Contemporary trends in Business Process Simulation and Business Process Modelling

A Case Study of the Creative Core Project (FISNM-3330-13-500033 "Simulation")

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Abstract

This research report presents up-to-date results of the European Union project called Creative Core: Simulation executed at the Faculty of Information Studies in Novo mesto, Slovenia. The project is financed by the European Regional Development Fund within the framework of the Operational Programme for Strengthening Regional Development Potentials for the period 2007 – 2013 within the development priority 1: competitiveness and research excellence and priority guideline 1.1: improving competitive skills and research excellence. The report presents a state-of-the-art analysis in the area of business process modelling and business process simulation, and consequently links together contemporary trends in a contextual literature review on one hand, and timely project results on the other. The significant contribution of this report is the identification of the most important trends, advances and challenges in the Business Process Simulation and Business Process Management domains. It is expected that these trends, advances and challenges are the result of new technologies, as well as changes in the business approach towards customers, partners and the wider environment. The authors maintain that the near future in terms of business processes will revolve around increased customer involvement through identification of social business processes, as well as an increased tacit knowledge intensity of business processes.

1. Introduction

This report presents the results of an analysis in the area of business process modelling (BPM) and business process simulation (BPS). It was conducted in order to describe the background of the research for a Creative Core: Simulation project. The current BPM/BPS landscape is a very complex one, with a number of methodologies, tools, techniques and technologies available. This report's purpose is to present this landscape with a view to how these methodologies, tools, techniques and technologies can support BPS/BPM projects. The methods utilized to achieve this goal were mainly a contextual literature review, a comparison of the variety of methodologies, tools, techniques and technologies, an in-depth review and presentation of the Creative Core: Simulation project and critical reasoning.

This report is structured as follows. First an overview of the Creative Core: Simulation project is presented. Next a contextual literature review is performed and major challenges and trends in BPM/BPS areas are presented. These are followed by contemporary approaches, tools and technologies in BPM/BPS. At this stage a summary of BPS/BPM methodologies and tools is provided in the form of a table and a figure. Subsequently the focus of the report slightly diverges to present the relationship between BPS/BPM and Knowledge Management (KM). Further, the role of tacit knowledge in BPS is covered. At the end conclusions are drawn and acknowledgements are presented.

2. Creative Core: Simulation. Overview of the Project

The full description of the Creative Core: Simulation project was included in the application submitted to the European Union as Creative Core FISNM-3330-13-500033 'Simulation' under The European Regional Development Fund. This application was a joint effort by a number of researchers: Janez Povh, Nadja Damij, Blaz Rodič, Zoran Levnajić. The following sections provide a summary of the most important and crucial facts related to the project and are (to a high degree) based on the content of this joint application.

We live in the age of information. With the rise of informatisation in the past century, computers became indispensable not only for modern science and technology, but also for our daily lives. Accordingly, the power and capacity of computers grew exponentially over the past few decades, allowing complicated scientific problems to be dealt with far more efficiently and exhaustively than ever before.

Yet the usage of modern computer techniques has only recently entered certain scientific areas. This primarily refers to the social sciences and humanities, but also to some natural sciences such as biology. Namely, in order to establish a basis for quantitative analysis, one firstly needs to design a model of the system under investigation. Modelling allows an adequately simplified, although still realistic representation of the system to be developed in accordance with the required investigation. Once constructed, the system model can then be studied through a variety of computer and numerical simulations, yielding quantitative results, that not only illustrate the functioning of the real system, but also allow prediction of the actual experiments.

The Creative Core: Simulation project aims to close this gap. Computer simulations will increasingly be employed in a variety of scientific fields where they have so far been heavily underused, mostly due to a lack of quantitative models. In particular, this refers to the four main topics of our study which we present hereafter.

The Creative Core: Simulation project was created with the purpose of becoming one of South-East Europe's recognised centres for research excellence in the field of simulation. Its development and purpose are based on the Faculty of Information Studies' Strategic Plan 2009-2014, as well as on the European Growth Strategy Europe 2020, the Lisbon strategy, the Bologna strategy, the Republic of Slovenia's Development Strategy and the Slovenian National Programme of Higher Education. The cooperation between the members of staff of this Creative Core: Simulation project and other research groups will support polycentric development and will thus further the goals of the EU Cohesion policy in accordance with the Green paper on territorial cohesion. In accordance with the Law on research and development, the project will promote the social importance of research and development activities by supporting polycentric development of science networking of research organizations in science, education and the economy. The Creative Core: Simulation project consists of in silico exploration of frontier interdisciplinary topics in modern social and natural sciences. In particular, it engages in (i) simulation of bio-inspired technological networks, (ii) categorisation and simulation of document flows, (iii) business process simulation, and (iv) manufacturing, services and transport/logistics simulation. By contributing novel results in these different scientific fields through applying related methodologies, it is expected to extend the range of current scientific and applied usage of computational modelling and simulation. The research projects proceeded along the lines pursued by the research groups within the Faculty of Information Studies.

The creative core SIMULATION consisted of four interlinked research projects:

- CCSimRDP1: Simulating Bio-Inspired Technological Networks (SBITN)
- CCSimRDP2: Categorisation and Simulation of Document Flows (DCS)
- CCSimRDP3: Business Process Simulation (BPS)
- CCSimRDP4: Simulation in Logistics, Manufacturing and Service Systems (SLMSS)

The objectives of the Creative Core: Simulation project were:

- To develop new and original methods and tools in the scientific field of simulation and modelling.
- To develop solutions for real-life optimization problems in manufacturing, transport/logistics and service systems within the regional and national economy.
- To create an online environment for the development of visual interactive simulation models using methods of system dynamics and discrete event simulation.
- To help the business process innovation team obtain a holistic view of the process being studied.
- To visualize the impacts and implications of new and modified processes.
- To test various simulation techniques.
- To develop numerical simulations that capture the dynamics and functioning of selected biological networks.
- To analyse computationally the specific topological properties of bio-networks that are responsible for their superior functionality in comparison with man-made technological networks.

- To construct engineering methods of implementing the desired bio-network properties into the design of artificial technological networks.
- To develop a new methodology to categorise document flows based on their semantic properties with minimum error rates;
- To develop software modules for document categorisation with special focus on supporting modules for the Slovenian language and for advanced statistical analysis and machine learning on texts.
- To develop a desktop and web application to automatically snap and categorize document flows from a given domain.
- To simulate the classification and categorization process for the case of web and paper-based document flows.

Figure 2.1 presents the organisational structure of the Creative Core: Simulation project as well as the interlinkage between the four research projects.

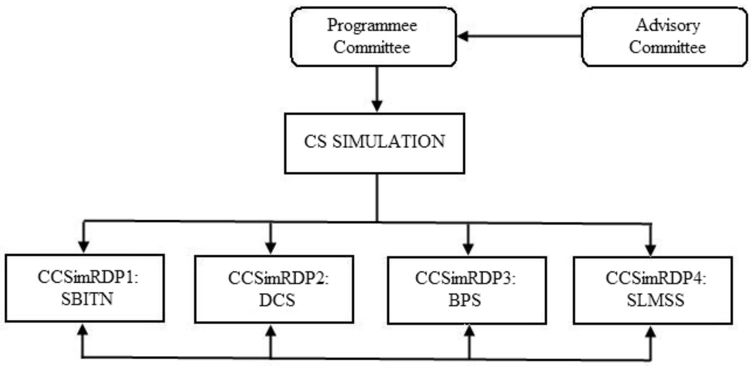

Fig. 2.1 Organizational structure of the Creative Core: Simulation project

Key results of the Creative Core: Simulation project were expected to be the following:

- Publication of novel scientific articles and monographs and citations by the Slovenian Research Agency’s criteria.
- At least one new patent from the area of simulation and modelling.
- New developed models, methodologies and algorithms.
- New web-based simulation and modelling tools.
- Testing and application of the developed models, methodologies and algorithms in real-world cases.
- Development of new open source software implementing models and methodologies.
- New agreements concluded with foreign research organisations and guest visits at foreign research institutions.
- New agreements concluded with companies in relation to (free) usage of the results of the creative core.
- Transfer of the knowledge developed within the creative core to students at the Faculty of Information Studies and other faculties;
- Stronger scientific potential of the Faculty of Information Studies in the area of simulation (inclusion of new foreign researchers).
- Easier access to interactive, freely accessible web-based tools for modelling and simulation, a better understanding of modelling and simulation methods and their potential in educational organizations and companies.

The Creative Core: Simulation project was organised and managed as a project-based research study as it is believed that this enabled the right amount of engagement from the participants in going through the various stages of innovation and research. By focusing on the four projects rather than the organisation itself, the Creative Core development indicated the benefits of strong projects, the leadership requirements for ‘heavyweight’ teams as the projects assumed increasing importance across various high technology industries. The Creative Core: Simulation was managed by the programme committee instead of top management. The committee consisted of the committee leader, the project coordinator, the legal liaison and the accountant. The programme committee was responsible for content and research development, as well as day to day activities such as management, human resources and coordination between the four projects and control. The programme committee was monitored by the advisory committee. The advisory committee consisted of four members - three from universities abroad and one member from the programme committee. The advisory committee met at least three times during the duration of the project. The four project leaders lead each of their projects as defined in the contract with the Ministry, as well as in coordination with the programme committee. Each of the project teams met according to the project dynamics. If necessary, various specialists from the business sector and academia were included, but will be financed from other sources (young researchers, young researchers from business, PhD students, post-doc students, etc.).

The proposed RDPs are based on the long term strategy of the Faculty and the development strategies of individual institutes within the Faculty and therefore represent long term projects that will be further developed beyond the scope of the project discussed. Funding for the continuation of the work carried out in this project was sought in national and EU calls and via cooperation with industry before project termination in order to ensure continuity of research.

The Creative Core: Simulation project was developed in terms of knowledge development and research group growth through collaboration with leading researchers working on related problems in the fields of economics, mathematics, and social sciences, and the exchange of researchers through the Erasmus and other programmes, ensuring the development of an interdisciplinary approach and methodologies, and improving the circulation of ideas between institutions and research groups.

Collaboration was built with other research groups through organization of and participation in scientific events, publication of papers in scientific and professional journals and collaboration with industry in joint projects which resulted in application of the methodologies and solutions developed. This also improved the competitiveness of the economy and contribute to the increase in added value. The cooperation between the Creative Core: Simulation and other research groups supported polycentric development and will thus further the goals of the EU Cohesion policy in accordance with the Green paper on territorial cohesion. Simulation and modelling tools were developed according to the open source licensing model and made freely available to the scientific community and other interested parties. In order to develop a new generation of researchers and application specialists and renew the Creative Core, the didactic results of the project were integrated in study programmes for students at undergraduate and postgraduate level.

The main result of the proposed Creative Core: Simulation was the scientific, professional and infrastructural development of research institutes at the Faculty of Information Studies in the most demanding tasks in the area of simulation. At the end of the project the Faculty was ought to be recognized as the most important centre in Slovenia and the region in the field of simulation and modelling. The direct results of the proposed creative core strongly connected the Faculty of Information Studies with the international scientific community and with the local scientific community and the industry. While running the research and professional activities within the proposed research and development projects the researchers have (i) published at least 60 scientific papers in scientific journals, (ii) published at least 10 scientific monographs, (iii) obtained at least 80 new normalized citations within Web of Science (WoS) and Scopus, (iv) patented at least one new patent, (v) signed at least 10 new agreements with research organizations abroad, (vi) organized at least three international scientific conferences, (vii) signed at least 14 agreements with companies in relation to (free) usage of the results of the creative core, (viii) developed at least three open source software packages in the field of simulation, (ix) transfered the knowledge developed within the Creative Core to students in more than 4 study programmes at the Faculty of Information Studies and at other faculties, (x) organized at least 3 presentations of the results to the general public and (xi) involved at least four new researchers to work on the projects within the Creative Core: Simulation.

3. Contextual Literature Review

One of the objectives of this project is to utilize the results of this analysis in order to identify and investigate real business needs, as well as good and bad practices. In order to achieve these objectives it is necessary to briefly introduce the concepts of business process modelling and business process simulation.

The main difference between modelling and simulation is that former strives to *represent* reality, while the latter typically *imitates* it (Turban et al. 2007, p. 165). Apart from that simulation is a technique for conducting experiments. It involves testing specific values of inputs and variables and investigating their impact on the outputs. Simulation is a *descriptive* rather than a *normative* method. There is no automatic search for an optimal solution, but instead a description or prediction of the characteristics of the system under different conditions. Once these characteristics are computed, it is possible to select the best of several alternatives. The simulation process usually repeats an experiment numerous times in order to estimate the overall effect of actions. Simulation is used in cases when there is a high degree of complexity, which may make the use of numerical optimization techniques difficult.

Business Process Simulation is a tool that originated in the manufacturing sector; however now it is used in a variety of sectors and settings. It is very useful in analysing change from a process perspective. Simulation can refer to a range of model types ranging from simple spreadsheet models to system dynamic simulations and discrete-event simulation modelling (Greasley 2003, p. 408). In the case of a "discrete-event simulation model", the model changes at a discrete set of time points. BPS allows understanding and analysing the current behaviour of a system as well as predicting the performance of the given system under a number of possible scenarios. Such scenarios are based on real-world conditions and devised by the decision maker.

BPS has the important feature of being able to capture the dynamics (time-dependence) of a process. In this context there are two aspects that need to be mentioned: *Variability* and *Interdependence*. In the case of variability it can take many forms in a business system (demand - e.g. customer number, time-duration of a given process – e.g. customer service time). Simulation makes it possible to incorporate statistical distributions and therefore provide a better indication of both the range and variance of the process performance. In some cases this may be important. For example in the healthcare sector it is necessary that the system not only achieves a given average performance, but also offers a decent minimum. Interdependence is a characteristic that has to do with the fact that most modern systems consist of a number of decision points. The decisions taken at these points influence the overall system's performance. Simulation can utilize statistical distributions to model the likely decision options taken. It can also assess the effect of synergy between the points on the system's behaviour over a given time period (Greasley 2003, p. 409).

