The Role of Business Process Management Systems and Business Intelligence Systems in Knowledge Management

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***Abstract*—** Knowledge has a strategic role in the modern company. Therefore, company must know how to manage knowledge. Knowledge Management (KM) is the concept of the systematic collection, organisation, archiving and sharing of knowledge aimed at achieving the objectives of the company. The increase of the quantity and dynamics of knowledge have opened the need for use of information technology, referred to as the Knowledge Management System (KMS). The success of a business depends on its successful management of business processes and successful decision making processes. The company can achieve this success by usage of Business Process Management System (BPMS) and Business Intelligence System (BIS) as key parts of proposed knowledge management system framework.

The main purpose of this paper is to present features of business process management system and business intelligence system as key segments of knowledge management system and explain their role in knowledge management to support creation of added value.

***Keywords*—** Organizational knowledge; Business processes; business rules; Data warehouse; OLAP; Data mining, Knowledge discovery, Framework

I. INTRODUCTION

Knowledge is dynamic, as it arises through complex social interactions between the individual and the organisation. Knowledge is contextually specific, as it depends on the time and manner of use.

Science and new technologies have created the need for constant change in the organisation and its surroundings. Corporate and management issues in society and operations are becoming increasingly complex, and the quantity of new knowledge is rapidly on the rise. In order to achieve excellence, it is necessary to constantly invest in the knowledge of the individual, and the organisation to which he or she belongs. A company's special values are its personnel, their knowledge and the use of that knowledge. An organisation can achieve a competitive edge by creating and using knowledge. Knowledge has a strategic role in the management of modern organisations. Therefore, knowledge needs to be managed, and thus an entire field of management known as knowledge management has arisen. Knowledge management deals with the processes of creating or recognising knowledge, its collection and use for the purpose of achieving the ultimate goals of the organisation, and for finding the best manner to maintain and adapt a company, and make it more competitive in an environment of constant change.

Knowledge management system needs first and foremost to provide knowledge to support the more efficient execution of business processes and decision-making processes. This defines the key functionalities of knowledge management system – business process management and business intelligence.

Companies are often not aware of the opportunities provided by business process management system and business intelligence system in the field of knowledge management. One of the goals of this paper is to explain the position and importance of using business process management system and business intelligence system in knowledge management implementation. We believe that the framework proposed by this paper could help companies to change their approach and use their business process management system and business intelligence system to improve their knowledge management.

This paper is structured as follows. Following an introduction, in Section II, the KM, BPMS and BIS are shortly presented. In Section III, BPMS as functionality of KM is presented. KM functionality of BIS is shown in Section IV. In Section V, the integration of business process management system, business intelligence system and knowledge management system is shown. In Section VI, knowledge management system framework and its key functionalities by usage of BPMS and BIS is shown. Finally, in Section VII, the main conclusions are drawn.

II. REVIEW OF KNOWLEDGE MANAGEMENT, BUSINESS PROCESS MANAGEMENT SYSTEMS AND BUSINESS INTELLIGENCE SYSTEMS

A. *Knowledge and Knowledge Management System*

Knowledge is a group of facts, information, intuition and skills attained through education or experience, and intended for theoretical or practical comprehension and problem solving. In combination with wisdom, the knowledge of how to use knowledge, this becomes a valuable asset essential in all spheres of decision making. Knowledge is integrated into the

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products and processes of a company, found both within the organisation and in its environment.

Knowledge can be divided into explicit and hidden knowledge [5], both of which are possessed by the individual and the organization (Fig. 1). Explicit knowledge is available to everyone in the organisation. This can refer to information, facts and results of scientific research that the individual becomes acquainted with, thereby expanding his or her individual knowledge. Explicit organisation knowledge is knowledge owned by the organisation, and is stored in the form of databases, procedures, rules and copyrights (patents, copyrights, brands), and is available to all individuals within the organisation. Hidden knowledge is not documented and accessible to all, and is shown through skills, intuition and experience (in carrying out organization tasks) of the individual. The collection of hidden knowledge of employees comprises the hidden organisational knowledge, built into the products and services, and in the manner of executing business processes.

