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A Flexible Enterprise Needs an Adaptable e-Business Architecture in order to Satisfy Naturally Evolving Requirements

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***Abstract*- Standards for exchange of purchasing information, such as ANSI X-12 for EDI, have been used by large industries (e.g. retail and auto) for almost 30 years. Newer web-based tools and new standards hold the promise of reduced cost and wider applicability. For many small to medium sized enterprises, the cost and rigidity of existing tools out weight the prospective gains, which must be amortised over comparatively few transactions. In this paper, we describe the development of an N-tiered, object-oriented, architecture for interacting with suppliers based on emerging web tools. We explore the ways in which the project was required to adapt to existing purchasing systems and the ways that the project evolved during its development. We identify patterns in the inevitable evolution of requirements during the implementation, and we describe the ways that the architecture facilitated the satisfaction of these changing requirements. By analysing the major "transition points" during the development, we attempt to document the fundamental nature of evolving requirements and the need to explicitly reflect them in adaptable e-business architectures.**

I. Current Business-to-Business Standard solutions Fail for Specialised Purchasing

The success of standard systems such as EDI comes, in large part, because it can be applied to large and relatively homogeneous business-to-business transactions with large economies of scale. For a number of small to medium sized enterprises (SMEs), neither the degree of standardisation nor the economies of scale apply. For these situations, there may be a wide range of relationships between customer and supplier and each might, in principle, require a separate standard for interaction. In this paper, we describe our experience with a real world problem of developing a web-based system for mediating the communication between an SME and its suppliers.

According to a recent study [1], a majority of IT projects are either cancelled or "challenged" by cost/time overruns. In our experience, we have found that e-business applications for SMEs provide special problems that relate to agile nature of many SMEs. An agile enterprise will, naturally, have flexible methods of interaction with a variety of suppliers. In addition, the typical SME will be able to respond to changing market forces by rapidly evolving new products and new patterns of interaction with suppliers. Thus, an agile SME will require that any e-business support both their flexibility of existing interaction patterns and the rapid evolution of the enterprise [2].

The flexibility that is normal in a typical SME gives rise to a requirement that any e-business solution be able to match the current diverse configuration of interactions and to evolve along with the organisation. In our development work, we have identified the need to respond to variations in requirements as a fundamental part of designing and building e-business applications. We differentiate variation across situations (such as the different communication patterns with different suppliers) from variations across time (such as the evolution of the relationship between Breton and a supplier). We have found that inadequate attention to this requirement fundamentally limits the possibility of developing a successful e-business application for small enterprises. The reason lies in the fact that agility is a fundamental need for an SME and must be effectively reflected in the applications supporting the company operations.

II. Breton: An Agile SME with Variation in Requirements for e-Business

Much of our thinking about the importance of building an adaptable architecture for e-business applications comes from our experience with the SME, Breton. Breton is a manufacturer of production lines for finished stone, and has a leadership position in its market. It is located in the north east of Italy, a region characterised by the presence of a large number of successful SMEs, and it employs 400 people. The company turnover has grown from 30000 Euro in 1963 (year of foundation) to over 75 million Euro today. The company has interaction with approximately 450 suppliers (90 of them cover 80% of purchases and are considered critical) and has widely varying patterns of interaction with suppliers. Breton maintains a variety of relationships with suppliers: some supply interchangeable parts while some suppliers become preferred and stable partners. Some contracts are given to keep alive a relationship or to test supplier's ability in producing critical components. There are 12 buyers directly in touch with the suppliers and everyday they interact mainly by phone to update, remind, and redefine conditions and details. They work as gatekeepers between the firm's production plan (they used to print a report that lists the order to be received) and the suppliers production scheduling. The buyer is a communication joint between the internal needs (production scheduling) and the external response (actual delivery time). Such a role is accomplished by accumulation of constantly updated knowledge provided by daily interaction with the suppliers. The purchasing department is divided in four areas, each responsible of a subset of suppliers, grouped by product category. Such a distinction appears to be relevant as product peculiarities (e.g. custom made versus catalogue items) induced different patterns of relationships and communication needs. A relevant example in this case deals with the production of custom components, which requires an iterated exchange of documents in various formats (e.g. CAD drawings and technical specifications) and direct interaction.

