Over the last few years there has been a tendency of an ever wider application of the process approach to management. This suggests defining a set of business processes performed within the organization, which further become a major object of analysis, re-engineering and optimization, management and automation. The following have been identified as key advantages to the process approach: Lower cost and faster creation of new products; lower, fixed and predictable expenses; capability of dynamic improvement of the activity of an organization.

The process approach to management brings forward new demands concerning the information systems that support the activity of the organization. In them a number of projects dealing with the incorporation of ERP and CRM systems are implemented with the objective to improve and integrate the executed processes. These systems are a suitable solution to the automation and management of those business processes that are relatively well structured and sustainable in time. However, for the automation and management of complex and dynamically changing processes occurring in various business entities and involving many process participants, as well as the use of various information systems and technologies it is recommended that there are used specialized software business process management systems (BPMS). They are systems of a new class, where business process automation and management are performed based on their models. Therefore, they can also be defined as business process modelling systems.

BPMS comprise one of the fastest growing and most promising segments of the IT industry with an estimated 12%-16% annual growth in sales. Well established companies, such as SAP, IBM, Oracle, Pegasystems, Software AG, Adobe feature among the vendors of such solutions.

At the same time, new research conducted over the period 2011-2012 has found out that while users demonstrate increasing interest in implementing BPMS, they often limit their use to certain aspects of these systems only (e.g. business process modelling or re-engineering) and fail to avail themselves of all the advantages of the systems. Nearly 70% of the participants in another study define their organizations as beginners.

5 BPM in the cloud: Reaping rewards, avoiding pitfalls. BPM Quarterly e-zine, December, 2011.
in their attempts to adopt and use BPMS. Based on this data we can conclude that the major barrier to the wider and more efficient use of this class of systems appears to be the fact that users are not ready to switch to them and do not have adequate knowledge of their features.

With reference to this, the aim of the present publication is to define the conceptual architecture of the business process management systems so as to offer a general view of the systems' capabilities and features, their components and the basic mechanisms of their functioning, while covering the latest tendencies in their development. We consider this to be a key prerequisite for the adequate application of the process approach in organizations and better realization of its advantages. In our opinion, to achieve the objective set, it is necessary that the approach applied be business process-oriented as well as focusing on the processes life cycles in BPMS, so that their objectives and capabilities are better revealed, along with their role in the organization. In this context the following tasks must be carried out:

- Study the basic characteristics of a business process as an object of processing in BPMS;
- Study the life cycle of business process management and automation in BPMS, taking into consideration the latest developments in this field;
- Identify BPMS basic functions by stages of the business processes life cycle;
- Define the essential subsystems and components pertaining to the conceptual architecture of BPMS and the relationships among them.

Before we move to the realization of the objectives we set, we need to specify that the literature in the field, when BPMS are presented, the de facto standard that is used is the so-called “reference model of WfMC”\(^6\), published in 1995. This model defines the basic components and interfaces of the workflow management systems, which are seen today as an earlier stage in the development of BPMS, and one that does not reveal the latest achievements in the field. The reference model also lays the foundations of a number of standards methods and tools for business process management. It is obvious, however, that the model is not meant for managers and users of BPMS, but is aimed towards the construction of these tools and towards standardization of the technologies they are based on.

Documentations on a number of business process management tools also refer to some of their architectural aspects. However, a careful study suggests these references are mostly oriented towards the structure of the respective products and towards particular decisions made while building them, in other words – they concern technological architectures. Thus, for instance, from the architecture of Metastorm BPM – a product rated “leader” in Gartner’s Magic Quadrant for business process management tools\(^7\) – we can generally get information on the standards and technologies this tool is based on – XML, SOA, WSDL, etc. Product users like designers, developers and clients have been catered for, but little can be learned about the functions that

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\(^6\) Hollingsworth, D. Workflow Management Coalition. The Workflow Reference Model.