	INDIVIDUAL	**ORGANISATION**
EXPLICIT	- information - facts - science - research	- databases - systems - procedures - rules - copyrights
HIDDEN	- skills - intuitions - experiences	- knowledge built into products and services - knowledge built into business processes - company brand

Fig. 1 Types of knowledge in organisation

Organisational knowledge also includes the knowledge built into the management system, in the defined values, standards, business rules and procedures of the organisation.

Lai and Chu [14] list three sources of organisational knowledge: (1) human capital that includes employee knowledge, skills and creativity, (2) organisational capital that includes the organisational structure and culture, processes and patents, and (3) client capital that ensues from relationships with business partners, customers and suppliers.

Fig. 2 shows the cycle of creation and usage of knowledge in the company. The company knowledge is accumulated and constantly supplemented through business experience obtained within the company, or in its contacts with the environment. Explicit knowledge is implemented via continuous changes and advancement of business rules and methods of executing business processes and decision making processes, and therefore influences the creation of added value for the company. Hidden knowledge of the individual, like hidden organisational knowledge (built into technology, equipment, products and services of the company) is also used in the creation of added value, and impacts the realisation of business results. Simultaneous by to creating business results (production and sale of products, provision of services), new business experiences are also created, and these in turn impact the increase of total company knowledge [4].

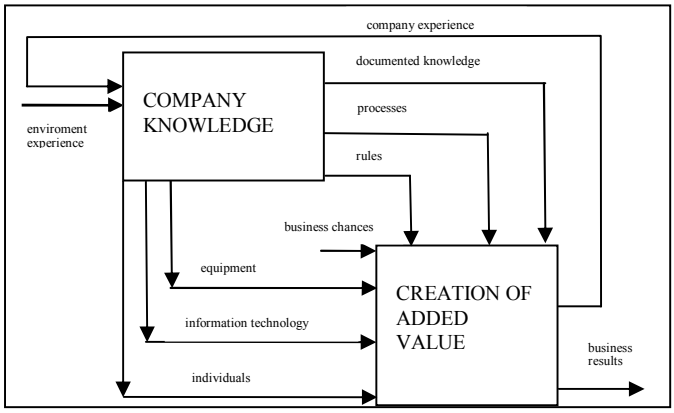

Fig. 2 Creation and usage of the knowledge [4]

The knowledge needs to be managed, and thus a field of management known as knowledge management has arisen. Knowledge management is classified among the most important approaches to changes in operations. Some authors connect the knowledge management with disciplines such as organizational information processing, business intelligence, organizational cognition, and organizational development [21]. The first is oriented to IT, the second to information services, the third to research on organizational innovation, learning, and sense making, and the fourth to business strategy and human resource management. Early on, the knowledge management was exclusively addressed through information technology for the collection, archiving and dissemination of knowledge. Later, the focus of interest was directed towards organisational change, intellectual capital management and responsibility management [6], [7]. Though there are many definitions of knowledge management, they all imply the need to connect persons seeking knowledge with the source of the knowledge. Knowledge management includes various skills, among others those relating to intellectual, human capital in the company's knowledge. Knowledge management considers the manner of interaction between people and the manner of spreading knowledge aimed at developing greater company efficiency. Knowledge management develops the mentality of sharing knowledge, and opens new channels for the flow of knowledge. In recent years, important elements of this approach include the intelligence society, innovation management and change management [1], [21]. It also refers to the field of competence management, organizational learning and knowledge society [21].

The complexity and dynamics of knowledge management require the use of information and communication technology (ICT), and the creation of different, sophisticated program solutions to support knowledge management. The computer

based solution that supports knowledge management is knowledge management system (KMS).