Breton's relations with its suppliers form an extremely heterogeneous system of interactions: a variety including both spot purchases of standardised goods and stable relationships among actors who develop customised solutions together. While the former is quite similar to what today is offered by business-to-consumer e-commerce, the latter

exhibits a high degree of variety which depends on the context (actors involved) and content (the specific object of the interactions). Traditional e-business techniques can handle the standardised interactions but are not rich enough to deal with the more customised solutions. Early in the discussion process with Breton, we saw that business-to-consumer models and standards like EDI would not meet the need for varying requirements across suppliers and across time.

The variety of interactions with suppliers is related to the role played by both the suppliers and the components:

- size of suppliers – from the toolmakers to multinational companies;
- degree of trust – the amount of company knowledge that is shared with a supplier (e.g. CAD drawings);
- role of the supplier – from being one of the many suppliers for a component to being the "preferred" one. In fact, for each component Breton identifies a set of dependable suppliers among which one is selected;
- time span of the relationship – new suppliers (or possibly a new product supplied by an established supplier) versus long term suppliers;
- reliability in delivery time – suppliers which do not have a reputation of being dependable in delivery are closely monitored as deadline approaches;
- cost of product supplied – both for the direct purchasing cost and for the opportunity cost for alternatives;
- idiosyncrasy of supplied component – related to the degree of customisation of the part supplied, from standardised catalogue items to fully customised products;
- physical proximity of the supplier to Breton – representatives of very small companies in the area travel almost daily to Breton for deliveries and can interact with buyers directly;
- communication medium – from simple fax or exchange of CAD/CAM drawings to face to face interaction.

Depending on these dimensions the order may imply different procedures, e.g. tacit confirmation, explicit confirmation, explicit notification of delay. The system should support the variety of documents and computer files associated with the kind of supplier interaction and components described in the list above. Moreover, there is the need to be responsive to the evolution of the relationship and to keep track of the order processing. Finally, the information system to be completely effective would need to provide quick answers to unexpected problems.

As a leader in its field, Breton was interested in streamlining this procurement process while providing better access to information for its purchasing agents and its suppliers. The company growth in the last decade has pushed Breton to adopt a standardised production planner which requires to change the system of relationships with the suppliers previously characterised by informality and customisation. In the remainder of this paper, we discuss the nature of e-business as a solution to the supply chain management needs we found at Breton. Then we present the architecture of the computer information system we developed for mediating interaction with suppliers, and what we have learned about building such systems.

III. An Adaptable e-Business Architecture

Early in the project, the activities of the buyers in the purchasing department were analysed, by means of interviews and participant observation for a period of two months. We collected data about the patterns of interactions that buyers have with both other internal departments and suppliers. From these macro activities three predominant use cases were identified as the ones to be supported by the system: 1) a buyer reviewing the status of outstanding orders, 2) a buyer interacting with a supplier to complete a purchase transaction, and 3) a supplier obtaining supporting information and/or clarification of an existing order. These three use cases drove the early development phases of the project. Modifications to the presentation of information and to the interaction with the system were later made based upon two levels of pilot use of the system.

From the start, Breton identified the development of a web-based system using standard Microsoft based tools as a constraint for the project. An intuition that emerged from Breton was to develop several "cartridges", modules that could be used for different purposes. Following such a rational, an architecture based on components was the natural choice. The articulation with the existing internal purchasing system was an additional hard constraint. Additional constraints relating to security and operating modes evolved during the course of the project based upon experience with the emerging prototype. As we will see later, the nature of the interaction between Breton and a university group imposed some additional constraints on the nature of the project.

N-tiered Architecture Separates Issues

Due to the evolutionary nature of this entire project, we adopted an N-tiered architecture from the outset. As the figure below shows, the strongest disjunction occurs in the separation of the user interface layer from the distributed business objects layer and the data layer. By separating the layers in this way, we were able to allow each of the layers to evolve independently with minimum ripple effects to the others. For example, the initial prototype was a single Visual Basic program with no web connectivity at all. By packaging the user interaction layer in reusable ActiveX controls and introducing the business object proxy, we were able to adapt the system to web-based communication with only small revisions.

