KEY-PROBLEM BASED INFORMATION SYSTEM DESIGN AND INTEGRATED ENTERPRISE MODELLING

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Abstract: In today's highly competitive global economy enterprise integration (EI) can take a major role in performance improvement. The more the scope of EI is enlarged, the more users, who are not integration experts, are involved. This fact generates communication problems. For the information system (IS), which remains the main integration vehicle, the situation is obviously similar. In this paper, it is proposed to analyse IS design techniques and develop a key-problem based approach, because it involves efficiently users. Then it is shown how to use them to improve the carrying out of a model of an integrated enterprise.

Keywords: information systems, information technology, design, enterprise integration, enterprise modelling.

1. INTRODUCTION

In today's highly competitive global economy, the necessity for 'integration in the enterprise' has been acknowledged and developed amongst others in (AMICE, 1993), and more recently in (Vernadat, 2002). Enterprise integration can be seen as the task of improving the performance of complex organisations by managing the interactions among the participants (Petrie, 1992). This improvement and the integration concept is evolving from a technological focus to a more global organisational one. In this boarder, information systems (IS) and related information technologies (IT) occupy a prime position. The drive for an integrated enterprise is mainly generated from the need of enterprises to provide timely availability of data and information to both internal participants and external partners (Huat Lim *et al.*, 1997). In other words, IS is the backbone of an integrated enterprise. Even if an integrated IS does not assume that enterprise activity has been integrated, IS remains the main 'integration vehicle' (Alsène, 1999).

Therefore, because of the enlarged scope of EI, the IS includes more and more users, who are not integration and IS experts. Only a few people are directly involved in the business process integration and in the design of the related IS. However, to be successful,l EI requires the efficient participation of all users during the integration project. So, relevant models supporting communication and common understanding among users have to be provided. In this boarder, there are many separate research streams that attempt to address EI (Giachetti, 2004). The most significant contributions are on the one hand linked with enterprise modelling and on the other hand with IS design and development. However a few efforts are made to use them in a complementary manner in order to benefit from a cross-disciplinary enrichment. The scope of this paper is to propose a reliable approach centred on the IS and its architecture. This approach enables to gather the relevant knowledge required for carrying out the conceptual model of an integrated enterprise.

The second section is devoted to a brief description of existing approaches for EI in the enterprise modelling and the IS design fields. These two standpoints are described from the shared representation and communication support perspectives. They are analysed in order to

emphasise their advantages, drawbacks and complementarities. In the third section, a brief study of the approaches currently used to build an IS architecture is made. In the fourth section, the proposal to improve IS architecture reliability is developed. This proposal is based on a key-problem framework and a procedure to exploit it. In the last section, the proposed approach will be discussed according to the EI and modelling perspectives.

2. ENTERPRISE MODELLING AND INFORMATION SYSTEM RESEARCH STREAMS FOR ENTERPRISE INTEGRATION

2.1. Enterprise modelling and enterprise integration

Enterprise Modelling is the art of externalizing enterprise knowledge which adds value to enterprise or needs to be shared. It consists in making models of the structure, behavior and organisation of the enterprise (Vernadat, 2002). Enterprise modelling is a pre-requisite to EI (Vernadat, 1996). Indeed, to carry out the project of master planning and implementation of an 'integrated enterprise system' is an extremely complex process which involves different technological, human and organisational elements (Chalmeta *et al.*, 2001). In order to make the study of existing systems easier by reducing the complexity level, it is necessary to establish a step by step development 'methodology' and to 'formalise' the creative process in each phase of the whole project (Pantakar *et al.*, 1995)

Thus, the management of EI projects evolves from informal and unstructured management based on past experience to more robust procedures derived from 'analysis based on models'. Various approaches like PERA (Williams, 1992), CIMOSA (AMICE, 1993), etc. have been proposed in the enterprise modelling field to deal with EI. Generally, these approaches are carried out as a part of reference architectures. A reference architecture is a framework, which guides the project of design and implementation of an integrated system by means of a structured methodology, the formalisation of operations and the support tools (Burkel, 1991). These reference architectures must enable to improve the EI process by decreasing the necessary time to develop the system and by improving the quality of the produced solutions. Indeed, they must guide the development and application of all the disciplines involved in the EI project, systematically modelling all parts of the life cycle of the enterprise (Chalmeta et al., 2001). In other words, these proposals focus on the modelling of one or several aspects of the enterprise (function, decision, information, etc.). However, according to the analysis of these proposals made in (Ortiz *et al.*, 1999), several issues are not addressed:

- Most of the proposals do not cover fully the handling of the enterprise strategy (mission, vision, values, critical success factors, strategies). It could go beyond a simple definition prospective, and should make the strategy relevant in the development of the whole EI program (Porter, 1996)
- The necessities in terms of model languages adapted for management levels (i.e., user-friendly, simple and easy-to-use) have not been adequately addressed. In these management levels, the emphasis is on simple models with information centred on the parameters which allow management to make decisions. These models have to reflect reality, they should aggregate relevant information especially on resource capabilities and on time behaviour of any model to support decisions.

