The Development of Process-Based Information Systems: Methodological Requirements

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Abstract. At the present time several issues are dramatically challenging the way we build and maintain information systems. On the one hand, owing to the extremely competitive conditions and dynamics of the business environment, it is vital for organisations to be able to develop and modify their information systems as quickly as possible, in order to succeed or even to keep in business. On the other hand, new technological developments have recently brought to the information systems infrastructure a set of new technologies with enormous potential to improve the way information systems support organisations. Collaborative technologies and, in particular, workflow, are notorious examples. In this paper, we propose a new information systems framework (Process-based Information Systems), which is able to provide organisations with the means to respond timely and adequately to the opportunities and threats of the business environment. Regarding this framework we try to identify the limitations of conventional Information Systems Development methodologies and, therefore, propose a set of new methodological requirements.

Keywords: Process-based Information Systems, BPMS, Collaborative Applications, Component-based Architectures

1. Introduction

It is generally accepted that organisations have never had the information systems they need to properly conduct their business. Nowadays, the situation is getting worse. Due to the globalisation of the markets, the competition and the pace of change in business have increased to levels never seen before (Hernaus, 2011). To succeed, or even to survive in this turbulent environment, organisations must be flexible, innovative and react quickly and adequately, as a whole, to the constantly changing conditions of the markets (Rosemann and vom Brocke, 2015). Obviously, in this demanding scenario, the pressure put on the information systems' development and maintenance activities is higher than it has ever been.

Nowadays, more than ever, organisations need Information Systems Development (ISD) methodologies that deliver quick, adequate, integrated and easily maintainable systems, which take the maximum advantage of all the information technologies available today. Unfortunately, organisations continue to receive inadequate systems, which are delivered late, require large maintenance efforts and are typically disconnected from the other systems already in operation – the widely known "*islands of automation*" (Liao and Tu, 2007).

Clearly, a new information system concept is needed. A new information technology infrastructure has to be defined; one that makes full use, not only of the more conventional information technologies, but also of the emerging collaborative technologies (Pereira, 2004). Additionally, a new approach to the development of information systems build over this technological infrastructure has to be defined.

Concerning this paper's organisation, in the next section we present some justifications for the actual panorama of information systems in organisations and argue for new ISD approaches. In the third section we describe, very briefly, the fundamental characteristics of the groupware and workflow technologies, which are fundamental to our proposal. In the fourth section we define the proposed

information systems framework that will provide organisations with the means to succeed in today business environment. In the fifth section we identify the limitations of current ISD methodologies regarding the proposed framework and define a new set of methodological requirements. Finally, in the sixth section we conclude.

2. The need for new approaches to Information Systems Development

As defined by Brodie and Ceri (1992), an information system "*consists of a collection of applications that implement required functions (representing state retrievals and changes) over a collection of shared, persistent information repositories (representing the pertinent aspects of the state).*" In this conventional perspective, an information system consists of a collection of related computer-based artefacts (applications and data stores) developed to support an identified set of required functions.

Despite all the efforts around Information Systems Planning (ISP) in the past, the development of information systems in organisations has originated, almost invariably, a collection of autonomous, independent and poorly connected systems, whose mission is to support the information processing needs of each organisational unit, independently from the others. Moreover, as each organisational unit has some degree of decision autonomy and is separately managed, it is not uncommon to find in the same organisation several systems, developed with different technologies, sometimes very difficult to make compatible. For those reasons, as already mentioned, nowadays the information systems organisational landscape is made up of what is commonly known as "*islands of automation*" (Liao and Tu, 2007). Of course, this fact has undesirable consequences in terms of a non-integrated view and treatment of the organisation's information assets and operations.

This situation has historical justifications, some of organisational nature and some of technological nature. On the one hand, owing to the predominance of the functional model on which the organisations were structured, it is natural that the development of information systems should have been conducted according to the same paradigm, resulting in information systems that support the processing requirements of single functional units. On the other hand, as a consequence of the evolution occurred within the information and communication technologies, solutions that are now easy to conceive, were previously not even thinkable. In other words, the developed information systems have also been constrained by the technological possibilities of the time they were built.