Simulation can also be used to aid visualization of the impact and implications of new processes. Visual Interactive Simulation (VIS), also known as Visual Interactive Modelling (VIM), is a technique used with a great degree of success in operations management (Turban et al. 2007, p. 172).

3.1 Statement of the Problem

The process-centred view of organizational management was introduced by Hammer and Champy (1993). Since then business process modelling became prominent for both the management community as well as the systems engineering community (Nurcan et al. 2005, p. 628). The management community strives to utilize process modelling in order to gain insight into processes and therefore be able to improve organization performance via process reengineering. The engineering community, on the other hand, hopes to (re)design the technology behind the processes so that it best fits with the reengineered processes (Nurcan et al. 2005, p. 628). As a result a large number of process models have been developed, as well as tools that support their design. Most of these models focus on "description of the operational performance of tasks to produce results" (Nurcan et al. 2005, p. 629). In other words they try to capture "who does what and when". Companies over the past few decades have structured their activities and businesses along end-to end business processes and such a "process-centric" perspective of an organization became prevalent (Münstermann et al. 2010).

Despite its obvious benefits, the traditional process modelling approach may be insufficient in helping organisations face the challenges of the modern era in a constantly changing environment (Nurcan et al. 2005, p. 629). Rummler and Brache (1995) state that a broader holistic view of an organization is needed to handle contemporary problems. Nowadays businesses around the world are undergoing tremendous changes as a response to changes in the environment. These changes are (among others) a result of globalization, differences in customers' behaviour patterns, increased competition and the dawn of new technologies. Business process modelling and business process simulation as techniques aiding decision making need to take into account the factors mentioned above. Some of these changes, as well as possible responses from the business process modelling and simulation areas are mentioned in a very recent article (May 2013) by Davis (2013). The author is a recognized expert in business process management with experience in the telecommunications sector. According to the author the business world is changing very fast not only because of technology, but also because of rapid cultural changes. More and more business processes are actually carried out on the move with extensive use of iPads, Smart Phones and Personal Assistants. “Today, business is about the here and now – wherever here happens to be at whatever now” (Davis 2013, p. 1). Traditional businesses' reliance on documents, forms, and even emails is being suppressed by the necessity of being “always online”. More and more business people, instead of having numerous data sources and going through lots of text, prefer to have the information and knowledge needed at their fingertips. This can be achieved for example through social media driven collaboration.

Traditional business processes and business process management may be perceived as very document-centric, to some degree bureaucratic and slow to react to business needs. It is necessary for business process modelling and business process simulation to be able to adjust their practices to embrace the changing nature of business processes. The following sections will look in detail into such changes, as well as possible ways of adapting to them.

3.2 Challenges in Business Processes

The traditional approach to the analysis of business processes needs to be adjusted to accommodate the changes demanded by the new trends in technology and culture. Davis 2013 mentions four main areas that affect current business processes: Social Media, Mobile Computing, the Cloud and Big Data. Of course these are the modern buzz words and have a lot of hype and promotion associated with them. Therefore it is necessary to carefully distinguish what could be their real impact on business processes. Social media can be utilized to collaborate in order to improve business processes and to get insight from process analysts’ peers as well as professional networks – “the ability to collaborate on design and implementation of processes is something that business for a long time has been crying for" (Davis 2013, p. 2). It is possible to perceive this change as tremendous as the change that occurred not long ago when the analysis of a narrow specialist domain became approachable because of the availability of dedicated software packages.

Business processes analysis (given this approach) may become a collaborative task that involves not only professionals, but also a wide range of stakeholders. Due to this fact it is easier to acquire the necessary knowledge, as well as "ensure processes are for the people and involve all people", but still designed by professionals using specialist tools. In this case it is relatively easy to engage "the wisdom of the crowds" e.g. in terms of feedback, suggestions for process improvement, testing and error finding.

3.3 Collaborative Business Processes on the Move

It is a common truth that elaborate business process analysis and simulation require a lot of computing power and time to be carried out successfully. However with more and more professionals continuously travelling from one location to another, it is vital that they make use of tablets, iPads, Smart Phones to e.g. gather necessary data for process simulation, record the most important meetings, or present ideas and processes, as well as results of partial or full analyses. A mobile environment makes it possible to capture processes on the move, instead of using static analysis. It is true that this is only the beginning, but it may become an important feature of future business process modelling and simulation.

Mobile processes become even more efficient if they are combined with the power that is offered by the technological solutions based within the Cloud environment. A simple smart phone, tablet or iPad may not have enough computational power to carry out the most sophisticated process simulation and analysis. This same device when connected to the Internet may be a useful tool to access the computational power of the Cloud – such as supercomputers or mainframes. In this case it will function as a "stupid terminal". A business process analyst may then aid the simulation using real world data and via a mobile device carry out the simulation on a supercomputer. Cloud computing also allows collaboration with other analysts and stakeholders, and aids the social aspect of business processes as well. Process analysis tools can be hosted on a private or public Cloud along collaborative suites. In this way it is possible to combine both these perspectives.

Apart from these features Cloud can also be utilized to store the processes' analysis data and made available through different devices. It also makes it possible to employ the huge amounts of data that result from business processes. It is possible to extract relevant information, investigate business events and changes. All these areas are the domain of another recent trend, namely "big data". It is possible to store and analyse even beyond static business processes – to observe the dynamic data. This recent trend is called Process Intelligence (PI). It allows a detailed understanding of process performance and is closely related to Business Intelligence (BI).

Taylor (2012) suggested that there is a need for a BPM/KM/social system, offering extended capabilities for process ownership and information sharing. Process ownership also includes the ownership of the process outcomes and results, as well as key elements of knowledge. Ownership is something that prevents chaos and entropy.

In the past Knowledge Management and Business Process Management were deemed to work together; however it is the social networks and media that make it possible. It is the ability to "communicate knowledge at a particular point in the process" that is available for everyone not only to a narrow range of specialists that makes the difference (Taylor 2012).

3.4 Individual and Collective Process Knowledge

As was explained in the previous paragraphs, it is believed that modern business process management needs to take into account the views of numerous stakeholders. Modern business process management needs to have a holistic approach encompassing strategy, people, processes and systems (Seethamraju and Marjanovic 2009, p. 920). Such holistic approach led to the increased recognition of the expertise and knowledge people possess, develop, use and share while performing modelling, simulation, execution and improvement of their business processes. In this view knowledge (both individual as well as collaborative) is not something that exists beyond business processes, but is rather an integral part of them. It needs to be managed together not separately. It may be created by individuals as well as groups of people who share and utilize their knowledge and experience within the domain of business process analysis.

It is a common truth that both individual expertise as well as the collective "know-how" is often neglected during business process simulation and modelling, as the usual focus of these is on explicit knowledge. Such knowledge can be much easier to capture by business process models. The main concern is to be able to establish as close a relationship between the intentions of the process initiators' and the actual execution as possible (Nurcan et al. 2005, p. 922). Following the example of "who-what-when" provided previously, it is necessary to add another element "why" in order to form the relationship "who-why-what-when". The "why" element captures the strategic goals of the organization, the intentions of a team or individual, while the "what" describes how these are achieved through tasks and activities. This new element allows focusing on the essence of the business and helps avoid unnecessary details. The relationship itself allows observation of the reasons for change, as well as the transition of intentional changes in to operational ones.

4. Significance of the Problem

As mentioned in the previous paragraphs, there are tremendous changes occurring within the business environment. Business Process Modelling and Simulation need to take these changes into account. This will become more and more important for organizations that are involved in BPM or BPS.

A process-based change approach can involve another important aspect; that is the understanding of the human factors such as motivation, culture and leadership style. This approach can also provide a framework which will ensure that real-life design scenarios are analysed during the simulation phase and that both the simulation and assumptions take into consideration the overall organizational target environment (Greasley 2003, p. 418).

4.1 Business Process Improvement (BPI) versus Business Process Reengineering (BPR)

Due to their numerous benefits (reduced cost inefficiencies, improvement of customer service, shorter time needed for a product or service to reach the end customer), Business Processes and Business Process Improvement have been pushed to the top of business organizations' priority list (Zellner 2011, p. 921). They are an effective way to manage an organization at all levels and a very efficient mechanism to support its strategy and goals. Therefore they are considered among the most valuable corporate assets. Their continuous improvement has become crucial for many business organizations (Zellner 2011, p. 921).

Business process modelling and simulation have their roots in earlier disciplines, most notably in organizational science and operational research. There are many business process improvement methodologies that originated from the mentioned disciplines. It may be stated that processes can be either changed by radical business process reengineering (BPR) or through incremental continuous improvement. The process reengineering approach is considered by many as obsolete and impractical. This is due to its radicalism, top-down approach, and too strong a focus on business process automation. Moreover, Business Process Re-engineering (BPR) initiatives often resulted in failures and problems. On the other hand, process design, process improvement is still alive and often used by the consultants and practitioners (sometimes under different names) (Seethamraju and Marjanovic 2009, p. 921).

Business Process Improvement (BPI) is an approach utilized by companies to adjust to the changing business environment. In other words this approach is utilized to adapt business processes to organizational, technological, political, cultural and other changes. Improvement of business processes was the number one priority in terms of business priorities in the 2009 Gartner's survey covering more than 1,526 CIOs (Zellner 2011, p. 203). Given that the BPR trend faded in the early 90s', there were more tools, techniques and methodologies developed with the BPI approach in mind. One of the most important requirements is that process improvement became an everyday task and part of the processes themselves.

4.2 Business Process Simulation (BPS): Barriers and Disadvantages

Business Process Simulation (BPS) as explained in the previous paragraphs is an approach that includes variability and interdependence factors in the analysis of a given system. The simulation can also be used to predict process performance from a variety of perspectives such as time, resource usage and costs.

These benefits do not come free however. One of the major barriers hindering many organisations from using continuous process improvement and business process simulation are the time and resources needed to prepare and introduce such techniques within the organizational context. Apart from that there is a great need for a simulation project sponsor as well as for a simulation champion. The first acquires the necessary funds and support of the top management, while the other disseminates knowledge and information regarding this technique, as well as provided training to the users of e.g. simulation software.

BPS is also said to be the factor that increases the scope of analysis, which in turn increases costs and the time needed. In order to overcome this barrier, it is necessary to have a clear focus on what areas need to be simulated. It is not a good approach to model every aspect of the system; instead the level of detail and scope of the model should be identified based on the study objectives. It is also necessary to prioritize those aspects of the system essential for a successful decision (Greasley 2003, p. 417).

The business process simulation analyst should also be careful in differentiating between the “as-is” simulation models and “to-be” designs. Simulation should be used to compare different “as-is” and “to-be” models, as well as validate the completeness of the “to-be” models (i.e. whether they are modelling the entire phenomenon and all related interdependences). Simulation should rather not be used to design“to-be” models (Levas et al. 1995). Simulation has a limited ability to craft new system designs and system design should not be limited by the available simulation capabilities. It is the system design that comes first and helps to frame simulation design.

The areas of research mentioned previously contribute greatly to the significance of the problem. Another important aspect that should be considered is whether it is possible to increase the performance of a given business process by the use of “process standardization” (Münstermann et al. 2010). Business processes may be a subject to standardization like other products or services. In this view a business process is a set of logically or operationally related tasks, which are performed in order to achieve a previously defined business outcome. Standardization in general refers to the approach adopted by a given organization or recognized body in order to provide a common framework for repeated activities, rules, guidelines or results. Its aims are to reduce the time and costs associated with the development of guidelines to carry out the same tasks over and over again. Process standards are identified as one of the three most important areas for future research by Venkatesh (2006). It is expected that more research into process standardization will lead to increased cost savings. Swaminathan (2001) proposed process standardization as a means for better operational process performance. In his view the process standardization requirement is that at least some of the processes are modular. In other words it is possible to identify processes which will lead to a semi-finished product or service. In this approach companies can “store” the inventory (before full information from the customer(s) is available) and later customize it to meet the requirements of a given customer or market. Furthermore, process standardization can lead to increased manageability and transparency. Apart from that it can also be a useful tool for business process modelling and business process simulation. Standardized processes can be utilized as a “template”, in which most of the variables and dependencies are already computed. In this approach there is no need to simulate the same processes over and over again. This reduces the time and resources needed to deliver an overall business process simulation.

Despite the benefits and opportunities that it provide there is a general lack of scientific study or practitioners’ experience on the impact of process standardization. As noted by Ungan (2006): “despite its great attractiveness, academics and practitioners’ work on process standardization is conspicuously absent”. It is hoped that this gap can be filled in the next stages of the Creative Core: Simulation project.

5. Current Business Simulation Approaches

Business Process Simulation is nowadays a well-established scientific discipline with a wide range of approaches, methodologies and tools. The idea behind business processes can be traced back as far as the work by Smith (1776) and his description of the division of labour in a pin factory. After the 1950s the statistical approaches to Business Processes (BP) emerged with the works of Shewhart, Juran and Deming on quality management. Untill the 1980s these approaches focused almost entirely on production and manufacturing processes. After this date the use of BP for improving organizational efficiency through Business Process Re-Engineering also became a prominent field. At the end of the twentieth century, computing power growth and the speed of communication made it possible to digitize the entire organizational BP. This initiated technology-assisted BP change and tools. Among most important advances are business process management systems (Sidorova and Isik 2010).