It is possible to identify eight distinct layers spread across the three fundamentally separate tiers:

1. Web browser – user interface host;
2. ActiveX controls – encapsulation of purchasing interaction with both suppliers and buyers, based on type of interaction and security level;
3. Business Object Proxy – simple client side caching and data validation along with support for the network communication;

4. WWW connectivity – use of public web connections for communication using security and encryption measures for ensuring privacy;
5. WEB Server – providing connectivity to clients and instantiating the business objects that control the interaction and supply the data;
6. Object Model of Procurement – an explicit model of the relationships between the various elements of the procurement process (e.g. order items, drawings) and the business rules that govern their creation, access and evolution;
7. Object to relational server – a data tool that encapsulates relational database tables as objects and collections of objects, there by allowing the object model for procurement to be written as though it was supported by an object-oriented database;
8. Specialised data store level – supporting both relational and indexed sequential files for providing access to legacy databases along with the security and status database developed for this project.

The clear and rigid separation of the eight layers above provides a large measure of the adaptability of the system. For example, by replacing the Business Object proxy to Web server connection with DCOM, we can produce a much more efficient internal data access system for use by the buyers at Breton. We have already been forced to replace low level data access modules for connecting to the legacy databases because of programming incompatibilities. The Object to relational layer has insulated the remainder of the system from these low level changes.

Business Object Modelling "Matches" the Organisational and Operational Structure at Breton

The N-tiered separation of function is largely a computer programming architecture designed to avoid the contamination of a model of the business rules with either user interface or data access details [3,4]. Although the structure of the user interface, which must flow naturally out of the business object structure, is what the user uses to evaluate the suitability of the system, it is the structure of the business objects that ultimately decide the fate of the system.

The business object model we developed for this project evolved out of the collection of organisational and operating patterns at Breton supplemented by identification of the three predominant use case interaction patterns. The model we developed contained approximately twenty business object classes. The classes were generally arranged in a containment structure, e.g. an order contains order items, which, in turn, contain part identification and (optionally) drawing information. General relationships among business objects were also modelled explicitly, e.g. the association of some suppliers to a particular buyer at Breton.

After developing the initial business object model and the relationships between the various objects, we identified the business rules that must be enforced for this project, e.g. data visibility as a function of user identity and status, or progress of an order through the system. These business rules were then attached to the business object containing the data most central to the operation of the business rule. Finally, the rule was attached to the user interface to allow it to be invoked at the proper time.

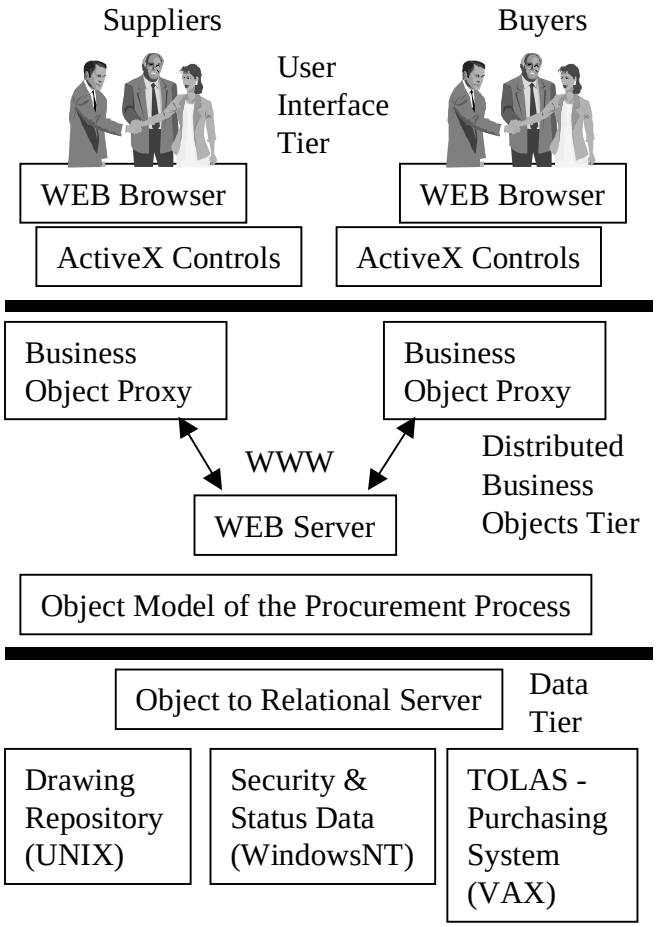

Figure 1. The N-tiered model showing how the interaction between buyers and suppliers can be divided between user interface, business objects and data access.