Obviously, the ISD methodologies should be adapted, at every moment, to the characteristics and requirements of the organisations they are going to be applied to, and also to the emerging functionalities made available by the Information and Communication Technologies (ICT). In other words, the ISD methodologies must be permanently aligned with the organisational and technological circumstances of the moment. Regarding this matter, there have recently been some significant changes and advances both on the organisational and technological domains.

In the organisational domain, since the beginning of the 90's, and most notoriously with the work of Davenport (1993) and Hammer and Champy (1993), a new organisational paradigm has begun to take shape, associated with a set of organisational change programmes, among which the most widely known today is *Business Process Management* (BPM) (Rosemann and vom Brocke, 2015; Weske, 2012; Trkman, 2010; Dumas et al., 2013).

Contrarily to the hierarchical and functionally structured organisations, based on the Tayloristic model of work division, which was the standard organisational structure in the past, the concepts of *organisational process* (also known as *business process*), *teamwork* and people *empowerment* have emerged as the new paradigm on which the organisations should be based (Pereira, 2004). This new paradigm which promotes an integrated view of the organisations, is expected to prepare them to react adequately to the rapidly changing conditions of today's markets.

In the technological domain, as a result of the remarkable developments in the hardware and data communications fields, a set of new technologies, globally known as *groupware*, or *collaborative technologies*, has emerged. These technologies are primarily intended to support the communication and collaboration needs of people working together and thus, may help to achieve the integrated information systems infrastructure (Li et al., 2015).

This set of new technologies, also known as CSCW (*Computer Supported Cooperative Work*), is increasingly being used by organisations, as they understand that, today, sharing information and working in teams is the most effective way of doing business (Coleman, 1997). One of those technologies – *workflow* – is particularly suitable to support the co-ordination of work according to an organisational process.

Unfortunately, groupware technologies are being introduced into organisations in a very ad-hoc way, preventing them from taking full advantage of these technologies (Li et al., 2015). Obviously, the groupware technologies, in the same way as the more conventional information technologies, are going to be part of the global information systems technological infrastructure and so, they should be involved in the overall information systems development effort right from the beginning.

Besides the new paradigm which organisations are being forced to adopt in order to succeed in the market, and the new technological infrastructure available, another issue with a huge impact on the way information systems are developed is the rate at which the business environment is changing nowadays. In the past, even when the markets were stable and the levels of competition were moderate, the ISD methodologies in use were already incapable of delivering adequate solutions on time. In fact, that was one of the most often heard criticisms about ISD methodologies. Today, owing to the dynamics of the business environment, the situation is much more complicated. Indeed, if organisations keep on using those conventional ISD methodologies, they will end up with an even greater information systems backlog.

Of course, the same problem exists regarding information systems maintenance. Organisations must be able to change their information systems in a very rapid way, otherwise they will not be fast enough to react timely to the opportunities and threads that are continuously appearing.

In an effort to support the organisations more effectively, the ISD methodologies must take into account the facilities provided by the new technologies, the dynamics of the business environment and the new organisational paradigm (Pereira, 2004) (Fig.1).