\(^7\) Sinur, J., J.B. Hill, Magic Quadrant for Business Process Management Suites. Gartner RAS Core Research Note G00205212, 18 October, 2010.
have been assigned to these users. Similarly, the architecture of Intalio BPMS\(^8\) presents open code components which make up the system - Apache Tomcat, JBOSS, etc., as well as the technologies for integrating these components and implementing the user interface – XForms, Tibco GI, UI-FW. At the same time some functions of the system have been identified, but certainly not clarified\(^9\).

The conclusion that can be made is that the above mentioned architectures, like other similar ones, are again mostly aimed at IT specialists – system architects, designers, programmers who build up BPMS and put into practice the projects concerning their implementation. Logically, these architectures reflect the viewpoint of the developing company and mostly underline innovations and unique solutions that a product provides. We can also notice that architecture usually features as an end result and no presentation is made of the approach adopted to define it.

1. The business process as a basic object of processing in BPMS

The business process is viewed as a means for organizing the company activity that provides opportunities for continuous improvement. ISO 9000 defines the process as a set of interrelated and interacting activities transforming the input they obtain into an output that a client finds useful\(^11\). Obviously this is a fundamental definition of an underlying character, describing the essential characteristics and elements of the business process.

Other definitions bring to the fore the information-related aspects of a business process as well as the opportunities for its automation. Thus, according to Leymann\(^12\) a business process is a sequence of steps taken by various people with the end result being a document, decision, etc.

We can generalize that the above mentioned definitions reflect the objective direction and the structure of a business process. Some aspects of a business process management and automation are also mentioned. However, these definitions do not focus on how activities are performed in the process, not on the mechanisms of turning the input into output, yet these questions are essential to the process automation and management, as well as to process modelling and formal representation. Therefore, from the point of view of business process automation we can specify that a business process is a set of activities aimed at achieving a particular goal and performed in a coordinated manner, which transforms the obtained input into output that is useful for the consumer in accordance with predefined rules and mechanisms.

The implementation of a business process requires the participation of humans (employees, clients, etc.) and software systems. Hence, the activities that constitute a business process can be divided into three groups\(^13\): activities performed by humans

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\(^9\) An open code product with a number of implementations, incl. in BNP PARIBAS, Deutsche Bank, Santander etc.

\(^10\) http://www.citeck.co.uk/intalio-architecture (March, 2013).


A point should be made that BPMS are mainly designed to support interactive and systemic activities. It is also possible, by means of interactive activities for the system to cover some human-performed activities. For example, receiving a parcel is typically confirmed by the recipient’s signature, but since this is important information, it must be registered in the system by entering the necessary details – date and time of delivery, sender’s name, recipient’s name, etc.

The management of the sequences in the execution of activities within the business process is implemented on the basis of managing patterns. These are defined on the analogy of the managing constructs in programming languages. The following can be identified as examples of essential managing patterns: sequential execution; alternative choice; repeat execution; parallel execution\(^{14}\).

In order for an organization to function, it needs to support a number of interrelated processes, where often a process output becomes the next process’ input. This calls for requirements concerning their coordination and synchronization, for the management of the interaction between them. The terms “orchestration” and “choreography” are often used in that respect and frequent discussions take place in the specialized literature concerning their meaning, the approaches leading to their realization and the connection between them\(^ {15}\).

Orchestration is associated with the centralized management performed by specialized software, as well as with the sequence of the activities performed, which constitute the business process. Centralized control of this kind resembles the performance of an orchestra guided by its conductor and this similarity helped reinforce the term process “orchestration” into the theory on the subject. Orchestration makes sure that activities in the process are executed in accordance with the limitations that are specified in the process model.

The interaction within a set of business processes is described by means of their “choreography”. The term shows the lack of a central component that manages and coordinates the activities performed in different business processes and the interaction among them is carried out by sending and receiving messages. The processes engaged in interaction must conform to the common rules designed to enable interaction, i.e. a common choreography.

From a pragmatic viewpoint, we need to provide an answer to the question in which cases in business process management is it suitable to use orchestration, and in which of those choreography. Clearly, if we take into consideration automation, orchestration is easier to implement (no wonder orchestration is being supported in nearly all modern tools of business process management). In our opinion, centralized


control that is inherent to orchestration is suitable for relatively simple processes, that is, processes of a more static character, fewer participants and a clear, consistent structure. On the other hand, choreography can be applied to more complex processes of intricate logic, consisting of many steps and stages and involving large numbers of participants. Choreography is the only alternative to inter-organizational (including B2B) processes, which employ numerous and different automation tools, are subject to various management standards and policies and aim to achieve different objectives.

