

Effective data management and data sharing are essential activities in **manufacturing and business analysis, in particular in VM**. Computer graphics coupled with simulation, animation and 3D modeling techniques leads to realistic management of virtually displayed processes ready for dynamic and interactive examination [82], [83]. Simulation is proven to be one of the most flexible and useful analysis tools in manufacturing system design and operation [84]. The literature review of this fields leads to identification of new application areas of DES, uncovers the trends in the literature, and highlights the emerging topics in the field manufacturing. Most popular areas seems to be manufacturing operations planning, followed by maintenance operations planning and scheduling, real-time control, and operating policies. A new trend where the usage of DES is increasing rapidly through the last 10 years is maintenance operations planning and scheduling, as well as simulation optimization and metamodeling.

The benefits of DES for **process redesign** are not exhaustive. For example, DES has been used in a BP in a gas sector for redesign the companies BPs and the information systems supporting these processes, while achieving high-performance gains [27]. The resign of a workflow process in a Dutch governmental organization responsible for collecting fines, lead to better management of the increased number of systems and to meet the processing needs for the higher number of fine collection process instances per year. The process redesign improved the throughput time and decreased the number of bottlenecks. Finally, the redesigning of a Web-based decision support system (DSS) that supports agricultural users has lead to discovery of usage patterns different from the originally planned once [100]. In particular, redesign has been required when the the web pages corresponding to the DSS are visited to a comparable extent.

4.2.1 Benefits that comes from using business process modelling tools

As mentioned before, the modeling tolls in this study are classified in three groups, for which we define their particular merits.

1. Business process modelling tools. They help in establishment of control flows of BP, provide an overview of the involved resources as well as their roles in the BP, provide a documentation and guidelines for executing the BP. Hence they help in generation different reports, manuals, functional specifications, etc.

2. Business process management tools. Their core role is management of BP workflows by using “methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information” [3].

3. General purpose simulation tools. Their main benefits are providing and defining templates for complex repetitive logic, e.g., for packaging and contact centers.

4.3 Drawbacks and challenges

Regardless of the many benefits of DES, it faces some well-known drawbacks and challenges. In particular, DES is a computer simulation, which naturally is considered as artificial because it is based on models, which usually reflect closely the reality, but never the less cannot reflect it fully [76]. Consequently, one of the most important challenges of DES is to create simulation models that accurately reflect the real business process. It takes time and expertise, to be able to set up a good and representative simulation model. Most simulation models are flowed, because of incorrect inputs and naïve interpretations of the reality [77].

The major challenges of DES in healthcare are presented in [101], which can be considered as an early introduction into the advantages and challenges BPM and simulation in healthcare [79]. Some of them are following:

4. Modeling of a patient’s individual test trajectory is often not straightforward. This is because assigning the patient a specific trajectory largely depends on the physician’s assessment based on the diagnostic information at hand. As such a physician may request multiple scans from one patient while for another patient a few scans may suffice. Indeed, patients will often exhibit varying test trajectories, and as such, statistical combination of all possible trajectories is a rather daunting task. However, reliance on expert judgment when developing a plausible patient’s trajectory, may negatively influence the model validation. This leads to discrepancies between the actual patient statistics and the simulated results. One possible approach to overcome these difficulties is to introduce heuristic evaluation approach for modeling the patients test sequence taking into account the physician’s experience.

5. Moreover, current research on simulation modeling in hospitals focuses on specific departments and almost never links all departments within the hospital. Thus a simulation modeling approach that mimics a patient’s care pathway through all departments could be one field for future research.

In manufacturing, there is a lot of effort done to process information systematically and to make use of the advent technologies in computer graphics to solve manufacturing problems. There is a strong need for a comprehensive study that would integrate the design, manufacturing, assembly and the ability to simulate the actual management of the product [82]. Most simulation techniques are not robust to the growing complexity of manufacturing operations. To tackle this problem one needs to consider hybrid approaches in simulation integrating one or more techniques. Several examples that have emerged are simulation with artificial neural networks and genetic algorithms, as well as Kriging method, data envelopment analysis, fuzzy logic, and multi-agent systems. In the field of manufacturing, it is expected that the adoption of such approaches have high advantages over traditional simulation, however are not recognized by the research community in manufacturing. [83] Another expectation is embedding DES in enterprise planning and scheduling tools in the future [84].

BPR consists of several redesign goals that can be revealed by pinpointing desired performance criteria defining in which way to evaluate business process [27]. BPR goals can range from basic process modifications to drastic organizational changes leading to BPR project management [102]. Not just goals, also BPR focus may differ by its aspects: product standardization, task design, prioritizing, and information exchange, work allocation, IT support, process information, production control, and management style [31]. We can run BPR through top-down approach, based on process documentation, or bottom-up approach, based on process data. When using the latter, we can build process model with automatic gathering of the data, called process mining. Many organizations use information system capabilities to register the tasks or activities, ongoing in the organization. Such log files are the primary input for the process mining. Following is the identification of the complexity of data in the log files. It is very important, when conducting process mining, that data in process logs are comparable and consistent. Task of modelling the process from the log files in not simple, therefore it is advisable to take in consideration advise from the domain expert. After the model is concluded, the essential phase of redesigning methodology is the process simulation. Through the simulation we can achieve the final goal of the BPR project, that is improving As-Is process design.