Knowledge management system has multiple roles: it generates new knowledge, collects and archives knowledge, shapes knowledge into the appropriate form and ensures its accessibility to users. Knowledge management system needs to ensure support to the basic activities of knowledge management, which are: (1) creating knowledge – this includes existing knowledge, revealing knowledge, searching for knowledge; (2) organising knowledge – archiving knowledge and managing archived knowledge, and (3) sharing (spreading) knowledge – cooperation, exchange and transfer of knowledge [10]. In order to carry out these activities, the knowledge management system must ensure a series of functionalities that support the management of business processes, business decision making, managing human capital, managing innovations and change, cooperation, communication, learning, etc. However, the fundamental functionality that Knowledge management system has to offer in order to achieve the activities of creating, organising and spreading knowledge is the support of the management of business processes and decision making. In that way, business process management system and business intelligence system make up the key components of KMS.

B. *Business Process Management System*

Raising efficiency, also demanded by companies' regulators, has its external limitations in terms of total number of customers that can be attracted, or revenue that can be generated on saturated and regulated financial market. Companies are thus investigating optimization of internal processes as the last frontier in battle for efficiency. First efforts in process management in company were primarily concerned with the management of the quality of operations and are generally related to adoption of ISO quality standards and procedures to assure services with a high, consistent and predictable quality

Modeling, deployment, and monitoring of the business processes in the continuous cycle has to be supported by specialized software tools, with graphical user interface that facilitates the stages of business process cycle. Software tools that integrate some or all of the features are called business process management system (BPMS).

Business process management system is the platform for the integration of the business architecture, business processes model, the management system for business flows and information infrastructure as support to the execution of business processes [12], [11]. Business process management system has been developed gradually and continuously over the past decade. The initial focus was on process automation, managing the flow of business processes and events, the transformation of data and development of software solutions for connecting different information systems and platforms within companies. At the end of the 1990s, the attention was redirected at forming connections with the information systems of business partners, the development and connection of systems for electronic operations, the connection of systems in supply chains and vertical industrial chains.

Simply put, the business process management system should allow for the tracking of a company's operations and taking corrective actions to improve operations. Such a system includes the entire life cycle, i.e., all phases of business process management: from the model of business processes, to simulations of business processes, the use of information available on the company's portal (intranet).

The expected benefits of the implementation of business process management system are: (1) documented and standardised business processes, (2) transformation of manual and "paper" business processes into electronic processes, (3) integration of program applications due to the automation of the entire business process, (4) implementation of control functions that will eliminate human or system errors, (5) quicker and more efficient execution of business processes, elimination of backlogs, bottlenecks and loss of time, (6) tracking the execution of business processes in real time, (7) measuring costs and time, optimisation of business processes [3].

C. *Business Intelligence System*

The value of information increases with the number of users who can access that information, multiplied by the number of business areas in which the user works [16]. Companies desperately need timely and relevant information and knowledge. For this purpose, companies are accumulating vast amount of data from disparate internal and external sources such as transaction systems, third-party agencies, Web, publications, research results, etc. Problems of capturing different types of structured and unstructured data relate to normalization (determination of common metrics), filtering, grouping, cleansing, and data enhancement.

Next important question is how to extract hidden knowledge from the data with issues in consistency, exactness, timeliness, and data complexity. Implementing a business intelligence system for knowledge discovery is a common approach to the problem. Business intelligence can be defined as an ability of an enterprise to comprehend and use information in order to increase the performance [18]. Computer based solution that support business intelligence activities are known as business intelligence system. Business information system offers to enterprises „one version of truth", providing consistent and harmonised data to every department in an organisation [2].

Business intelligence system comprise a number of activities, procedures and applications, such as: data warehousing, data marts, on-line analytical processing (OLAP), extraction, transformation, and loading (ETL) of data, information portals, data mining (DM), business modelling, etc. The most commonly adopted technologies are: data warehousing, analytical processing, and data mining.

Undergoing processes of company mergers and acquisitions happening around the globe have inevitable made company's information systems highly heterogeneous, with disintegrated applications, overlapping sets of data, and disperse points (in location and time) of data collection and processing. To assure a timely and efficient support to decision makers in such heterogeneous and dispersed environment was nearly impossible without new technologies. The idea to collect and unify the data form disparate sources has led to the concept of

data warehousing. The original label that pre-dates the data warehouse is still the best description of what we are designing: a decision support system [13].