Our explicit business object model provided good support for the evolution of the system over time. Subsidiary business objects were added to meet additional requirements and additional business rules were added as the system was asked to support an ever-increasing portion of the supplier interaction.

IV. Transition Points as a Tool for Describing our Experience at Breton

Although not originally structured as a participatory action research project [5,6,7], we have seen that our work naturally followed many of the properties of such methodology. The primary purpose of the project was to conduct an intervention at Breton for the purpose of effecting positive change in the handling of orders. In addition, the staff at Breton wanted to gain experience with the use of the web for e-business and to identify additional opportunities for enhancing their business processes using this technology.

Our university group, for its part, was interested in learning about how to conduct interventions with industry for the purpose of introducing web-based e-business applications. In

addition, this project was an opportunity for bringing together our research groups from business administration and information systems, reflecting the mission of our Department, which brings together competencies in management and computer science. We were, again, interested in learning how best to exploit this collaboration of differing expertise as part of the project. The development of the working prototype of this system, although a vital part of the project, was strongly complemented by these additional learning objectives of all the parties.

In the spirit of Action Research and as part of our objective to formalise our experience to the degree practical, we have chosen to characterise our experiences in terms of "transition points." For our purposes, a transition point is an event characterised by a choice between competing alternatives. The decision may be implicit or explicit and may produce irreversible consequences. In some cases, we were directly aware of the choice at the time, e.g. during the initial negotiation to determine relative roles. At other times, the transition point was only visible in hindsight as we looked back over the path we had travelled and noted the change. Irreversibility of choice consequences are due to some actions that intervene after decisions are taken, like for instance, individual perceptions and judgements which may later change but not forgotten. A different kind of *de facto* irreversibility is related to the cost of renegotiating issues after actions are taken. Finally, decisions taken by external agents produce as well consequences that are out of control of the project. In general, these transition points correspond to discontinuities in the evolution of the project or the development of the prototype. We use these transition points to compress the description of our experience and highlight the important places where decisions were taken that ultimately determined the success or failure of the project. According to this view, transition points also identify steps in the project when the requirement evolution shows up.

In some cases, a transition point corresponded to a crisp point in time. In most cases, the transition point was more of a "point of departure" than a "point in time." Transition points sometimes extended over days or weeks of time, but they were always brief when viewed within the 20-month time scale of the overall project. In this way, the transition points can be seen to punctuate the evolution of the relationships within and among the participant groups as well as the development of the system itself.

One of the prominent elements qualifying a transition point is the actors, either playing the role of decision-makers, or directly affected by the consequences of the action. For the purposes of the present research, we identified three main actors: our University group, Breton and its suppliers. As we collected the transition points for our project, we were able to group them into different categories, based upon the actors involved.

V. The Case Study Viewed as a Series of Transition Points

This section presents a chronological sequence through the case study in terms of transition points, which allows us to give a compact and rich description of the project.

In Table I below, significant transition points are grouped on a season scale. For each transition point the second column marks the actors involved. Besides Breton (T), University (U) and Suppliers (S), also the e-Business system is considered as an actor in this context (E). In fact, the system itself has an evolution, needs, and is perceived by the other actors as a demanding counterpart rather than a transparent medium.

TABLE I
Chronological Transition Points

Spring 98	
Preliminary meeting between Breton and University group	TU
Acquisition of data about organisational structure and business processes	TU
Negotiation of contract: research, development or consultant	TU
Conflicting goals: Breton wanted RFQ and University a joint project	TU
Initial choices included Web-based and not utilising EDI	TUE
Departure of person providing liaison between University group's competencies	U
During negotiations, University tried to avoid support for drawings and Breton insisted	TUE
Derivation of use case models from organisational and process data	U
Formation of object diagram from preliminary use case data	U
Summer 98	
Explored technology alternatives (commerce pipeline)	UE
Rejection of commerce pipeline	UE
Presentation of the project to the suppliers involved	TUS
1st list of 7 suppliers for the pilot project	TS
Business rules formalisation	U
Continued acquisition of data about Breton organisational structure and business processes	TU
Acquisition of data about suppliers' organisational structure and business processes	US
Fall 98	
Extension of role of University to include implementation (no external developer)	TUE
Definition of user interface	TUE
Conversion of initial Visual Basic prototype into distributed N-tier Web tool	UE
Winter 98	
Emergence of a single major point of contact at the Purchasing Dept.	TU
Informal communication about Breton's expectations on project scheduling	TU
The person who made the participant observation at Breton left	U
1st working prototype of the system	TUE
Revised list of suppliers: 2 removed	TS
Spring 99	
System revision prompted by early visits to suppliers	USE