From the point of view shared representation, the required skills and knowledge to fully understand the used models remain a problem. Indeed, these models often deal with languages, which require to be an expert to master them. This harms their potential use. These shortcomings are all the more harmful since EI involve not only 'integration experts' but also all users and actors of the domains to be integrated (for example: business process and/or application integration).

2.2. Information system development and enterprise integration

In the IS design and development field, contributions concerning EI like (Hasselbring, 2000 ; Papazoglou *et al.*, 2000) focus generally on IS strategic alignment. IS strategic alignment is the linkage of the firm's IS and business plans. This linkage must be particularly relevant in an integrated enterprise. These works generally deal with the notion of IS infrastructure or architecture. The IS architecture is composed of the definition of the **components** of the IS, a description of their **interconnections** (both 'logical' and 'physical' within a network, for instance) and finally, their **interaction in time** (system dynamics).

The management of related projects is generally structured as generic time segments, the main phases of which are as follows: preliminary study, detailed design, realisation, implementation and assessment. The communication among users and developers is based on the 'collective' design, during the

preliminary study, of the IS architecture. This concept offers the advantage to be understood by all users involved in the project. Indeed, it encompasses among other things components, which reflect the reality. However, the last four generic phases of IS design and development are organised according to project characterisation criteria; most of which are quantified on the basis of the IS architecture defined previously. Consequently, calling the 'preliminary' architecture into question during the detailed design phase, for example, implies not only rerunning this phase – at least in part – but also reconfiguring all the downstream phases. This harms this standpoint.

2.3. Synthesis

In this sub-section, it is proposed to analyse the EI situation according to these two standpoints. In order to improve the analysis, the situation is intensified.

From the point of view enterprise modelling, the IS design situation seems not surprising. It is normal that a 'preliminary' IS architecture designed at the outset has to be called into question and redefined. Indeed, the coherence of the underlying integrated business processes has not been checked formally through modelling at all levels of abstraction (even conceptual level and not only architectural level). However, experience from industrial practice shows that the definition of workflow models is a very time consuming and error prone task (Herbst *et al.*, 2004).

So from the standpoint of IS design and development, means to guarantee the reliability of IS architectures, determined during the preliminary study, seem crucial. The existence of such an efficient process (in terms of reliability and consumed time) should enable to save the carrying out and the maintenance of an enterprise model. However, the enterprise model remains in the heart of EI and could be improved through IS architecture design. Indeed, the design of a 'preliminary' IS architecture could be considered as a preliminary stage for enterprise modelling. During this stage, the gathering of relevant and reliable information, required to build the model of an integrated enterprise, could be achieved. Indeed, the IS is the backbone of the integrated enterprise. So, improving the reliability of IS architecture design contributes to improve the carrying out of the model of an integrated enterprise.

Within this context, the aim of this communication is to suggest a reliable approach to working out an IS architecture. To do this, a dialectic analysis, as put forward in the OTSM-TRIZ theory (Khomenko *et al.*, 2002), is proposed. Before describing the proposed approach which is based on a key-problem framework and a procedure to exploit them, a brief study of the approaches currently used to define an IS architecture is conducted.

3. CURRENT APPROACHES IN INFORMATION SYSTEM ARCHITECTURE IDENTIFICATION

Working out the IS architecture can be approached in two different ways: with or without an a priori choice of target technology. An extent description of the current approaches in architecture identification can be found in (Goepp *et al.*, 2004).