2. Identifying BPMS functions

Essentially BPMS are designed to support an organization’s business processes by managing their execution and enabling the creation of new automated processes. For this reason as a source point in identifying and systematizing the functions of BPMS it is appropriate to study the process life cycle in these systems.

Having in mind process management and automation through BPMS, the life cycle of the process can be broken down into 4 basic stages: design, implementation, usage, evaluation. In order to more precisely define the range and content of these stages, we have studied the capabilities of several products with process-oriented features, such as Oracle BPM Suite, Metastorm BPM, ARIS Express, Intalio BPMS, Microsoft Dynamics CRM, etc.

In the design stage, design or redesign of business processes is performed, based on needs analysis. The result of the realization of this stage is the development or alteration of the visual model of the business process, which, as we pointed out, is an essential characteristic of BPMS. It is based on the visual model that automation, execution and control are performed on the process in the following stages of its life cycle.

Some suites (for example, Intalio BPMS, IBM BPM, Oracle BPM Suite) provide opportunities for using various modelling methods and methodologies, for widening their scope and for pattern import and export. Thus no limitations are necessary for the use of a particular method or methodology and their advantages can be integrated; besides, conditions are created for the iterative use of models and the creation of pattern libraries.

The business process model contains a set of models of the constituent activities that make up this model, as well as the limitations concerning their execution. Presented in the business model are the process participants – humans and systems, as well as the resources needed for the process’ implementation. It is necessary that a capability be provided for the specification of the various patterns for managing the sequence of activities that constitute the process, for events and business rules that manage the execution of the process. Similar capabilities are provided by methods such as BPMN, UML, EPC, which feature among the most widely used ones in BPMS.

Based on the model, the process can be verified and trial-tested as early as the first stage of its life cycle; its execution can be simulated under particular conditions – for example the number of orders that have to be processed simultaneously, the number

of employees engaged in the process, etc. Thus not only can the process model be tested, but the time for its execution can be measured, the necessary staff and resources can be allocated, procedures for processing exceptions defined and the cost of the process calculated.

The study of the first stage of the business processes life cycle in BPMS provides us with the well-founded conclusion that it is more appropriate to call this stage “modelling”. In our view this notion corresponds more precisely with the content of this stage, gives a better idea of the methods and means used in this stage, as well as in the next ones and, generally, better reflects the nature of BPMS. It is important to bear in mind that with using BPMS a major change takes place in the way software applications are created, emphasizing on the building and control of the business process model.

During the execution stage, the process model is transformed into an executable definition. The definition of the process must specify precisely and unambiguously, i.e. formally, the process components and logic. Our research has found out that for the representation of the definition there are used specialized languages such as BPEL и WS-BPEL, XPDL, XAML, XLANG, WSFL. In order to implement certain more specific capabilities that cannot be represented in the process definition, a need may arise for building additional software applications, web services and forms of interaction with users.

During the execution stage testing and execution of the business process is carried out as well, including the preparation of the users, so that they are able to make use of the process. The basic computer tools that support the business process functions are configured – for instance, platforms for the integration of applications such as BizTalk Server, MQSeries, WebSphereMQ, Tibco EAI.

During the usage stage the implemented business process is performed and based on the process definition process copies are created. The process copy is testing the model under certain conditions with certain participants and consists of copies of its constituent activities. Its creation is initiated by a certain event. Thus, for example, for every new client’s order a new copy of the “Order processing” process is created and performed. At a certain moment various clients’ orders may be processed, which means that several process copies are processed concurrently.

In the process usage stage the BPMS runs applications for automating certain activities, and coordinates and synchronizes the actions of the people who are involved in the process. During the management of interactive activities tasks are created and assigned to the users, participating in the business process and individual participants are promptly informed of any new tasks, deadlines for performing them, etc. The possibility is ensured for the input and output of data and for making choices, if necessary. Therefore, BPMS can be defined as an integrating platform for business processes execution.