Revised list of suppliers: 2 added (the sample became biased)	TS
One area of the Purchasing Dept. became the major user of the system	TE
New University person in charge of data collection at Breton and suppliers sites	TUS
Increased attention to the suppliers use of the system	T
Summer 99	
Analysis of Logs file to identify patterns of use of the system	U
Shift of relative importance of security and performance	TUE
Replaced low level database tools based upon system incompatibilities	E
Fall 99	
Substitution of low level data access modules	E
Replace of local word processor with HTML for producing printable orders	TSE

As is evident in the list above, our project involved both organisational and technology aspects. This consideration strengthens the opportunity to assemble a team from business administration and information systems, in order to bring into the project heterogeneous competencies [10].

Beside the list of transition points and involved actors, the representation of the evolution of the project should be integrated by an explicit description of the relationships among the actors and how these change as a consequence of the transition points. Some of the points are in fact related to internal evolution of the actors, while others connect this aspect with an evolution of the relationships. The discussion in the next section represents our effort to combine all these elements together.

During the development of the system some process last for a significant span of time, so that should be regarded as transition processes rather than single events and therefore described as a unique entity. The remainder of this section presents four significant processes.

Perception of the other actor role. Our perception of the Breton expectation on University group role shifted along time. At the beginning of the project Breton conceived our relationship within a consulting-like framework, while our reference was the one of a joint research group. In fact, at that time, Breton was more concerned about our performance rather than about the result of the whole group. Later on the frameworks of the two actors increasingly overlapped without an explicit statement. An example of this blurring of the roles is the redefinition of the halting conditions for the project. From an initial attempt to define these conditions in a contract, we shifted toward a situation in which two actors having the shared goal of building an enabling technology continuously evaluate the ongoing progresses.

Diffusion of contextual knowledge. In order to build a tool fitting with Breton actual needs the focus of our attention was toward the work practices and the integration with Breton legacy system. The methodology used to collect data was inspired by ethnographic contextual design [8,9] and participant observation, put into practice by the set-up of a joint work group involving Breton and University people immersed in Breton activity site. The goal of this participant context was to define the current practices and from these to infer guidelines for the construction of the e-Business system. This process did not terminate with a requirement list but extended along the whole time span of the project. In fact, at the beginning of the work, relevant information on local practices and contextual knowledge was distributed across the whole company. As a result of the participatory nature of the process, such knowledge increasingly diffused among the actors that became sources of organisational memory. Because of knowledge redundancy, the project as a whole became fault tolerant to members abandoning it and the span of the participant context narrowed. The process of identifying the legacy information system structure and the links between data structures and company coding standards was one of the activities that better shows how scattered and distributed knowledge come together by means of participant context dynamic.

VI. Analysis of Transition Points for Variations in Requirements and Adaptability

The portrait of the activity of system development obtained by the transition points and the major processes outlined in the previous section is more than mere static analysis of the work, but still does not unfold the whole dynamics of the project. In order to complete the picture it is necessary to join snapshots within movies, that is to represent changes occurring both within actors and between them.