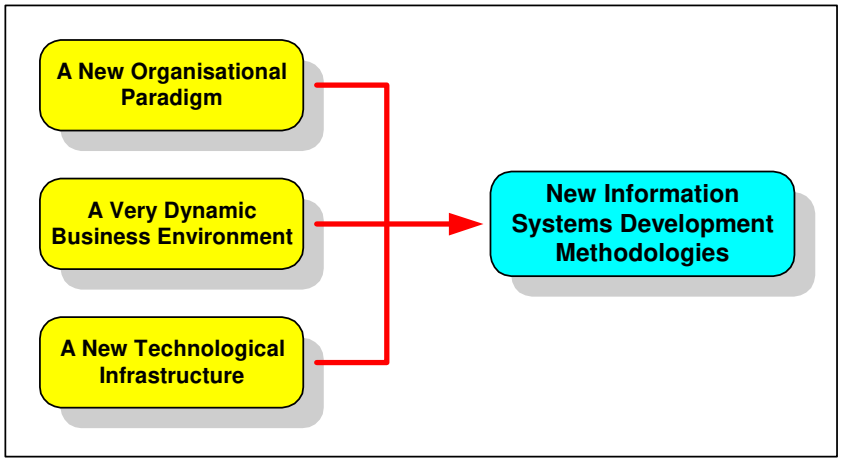

Fig. 1 - The need for new ISD methodologies

Nowadays, despite the huge number of ISD methodologies available (already in the nineties Avison & Fitzgerald (1995) mentioned the so-called "methodologies' jungle"), none of them takes into account these new and radically different organisational and technological environments, as they were developed with the specific organisational conditions and technological targets of the past in mind, and now fail to cope adequately with the new development environment. Obviously, the ISD methodologies should be adapted to the new organisational and technological context. In a sense, they need to be reviewed and adjusted to the new realities.

3. Collaborative Technologies

Groupware was defined by Ellis et al. (1991) as "*Computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment.*" The principal objective of this set of technologies is to facilitate the interaction between people working together, making them more effective and efficient. Electronic mail, videoconference, team rooms, group editors, discussion groups and workflow systems are just some examples of groupware technologies (Li et al., 2015).

A commonly used classification for the various groupware technologies is Johansen's Time/Space Matrix (Johansen, 1994). This classification tries to distinguish among the different groupware technologies, classifying them in time (synchronous/asynchronous) and space (centralised/distributed) dimensions (see Fig. 2).

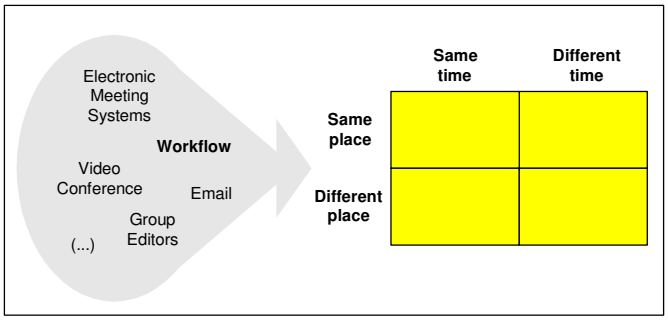

Fig. 2 - Groupware technologies and the Johansen's Time/Space Matrix

Although workflow systems are normally viewed as a kind of groupware system, there is a subtle but significant difference between workflow and the other types of groupware. While all of them intend to facilitate the communication and collaboration among people, the workflow systems aim, more specifically, to coordinate their interactions according to a particular organisational process (Van der Aalst and Van Hee, 2004).

Among other authors, Davenport has defined the concept of organisational process as "*a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action*" (Davenport, 1993). As an enabling technology, the fundamental idea behind workflow is the combination of individual tasks into a sequence of actions that achieve a goal, thus supporting directly the concept of organisational process. Consequently, the explicit support of organisational processes is the differentiating characteristic between workflow and the other groupware technologies.

The Workflow Management Coalition (WfMC), a non-profit international body created for the development and promotion of workflow standards, defines workflow as "*The automation of a business process, in whole or part, during which documents, information or tasks are passed from one*

participant to another for action, according to a set of procedural rules" (WfMC, 1999). Therefore, the notion of process automation is central to workflow technology.