Data warehouse filled with complete and purified (cleansed and enhanced) data is a prerequisite for the task of transforming information into knowledge. On-line analytical processing and data mining are common methods for retrieving hidden knowledge from the data stored in a data warehouse [15], [22].

On-line analytical processing enable manipulation and analysis of large amount of data, comparison of different types of data, complex computations and, most importantly, an intuitive graphical user interface (GUI) for presentation of results in various perspectives including drill-up and drill-down capabilities. On line analytical processing tools are essential component of today's business information systems and Information Portals.

Data mining is founded on algorithms for detection of unknown and unexpected patterns in large sets of data, clustering and segmenting of data and finding dependencies between multidimensional variables. The results of data mining analysis are presented graphically with the dominant and unexpected behavioural patterns marked.

III. Business Process Management Systems as functionality of knowledge management

From the perspective of knowledge management system, the functionalities that the business process management system should have are: modelling and analysis of business processes, managing the execution of business processes and managing business rules.

Modelling and analysis of processes form the backbone of every business process management system, as the process models are not only used for analysis and improving the processes, but also to develop the execution components of the system that then enable management and control of processes.

During the development business process management system, it is necessary to define the business rules. Business rules are procedures that regulate the manner of conduct, action and decision making for individuals in an organisation [4], [8]. They are defined by the company's business policy and legal regulations. Business rules are comprised of terminology and facts.

Terminology is words or phrases that define and describe the business facilities in operation, and their meaning is understandable to employees and business partners. Facts are sentences that define the ties and relationships between the terms in the terminology. Business rules are clauses of statements that supplement the terminology and facts with compulsory expressions or recommendations. Business rules restrict the freedom of conduct and decision making of the individual or business system and demand the establishment of a system (within the company or in its environment) that makes their implementation automatic and controls their compliance.

Rules containing recommendations cannot simply be made automatic, considering that the decision is left to the knowledge and judgment of the individual. Rules which clearly define the conditions and restrictions of carrying out activities and work tasks can be made automatic and are most often supported by the company's information systems. In that case, the control system is built into the algorithm, i.e. the program that is used by users in carrying out work tasks. Both control and knowledge about how to carry out the work task (operation, step) are built into the algorithm. The rules by which business processes are executed in a company are built into a business process management system, and the knowledge about the manner of executing business processes is shown in the form of a definition of the business process used by the business process management system. In both cases, this refers to explicit, organised knowledge that very precisely defines the rules, i.e. the procedure of resolving the business problem, at a level of very fine detail. At the higher, global level of the company, explicit knowledge (about what, when and why to do something) in a specific business situation is structured into the form of business documentation, rulebooks and instructions. Explicit knowledge (about who should do something and where within a company) are shown in the form of job descriptions and work task descriptions.

For the collection, archiving and spreading of organisational knowledge, tools for modelling and managing business processes are used, while integral business process models become knowledge repositories.

IV. Business intelligence Systems as functionality of knowledge management

Data warehouse is directed at the collection, structuring and archiving of explicit organisational and individual knowledge, and spreading that knowledge in a manner that ensures its accessibility in a form and content that is suitable for users. The typical dimensional structure of data warehousing ensures simple and quick access to knowledge.

Hidden knowledge, in particular employee capabilities (individual hidden knowledge) is very (even the most) important for a company's operations in order to recognise the problem to be solved, to understand the best way to solve the problem and to possess the knowledge and skills necessary to solve it. Techniques of knowledge discovery such as on line analytical processing and data mining, though they support the management of explicit knowledge, help in mastering the hidden knowledge of the individual in the decision making process. The decision making procedure can be observed as decision making based on rules and decision making based on skills and knowledge. Business process management system deals whit rule based decision making process. Business intelligence system (OLAP and DM techniques) allows for dynamic reporting and demanding analyses which, only with skills, intuition and experiences (hidden knowledge), can give the user answers to more complex business questions, such as why something is happening and what should be happening. In that way, the uses of business intelligence system (techniques of revealing knowledge) allow, but also stimulate the individual to create and use hidden individual knowledge.