3.1. Approaches based on target technology

This kind of approach consists in characterising the technological components which can be implemented and in defining the minimum approach required to identify their application potential within a target system. In this category, the following approaches can be observed:

- proposing an architecture based on knowledge of the pair target technology/application conditions like the approaches proposed in (Shakshuki *et al.*, 2003)
- proposing an architecture for workflow type applications through workflow mining like in (van der Aalst et al., 2004)

3.2. Approaches not based on target technology

The second kind of approach focuses on the basic system requirements in order to start the analysis at conceptual level. But difficulties are still encountered when establishing the link with the technological components at the architectural level. The following approaches fall into this category:

- The architecture is designed from the results of a requirement engineering (RE) phase like in (Rolland *et al.*, 1998)
- The architecture can be built up by confronting the life cycle of the IS with other sub-systems within the company which are in the IS environment. An analysis framework must help determine the components which will be implemented according this confrontation. Such an approach is proposed in *(Goossenaerts, 2000)*

3.3. Synthesis

Most architecture design approaches are built up around an a priori choice of technologies whereas others are based on identification of the basic requirements that the IS has to fulfil. These

requirements are in fact, in the scope of enterprise modelling, a conceptual view of the IS. In these approaches, the conceptual nature of the analysis makes the link with technological components difficult. In other words, processes to support and guide the effective construction of the architecture are lacking. Specially, the involvement of the users during conceptual work is still a problem. In the field of enterprise modelling, GIM methodology, exposed in (Chen *et al.*, 1997), shows that discussions around the concept of problem are efficient to involve users during design of decisional system.

So, it is proposed to combine the use of semiotics, to work at conceptual level, and the use of the concept of problem, to work efficiently with users. This combination is completed into a dialectical approach in order to make a in depth analysis, as demonstrated in (Bratteteig *et al.*, 1994) for the IS field. The proposed dialectic analysis is based on OTSM-TRIZ (Khomenko et al., 2002).

4. INFORMATION SYSTEM ARCHITECTURE DESIGN APPROACH AND ENTERPRISE MODELLING

4.1. Key-problem framework

As a first step, a semiotic analysis framework and the dialectic approach of OTSM-TRIZ are used to build a key-problem framework. The central point of this approach is the contradiction concept. Different contradiction classes are defined. The most general angle is the 'evolution' contradiction, which is defined as:

- The contradiction for a class of systems to limit the study field
- The contradiction associated to a generic function to be fulfilled by this class of systems
- The contradiction between two performance parameters of this function
- The contradiction expressed through a characteristic element of the function.

The complete method to formulate contradictions has been developed fully in (Goepp *et al.*, 2003) using the semiotic framework proposed in (Stamper *et al.*, 2000) to determine generic IS functions. The outcome is a key-problem framework (cf. Fig. 1), representing the generic set of problems to be solved, on a macro level, during the architecture design phase. It contains three contradictions related respectively to the amount of information, its degree of specificity and decision-making freedom. Each contradiction exists because of the individual and collective duality of the performance of the 'store', 'adapting' and 'framing' functions. Indeed, performance on the individual level is characterised by action efficiency, whereas on the collective level, the key element is the emergence of shared representations. This duality is expressed via a characteristic element of each function.

The characteristic element associated with the 'store' function is the amount of information. The associated contradiction is: **the amount of information made available to each person must be increased to enhance coordination and the improvement of the organisation, BUT it should not be increased because too much information harms the efficiency of the action.**

The characteristic element associated with the 'adapting' function is the degree of specificity of the information. The associated contradiction is: **The degree of specificity of the information available to each person must be increased so that the data is exploited efficiently, BUT this must not be done because it harms the coordination and improvement of the organisation**.

The characteristic element associated with the 'framing' function is the freedom to make decisions. The associated contradiction is: **Freedom to make decisions must be reduced in actions in order to limit "non quality" and be efficient in the action, BUT this must not be done because the people need a certain autonomy which is essential to implement organisational learning.**

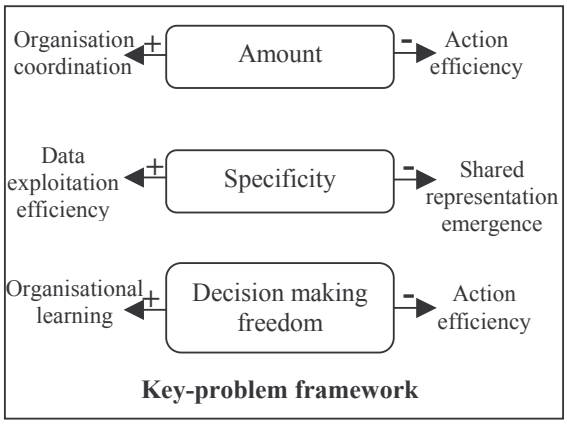

Fig. 1. Key-problem framework overview.

Next section presents a procedure to exploit these contradictions.