A widely accepted classification of workflow products distinguishes among four categories: ad-hoc, collaborative, administrative and production workflow (Hollingsworth, 2004). The differences among them consist, very broadly speaking, in the more or less rigidity of the process enactment. Thus, in one extreme, we find production workflow, which aims to support the enactment of completely pre-defined processes, executing them in a very rigid and strict way. Obviously, these workflow systems are adequate to support mission-critical business processes, where nothing can fail and everything must be executed according to the pre-defined process models. In the other extreme, we find collaborative workflow, where the focus is not so much the process per si, but the sharing of information among the people (actors) involved in the process (Becker et al., 2002).

In Marshak's opinion (1997), "*although these categories are very useful and have helped customers get their minds around a very complex and diverse set of products (…) it is important to remember that processes often span categories of applications.*" And she adds, "*a continuum is a better metaphor for viewing workflow categories.*" (Fig. 3).

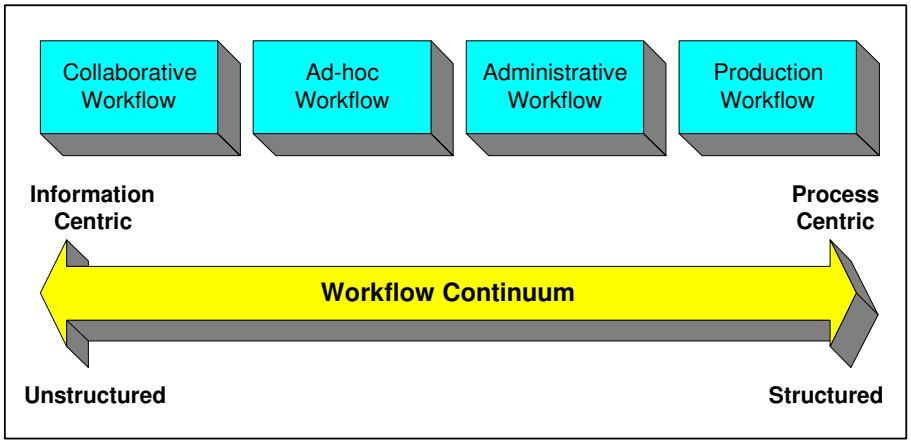

Fig. 3 - The Workflow Continuum

Structured and ill-structured processes coexist in any organisation. In real work environments there are no completely structured processes. The most common situation is a mixture of structured and ill-structured parts in the same process specification.

Business Process Management Systems (BPMS) are the modern software systems that implement the workflow concept by managing the execution of business processes, according to their specification models. During the execution of a business process, the BPMS delivers work to actors (humans or machines) according to the correspondent process model and the execution context of each particular process instance. In doing this, the workflow engine of the BPMS invokes the suitable available applications with the corresponding data involved, thus creating the adequate execution context for each process activity (Dumas et al., 2013).

The success of the business process paradigm has led to the development of many commercial BPMS. These include Oracle Business Process Management Suite, TIBCO ActiveMatrix, AuraPortal, Bizagi BPM Suite, and so on. In the open source community BPMS products like jBPM, Bonita BPM or Intalio are also very successful in the market.

One of the main characteristics of current BPMS lies in the implicit assumption that each activity is an individual activity. In other words, each activity is executed by a single actor (human or machine) during a time interval. Obviously, we can think of many situations in which two or more actors have to collaborate at the same time (being in the same or different places) in the execution of the same activity (e.g., a meeting to make a group decision). The general idea here is to relax the former constraint and be able to see an activity also as a group activity (Fig. 4).