In the past, companies had well trained and experienced employees and workers were able to learn from more experienced. Work force in today companies is predominantly

young, and more experienced and skilled workers are either unavailable or too expensive. Information and knowledge in business intelligence system, together with their delivering IT technologies, are becoming the main resource.

Business intelligence system becomes an indispensable and crucial technology in the finding, organizing and disseminations of knowledge, and thus represents a key functionality of knowledge management system in the company.

V. Integration of Business Process Management Systems and Business Intelligence Systems in Knowledge Management Systems

Implementation of a business process management system means integration of human interaction with various IT systems.

During process execution, business process management system switches control from human to IT systems, possibly, a business intelligence system for analysis of sales, suppliers, customers, current services and products used, open transactions, et., to obtain, so called, 360^{o} view of business, which cannot be done by using some application alone.

To interconnect different IT systems in a common process execution task requires use of standard services between various IT sub-systems which are used when needed. Concept of Service Oriented Architectures (SOA) and related technologies emerge as de-facto standard for interconnection of IT subsystems. SOA proved particularly useful and applicable for implementation of business process management system [19]. As business intelligence system facilitates collection of data (knowledge) from heterogeneous, external and internal, and disparate sources, the SOA is suitable for interconnecting of people, processes, and various IT systems, sub-systems and their services. Modern companies trying to leverage on residing information and past investments in IT systems to further optimize their operations are embracing SOA concept as a key technology for integration of business intelligence system, business process management system, transaction, and other IT systems.

Once adopted, business process management system itself becomes a new data (knowledge) source generating vast quantities of data about organisation's operational details. BPMS record into process logs many types of events that occur during process executions. The logs contain data (knowledge) about start and completion time of each activity, its input and output data, resources involved exceptions, etc. By cleaning and aggregating process logs into a warehouse and by analyzing them with business intelligence technologies, we can discovered and extract (new) knowledge about the circumstances in which high- or low-quality executions occurred in the past, and use this information to explain why they occurred as well as predict potential problems in running processes [8]. Process mining technologies can be applied to analyze and predict the business metrics that business users consider significant to assess the quality of their operation.

A set of tools, applications and research in area of applying business intelligence techniques to business process management system is becoming recognized under the name Business Process Intelligence, which is also defined as the application of performance-driven management techniques from business intelligence to business processes [20]. Business process intelligence claims that the convergence of business intelligence and business process modeling technologies will create value beyond the sum of their parts and aims at enhancing the analysis power of business process management systems by employing data warehousing and data mining technologies [20], [17].

VI. Framework For Knowledge Management Systems

A. *Business Process Management System and Business Intelligence System as a parts of Knowledge Management System framework*

Fig. 3 extends the concept presented in Fig. 2 and shows knowledge management system framework and its key functionalities by usage of business process management system and business intelligence system.

Knowledge management system accumulates and constantly supplements the (new) knowledge through (new) business experience in the company (BPMS and BIS), or in its environment (BIS). Business process management system (and fewer BIS) implements explicit knowledge via continuous changes and improvement of business rules and (business and decision making) processes, creates (new) added knowledge, therefore, improves business performance and helps to recognize business chances. This leads to creation of added value and realization of business results. Hidden organizational knowledge (in new business process, in (new) decision making processes, in (new) technology, (new) equipment, (new) products and services), like hidden individual knowledge (skills and experience) can be discovered and used through business intelligence system (new added knowledge) to recognize business chances and improve company performance, and also impacts creation of added value and the realisation of business results (Fig. 3). Thus, knowledge management system increases total company knowledge and efficiency connects persons seeking knowledge with the source of the knowledge, which means added quality of the knowledge management.

B. *How to use knowledge management system framework*

To recognize business chances and improve business process and performances, and finally to support the creation of added value knowledge management system framework could be used in: the definition of business strategy, the improvement (change) of business process and rules and the improvement (change) of decision making process.