4.2. The phases in the architecture identification method

The proposed approach consists in analysing the particular conditions of IS integration from the angle

of ‘evolution’ contradictions. A target architecture is defined using the acknowledged contradictions as a basis. The proposed method includes following stages: (1) Finding acknowledged contradictions, (2) Determining the ‘extreme architectures’, (3) Moving from ‘extreme architectures’ to a target architecture.

4.3. Finding acknowledged contradictions

The first stage consists in determining the acknowledged contradictions for the IS under study. Identifying the ‘individual’ and ‘collective’ roles of a specific IS under study enables the three ‘evolution’ contradictions to be reformulated so that they can be assessed by the IS users. Interviews are conducted to carry out an appraisal of the framework. At this stage, the integration needs can be gathered without taking operational difficulties into account. Moreover, it is supported by the framework.

4.4. Determining ‘extreme’ architectures

This phase uses the acknowledged contradictions to define ‘extreme’ architectures. An extreme architecture is an architecture corresponding to a combination of the basic intensification of the acknowledged contradictions. For each contradiction, two basic intensifications can be envisaged: one focusing on the collective aspect and the other on the individual aspect. Thus, for the contradiction relating to the amount of information, focusing on the individual aspect means reducing the amount of information, at the most. For the same contradiction, focusing on the collective aspect means increasing the amount of information, at the most.

During this stage, acknowledged contradictions are linked to architectural elements, which assist the communication with users involved in integration. These different architectures are asymptotical architectures to real situations. They intensify the number and type of components to be implemented. It provokes user reactions. These are essential to gather important information from the users such as specific hidden limits. Sometimes, the absurd nature of certain extreme architectures is highlighted and enable thus to scan different integration possibilities.

4.5. Moving from extreme architectures to one ‘target’ architecture

In practice, having set aside the absurd ‘extreme’ architectures, the remaining architectures are made to converge towards a target architecture. To do this, the ‘multi-screen’ view is used. It enables (cf. Fig. 2) to relocate the system under study both on a time scale (past, present, future) and on a systemic scale (sub-system, system, super-system).

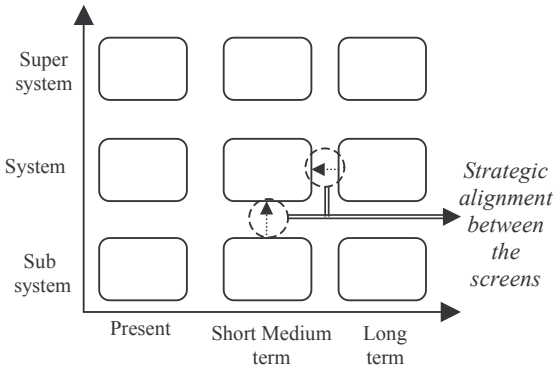

Fig. 2: “Multi-screen” view tool

This graph provides a structuring support giving coherence to the IS and its environment. It forces to check consistency between the IS and related systems. The use of a time scale emphasises not only the information processed through the IS but its coordinated evolution within the company context. The combination of a systemic and a ‘time horizon’ analysis provides a roadmap of the IS to assess the choices made at the architectural level. This is essential for EI where all parts of the company have to be coordinated. It enables to support and integrate the formulation of coherent strategies. Through this analysis, remaining integration problems, which can not be solved through the IS, are highlighted. These problems can then be carefully treated using enterprise modelling techniques.

5. CONCLUSIONS AND PERSPECTIVES

In this paper, it is proposed to link IS architecture identification to enterprise modelling in order to improve the carrying out of the conceptual model of an integrated enterprise. The work at the ‘architectural’ level is based on a key-problem framework. Discussions around problems combined with principles, such as intensification and ‘multi-screen’ view, provide a reliable approach to carrying out an IS architecture. It avoids the a priori choice of technology, which is too restrictive in the EI context. It enables to guide effectively and check carefully different evolution possibilities for the IS in terms of information technologies and related organisational changes. Moreover, the proposal enables to support and improve communication between the users involved in the integration project. In other words, the definition of shared architectures is proposed to be a preliminary phase for enterprise modelling. The gathered knowledge concerns integration objectives and requirements, possible solution directions for IS integration and remaining integration problems.

However, the use of this method is limited to medium-scale projects for two reasons. First, the project leader has to be able to determine the state of a contradiction (acknowledged or not) for the whole field of study. Secondly, he should be able to perform an abstraction from the target architecture to the integrated model of the process, in order to check consistency of this model. For larger scale projects, a gradual breakdown of the analysis level of the state of contradictions will probably be required. Moreover, it would be useful to link several conceptual models designed by several experts to check consistency of the integrated process.

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