Due to the changes presented in the previous paragraph BP simulation became a truly multi-disciplinary scientific discipline, with contributions ranging from organizational theory and management science to computer science and industrial engineering. The diversity of BP research makes it difficult to keep up-to-date with recent developments on all of the different facets of BP research and eventually led to the creation of BP research silos and themes. Sidorova and Isik (2010) identified around twenty prevailing factors in the BP literature based on the text-mining technique: namely Organizational implementation, BP initiatives, Web services and Software Oriented Architecture (SOA), Simulation and BP optimization methods, Marketing and Customer Relationship Management (CRM), BP outsourcing, Supply Chain Management (SCM), BP re-engineering, Enterprise Relationship Planning (ERP), Total Quality Management (TQM), Institutional issues in BP research, E-commerce, Auditing, KM and innovation, Performance measurement, BP in the public sector and in specific industries, Six Sigma, Human Resources (HR), BPR, Workflow management and Manufacturing, industry and firm size. Their framework further identifies four cornerstones of core BP research: BP design, BP-supporting IT, BP organizational implementation, and BP on-going management and control. The overall picture is presented in Figure 5.1.

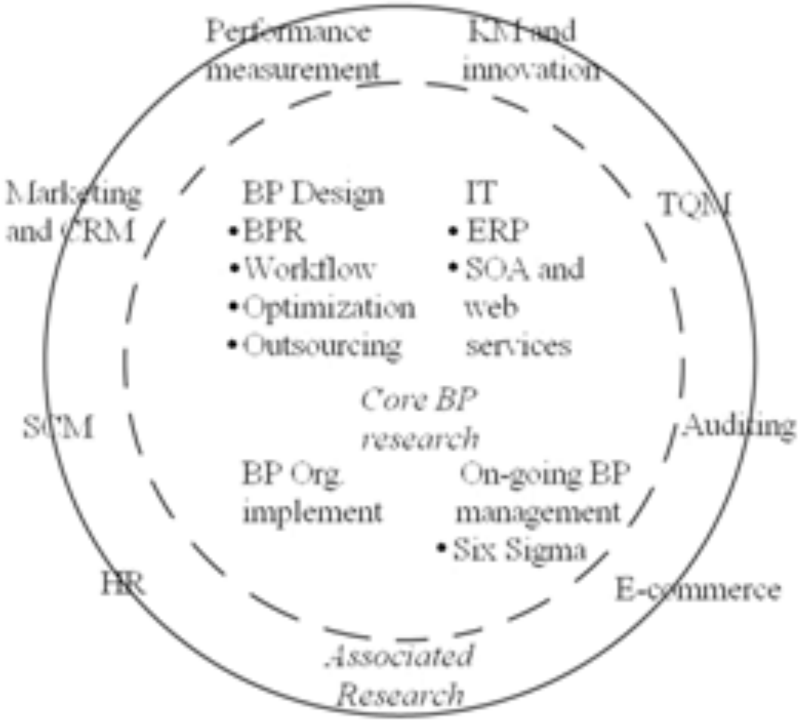

Fig. 5.1 Overview of BP research themes (adapted from Sidorova and Isik 2010).

These research themes correspond to potential contemporary approaches to business process simulation. Therefore it is likely that there will be approaches to BPS originating from such disciplines as TQM, Marketing and CRM, KM and innovation, etc. The most relevant questions these approaches will try to investigate are in the area of Core BP research. For example, in the case of the KM approach to business processes, simulation research investigates BP as a source of knowledge creation (Bera et al. 2005), or from the viewpoint of knowledge flow (Smith and McKeen 2004), as well as knowledge extraction and use (Tuggle and Goldfinger 2004). Based on this, process-oriented knowledge management (pKM) has been proposed as a potential solution (Wang et al. 2005). This approach integrates KM into BPs and allows for increased innovation. In the next section an overview of existing methodologies, methods and tools for Business Process Simulation will be presented.

5.1 Overview of Methodologies, Methods, Tools for Business Process Simulation

Since Business Process Simulation is a well-established scientific and business discipline it resulted in a wide range of available methodologies, methods and tools. Based on a literature review it is possible to provide an overview of such methodologies, methods and tools (Barber et al. 2003):

- Structured Analysis Design Technique (SADT) (Ross and Schoman 1977);
- Structured System Analysis Design Methodology (SSADM) (Longworth and Nicholls 1986);
- Soft System Methodology (SSM) (Checkland 1984);
- Unified Modelling Language (UML) (Fowler and Scott 1997);
- Data Flow Diagrams (DFD) (DeMarco 1979);
- Concept Mapping (CM) (Neely and Byrne 1992);

- Jackson Systems Design (JSD) (Jackson 1983);
- ICAM Definition (IDEF) (USAF 1981);
- Architecture For Integrated Information Systems (ARIS) (Scheer 1998);
- Discrete Event Simulation (DES) (Ingemansson et al. 2005; Moon and Phatak 2005).
- Tabular Application Development (TAD) (Damij 2007)
- Business Process Management Notation (BPMN) (Allweyer 2010)
- Agent Based Modelling (ABM) (Siebers et al. 2010)

Further sections will provide a quick overview of each method with simple examples.

5.1.1 Structured Analysis Design Technique (SADT)

The structured analysis design technique was developed to describe activities. It is part of the wider domain of Structured Analysis (SA) – a well-known software engineering technique utilized to "convert" business requirements into specifications. These specifications can in turn be turned into computer programs, hardware and network configurations and related manual procedures.

SADT was created by Douglas T. Ross and his colleagues during the 1960s and early 1970s. It is a methodology often described as a "graphic language for blueprinting systems". Initially it was used to describe such complex systems as the design of a "factory of the future" and the US Air Force Computer-Aided Manufacturing Project. SADT has been applied successfully in hundreds of projects involving thousands of people across such diverse industries as telecommunications, aerospace and software development. In the case of service implementations, SADT has been most often used to model back-office operations (e.g. cheque-processing operations, cash management, wholesale lockbox systems). SADT focuses on activities which are the building blocks of services. This model can help employees at each organizational level understand the underlying functioning of the service delivery. Moreover SADT is the only methodology that provides (in a structural fashion) such important attributes of service description as:

- By whom or what is a given activity performed (SADT term “mechanisms”).
- What are the guides or limits of the activity (SADT term “controls”).

Apart from that SADT is very efficient in improving internal communication because the model-building process includes a protocol to involve employees, other people who perform activities, customers and management. In other words SADT involves the major stakeholders of the activity and allows them to communicate in a common protocol. The result of such communication can clarify activities and actors’ roles, and promotes consideration of process redundancies and improvements. It provides boundaries for organizational consensus on a process. For the reasons described previously, SADT seems to be an ideal methodology for modelling services (Congram and Epelman 1995).

The SADT model is a set of interrelated diagrams that together describe a system from different aspects. The diagrams are organized hierarchically. The top diagram is a summary of the diagrams below, and each successive level is increasingly more detailed. The methodology together with the graphic language, grammar and diagrams provide the modeller with a precise and easily comprehensible format for describing a service process. The service description is created in three steps: formulation of the questions (the description is supposed to answer them), a statement of the purpose of the model, and determination of the viewpoint of the model. Figure 5.2 presents an example of an SADT context diagram (for the process individual tax return), while Figure 5.3 presents the SADT grammar of the previous SADT context diagram.

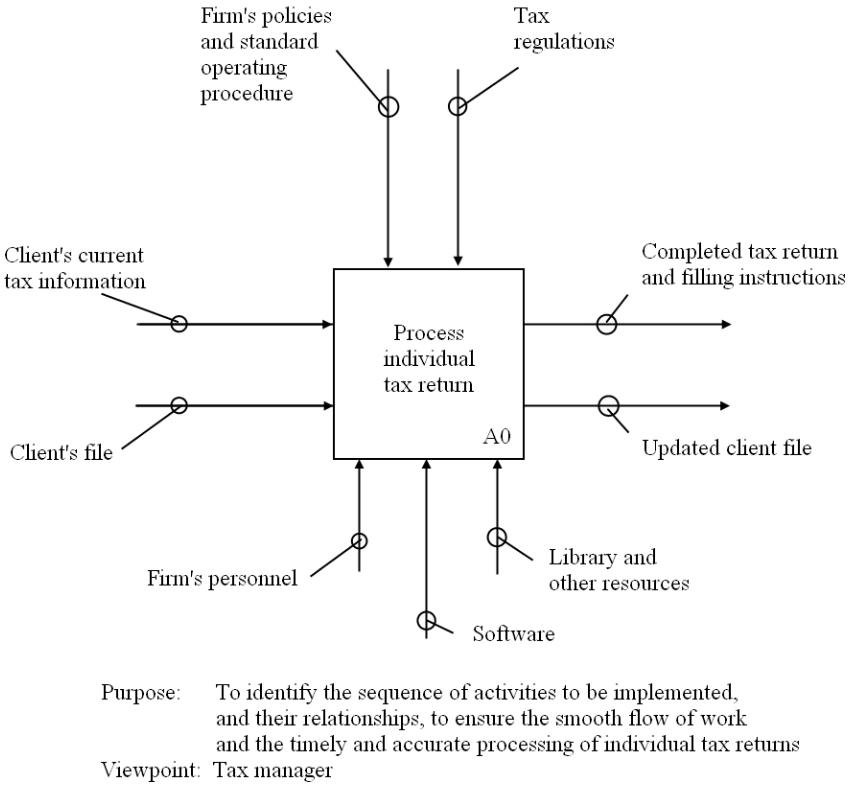

Fig. 5.2 Sample SADT context diagram (adapted from Congram and Epelman 1995).

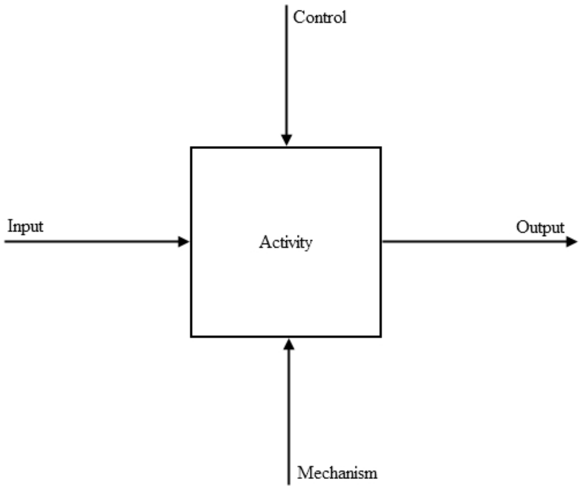

Fig. 5.3. Sample SADT grammar (adapted from Congram and Epelman 1995).

In the later steps of SADT methodology more and more detailed diagrams are created until they reach the level desired by the activity stakeholders.

5.1.2 Structured System Analysis Design Methodology (SSADM)

Structured System Analysis Design Methodology (SSADM) was created by Learmonth and Burchett Management Systems for the British Central Computer and Telecommunications Agency (now the Office of Government Commerce) in 1981. It was supposed to be a standard analysis method and became mandatory for several government developments. Its strength is that it covers both the software as well as the hardware parts of the Information System (IS). SSADM was developed with the following objectives:

- Ensuring that projects can successfully continue in the case of staff loss

- Overall better quality of IS
- Improvement of the control and management functions of the projects
- More efficient use of experienced and inexperienced staff
- More efficient staff development
- Easier use and support by computer-based tools, e.g. computer-aided software engineering systems
- Improved communication between project participants
- More efficient IS framework

This method can be broken down into the following five stages (Figure 5.4 presents the overall diagram):

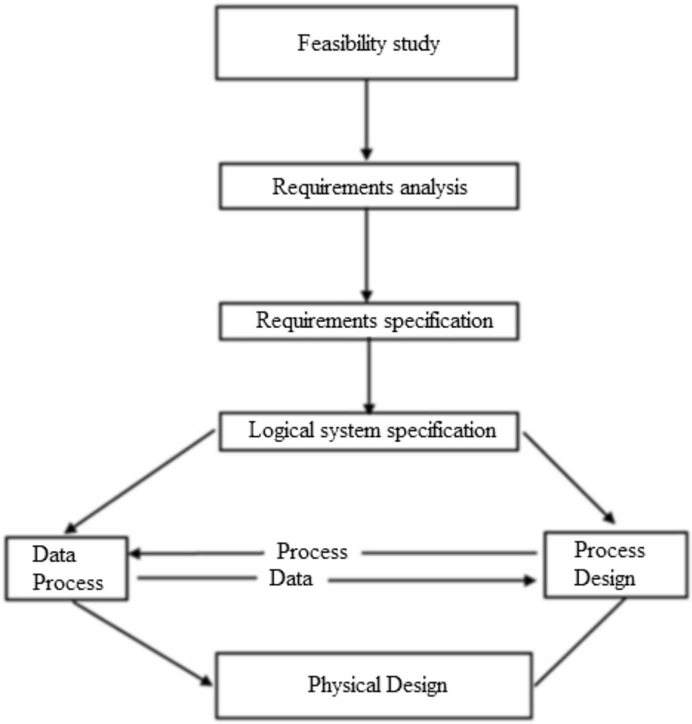

Fig. 5.4 Stages of SSADM

- Feasibility study
- Requirements analysis
- Requirements specification
- Logical system specification
- Physical design

Two very important phases of the System Development Lifecycle are not covered (implementation and maintenance). Moreover the strategy planning phase, although very important, may need to be altered or abandoned in the case when an organization has its own procedures to cover it. Another weakness of this method is that (as said previously) it does not provide support for the implementation phase, which may be a source of some performance issues. Hence, there may arise certain points, issues or problems that can have a tremendous influence on the initial planning. In a similar fashion during the maintenance phase the organization could face some challenges which make it necessary to adjust the IS to the real life problems. This in turn can change the entire initial planning.

Structured System Analysis Design Methodology (SSADM) utilizes a range of techniques in order to identify, model and document the IS:

- Logical data modelling is used during the data requirements phase.
- Data flow modelling is used to investigate how the data moves around an Information System (IS).
- Entity behaviour modelling focuses on events occurring in the IS which can affect each entity and the sequence of the events.

Additionally there are several techniques which were not incorporated into the method, but are compatible and often used with this methodology. An example of that is cost/benefit analysis, which is utilized to provide insight into the costs and benefits of the IS.