It is also necessary to provide a capability for observation and control over the process’ copy in real time. For the purpose of using the process model the execution of its copies is visualized. Thus, for example, a manager can, in real time, get an idea of the stage that sales generated by each broker have reached, monitor each employee’s workload and which of their assignments they have accomplished (if necessary, tasks
can be re-assigned), establish the reasons for non-performance of tasks, etc. In some of the products we studied (IBM BPM, MS Dynamics CRM, Oracle BPM Suite, etc.) it is possible to use a control panel and thus monitor key indicators of the process execution, including the state of the constituent activities. Should critical situations emerge a capability is provided for flexible change of the business processes copies executed, and should problems arise or certain exceptions be thrown, these cases are solved with the help of specialists in the respective field.

The result of the execution of separate steps in the process, the events governing the process as well as the errors and exceptions that occurred must all be registered into events journals (log-files) for the purpose of further control, analysis or audit.

During the evaluation stage the information that was generated during process execution is analyzed, problems are identified, as well as opportunities for optimization. With this objective in mind, a number of various reports are compiled concerning process execution. Based on the analyses of log-file information, conclusions can be made and decision formulated referring to the process re-engineering and optimization, to improvements in process management and security as well as identification of new business processes. For instance a certain activity may prove to be too time-consuming, the reason being delays in the supply chain of the resources necessary for the activity’s execution. Retrieving such knowledge from the information on process execution by means of automated tools is known as “process mining”. This is a new area in business process management enabling the retrieving of models from event log-files, checking for a match between the process copies executed and the process model, automated construction of new models, correcting existing models and identifying trends\textsuperscript{17}. Thus a direct link is established between the business process model and actual data concerning its execution with the capability to change the model if necessary.

The study of the content of a business process life cycle reveals that throughout its lifetime the business process model assumes different forms: a visual model, that can be viewed as logical, since it is independent from the process execution environment; a definition or a physical model that can be executed in a certain environment and IT infrastructure; a copy of the physical model; an improved logical model.

Following the study we conducted of a business process life cycle, the functions of BPMS can be determined – they are presented in greater detail in Fig.1, grouped according to stages in the process life cycle.

We believe that in the particular set of functions a core of minimum necessary functions can be identified that must be supported by any BPMS. Taking into consideration the best practices in using the suites and the current stage of their development, we are of the opinion that the minimum necessary set of functions should include visual construction of models; definition generation based on the process model; execution of definition copies with capability provided for process orchestration; interaction with users; project execution management – visualization, monitoring and control; creation of log-files and report compilation.

Minimum necessary functions must be given priority when BPMS are implemented. The remaining functions enable a wider range of capacities and advantages, but their implementation can be carried out step by step in time.

**Note:** minimum required functions are underlined.

**Fig.1. Basic functions of BPMS**
3. Basic components of BPMS conceptual architecture

The primary objective in defining conceptual architecture is to establish the subsystems of the system that has been studied – in this case BPMS, to present their components as well as the existing relationships between them and basic mechanisms, without covering the specific ITs that are necessary for these subsystems implementation. In other words, conceptual architecture has an abstract character; it represents the basic capabilities of the system.

Analysis of BPMS functions defined above shows that these functions can be divided into two groups. The first group consists of the functions concerning business processes automation, i.e. their modelling and implementation. They are static in character, are implemented only once per process and play a preparatory role to process execution. The second group of functions is connected with the usage and evaluation of the automated processes. They are dynamic in character and are subject to multiple execution – i.e. for each copy of the business process. All this is a good reason for establishing two basic subsystems in the BPMS conceptual architecture (fig.2).

The first subsystem supports the business processes design and implementation; it is oriented towards model building and model management, towards the conversion of models into definitions and programming code – that is, the process model is the main object of processing. The second subsystem supports the business process execution and evaluation – i.e. the automated process that is executed is itself the object of processing. It is therefore suitable, in our opinion, to call the two subsystems “Model manager” and “Process manager” respectively.