BPR implementation can affect any of the framework components; therefore, we classify best practices in a way, compatible with the adopted framework [96]. We find best practices, oriented towards: customers, business process operation, business process behavior, organization, information, technology, external environment. To be able to conduct efficient classification, there is still need for further research of the impact level of each best BPR practices to different industrial sections.

4.3.1 Challenges and drawbacks of business process modelling tools

Even though DES is the most popular simulation technique, it has lower stakeholder engagement than other simulation techniques, such as systems dynamic, traffic simulation or gaming. In particular, there is a need to develop simulation tools that could be used in one layer, and tools that would help understand the relationship between different layers in the organizations in order to deal with the system as a whole [86]. Very often in the search of more efficient simulation methodologies, the newly proposed methodology leads to explicitly addressing less structured processes, which are supported by various (legacy) information systems [27].

We point out some of the major challenges in the three classes of BP tools form modeling and simulation.

1. Business process modelling tools. In this class, we provide the drawbacks of two well-known tools: Protos and Aris. In Protos, there is a need to assign different roles to one task and to specify part time work and overtime. Airs does not support model verification.

2. Business process management tools. Most of the well-known BPM tools do not provide simulation facilities.

3. General purpose simulation tools. The weakest point of simulation tools that belong to this group are: the require time for BPS as well as the complexity of the process to create simulation models. For example to use Arena, one must have a good knowledge about all necessary building blocks and their exact specifications. To use CPN Tools, the modeler must have a detailed knowledge about the resource handling and corresponding timing aspects. Also, some constructs can only be modelled indirectly leading to difficulties in general understanding of the model by the business process owners. Consequently, models require a significant effort.

4.4 Collaborations

Combination of the simulation and the empirical data could be very effective path to overcome gap between academic and managerial overview [76]. This pattern occurs in several disciplines that deals with BP modeling and simulation.

Development of a comprehensive study for integration of the advanced computer graphics and simulations is a way to provide a strong relationship between industry and academia. Industry has knowledge regarding the manufacturing processes, while academia has the knowledge of all advanced and state-of-the-art technologies for graphic design and simulations [82].

The incensement of computer power (memory and programming tools) leads to several vendors that provide product specific simulation tools thus are a potential for collaboration between industry and academia [84].

A need for collaboration in the enterprises has been observed in several studies.

Business process simulation holds reputation of being capable of assisting in strategic decision-making, but at the same time it has not been considered as a mainstream tool for decision-making support, due to complexity of setting it up [78], [103].

Obviously, there seems to be a few studies on the application of DES for long-term planning, where it seems that there is a strong need for improvement of the integration of simulation with upper levels of management and enterprise control systems to enable incensement of the stakeholder's engagement [83].

4.5. A holistic table – 4.1 do 4.4

Here we present a holistic overview of the previous chapters sublimated in the Table .

Table 3 A holistic view

Fields	Operations management	Business process management	Operational decision making	Healthcare decision making	Manufacturing and business analysis	Business process redesign
Benefits	analyze BPM in terms of time, costs and resources		perform stochastic, as well as quantitative modelling	provide insight into the impact of operational changes	realistic management of virtually displayed processes ready for dynamic and interactive examination	redesign the companies BPs and the information systems supporting these processes, while achieving high-performance gains

Fields	Operations management	Business process management	Operational decision making	Healthcare decision making	Manufacturing and business analysis	Business process redesign
Drawbacks and challenges				Modeling of a patient's individual test trajectory is often not straightforward; discrepancies between the actual patient statistics and the simulated results; a simulation modeling approach that mimics a patient's care pathway through all departments could be one field for future research	a strong need for a comprehensive study that would integrate the design, manufacturing, assembly and the ability to simulate the actual management of the product; Most simulation techniques are not robust to the growing complexity of manufacturing operations it is expected that the adoption of hybrid simulation approaches have high advantages over traditional simulation, however are not recognized by the research community in manufacturing	complexity of data in the log files as data in process logs are rarely comparable and consistent to research of the impact level of each best BPR practices to different industrial sections

Fields	Operations management	Business process management	Operational decision making	Healthcare decision making	Manufacturing and business analysis	Business process redesign
Collaboration	Combination of the simulation and the empirical data could be very effective path to overcome gap between academic and managerial overview	A potential for collaboration between industry and academia	A potential for collaboration between industry and academia	A potential for collaboration between industry and academia	A potential for collaboration between industry and academia; improvement of the integration of simulation with upper levels of management and enterprise control systems to enable incensement of the stakeholder’s engagement	A potential for collaboration between industry and academia

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