SSADM places physical design at the end of the system design phase. At this point the security issues are usually addressed as well. During the implementation phase (not covered by SSADM), the organization starts pilot operation of the system. After that the system is put into the production phase. Moreover SSADM divides the project into small sub-systems with well defined objectives. SSADM methodology is utilized for each implemented sub-system of the IS. Even when there is an older IS that is going to be phased out by the one being designed, the organization is supposed to rely on the new system as early as the beginning of pilot operation of each sub-system. As the new sub-systems of the IS begin their operations, the organization is supposed to abandon the old system and its functions. This is true even if the new IS is not yet entirely in the production phase. This reveals another potential weakness or threat in the SSADM methodology. The organization, which has to rely on the new system, may be at greater risk of failure. Sometimes such a risk may be greater than the same organization running the old IS. Apart from the already existing causes of failure the new IS faces additional risks (due to the fact that it is new and untested) such as:

- The system functions are not stable (both in the case of software as well as hardware).
- Final documentation is missing (due to the fact that there are frequent corrections or alterations to the system).
- A large number of security objects have not been completely checked or have not been implemented.
- Untrained staff (staff are not yet completely familiar with the system, nor with its troubleshooting).

SSADM has a wide range of benefits:

- Timelines – planning, management and control of a project is very efficient. This allows the IS to be delivered on time.
- Usability – emphasis is put on the analysis of user needs. In parallel, the system model is developed and a demand analysis is conducted. Both are compared and tested in order to evaluate whether they are well-suited to each other.
- Responsiveness to changes in the business environment – business objectives and business needs are considered during the project development. Therefore it is possible to tailor the planning of the project to the actual business requirements.
- Efficient use of skills – it does not require a narrow range of special skills to be operated. It is accessible to the existing staff and can be easily taught. Common modelling tools can be utilized.
- Improved quality – Reduced error rate of IS due to a pre-defined quality level and constant checking of the IS.
- Cost reduction – SSADM separates the logical and the physical systems design. On that account the IS does not have to be implemented again should new hardware or software be introduced.

SSADM also has some disadvantages that need to be taken into account:

- Danger of over-analysis – due to the emphasis on analysis of the system and its documentation. This can be very time and cost consuming.
- Consistency problems – due to the various types of descriptive methods that can be utilized. Consistency checks are very difficult to carry out.
- Increase in the size and complexity of the IS – in some cases the SSADM designed IS can grow to a relatively greater size than if other methodologies are utilized. This

poses problems with staff training and the learning curve of the IS.

5.1.3 Soft Systems Methodology (SSM)

Soft Systems Methodology (SSM) has been developed through action research since the 1960s at Lancaster University, U.K. One of the best known members of the development team is Professor Peter Checkland from the Department of Systems and Information Management. SSM was developed mainly as a result of consultancy work. It has grown continuously as more experience was gained through handling a variety of problems, situations and challenges. The outcomes of the learning process ware analysed and incorporated into the methodology. SSM is a result of these experiences and may be seen as a generic methodology, which can be adopted to any given situation.

SSM focuses initially on problem formulation at the strategic level. It aims at assigning a structure to previously unstructured situations, instead of simply solving well-structured problems. It can handle “fuzzy” problem situations. In such situations people are viewed not as passive objects, but as active subjects, where the objectives are unclear or where multiple objectives may occur. This approach is one of the strengths of SSM and is more relevant to the contemporary situation on the market. In the past analysts or consultants have faced clearly defined problems and been able to come up with a pre-prepared solution. Nowadays there is an existing trend to involve the client(s) in the formulation and analysis of the area of concern. Therefore organizations also need to have a thorough understanding of the methodology employed. Previously the approach was to employ the consultant and a problem became his or her own, while nowadays the consultant is expected to facilitate the solution process.

SSM is concerned with human activity systems. Such systems are defined as a collection of activities and the relationships between the activities. People are engaged in such activities. It is possible to draw a boundary around a system in order to distinguish a group of activities which would give the system some desirable properties. SSM covers a wide range of methodologies developed to address different problems, situations or challenges. One of the best known methodologies is Checkland's methodology, which consists of the following stages:

A. The problem situation unstructured
B. The problem situation expressed
C. Root definitions of relevant systems
D. Deriving conceptual models
E. Comparing conceptual models with the "real" world
F. Defining feasible, desirable changes
G. Taking action

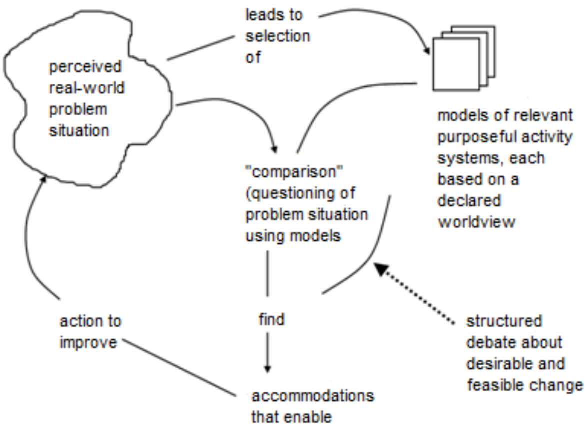

Fig. 5.5 The inquiring/learning cycle of SSM (adapted from Bunch 2003)

SSM provides techniques and guidelines for problematic situations. Moreover an SSM framework or model evolves with time and adjusts to the real world situations. It may provide a basis for an adaptive system. Figure 5.5 presents the inquiring/learning cycle of SSM.

Stages A, B, E, F and G can be perceived as working in the real world, while stages C and D are rather to be considered system constructs related to the real world (Platt and Warwick 1995). The SSM proposes several criteria which should be specified to ensure that a given root definition is comprehensive. These criteria clarify what the user or the methodology is trying to achieve and are necessary perspectives that need to be addressed. These criteria are known under the mnemonic term CATWOE:

- Clients – The beneficiaries or "victims" of the particular system
- Actors – People responsible for implementing the system
- Transformation – The way inputs are "translated" into outputs
- Worldview – what makes the system meaningful. What justifies the existence of the system
- Owner – who is managing the system and has the authority to abolish or change it
- Environmental constraints – what are the external constraints that this system needs to take into account

SSM can be characterized as a learning system and is part of a new paradigm for Operational Research. It can also be perceived as a front-end for IS design. It has diverse applications and therefore its descriptions have a wide range as well. Moreover SSM can produce various types of results. SSM has been used extensively in Information Systems Analysis and Design.

SSM includes Conceptual Models of Human Activity Systems. These take the form of notional bubble diagrams, in which descriptions of activities are enclosed in bubbles and the bubbles are linked to each other by arrows. They are not intended to represent what exists, but rather to represent a stakeholder's viewpoint. Figure 5.6 presents such a conceptual model. It should be realized that it is not intended to describe how a given activity is performed, but rather how the stakeholders think it is performed, how it should be performed or how they would like it to be performed.

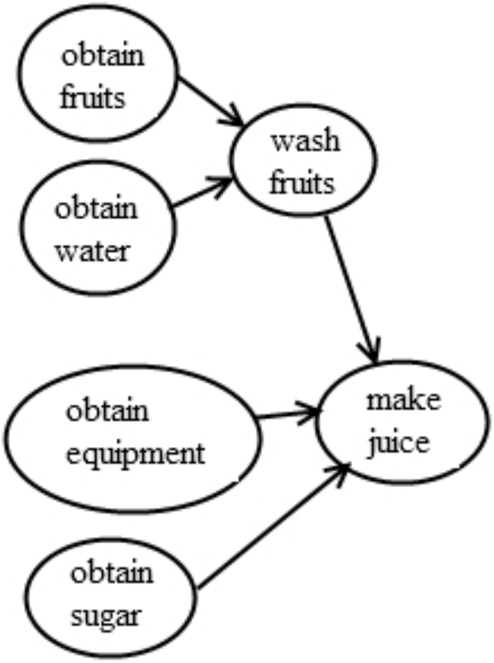

Fig. 5.6 Conceptual Model in SSM (source: unpublished computed data)

5.1.4 Unified Modelling Language (UML)

Unified Modelling Language (UML) is a general-purpose Modelling language utilized in the field of software engineering. It is standardized with ISO/IEC 19501:2005. UML includes a wide range of diagrams, which are utilized to model different aspects of the IS. UML was developed by Grady Booch, Ivar Jacobson and James Rumbaugh at Rational Software in the 1990s. After that it was adopted by the Object Management Group (OMG) in 1997. It has been managed by OMG since then. In 2000 it was accepted by the International Organization for Standardization (ISO) as the industry standard for modelling object-oriented software-intensive systems. The latest version of UML is 2.4.1 and was published by the OMG in August 2011. Table 5.1 presents an overview of UML diagrams.

Diagram Type	What can be modelled?	Originally introduced by UML 1.x or UML 2.0
Use Case	Interactions between your system and users or other external systems. Also helpful in mapping requirements to your systems.	UML 1.0
Activity	Sequential and parallel activities within your system.	UML 1.0
Class	Classes, types, interfaces, and the relationships between them.	UML 1.0
Object	Object instances of the classes defined in class diagrams in configurations that are important to your system.	Informally UML 1.0
Sequence	Interactions between objects where the order of the interactions is important.	UML 1.0
Communication	The ways in which objects interact and the connections that are needed to support that interaction.	Renamed from UML 1.x's collaboration diagrams

Timing	Interactions between objects where timing is an important concern.	UML 2.0
Interaction Overview	Used to collect sequence, communication, and timing diagrams together to capture an important interaction that occurs within your system.	UML 2.0
Composite Structure	The internals of a class or component, and which can describe class relationships within a given context.	UML 2.0
Component	Important components within your system and the interfaces they use to interact with each other.	UML 1.x, but takes on a new meaning in UML 2.0
Package	The hierarchical organization of groups of classes and components.	UML 2.0
State Machine	The state of an object throughout its lifetime and the events that can change that state.	UML 1.0
Deployment	How your system is finally deployed in a given real-world situation.	UML 1.0

Table 5.1 UML diagrams (adapted from: Hamilton and Miles 2006)

UML combines tools and techniques ranging from business modelling (workflows), through data modelling (Entity Relationship Diagrams - ERD diagrams) to object and component Modelling (object diagrams, class diagrams, package diagrams). Therefore it can be utilized through the standard software development lifecycle. Additionally it may be used across different implementation technologies. It offers a standard way to visualize the system's architecture, user interactions and other key elements. UML may be perceived as a synthesis of the notations of the Booch method, the Object-modelling technique (OMT) and Object-oriented software engineering (OOSE). It combines them into a single, common and widely usable modelling language. The aim of UML is to be a standard modelling language, which can aid the modelling of concurrent and distributed systems. Other advantages of UML are that it is extensible (offers two mechanisms for customization: profiles and stereotypes) and that it can be automatically transformed to other representations (e.g. Java). A profile in the UML provides a generic extension mechanism for tailor-made customization. It allows UML models to be "suited" to particular domains and platforms. A stereotype allows extensions to be made to the UML vocabulary in order to create new model elements. These new model elements are derived from the existing ones, but they may have specific properties that are suitable for a particular domain or otherwise specialized usage. Another advantage of UML is that it can suit a variety of software development model processes (e.g. waterfall, iterative, agile methods).

UML diagrams can be constructed and analysed in a number of perspectives depending on the real world needs. One mode of analysis is Kruchten's 4+1 view model (see Figure 5.7).

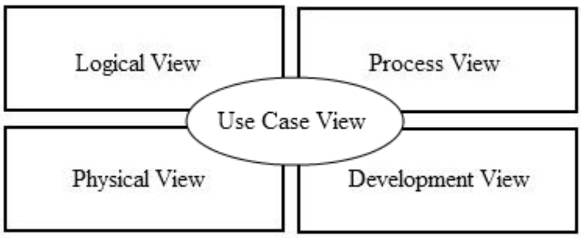

Fig. 5.7 Kruchten's 4+1 view model (adapted from: Hamilton and Miles 2006)

This view decomposes a UML model into a set of views, each capturing a specific aspect of the system: a logical view (an abstract description of the system's parts), a process view (describes processes within the system), a development view (describes how the system's parts are organized into modules and components), a physical view (describes how the system's design is realized in real life as a set of real-world entities), a use case view (describes the functionality of the system being modelled from the perspective of the outside world).

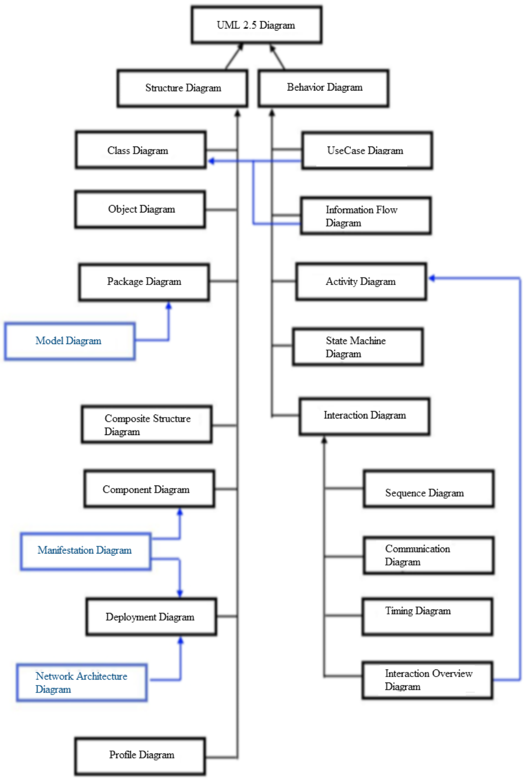

Fig. 5.8 UML 2.2 diagram overview (adapted from: http://www.uml-diagrams.org/uml-25-diagrams.html)

Specification UML 2.2 identifies a total of 19 types of diagram, which can be divided into two categories: diagrams related to structural information (structure diagrams) and diagrams utilized to represent general types of behaviour (behaviour diagrams). In this latter group four represent different aspects of the interactions. Figure 5.8 represents the diagrams categorized hierarchically.