A Model manager comprises model construction tools (including the importing of models that were developed with external tools) and simulation. The graphics editor for modelling should also support model transformation features, so that a model can be transformed into a definition, programming code or services. In order to achieve a more complex behaviour, scripts can be built into the models, as well as calls to programming modules developed by means of an in-built or external programming environment.

A basic component of the Process manager is the instrument for the process execution – the process engine, which creates and executes process copies, by interpreting the process definition in real time or by executing the programming code to the process automation. It supports the processes orchestration and choreography and creates log-files for their execution.
Note: in brackets there are given the functions from fig.1, in whose implementation there take part the respective conceptual architecture components.

Fig.2. Conceptual architecture of BPMS
To optimize process execution, which plays a crucial part for the speed of BPMS in general, there is a separate tool in the architecture for managing business rules, which, in turn, can be viewed as mini processes. The business rules used in process management are changed more frequently than the processes themselves. Therefore, setting business rules processing apart facilitates BPMS adaptation and configuration and enhances flexibility.

Under analogous considerations, a tool can be set apart for managing the events through which the interaction with the environment and interaction between business processes take place. Certain errors or exceptions – for example the system admin aborting the process – can also be processed like events, which stop or start the processing.

Within the Process manager an infrastructure for message management may be established as a component. The reason behind this is that messages function as a basic mechanism for integration in BPMS, as well as in process orchestration and synchronization, events processing, etc. Consequently, flexible intra- and inter-organizational processes can be implemented on a message base. In case the separate message management infrastructure is missing, this function must be distributed among the other components of the Process manager. For message management the message queues technology can be used in order to carry out communication between applications that are executed at different times.

As separate components of the Process manager we can also establish the instruments for monitoring and control over the process copies executed, for report development and for process mining.

An important component of the BPMS conceptual architecture is the centralized repository, containing metadata and business processes artefacts, for example, models and data related to them (version, developer, last-modified date), process definitions, services that business processes have been converted into, WSDL files, scripts and programming modules for their implementation as well as information about their execution. The repository is used in process modelling and process execution, in process management and monitoring and during process versions management.

In practice for the BPMS implementation various suppliers’ tools are often used. On the other hand, some of the BPMS functions may be covered by already existing tools in the organization. This means that it is necessary for BPMS to be used together with other tools and applications. It is necessary, therefore, to support capabilities for integration, expansion and data import and export. By means of these features BPMS connect with other information systems within the organization (ERP, CRM, SCM), with clients’ and partners’ information systems, with administrative bodies, electronic markets, social networks, etc.

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In this publication there has been made an attempt at defining BPMS basic functions and conceptual architecture. To achieve this, we have used an approach based on the analysis of the business processes characteristics and life cycle. In our
view, this approach corresponds with the viewpoint of managers and users, for whom it is particularly important to know to what degree BPMS can enhance and facilitate the management and implementation of business processes in the organization.

Architecture can be used by BPMS consumers to clarify these systems’ capabilities and basic mechanisms, hence – their more effective adoption and usage. Architecture may be the foundation for building a long-term strategy for BPMS development in the organization, for solving some methodological problems during the transition to this class of systems. All this points at certain guidelines our future research in the field may follow.

CONCEPTUAL ARCHITECTURE OF BUSINESS PROCESS MANAGEMENT SYSTEMS

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Abstracts

Business process management systems (BPMS) are specialized software systems, suitable for the management and automation of complex, dynamically changing processes, which are implemented in various business units with the participation of a great number of users and the use of diverse information systems and technologies. For the purpose of their more effective adoption and utilization, in the article there is made an attempt at defining their conceptual architecture and to that end there is used an approach based on a study of the characteristics of business processes and their life cycle in the BPMS. The applied approach is in our view in conformity with the standpoint of managers and users, for whom it is particularly important to know to what extent BPMS can aid and facilitate the management and realization of business processes in the organization. Through the architecture there are presented in a generalized manner the main capabilities and specific peculiarities of BPMS, their modules and the tools included in them, as well as some of their basic mechanisms.