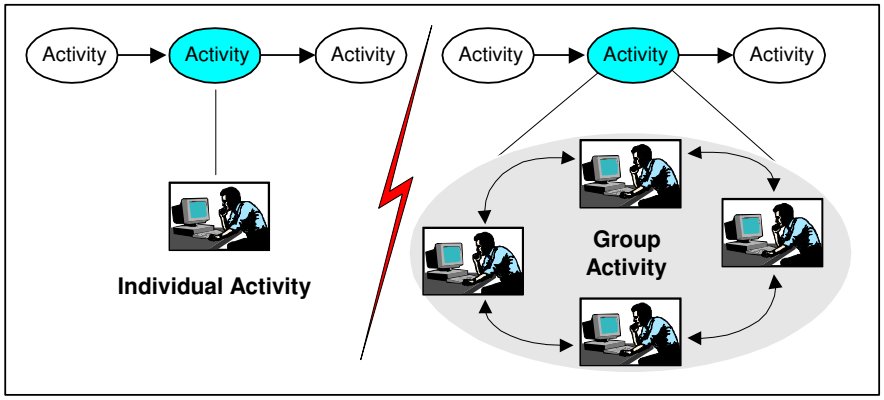

Fig. 4 - Individual Activities vs Group Activities

In fact, groupware technology may be regarded by the BPMS in the very same way as the other more conventional information technologies. Clearly, the ideal environment to support the enactment of organisational processes will be made of BPMS flexible enough to support all kinds of processes (the workflow continuum), and transparently integrated with both groupware technology for the support of group activities, and the more conventional information technologies which typically support individual activities.

4. Towards Process-based Information Systems

The integration of the large number of independent and disconnected computer-based information systems, which usually exist in a typical organisation, has always been considered a critical issue. Indeed, this integration is a way to create a global vision of the information and processing resources of the organisation, allowing their joint management.

The first systems integration efforts began with the Data Base Management Systems (DBMS). The general idea consisted in defining a common data model to harmonise and integrate all the organisational information resources in a unique data repository, available to all information systems – the *corporate data model*. In addition, since the construction of a centralised repository containing all the organisational data was not always possible or even viable, other solutions were built, such as distributed data bases in which the data was physically dispersed in several repositories but was seen by the application level as a unique, logically integrated, repository.

This kind of systems integration may be called *integration-via-data* (i.e., the systems are interconnected via data repositories). Nowadays, owing to the facilities provided by the new groupware technologies and, in particular workflow technology, a new possibility of systems integration has emerged, much more ambitious and promising than integration-via-data: the *integration-via-processes*. Moreover, this kind of information systems integration directly matches with the new organisational paradigm (Pereira, 2014).

In the heart of the integration-via-processes approach are the modern BPMS. In fact, a BPMS may be regarded as a very sophisticated form of middleware which, more than allowing a passive interconnection between different systems, allows their *active interconnection*, making them cooperate explicitly in the execution of an organisational process. Thus, a BPMS may be seen as a coordination level, which, if placed over the information and collaboration systems of the organisation, is able to control their cooperation (Pereira, 2014). To this global solution we call *Process-Based Information System* (PBIS) (Fig. 5).

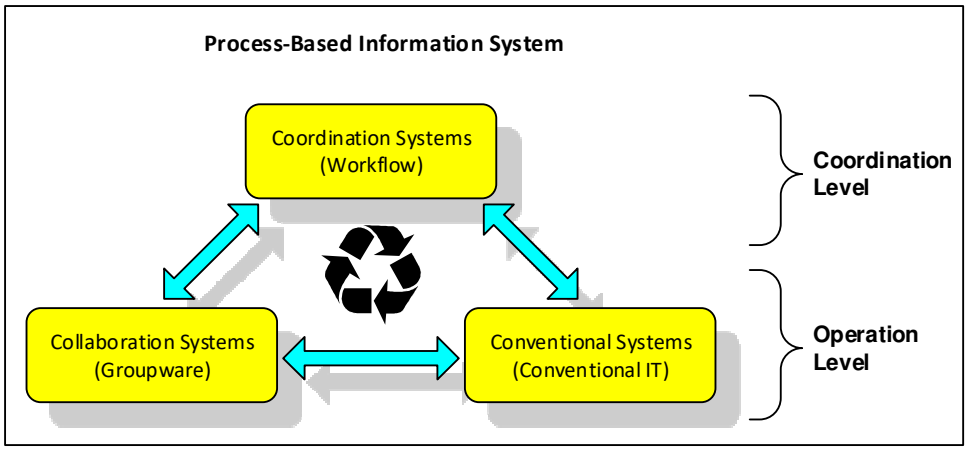

Fig. 5 – Process-Based Information System components

Due to the fundamental characteristic of BPMS that allows the explicit separation of the process logic from the applications which implement the activities in the process model, it is possible to change or redefine the organisational processes (*coordination level*) without affecting the existing applications (*operation level*). Thus, PBIS stand highly configurable, maintainable, and flexible (Fig. 6).