Structure diagrams describe the static structure of the system and its parts on various abstraction and implementation levels, as well as the way those parts are related to each other. The elements in a structure diagram represent the meaningful concepts of a system, and may include abstract, real world and implementation concepts. Behaviour diagrams describe the dynamic behaviour of the objects in the system, which can be described as a series of changes to the system over time. Interaction diagrams are a subset of behaviour diagrams and focus on the flow of control and data in the system.

5.1.5 Data Flow Diagrams (DFD)

The Data Flow Diagram (DFD) is a graphical representation of the "flow" of data throughout the information system. It is utilized to model its process aspects. DFDs are Yourdon's technique (Yourdon and Constantine 1979), and are often a preliminary step used in order to create an overview of the system, which can be later elaborated. Apart from that they can be used for the visualization of data processing. A DFD usually describes what kinds of information will be input to and output from the IS, where the data will come from and go to. It also describes how the data will be stored. It does not display information about the process timing, or on the order of execution of the processes. DFDs reveal relationships among and between the various components of the IS. It is an important modelling technique (especially for the high-level detail of the systems).

A DFD uses four basic symbols to model entity, process, data flow and data store. These symbols are utilized to trace and describe the movement of information (Chong and Balamuralithara 2011). Figure 5.9 illustrates the DFD symbols.

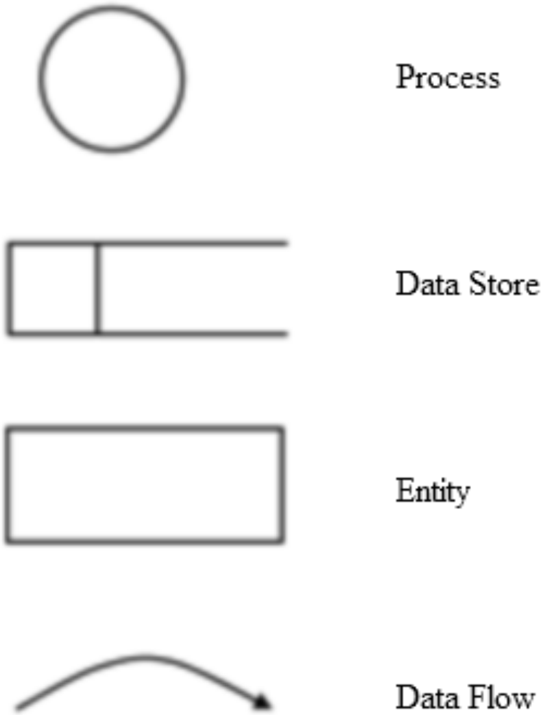

Fig. 5.9 DFD symbols

These symbols are easy to understand and DFD syntax remains the same by using simple verb and noun constructs. This constitutes one of the strengths of DFD – its relative ease of usage, learning and construction. Due to these properties DFDs are ideal for object-oriented analysis and parsing function specifications into predice DFDs for the systems analyst. To sum up, DFDs more easily understood by technical and non-technical audiences, provide a high-level system overview and provide a detailed representation of system components. Figure 5.10 presents a sample DFD diagram.

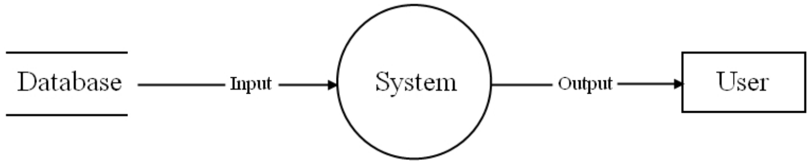

Fig. 5.10 DFD diagram

5.1.6 Concept Mapping (CM)

Concept mapping is one of a wide range of graphic organizing tools that includes mind-mapping, spider diagrams and other related approaches. It was developed in the 1970s by Joseph D. Novak and his research team at Cornell University. Initially it was utilized to represent the knowledge of students. Since then it was also used to assist meaningful learning in the sciences and other subjects, as well as to represent the expert knowledge of individuals and teams in education, government and business. A concept map is a hierarchical map of concept labels with large and inclusive ideas placed on top, while exemplary ones are situated below. Concepts are linked with arrows and the arrows are labelled to explain the nature of the association. Concept maps encompass a number of "propositional statements of understanding each of them made up of paired and linked concepts" (Hay and Kinchin 2008, p. 168). Each of these propositions is a statement of understanding, and the validity of each assertion is laid bare.

Concept mapping is relatively easy to learn. It may take only about 20 minutes to be taught and most people will find it possible to construct their own concept maps in another 30 or 40 minutes. Figure 5.11 presents an example of a concept map.

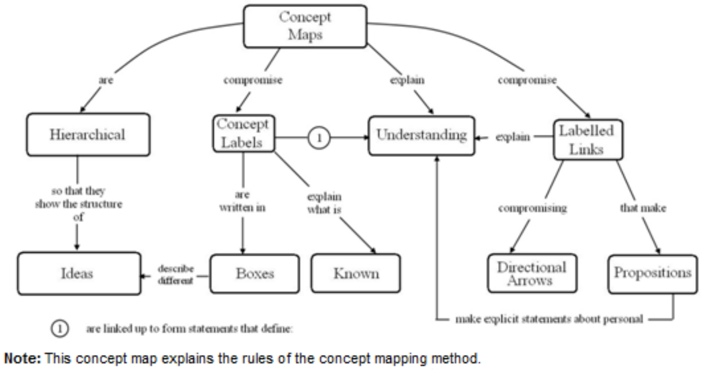

Fig. 5.11 An example of a concept map

5.1.7 Jackson Systems Design (JSD)

Jackson Systems Design (JSD) is an object-oriented, linear software development methodology designed by Michael A. Jackson and John Cameron in the 1980s. It was first presented by Jackson in 1982, in a paper called "A System Development Method" and in 1983 in "System Development". JSD covers the software lifecycle either directly or by a framework on which dedicated techniques can fit. However, in reality a lot of projects that have utilized JSD actually started slightly later in the lifecycle, performing the first steps largely using existing documents rather than directly working with the users. JSD since its inception continued to evolve, and several features were added to the method. Development of the JSD method came to an end in the early 1990s. Some of the advantages of the JSD are that: it is relatively easy to learn, a data model can be derived from JSD specification, and it is object-oriented (can be directly implemented in object-oriented programming) (Ourusoff 2003).

The basic principles of operation of JSD are:

- Development starts with a real world description and a model (not the top-down approach starting with the system)
- The model of the time related world has itself to be time related
- System implementation is based on the transformation of a specification into an efficient set of processes

JSD originally consisted of six stages: Entity/action, Initial model, Iterative function, Information function, System timing, System implementation. At later stages some of them were combined, which resulted in a method consisting of only three major stages: Modelling, Network and Implementation. Figure 5.12 presents the JSD diagram for the book loan process.

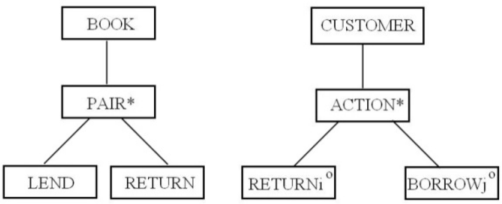

Fig. 5.12 An example of a JSD diagram (source: Jackson 1982)

5.1.8 IDEF Family of Languages (Original ICAM Definition)

IDEF was originally developed as ICAM (Integrated Computer Aided Manufacturing). ICAM was a US Air Force program, which aimed at the development of tools, techniques and processes to support manufacturing integration. It traces it roots to 1976 when it was founded and managed at the Wright-Patterson military base as a part of technology modernization efforts. This initiative was renamed in 1999 as Integration DEFinition (IDEF) and currently refers to a group of modelling languages which cover the area of systems and software engineering (Noran, 2000). IDEF languages found their uses in a wide range of domains ranging from functional modelling, through data, simulation, object-oriented analysis and design to knowledge-based systems. These tools are now in the public domain and are open to any potential uses. The most common and often used are IDEF0 (functional modelling language), IDEF1 / IDEF1x (information models and database designs), IDEF2 (existing model simulation method), IDEF 3 (model prediction method) and IDEF4 (design tool for OO languages) (Meyer et al. 1995). Figure 5.13 illustrates a generic IDEF0 diagram, while Figure 5.14 presents an IDEF1x diagram.

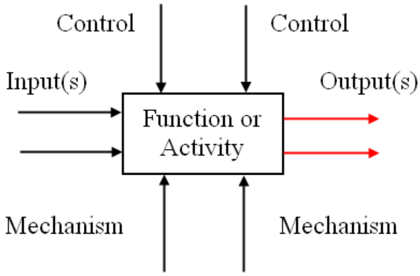

Fig. 5.13 A generic IDEF0 diagram (source: Meyer et al., 1995)

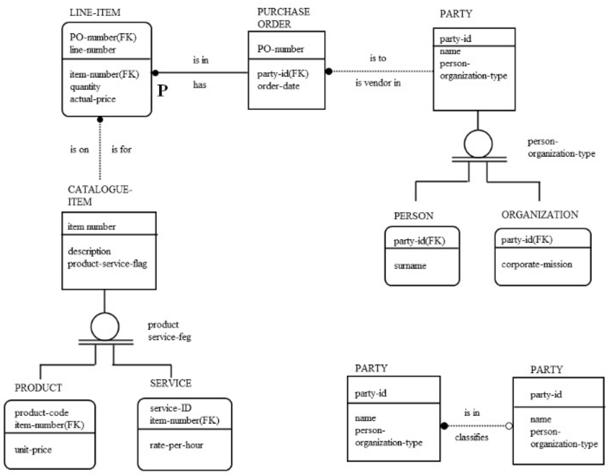

Fig. 5.14 A generic IDEF1x diagram (source: Meyer et al., 1995)

5.1.9 Architecture for Integrated Information Systems (ARIS)

Architecture for Integrated Information Systems (ARIS) is an enterprise modelling approach. ARIS offers a holistic view of process design, workflow, management and control, with a wide range of methods and tools to facilitate these functions. It is a generic and well-documented methodological framework, as well as powerful business process modelling tool. It has a good industrial background and is very widespread. Historically it started with the work of Professor August-Wilhelm Scheer in the 1990s. ARIS is composed of four levels of process engineering, process planning and control, workflow control and application systems. This architecture bridges the gap between business process modelling and workflow-driven applications. ARIS can model and structure Business Process Models and has been developed to implement business models in IS. (Scheer and Nüttgens 2000). Figure 5.15 illustrates the ARIS framework.

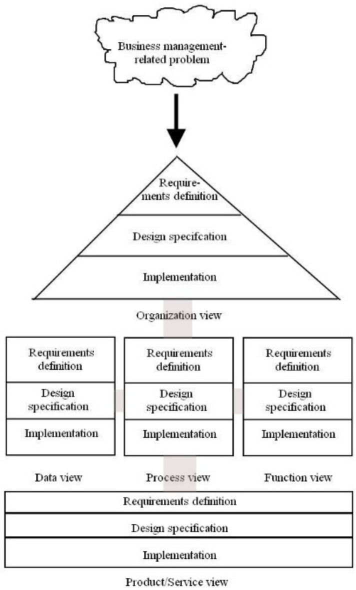

Fig. 5.15 ARIS framework (source: ARIS manual)

ARIS utilizes a modelling language known as Event-driven Process Chains (EPC). This is the centre of the ARIS methodology and connects all other views together by describing the dynamics of the business process. It provides four different aspects of applications:

- Architecture for describing business processes
- Modelling methods
- ARIS toolset software system
- ARIS House of Business Engineering (HOBE) – comprehensive computer-aided Business Process Management

5.1.10 Discrete Event Simulation (DES)

Discrete-event simulation (DES) is a methodology that belongs to the field of simulation. It models the operation of a system at the level of a discrete sequence of events occurring in a given timeframe. Figure 5.16 presents an overall view of the taxonomy of the system models. It may be observed that the discrete models are a type of stochastic, dynamic system models.

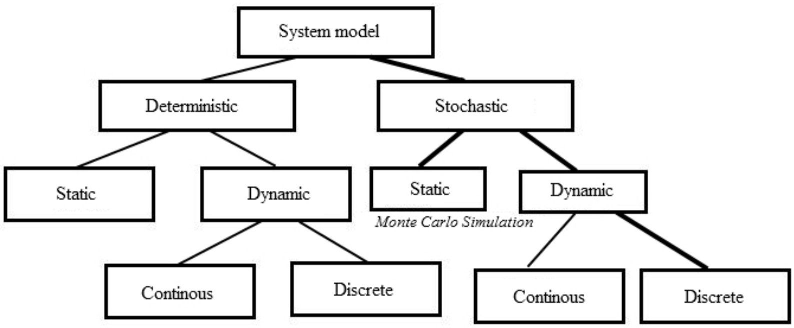

Fig 5.16 Taxonomy of system models (source: Matloff 2008)

In the case of DES each event is measurement of a system as it occurs at a particular time; one could say that it is a snapshot of the system at a given time. A given event is supposed to change the state of the system, whereas between such events, no change in the system is assumed to occur. On this basis, it is possible to navigate the flow of simulation from one event to another.

DES is a valuable tool whenever it is necessary to simulate a given system as it evolves through time. It should be remembered that the events simulated in the real world may also be continuous, but DES focuses on the key events that change the behaviour of the system. Hence (as compared with continuous simulation) typically DES can run much faster (Matloff 2008).

DES includes the following components:

- Clock – simulation keeps track of the current simulation time, whatever the measurement units are. Clock (unlike in continuous simulation) skips from one event to the next along the simulation time.
- Event List – the simulation maintains at least one comprehensive list of simulation events. This list is sometimes called the pending event set. This is due to the fact that the events in this list are pending as a result of previously simulated event(s) but have yet to be simulated. Any event can be described as a function of time (at which it occurs), type and other parameters
- Random-number generators – simulation has to generate random variables of various kinds, depending on the system model. Therefore random numbers need to be generated. Moreover they are more efficient than true numbers as they can be generated each time a simulation needs to be run.