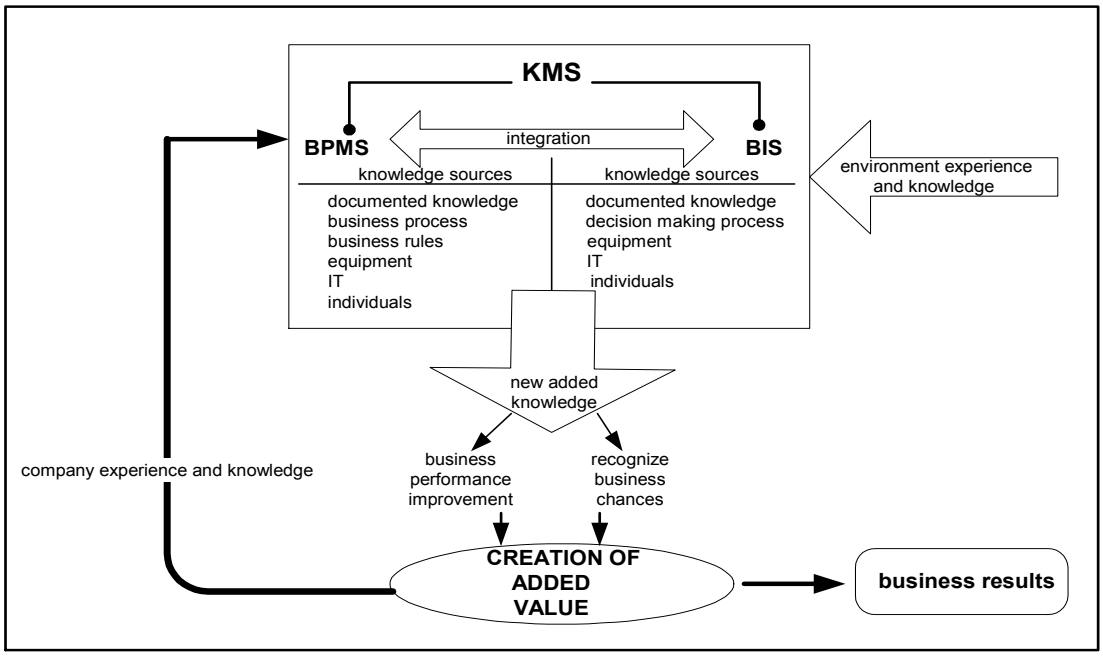

Fig. 3 Knowledge management system framework

To define business strategy, companies desperately need information (knowledge) from different sources (especially external). This means a huge quantity of different and inconsistent data. Knowledge management system based on business process management system and business intelligence system through knowledge discovery techniques can provide new knowledge necessary for determining courses of business strategy of the company. Knowledge management system through business process management system and business intelligence system effectively couples business strategies with information technologies leveraging on the existing IT infrastructure. Returns on investment in such knowledge management system are increased company's market and stock value.

Knowledge management system framework could be used to support the activities of business process (and rules) change and improvement. Knowledge management system (especially BIS) provides simple and quick access to knowledge in appropriate form that is needed for identification and selection of the process (rules), and analysis of its structure and flows. During the implementation stage, business process management system and business intelligence system are used in order to adapt the information system of the company to organizational changes and to new needs for information and knowledge that results from the change. Knowledge management system can be used to restructure and rationalize business operations raising efficacy of process management, and lowering operating costs.

Proposed knowledge management system framework could be used for decision making process change, through which new knowledge connected to a specific problem is recognised, and a new, clearer approach to fixing this particular problem is determined. Knowledge management system (BPMS and BIS) could initiate change in the not efficient existing decision making process. It could be also the result of conducting a business process change project. Interaction between decision making process change and knowledge management system is a way to improve the decision making process. On the other hand, the quality of the decision making process is the key element in business process change, and it depends on the usage and efficiency of business process management system and business intelligence system (KMS).

By usage of knowledge management system (BIS part), decision making process can also be accelerated through reduction a number of levels to strategic and operative level. Therefore, procedures, rules and knowledge should be harmonized among operative and strategic level, which requires organization to precisely define which knowledge are needed for a particular level. Besides changes in organizational structure, knowledge management system improves management of the company by enrichment of business processes (and rules).