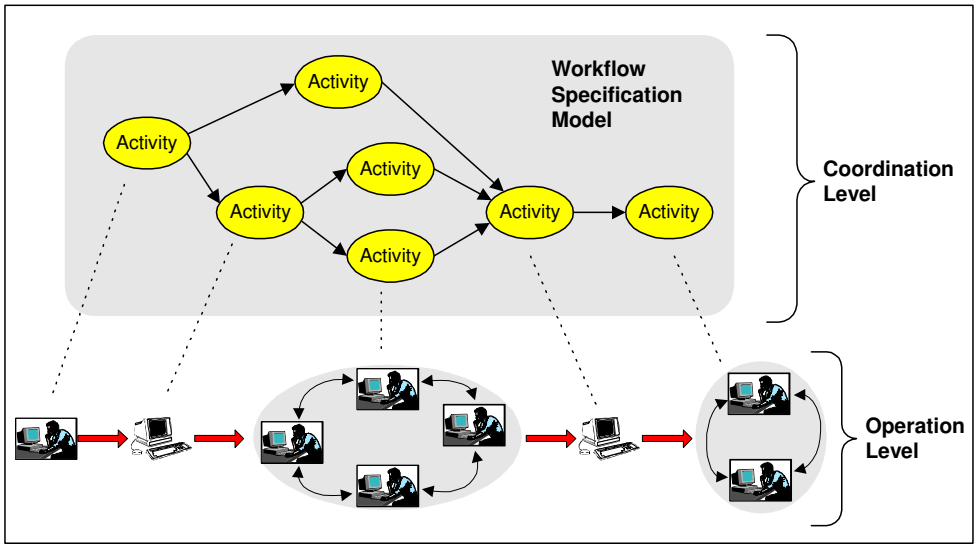

Fig. 6 - The PBIS framework

This approach promotes the incremental development of Information Systems. In fact, the PBIS is developed piece by piece, in a very modular way, by adding successive process models to the

coordination level, and reusing or, if not available in-house, developing or acquiring new applications in the operation level. As time goes by, the level of application's reuse will increase and, in the limit, the coordination level will be a fair representation of the *corporate process model*.

This ISD approach might also be regarded as a kind of component-based ISD, by analogy with component-based software development in the software engineering domain. A kind of "*programming in the large*", where complete software components, corresponding to autonomous applications, are combined and put to work together according to some organisational process specification. Furthermore, this architecture promotes the reutilization of those large software components by reusing them in several processes (Pereira, 2014).

Obviously, this is a framework which directly supports the new organisational paradigm (process-based organisations, teamwork and people empowerment), making use of the new technological infrastructure, and allowing organisations to develop and maintain their information systems quickly and easily (Pereira, 2014).

Clearly, the ideal environment to support the enactment of organisational processes will be made of BPMS flexible enough to support all kinds of processes (the workflow continuum), and transparently integrated with both groupware technology for the support of group activities, and the more conventional information technologies which typically support individual activities.

5. Requirements of a Methodology for Process-Based Information Systems

If a BPMS is simply used to automate the routing of electronic documents between workstations, then the process models developed with the graphic editors normally provided by the BPMS are, in principle, sufficient. However, if one wants BPMS to behave like a coordination system that interconnects pro-actively several people and/or computer-based systems, according to a set of organisational processes, then a systematic approach to the development of this kind of systems, with an appropriate life cycle, must be used (Pereira, 2004). In other words, a PBIS development (PBISD) methodology is needed.