- Statistics – the simulation keeps track of the system's statistics in order to measure the key facts of interest.
- End condition – the simulation has to specify the end condition. This is the condition that terminates the simulation. Because the events are run in sequence, without such a condition DES could run forever.

Figure 5.17 presents an example of a DES diagram.

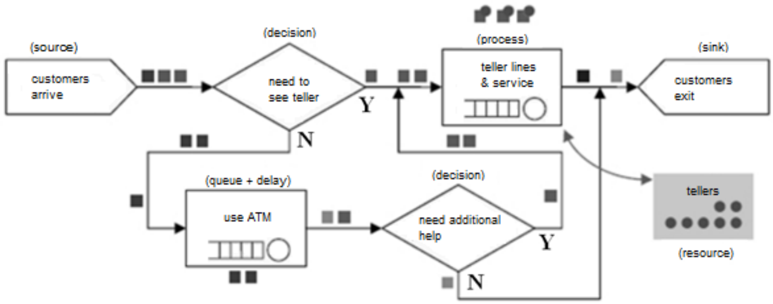

Fig. 5.17 DES diagram: Bank Kiosk (source: Borshchev and Filippov 2004)

5.1.11 Tabular Application Development (TAD)

Tabular application development (TAD) is an object-oriented methodology, which offers a unique approach to Business Process Reengineering and Information Systems Development (Damij 2007). According to this methodology the system can be described by utilizing several tables. These tables can be further analysed in order to investigate the necessary changes that have to be implemented to improve the functioning of the system. This methodology consists of six phases:

- Problem definition
- Business process modelling
- Business process improvement

- Object model development
- System design
- System implementation

The result of applying this methodology is the creation of a special table called the activity table, which is further utilized to model business processes. To achieve this it is necessary to analyse not only the current status of the system, but also its potential for re-engineering and improvement. This requires more than simple recording of the events and functioning of the system; it is also necessary for the user to facilitate interaction and analysis at the various stages of the model (Damij 2007). Figure 5.18 presents an example of a TAD activity table.

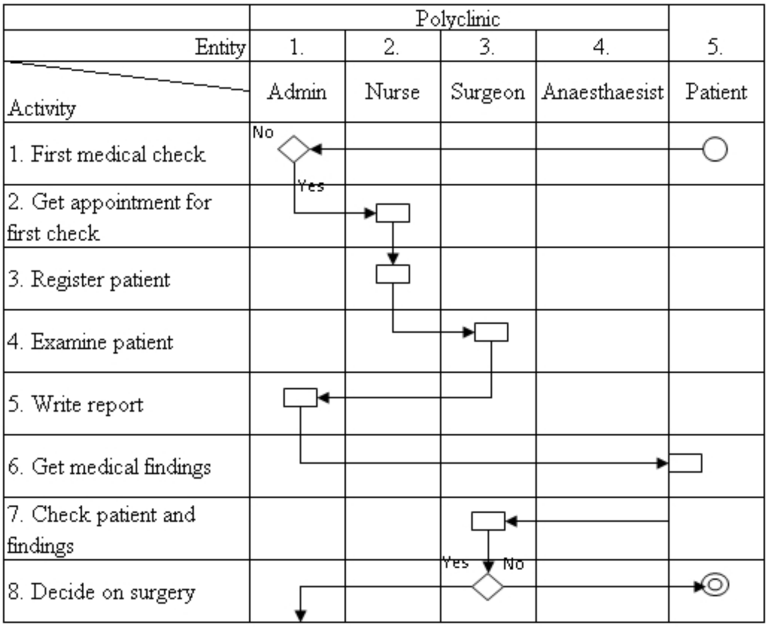

Fig. 5.18 TAD activity table (source: Damij 2007)

5.1.12 Business Process Modelling Notation (BPMN)

Business Process Modelling Notation (BMPN) was developed by the Business Process Management Initiative (BPMI). Its first version was released in 2004. Its primary goal is to provide a notation that can be easily understood by all business users ranging from business analysts (who create the initial drafts of the processes), through technical developers (responsible for implementing the technology), to business staff (who manage and monitor these processes). It provides a standard for business process modelling in the form of a graphical notation for specifying business processes – the Business Process Diagram (BPD). This diagram is very similar to activity diagrams from UML. BPMN creates a standardized bridge for the gap between business process design and process implementation (Business Process Management Initiative (BPMI), 2004).

BPMN also has the goal of ensuring that XML languages designed for the execution of business processes (such as BPEL4WS – Business Process Execution Language for Web Services) can be visualized by a business-oriented notation. BPMN consequently serves as a standard and common language between interested stakeholders.

BPMN is limited to support only the concepts of modelling applicable to business processes. Therefore it does not cover modelling of: organizational structures, data models, resources, functional breakdowns or strategy or business rules.

BPMN consists of simple diagrams, which are designed using a limited set of graphical elements that can be assigned to four major categories:

- Flow objects (events, activities, gateways)
- Connecting objects (sequence flow, message flow, association)
- Swim lanes (pool lane)
- Artefacts (data object group, annotation)

Flow objects are the main element of BPMN and consist of three core elements: events (representation of change occurring in the system), activities (representation of something that has to be done in the system) and gateways (represents forking and merging of task flows and paths). Connections are used to illustrate that flow objects are connected to each other. There are three types of connections: sequences (show the order in which the activities are performed), messages (represent what messages flow across organizational boundaries), and associations (used to link an artefact or text to a flow object). Swim lanes are visual aids that helping organizing and categorization of the activities. There are two types of swim lanes available: Pool (major process participants) or Lane (utilized to categorize and organize activities within a pool according to function or role). Artefacts are an aid which help to bring some information into the model/diagram. Figure 5.19 presents a sample BPMN model.

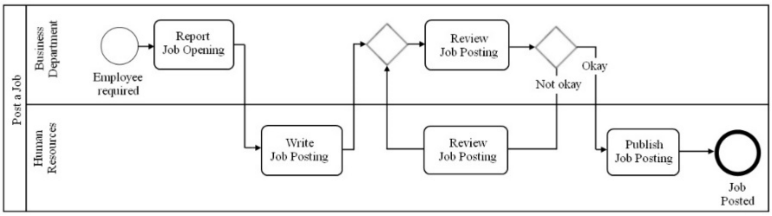

Fig 5.19 Sample BPMN model (source: Allweyer 2010)

5.1.13 Agent-Based Modelling (ABM)

Agent-Based Modelling (ABM) is a group of computational models for simulating the behaviour, actions and interactions between autonomous agents. The idea behind agent-based modelling was initially a simple theoretical concept formulated in the late 1940s. Due to the fact that it requires intensive computational power, it was not widespread until the 1990s. Its origin is in the work of Von Neumann and Stanislaw Ulam. Agents can be both individual as well as collective entities (e.g. organizations or groups). ABM is an interdisciplinary science and also found applications across scientific domains such as biology, social sciences and computer sciences. ABM helps to "understand better real-world systems, in which the representation or modelling of many individuals is important and for which the individuals have autonomous behaviours" (Siebers et al. 2010, p. 204-205). Autonomous behaviour means that is not scripted, but rather is a reaction to the simulated environment. This approach offers a wide range of real-world applications and may simulate many phenomena better than other simulation or modelling approaches. Agent Based Modelling can be viewed as a useful add-on to older and traditional approaches (Borshchev and Filippov 2004). Figure 5.20 presents a comparison between Discrete Event Simulation, System Dynamics and Agent-Based Simulation in terms of abstraction level and dynamics.

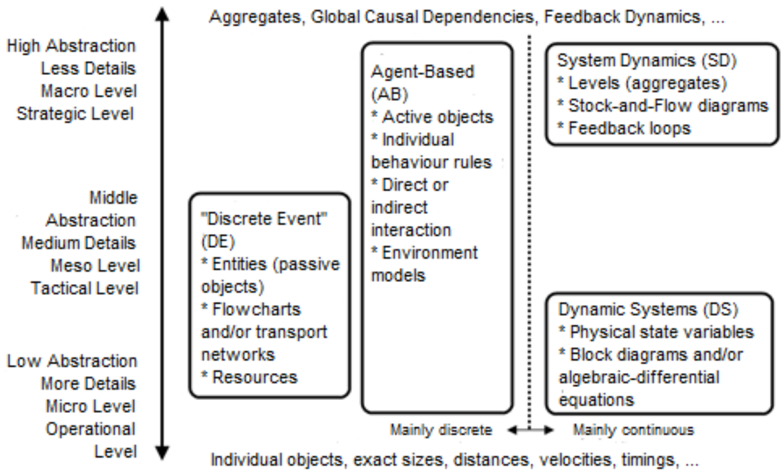

Fig. 5.20 Comparison of simulation methodologies (source: Borshchev and Filippov 2004)

It may be noticed that agent-based simulation covers areas from low abstraction to high abstraction. This shows how efficient this technique can be in real life uses. Agents may "cover" objects of very diverse scale and nature. At the bottom “physical” level they can model single objects such as vehicles, persons or dogs, at the middle level they can represent groups – e.g. customers, animals and at the highest level of abstraction (strategic level) they can represent conceptual objects – e.g. societies, companies, organizations.

In the case of ABM there is no notion (as compared with other traditional approaches) of a system-wide control of behaviour or dynamics. Instead, the modeller tries to define behaviour at the individual level. In this case the global behaviour of the whole system is the result of the behaviour of individual autonomous agents. The number of these agents can reach tens, thousands or millions of entities. Each of these agents conducts its tasks, interacts with each other and the environment. Because of these facts ABM is also called bottom-up modelling. Figure 5.21 presents a sample of how such simulation can take place in practice. In the case of this model part of a particular agent’s behaviour is defined as a statechart. Other parts of the environment (jobs, transport, houses) are represented as environmental variables. It is expected that the behaviour of the whole population of a given country will emerge as a result of the interaction between particular agents and between agents and their environment.

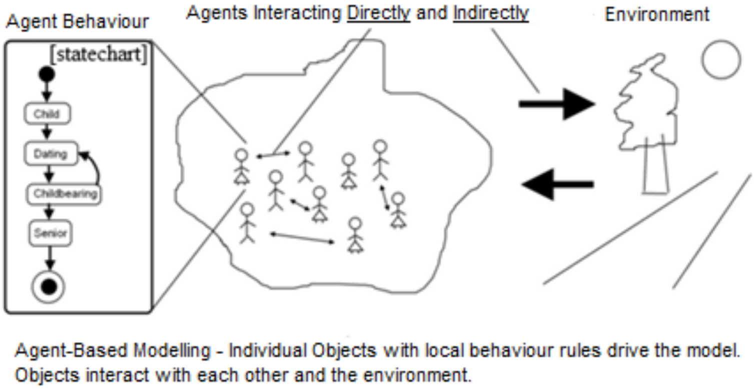

Fig. 5.21 Generic agent based modelling (source: Borshchev and Filippov 2004)

The real advantages of agent-based modelling can be best observed in situations when there is a need to model a large number of interacting objects (e.g. people, animals, vehicles, products). In these situations it is possible to say that ABM offers the following benefits (as compared to traditional approaches):

- Enables the capture of more complex structures and dynamics (ABM is more general and powerful)
- Allows models with little knowledge (or even its absence) related to the global interdependences (as these interdependences arise from the interaction between agents)
- Easier to maintain (changes to model usually occur at the individual agent level and not global level)

Apart from these advantages it is necessary to mention a few disadvantages of agent-based modelling. Due to the fact that it is a relatively new model and until recently non-existent outside the scientific community, it cannot provide as extensive case studies, nor practice-related information as traditional approaches. Apart from that, for uses with a relatively low number of objects it may be relatively more time-consuming to model the behaviour of each agent. It is far better to find some common characteristics of a large number of agents and model them as a "generic agent(s)". Additionally ABM usually requires greater computational resources than traditional approaches.

6. Relationship between Business Process Simulation and Knowledge Management

Knowledge Management (KM) became an established discipline in the 1990s. It involves a variety of techniques, tools and methodologies which an organization can apply to facilitate the generation, identification, representation, adoption and sharing of insights, expertise and experience (Hlupic et al. 2002). These in turn can either reside with individuals (personal knowledge) or be embedded as processes or practices in organizations (organizational knowledge) (Rao et al. 2012). Business Process Simulation (BPS) has been one of the best known and widely used decision support techniques since the beginning of the 20^{th} century. Some of these techniques include *de facto* industrial standards such as the Gantt chart, the flow chart or Unified Modelling Language (UML). A process-oriented approach encourages organizations to focus on processes instead of functions and procedures. Process-related thinking takes into consideration the chain of events in the organization (e.g. from order retrieval to sales).

BPS and KM appear to be separate in the literature; however it is believed they are not separable in practice (Hlupic et al. 2002, p. 1). They seem to be interrelated in many different ways. They both have mutual influence on each other. BPS involves collection of data and information from various sources and after its analysis it may result in the generation of new knowledge. In turn KM facilitates cooperation and collaboration between individuals and groups within an organization and this may make it easier to acquire the necessary knowledge and data to carry out simulation-related processes.

KM can facilitate all phases of the BPS lifecycle. Once a problem domain (system) is identified as a target for simulation, data is collected and analysed. The act of data collection can be supported by storytelling (a KM tool) as investigated by Santoro et al. (2010). Apart from that during this phase new knowledge can be generated. The next two phases of BPS relate to the development of conceptual and computer models (Hlupic et al. 2002, p. 2). These two stages can be facilitated by collaborative tools (KM tools) and more knowledge can be generated. During the next phase, an operational simulation model is proposed through verification and validation of potential models. Appropriate knowledge related to test cases may be generated with the help of KM tools and techniques. Further, as possible alternatives are evaluated, new knowledge about the system itself can be generated. The next stage (analysis of outputs) can be facilitated by collaborative KM tools, and finally the decision-making and recommendations that follow (last phase) can be based on them and generate new knowledge as well.