C. *How to use KMS framework: Airport Case Study*

Upon completion of the project to model and analyse the business processes of an airport, the assumptions were created for the launch of a process performance management project. Due to the inability to expand capacities in the way of constructing new runways and accompanying structures, the management decided instead to optimise and continually monitor the performance of business processes in real time. A functional process performance management was employed in the project as part of the knowledge management process technological platform (BPMS/BIS). The objective of the project was to develop a management system for process performance and the dispatch of passengers and aircraft.

The project was executed through several phases: identification of needs, definition and analysis of requirements, development of the system, system testing and implementation. A series of workshops were held in the first phase, some of which were focused on the development of a concept for the future system, while others dealt with the technical aspects of development and implementation of the system. In this phase, the user requirements for the future system were defined and analysed, like the technical preconditions for the development of the future system, primarily the possibility of linking process performance management to the existing information system of the airport in order to take over the necessary data.

During the second phase, segments of the process to be monitoring and measured were defined and the resources included in the processes established (organisation units, employees, material resources – equipment, devices, machines, vehicles). Measurement points, key performance indicators (KPI) and all data to be collected for the process analysis were defined. All data to be taken from the database of the operative information system and all data to be collected in field measurements were identified. Data collection in real time for each segment of the process measures the duration of the activity and the time gap that occurs when certain activities cannot be launched as there are no available resources necessary for their execution, or the conditions for their launch are not in place. Measurements are carried out for each instance (repetition) of the process in real time, and the data obtained through measurements can be analytically analysed or aggregated according to different (typically hierarchically organised) dimensions (e.g. dimensions of time – day, week, month, year).

Data from the information system are transferred daily into the data warehouse (BIS) where, together with (external) data collected in the field, they are used to analyse performance processes. A total of twenty key performance indicators (validating the balance scorecard method) were defined in the system and grouped into five dimensions: number of passengers, size of aircraft, day of the week, air carrier and duration of flight. The recognition and establishment of key performance indicators and dimensions was the result of an analysis of the requirements of the needs analysis defined by the management. These defined dimensions are used for more detailed analysis that enables the management to carry out quality decision making.

In the test phase, data previously entered into the trial system database were used. The parameters of standard analysis and appearance of standard reports to be periodically used by the airport management were used. The results of the analysis were validated and discussed during the validation workshop. Following training of users, the next step was the implementation and maintenance of the system.

The use of process performance management (part of KMS) has allowed managers to monitor and analyse the performance of key business processes in real time, to make ongoing changes to the process execution (meaning significant savings in time and money), and to analyse historical data on process performance in order to generate recommendations for improvement.

V. Conclusions

Knowledge management deals with the processes of creating or recognising knowledge, its collection and application aimed at achieving the ultimate goals of an organisation, and finding the best manner to maintain, adapt and improve competitiveness of an organisation in an environment of constant change. Regardless of whether this refers to explicit or hidden, organisational or individual, knowledge needs to be managed in order to create a competitive advantage for the company. Modern IT allows for the building of knowledge management system that "nurtures" the knowledge mentality in an organisation through key functions, such as support for business process management and decision making. Ultimately, it provides support for management of overall operations. As such, business process management system and business intelligence system ensure the fundamental functionalities of knowledge management system.

Today knowledge management system implementation requires integration of business process management system, business intelligence system and other IT system and companies accepted SOA concept for this integration. Knowledge management system itself becomes a new generator of knowledge that could (and should) be used to recognize business chances and improve company's performance and create added value and new quality of organisation knowledge management.

In the paper is presented how BPMS/BIS functionalities in knowledge management system framework could comprehend, create, discover and transfer knowledge from different sources, create new knowledge, ensure adequate access to the knowledge and support creation of added value.

Proposed knowledge management system framework brought the concept of usage of the knowledge which companies could quickly adopt for active support to business processes and decision making. Knowledge management system could support business change and strategic decision making in organisations by analyzing huge quantity of data derived from growing number companies and external IT systems. By usage of the proposed knowledge management system framework, companies could improve business strategy, business processes and rules, decision making process, raised quality and efficacy of business performance, which lead to creation of added value, and finally gain a competitive advantage.

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