Now, the obvious question is: "What are the specific characteristics of PBIS which distinguish them from the more conventional information systems?" The immediate answer is that, PBIS, besides conventional information systems, implies also the existence of coordination and collaboration systems (see Fig. 5). Therefore, fundamental concepts such as organisational process and teamwork are now present.

In a very simplistic way, we can say that conventional information systems are developed with a simple goal in mind: the automation of a set of processing tasks over some kind of data repository. When developing such a system, the critical issues are the identification of "*what needs to be done and how*" and "*which data is involved*". Thus, conventional information systems assume a task-oriented and data-oriented perspective.

Clearly, any approach to the development of PBIS must involve a joint analysis of the organisational processes (including their social and organisational issues), the applications required by the various activities that make up the processes, and the data processed by those activities.

Perhaps, the best way to characterise the scope of a PBISD methodology is to define the set of perspectives that must be considered when developing a PBIS. Besides the functional and informational perspectives of conventional information systems, we must analyse the coordination and collaboration dimensions of a PBIS.

Regarding the coordination dimension, Curtis et al. (1992) state that there are four critical perspectives in a process model:

- The functional perspective (*what needs to be done and how*)
- The informational perspective (*which data is involved*)
- The behavioural perspective (*when it is done*)
- The organisational perspective (*who does it*)

So, besides the functional and informational perspectives which are common to conventional information systems, at least two new perspectives (the behavioural and the organisational), with their corresponding modelling methods, must be considered in a PBISD methodology.

Concerning the collaboration dimension of PBIS we argue that the following three perspectives are essential:

- The group perspective (*who interacts with whom*)
- The interaction perspective (*what facilities are needed for the interaction*)
- The responsibility perspective (*who is responsible for the interaction*)

With these three additional perspectives, now we have, at least, seven perspectives we must consider in a PBISD methodology.

Business process models are the starting point for requirements specification of the systems to be developed. In this perspective, we assume that most of the issues and details that are needed to develop PBIS may be derived from business process models (see Fig. 7).

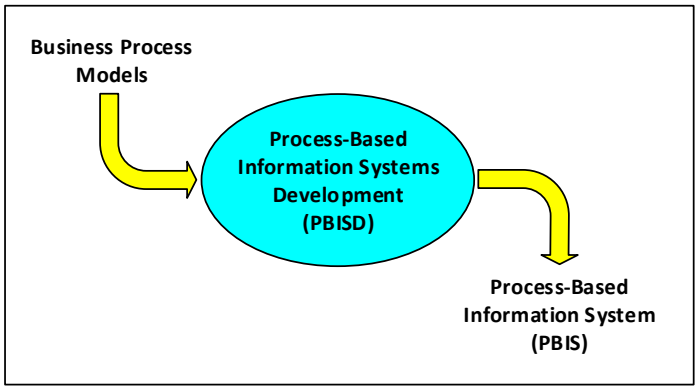

Fig. 7 - From Business Process Models to PBIS

None of the conventional ISD methodologies takes into account all of these perspectives. In fact, the coordination and collaboration dimensions, critical in the development of PBIS, are simply not considered in the conventional ISD methodologies that we are aware of. Therefore, it is our claim that a new PBISD methodology, that considers all the above perspectives, is needed.

6. Conclusion

Considering the functionalities made available by collaborative technologies, most particularly the workflow technology, it is now possible to evolve onto the integrated PBIS. Although there are today many information systems development methodologies, none of them takes into account the new technological developments, with characteristics radically different from the more conventional technologies, for whom those methodologies were made. Therefore, we need a new approach to information systems development that takes into consideration not only the more conventional technologies, but also the more recent collaborative technologies. In this paper, additionally to the definition of the PBIS concept, we have described the major requirements that a PBIS development methodology (PBISD) has to take into account.