The business process approach can be utilized to support knowledge management processes (and in particular knowledge intensive processes). KM projects are “stigmatized as demanding, fuzzy and complex, with questionable outcomes – more than 70% of them do not deliver what they promised” (Baloh et al. 2008, p. 1). It is believed that KM projects can be more successful if they are treated as business process-oriented organizational change projects (Baloh et al. 2008, p. 1). BPS can be utilized to investigate KM processes, knowledge flows and to simulate missing data needed for KM, or to evaluate alternative models of KM strategies. Apart from that, it can simulate the effect of applying new KM tools, techniques and practices on the organization (Hlupic et al. 2002, p. 3).

Mahomoodzadeh and Jalalinia (2009) provided a framework which combines the strengths of BP and KM. According to them, KM and business processes can be utilized to support business process outsourcing. In this view knowledge of processes is an enabler of business process outsourcing. Figure 6.1 presents the interrelationship between business process management and knowledge management.

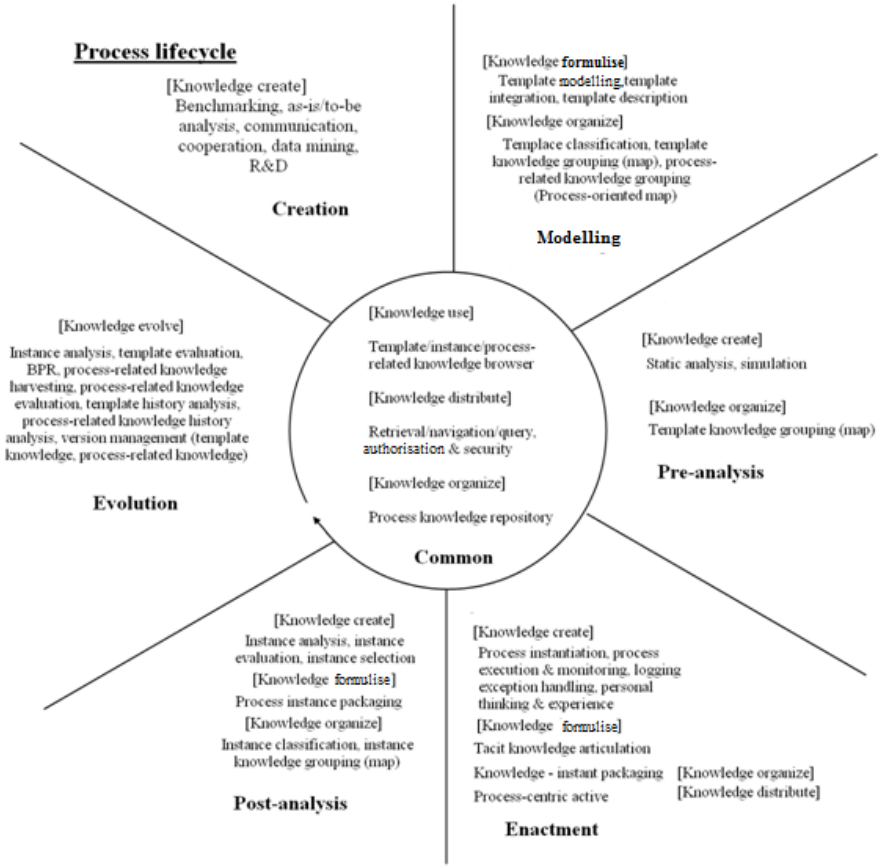

Fig. 6.1 Interrelationship between BPM and KM (adapted from Mahomoodzadeh and Jalalinia, 2009)

As shown in Figure 6.1 different kinds of knowledge and knowledge-related tools are present at each stage of the process lifecycle. The next section will provide a closer look at the role of tacit knowledge in business process simulation.

7. The role of Tacit Knowledge in Business Process Simulation

Knowledge is widely regarded as a critical asset in modern organizations (Teerajetgul and Chareonngam 2008). It has been seen as a source of income generation and a way to gain competitive advantage in profit-oriented organizations. However; in order to achieve these goals organizations face the challenge of properly managing their knowledge. Knowledge management can be perceived as a fundamental process for managing organizations (Bailey and Clarke 2000). This process is both technology- as well as people-dependent. Knowledge itself has been classified according to a variety of criteria. One such classification was made by Nonaka and Takeuchi (1995). This classification distinguishes explicit and tacit knowledge. The first kind is easy to codify into a form (e.g. written or electronic), which can be "transferred" to others. Tacit knowledge is less tangible therefore the processes of its generation and transfer are more complex.

Tacit knowledge may be perceived as a combination of education, training and real life experiences. An individual may acquire tacit knowledge such as mental models and technical skills through observation, imitation and practice (Teerajetgul and Chareonngam 2008). Furthermore tacit knowledge can be either perceived as such because of intrinsic difficulties in sharing it (e.g. amount, experiences that have to be lived through) or because the person, group or organization possessing it may be not fully aware of it. Polanyi (1996) provides an insight into the essence of tacit knowledge in the words "We know more than we can tell". Further clarification of these words can be in the form of examples such as riding a bicycle or swimming. Once these activities are learnt it is difficult to pass the knowledge associated with them. They may, however, be learnt by observation and experiencing them. Tacit and explicit knowledge are very closely connected to each other and the distinction between them must be treated with caution.

Tacit knowledge may be possessed by itself; however explicit knowledge must "rely on being tacitly understood and applied" (Senker 1995, p. 426).

As a person, group or organization progresses through real life experiences it acquires a lot of information. Some of this information is acquired unintentionally. The brain is known to record and store experiences from the senses; however not all of these experiences are fully processed. Some of the experiences and information may be quickly and effortlessly recalled, while others are difficult to remember. They may however be recalled in special circumstances when there is a vital need for them. Another example of tacit knowledge that may exist on the edge of awareness is the daily routine. These almost mechanical activities that (although they may differ in nature depending on the position) are performed in a similar way across the organization from a simple manual worker to a top executive. Quite often a person when asked how a given goal or task was achieved is unable to give a detailed response. This truth is a common fact experienced by any business process analyst. Moreover, tacit knowledge is usually built on top of experiences over many years. In order to effectively generate business knowledge, either explicit or tacit, it is a necessity for business leaders to imitate the experiences that built that knowledge in the first place. It is a common truth that business process simulation and modelling are an effective way to analyze even time consuming business processes that can span a wide timeframe. In other words, business simulations provide "a field of interaction where multiyear experiences are created in compressed timeframes" (Lefebvre 2011). In this view business process simulation serves as a tool that can be utilized to both gain insight into "not fully recognized" business processes, as well as the tacit knowledge transfer method that mimics long-life experiences.

Nowadays organizations have to operate in unknown environments, which moreover change rapidly. Decisions in such environments are often guided by intuition and lifelong experience. Moreover they often have far-reaching consequences and need to be taken in quickly. There is a crucial need to understand the nature and role of tacit knowledge, as well as possible ways of its dissemination both within the organization and externally. One way to achieve that is from a process perspective, which is “concerned with the accumulation of implicit knowledge acquired over time in organizational processes” (Venkitachalam and Busch 2012, p. 356). However, this perspective may not be enough in order to adequately comprehend all of the intangible dynamics intrinsic in tacit knowledge generation, adoption and diffusion. Apart from that tacit knowledge is recognized as highly contextual (Busch, 2008). Moreover its transfer, interpretation and application requires multiple stakeholders. Therefore merely discussing what tacit knowledge is or pure investigation of its features should have lower priority (in both scholarship as well as business disputes) than examining how tacit knowledge may be better made use of (Venkitachalam and Busch 2012, p. 357).

There is a crucial need for clarification and understanding of the significance of tacit knowledge and its potential application in certain knowledge management domains. Some of these domains include: the role of tacit knowledge in organizational learning, tacit knowledge codification and transfer techniques, the influence of tacit knowledge on intellectual capital, the use of tacit knowledge in communities of practice, group aspects of tacit knowledge (knowledge networks and teams) and the relation of tacit knowledge to technology. Modern organizations have realized the need for and advantages of investments in developing employee capabilities as part of their training and work environment. However, the “influence of employee profile in the use of tacit knowledge is not adequately evident in the literature” (Venkitachalam and Busch 2012, p. 364).

The KM discipline in the past focused too much on technology (e.g. expert systems) and therefore the human factor was often overlooked. This approach attracted a significant amount of criticism as it focused its attention on the technology itself and the design of e.g. “intelligent machines” using for instance artificial intelligence (AI) techniques, which was often inadequate for real world challenges. Instead knowledge management advocates the design of tools, techniques and technologies that augment the human capabilities. In addition there are many studies that examined the meaning and definition of tacit knowledge but comparatively very few studies which have investigated analyzing tacit knowledge (Venkitachalam and Busch 2012, p. 364).

7.1 Individual vs. Group Tacit Knowledge

Knowledge (both explicit and tacit) can be related and analysed at the level of the individual or group (community or organization) (Nonaka and Takeuchi 1995; Merx-Chemin and Nijhof 2005; Teerajetgul and Chareonngam 2008; Venkitachalam and Busch 2012). It is expected that at the individual level knowledge will mainly consist of tacit knowledge, which is not typically articulated, but may be codified depending upon the circumstances. At the group level one can expect a greater share of explicit knowledge. This is quite obvious given the fact that knowledge sharing processes (which require some sort of codification) occur more often at the group level. Some authors regard procedural knowledge as a form of tacit knowledge (Sternberg and Hedlund 2002; Colonia-Willner 2004; Bossen and Dalsgaard 2005). This sort of knowledge is usually used to carry out daily activities and is relevant to the person making use of it (individual level). On the organizational level this type of knowledge becomes the practical intelligence to the organization (Venkitachalam and Busch 2012).

The role of groups, teams, communities and networks in modern organizations and their approach to tacit knowledge is of crucial importance (Jorgensen 2004). There are a variety of factors that influence knowledge sharing processes within teams: e.g. trust, sense of belonging, the composition of the team, culture and technology. Another important factor to remember is that knowledge and in particular tacit knowledge is “sticky” by nature (Szulanski 2003). This indicates that the more valuable the (tacit) knowledge, the less likely the individual, group, team, community or society is to share or transfer it. In this view sharing or transferring such knowledge may mean losing a competitive advantage over other individuals, groups, teams or organizations. Some authors reveal that in some cases sharing of knowledge (and in particular tacit knowledge) causes the individual or team to become less important to the organization (Desouza and Evaristo 2004). Moreover, the more time and resources were devoted to generating such knowledge, the less likely its sharing or transfer is to occur.

7.2 Black Box (BB) Approach as a Generic Solution to Inclusion of Tacit Knowledge in Business Process Simulation

Tacit knowledge, owning to its nature (as it was explained in the previous sections) may pose difficulties in being included in the business process simulation. Moreover, the characteristics of tacit knowledge may differ from one industry to another and from one type of organization to another. In this study the authors would like to propose a generic approach that could be utilized regardless of the type of industry, organization or particular characteristics of tacit knowledge. In order to provide such a generic solution it is necessary to realize that tacit knowledge is very closely related to the individual, group or community and it is very difficult to separate it from the underlying base – “when recognizing the very contextual nature of tacit knowledge, it makes little sense to attribute properties to knowledge that does not exist outside human consciousness” (Venkitachalam and Busch, p. 361). Therefore the first step in the inclusion of tacit knowledge in the business process simulation is the identification of the resource (e.g. individual, group or community) that possesses the tacit knowledge which allows higher productivity. In other words, if a given individual, group or community achieves better results than others it may be an indication that it possesses a strategic tacit knowledge, which may increase the overall productivity. Inclusion of this tacit knowledge may provide a greater insight into the internal process-flow. This section will further investigate a potential solution as to how to include tacit knowledge in the business process simulation. It will describe an approach originating from the well-known Black Box (BB) concept.

BB is a term used in computer science which denotes that it is possible to observe, measure and analyse input(s) and outputs) of a given system, device, program, object, module or application, but that it is not possible to have an insight into the internal mechanics of the process behind "translating" input(s) into output(s) (Delinchant et al. 2007, p. 369). The BB approach, due to its characteristics, may establish a very good generic starting point for inclusion of tacit knowledge into the business process simulation. As was explained previously, tacit knowledge is intrinsically related to an individual, group or community. Therefore it may be not possible to measure its impact on business processes directly, but it may be possible to measure the difference in how the input(s) are "translated" into output(s) in two distinct cases. The first case is when a given resource (individual, group or community) that possesses the tacit knowledge is present (i.e. the business process takes full benefit of the tacit knowledge or rather the resource that possesses it). The second case occurs when the resource possessing the tacit knowledge is artificially removed from the business process or replaced with a resource which only possesses a generic explicit knowledge. The process analyst can easily compare the outputs of the two cases and deduce how important the tacit knowledge is to the successful completion of the business process, how much time or resources can be saved by the use of this particular tacit knowledge, and how well the input(s) will be translated into desired output(s). Such an analysis is relatively easy to carry out and should bear close similarities to the common tasks performed by the process analyst. Moreover, its ease of use meets the criteria for a generic approach (i.e. one that can be used in any situation with relatively low effort/cost). Once the information obtained through this step is available, the process analyst can decide whether there is a need to further investigate what particular tacit knowledge may be involved in the particular business process.

In some cases a reason for knowledge remaining in the tacit state might be due to the cost. "Whether a particular bit of knowledge is in principle articulable or necessarily tacit is not a relevant question in most behavioural situations. Rather, the question is whether the costs associated with the obstacles to articulate are sufficiently high so that the knowledge in fact remains tacit" (Nelson and Winter 1982, p. 82). At this point the process analyst should calculate these costs and if the costs are higher than the potential gains (as observed in the previous step), it would be advisable to simply disregard the tacit knowledge in the simulated process(es). However, it is important to remember that this situation may change in the future (i.e. the costs of articulation of tacit knowledge may be lower than the potential gains); therefore it is sensible to monitor changes in the process(es) as well, and should such changes occur to adjust the analysis by including tacit knowledge.

It is a common truth that tacit knowledge differs from industry to industry and from one organization to another. The BB approach allows disregarding such differences and assessing whether the inclusion of tacit knowledge in the business process simulation is an economically viable option. The next section of this paper will provide an insight into post BB analysis.

7.3 Post-Black Box Analysis

Once the BB approach analysis of tacit knowledge in business process(es) is concluded it may be reasonable to further analyse the whole situation. The previous section hinted at some of the most important questions that need to be answered (e.g. whether it is economically feasible to investigate the articulation of tacit knowledge). At this point it should be realized that the proportion and impact of tacit knowledge on a business process may be greatly influenced by the nature of the business process, as well as the industrial type or organization's profile. In the case of individuals who are mainly involved in manual labour (e.g. manufacturing industry, mining or agriculture), tacit knowledge (although still important) may have a relatively small contribution towards the final outcome of a given process that such an individual is involved in. This situation radically changes in the case of individuals who are mainly involved in cognitive labour (e.g. software programming, research and development, professional services).

It may be stated that the replacement (as suggested by the BB approach presented previously) of a manual labourer with extensive tacit knowledge by another who possesses only generic explicit knowledge or training in the field may only result in slight delays or output(s) of slightly lower quality. However, this statement would be totally wrong in the case of replacing, for example, an experienced software programmer with years of experience by another only possessing generic training. The difference in productivity in this case may reach up to twenty times more (Atwood 2004). On the other hand, manual workers and the corresponding manual processes more commonly occur. Therefore even a slight improvement in such processes may be multiplied (relatively easier than in the case of predominantly cognitive processes) by the numerous instances in which such a process is likely to occur. In other words, inclusion of tacit knowledge in predominantly manual processes that occurs very often may result in considerable better outputs or greater savings that can be observed on the mass scale. Predominantly cognitive processes may not be able to reach such a mass scale, given the lower number of workers involved in them. Moreover, predominantly manual processes usually have a lower cost of articulating tacit knowledge so that it becomes available to other workers as compared with highly cognitive processes.

At this point (regarding the information presented in the previous section) it is feasible to reconsider the economic side of tacit knowledge and the nature of the processes influenced by it. The process analyst should investigate how often a given process occurs in the real world and then re-evaluate (using the BB approach) whether it is feasible to include tacit knowledge into further analysis. At this point it should be remembered that any potential benefits may be multiplied by the number of occurrences of a given process in the real world.

Business process simulation can further aid the processes of tacit knowledge creation and transfer. As was explained previously, business simulation offers a field of interaction where “multiyear experiences are created in compressed timeframes”. In this view the process analyst provides an artificial environment to the process stakeholders, when they can observe the process (input(s), output(s), decision points, etc.). These stakeholders can learn from this observation in a similar way as they would learn from real-world experiences. It is however important to remember that business processes in such an analysis are an approximation to real-world business processes. They will never carry one hundred percent of the information that the real-world setting would convey. Nonetheless, this may be a cheaper, less time-consuming option to learn the tacit knowledge other people gained through lifelong experiences. However, this option should be available only once the previous steps have been accomplished.

This section of the paper covered the potential post BB analysis of tacit knowledge in business process simulation. It distinguished potential differences between tacit knowledge in mainly manual and predominantly cognitive processes. After that it suggested revisiting the comparison of potential costs incurred by the articulation of tacit knowledge with the benefits that may arise from the use of tacit knowledge in a given situation. At the end it provided an option of “compressing” long-lasting experiences, which may involve tacit knowledge, in the business process simulation, which may be further shared with process stakeholders.

7.4 Purpose

The purpose of this report is to provide a wider theoretical framework for future empirical studies in the area of business process modelling or business process simulation. Reports are intended to communicate the information and knowledge which has been compiled as a result of research and analysis of data and issues. This report does not differ from this generic purpose.

These are the core areas of crucial importance for any organizations in the modern economy. This is due to the fact that the competition is now “based upon capabilities or complex bundles of skills and accumulated knowledge, exercised through organizational processes” (McCormack et al. 2009, p. 793). Modern organizations are now viewed as a combination of highly integrated processes rather than a collection of functional areas. Processes themselves are viewed as assets requiring development, investment and innovation. Moreover, it is necessary to consider the perspective of inter-organizational business processes as well as those that involve the customers to a high degree.

8. Conclusions

It is generally believed that the process perspective can provide benefits to the analysis of modern organizations (Greasley 2003, p. 419). BPM and BPS are the two sides of this perspective. They can create a relationship between the aims of a BPS study and the strategic objectives of the subject organization. Moreover modern approaches can include the human or social factors. Social media "bring knowledge to a process in a less structured way" (Taylor 2012, p. 5). Apart from that they offer an extended reach – it is sometimes possible to obtain process knowledge from an unexpected and unforeseen resource.

This report presented a review of business process modelling and business process simulation trends both in the scientific literature, as well as in business-related sources. It is believed that some of the most important changes in these areas are (among others) a result of changing technologies, customers' behaviour patterns, and different cultural and organizational environments. Some of the most important areas for future empirical research are mentioned below:

- The use of social media and social networks in aid of BPM and BPS.
- Collaborative processes using the Cloud environment and mobile computing.
- Modular processes and process standardization.
- Relationships between processes and knowledge.
- Process simulation and modelling among different entities (e.g. processes interweaving between organizations from the public sector, a wide range of business entities and customers).

It is expected that the future empirical research with regards to the Creative Core: Simulation project will endeavour to cover some of these areas. Table 8.1 presents a summary of BPS tools, methods and techniques, while Figure 8.1 presents the timeline.

Name	Pros	Cons	Names of major contributors	Year	Most common uses	Community	Licensing	Certification	Comments
structured analysis design technique (SADT)	Service description Improved internal communication Stakeholder involvement	Narrow focus (as compared to other methodologies)	Douglas Taylor Ross	1978	Interpreting the system concepts into data and control terminology	Global	Public Domain	No	Part of a wider domain of Structured Analysis (SA)
structured system analysis design methodology (SSADM)	Usability Efficient use of skills	Greater risk in case of system replacement Danger of over-analysis Consistency problems Covers hardware and software	Central Computer and Telecommunications Agency	1980	Analysis and design of information systems	Local (mainly U.K.)	Registered trademark of the Office of Government Commerce	No	
soft system methodology (SSM)	Based on real world problems Focus on strategic level Human activity Expandable	Narrow focus Not as comprehensive as other methodologies	Peter Checkland Gwilym Jenkins Brian Wilson	1966	Real-world problems and challenges	Global	Public Domain	No	

unified modelling language (UML)	Very comprehensible Covers all IS areas Can be transformed into programming languages Flexible Many aspects of modelling	Risk of over-analysing Steep learning curve for beginners	Grady Booch Ivar Jacobson James Rumbaugh	1990s	Broad range of uses from Modelling to visual models	Global	Public Domain	Yes	ISO standard for modelling software-intensive systems
data flow diagrams (DFD)	Easy to learn and apply Quick overview	Narrow focus	Edward Nash Yourdon	1979	Modelling of data flow	Global	Public Domain	No	
concept mapping (CM)	Easy to learn and apply Modelling of the human aspect	Narrow focus Unable to cover hardware aspect	Joseph D. Novak	1970s	Displays relationships between concepts	Global	Public Domain	No	
Jackson systems design (JSD)	Object-oriented Easy to learn and apply Starts with the real-world Model of time constraints	Mastering may require OO skills	Michael A. Jackson John Cameron	1980s	Wide range of uses	Global	Public Domain	No	
ICAM definition (IDEF)	Comprehensive Widely used and tested		ICAM	1976	Modelling	Global	Public Domain	No	

architecture for integrated information systems (ARIS)	Comprehensive Widely used and tested “Bridge” between Business Process Models and Workflow-driven applications	Steep learning curve for new users	August-Wilhelm Scheer	1990s	Enterprise modelling approach	Global	Public Domain with proprietary tools	Yes	
Discrete Event Simulation (DES)	Efficient Time dependent Flexible applications Standard approaches Widely used and tested	Not all areas of IS can be modeled as discrete events easily	Bernard P. Zeigler	1976	Simulation of discrete events	Global	Public Domain	No	
Tabular Application Development (TAD)	Comprehensive Relatively easy to use Unique approach Present situation and potential improvements	Time-consuming Effort needed to conduct the interviews	Nadja Damij Talib Damij	1990s	Tabular representation of business processes	Local	Public Domain	No	
Business Process Management	Comprehensive Standardized Widely used and tested	Steep learning curve Risk of over-analysing	BPMI	2004	Modelling using a notation	Global	Public Domain	Yes	

Notation (BPMN)					which can be understood by all business users				
Agent-based Modelling (ABM)	Bottom-up approach Wide range of uses Simulation of real-world problems Each agent with own thread of control Macro behaviour of a system emerges from micro behaviour of each agent	Steep learning curve Difficult to simulate (requires major computing resources)	John von Neumann Stanislaw Ulam John H. Conway Thomas C. Schelling Kathleen M. Carley	1940s	Simulation of independent, autonomous agents	Global	Public Domain	No	Very useful for modelling of a large number of objects

Table 8.1 Summary of BPS tools, methods and techniques

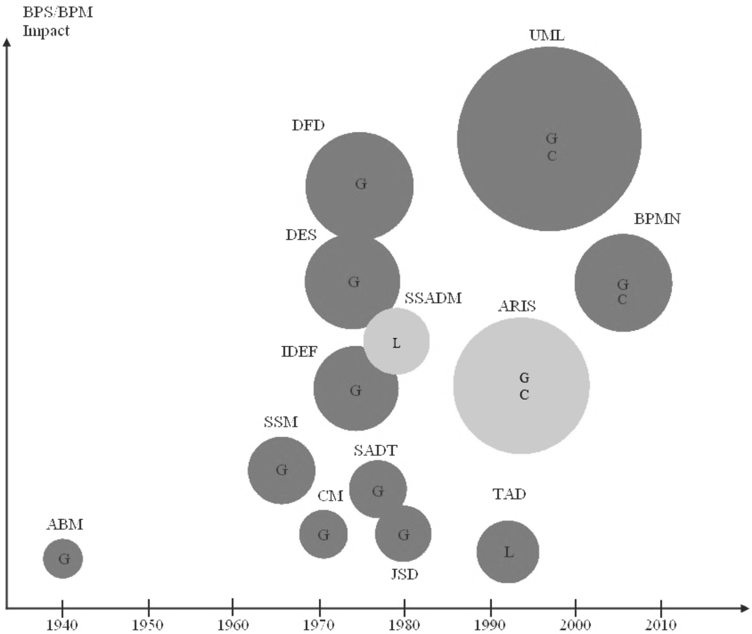

Fig. 8.1 Timeline of evolution of BPM/BPS methodologies and tools

Figure 8.1 presents a timeline of the evolution of BPM/BPS methodologies and tools. The size of the bubble represents the approximate size of the community; a dark colour of the bubble represents mainly public domain methodologies/tools, while a light colour represents mainly proprietary methodology/tools. It should be remembered that although a given methodology may be in the public domain, there may be some proprietary tools or software that make it easier to use it and vice versa; a given proprietary methodology may have some public domain or be offered for free add-ons. In this case the authors tried to extrapolate which is the predominant existing form and what can be expected by the common user of a given methodology. The letter G represent a global community of users/practitioners, while the letter L stands for the local community of users/practitioners. The letter C represent the availability of certification for a given methodology/tool.

It can be observed that one of the first methodologies was ABM and that it started already around the 1940s. At that time it existed mainly as a theoretical concept with few practical applications. It was not so very widespread due to the fact that it required immense computing resources not available at that time. Currently such resources are becoming more and more widespread and ABM is moving out of a mainly academic discipline towards a practical business one. It can be expected that methodologies and tools that are supporting ABM will be more widely used as well.

A variety of methodologies were developed in the 1960s and 1970s with such important examples as: SSM, SADT, SSADM, JSD, IDEF, DES and DFD. Nearly all of these methodologies from this period tried to address the challenges posed by real world problems. Structured Analysis and similar methodologies tried to approach it from the engineering perspective, while SSM tried to focus on the strategic level and offered solutions based on practical experience. DFD was more of a dedicated tool to model the flow, while DES offered a discrete approach to simulation. All of them now have a well-developed community and numerous case studies.

The methodologies presented in the previous section were further modified and developed in subsequent years. Nonetheless, in the 1990s new methodologies were developed that offered a holistic approach to BPS/BPM. Some of the most notable examples are UML, ARIS and TAD. They can be utilized to model nearly any aspect of the real world. UML became an industry standard and currently has one of the biggest communities of practitioners, numerous case studies and whitepapers. ARIS, although offering a similar holistic approach, is rather a proprietary solution. Nonetheless its efficiency was vital in making it a very valuable and widespread tool. One of the most crucial developments in the BPS/BPM area, which saw its dawn after those mentioned previously, is BPMN. It also offers a holistic approach and has a growing community of users and practitioners.

This report addresses the contemporary problems faced by BPS/BPM. It provides information on the most relevant existing trends in these fields, as well as potential development areas. Traditional approaches to BPS/BPM may be insufficient in the modern era and constantly changing environment. Therefore it is important to first have the overall picture of BPS/BPM methodologies and tools (as in the summary table and figure), and secondly how these can address modern challenges. Apart from that one should be aware of the existing and future trends in the BPS/BPM. At this point it may be to consider the areas for further research. Based on the content of this report, these would be:

- Adaptation of the existing BPS/BPM methodologies, tools, technologies and techniques to address the challenges faced by the modern era: a higher degree of collaboration, process modelling/simulation on the move and individual/collective process knowledge.
- Development of new BPS/BPM methodologies, tools, technologies and techniques in order to address the new challenges.
- The multi-paradigm approach to business process simulation/modelling. The methodologies or tools presented have their advantages and disadvantages. A

multi-paradigm approach would allow using a particular methodology in those areas where it is the most suitable.

- Investigation of the role of knowledge management and tacit knowledge in business process simulation/modelling.

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