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References

Avison, D.E., Fitzgerald, D., (1995), Information Systems Development: Methodologies, Techniques and Tools (2nd Ed.), McGraw-Hill.

Becker, J., zur Muehlen, M., Gille, M., (2002), Workflow application architectures: classification and characteristics of workflow-based information systems, in Workflow Handbook 2002, Layna Fischer (Ed.), Future Strategies,

Brodie, M.L., Ceri, S., (1992), "On Intelligent and Cooperative Information Systems: A Workshop Summary", *Journal of Intelligent and Cooperative Information Systems*, Vol. 1, No. 3.

Coleman, D., (1997), "Groupware: The Changing Environment" in Groupware: Collaborative Strategies for Corporate LANs and Intranets, Coleman, D. (eds.), Prentice-hall, pp. 1-38.

Curtis, B., Kellner, M., Over, J., (1992), "Process Management", *Communications of the ACM*, Vol. 35, No. 9.

Davenport, T., (1993), Process Innovation, Re-engineering Work Through Information Technology, Harvard Business Press.

Dumas, M., La Rosa, M., Mendling, J., Reijers, H.A., (2013), Fundamentals of Business Process Management. Berlin Heidelberg: Springer.

Ellis, C.A., Gibbs, S.J., Rein, G.L., (1991), "Groupware: Some Issues and Experiences," *Communications of the ACM*, Vol. 43, No.1, pp 39-58.

Hammer, M., Champy, J., (1993), Reengineering the Corporation: A Manifesto for Business Revolution, Harper-Collins.

Hernaus, T., (2011), Business trends and tendencies in organization design and work design practice: Identifying cause-and-effect relationships. EFZG Working Paper Series/EFZG Serija članaka u nastajanju, (03), 1-18.

Hollingsworth, D., (2004), "The Workflow Reference Model: 10 Years On" in Workflow Handbook 2004, L. Fischer (eds.), Future Strategies Inc., pp. 295-312.

Johansen, L., (1994), "Groupware: Future Directions and Wild Cards", *Journal of Organizational Computing* (2:1), pp 219-227.

Li, L., Guo, R., Zheng, J., (2015), Assessing and Promoting Groupware for Effective Team Collaboration – A comprehensive Study. In Proceedings of the Southern Association for Information Systems Conference, Hilton Head Island, SC, USA.

Liao, K., Tu, Q., (2007), "Leveraging automation and integration to improve manufacturing performance under uncertainty: An empirical study", *Journal of Manufacturing Technology Management*.

Marshak, R.T., (1997), "Workflow: Applying Automation to Group Processes" in Groupware: Collaborative Strategies for Corporate LANs and Intranets, Coleman, D. (eds.), Prentice-hall, pp. 143-181.

Pereira, J.L., (2004), "Sistemas de Informação para o Novo Paradigma Organizacional: O Contributo dos Sistemas de Informação Cooperativos", Tese de Doutoramento, Universidade do Minho, Portugal.

Pereira, J.L., (2014), Process-based Information Systems: A Component-based Systems Development Infrastructure, Proceedings of the 3th International Conference on Virtual and Networked Organizations, Emergent Technologies and Tools, Portugal.

Rosemann, M., vom Brocke, J., (2015), The six core elements of business process management. In Handbook on Business Process Management 1. pp. 105-122. Berlin Heidelberg: Springer.

Trkman, P., (2010), "The critical success factors of business process management", *International Journal of Information Management*, Vol. 30 No 2, pp. 125-134.

Van der Aalst, W., Van Hee, K.M., (2004), Workflow management: models, methods, and systems. MIT press.

Weske, M., (2012), Business Process Management: Concepts, Languages, Architectures. Springer Science & Business Media, Vol. 54.
WfMC, (1999) The Workflow Management Coalition Terminology and Glossary, WFMC-TC-1011, Workflow Management Coalition.