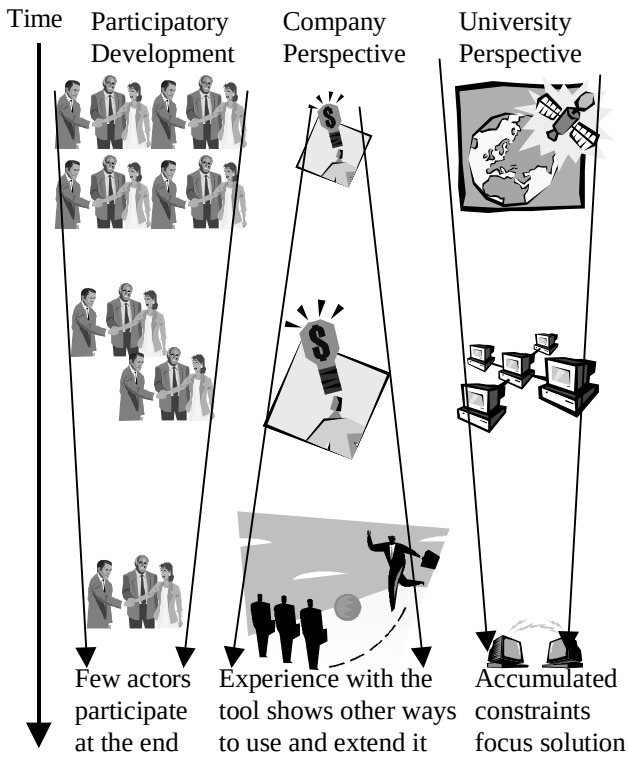

Figure 2. Actors' perspectives and participatory development dynamics

As a starting point for this analysis, we attempt to identify the evolution of Breton and University perceptions and

expectations on the project results in relation with the dynamic of the participatory development context.

Figure 2 summarises the overall progression of the participatory design and implementation process. Initially, members of both university groups met with representatives from the company and discussed the possible project. From the company's perspective, there was a relatively simple idea: use the emerging web technologies to facilitate and improve communication with suppliers. This simple idea assumes that the areas of application of the technology and the areas for improved quality will be readily seen. From the university perspective, there is a "world" full of opportunities. There are numerous different technologies to use, each with its own separate strengths and weaknesses. Also, there are very many different ways approach the improvement of the quality of interaction with suppliers. Some of these improvements might or might not be compatible with the existing constraints at the company.

As the picture shows, we started with the widest possible group of people that we could assemble during the early stages of the project. By ensuring the widest participation in the development process, we sought to avoid missing key aspects of the problem and we sought to maintain broadly based awareness of the project among the company participants. In retrospect, we have seen that the amount of participatory development gradually decreased during the project to the point that a core group of people from the university and the company were involved in completing the project. We now consider this narrowing of the participatory development group to be a natural by-product of the gradual emergence of the general shape of the solution and experience with partial prototypes. As the needs of some groups were met, they could drop out of the process, content that their input had been heard. As senior management saw the partial solution begin to emerge along acceptable lines, close monitoring of the project became less essential. Finally, only a few key actors remained in the participatory development group near the end of the process.

From the company perspective, the development process can be seen as a gradual unfolding of the details that followed naturally out of the initial simple problem model. For example, as the prototype emerged and became usable, the buyers were able to see how to use the system in their every day management of all their order – not just the orders that had been sent to suppliers over the web. Moreover, both buyers and suppliers asked for features that they could not get in the paper system, such as: trigger email, smart filtering ("show me similar orders"), shared notes. With regards to this last feature, it is worth noting that the initial request was to have personal notes attached to orders and order items. It was only with the use of the prototype that the users understood the potential of a shared note as a medium for communicating between buyers and suppliers. Finally, at the end of the process, the company participants were able to identify ways in which both the prototype and the development techniques used for the project could be applied to other problems in the company as well.

VII. CONCLUSIONS

The inevitable nature of evolving requirements is not a surprising characteristic of the development of such a complex system. In fact techniques as Contextual Design [9] were introduced in order to address these issues. What we introduced and experienced with this project were both an adaptable architecture and a methodology accompanying the whole project evolution, allowing the emergence of requirements to be naturally fulfilled without excess effort and costs.

The management of the system design and development at the beginning (upper part of Figure 2) and at the end (lower part of Figure 2) poses different problems in terms of organisational co-ordination, leadership, learning, competencies integration, problem solving, and decision making activities. We briefly outline some of these:

Leadership and organisational co-ordination. Roles ambiguities and interdependencies characterise the beginning of the project when a wider number of people are involved in the analysis and design processes. In this phase hierarchy still play a crucial role, while at the end the accumulation of competencies and relevant knowledge seems to be predominant.

Problem solving and decision making. At the beginning actors discussion is focused on alternative visions, where the major issue is the composition of diverging mental models, while at the end distinctive alternatives related to actual artefact shapes are confronted.

Learning and competencies integration. These issues are critical at the beginning and are the basis of a shared vision, while at the end they are not anymore instrumental but rather a measurable side effect of the whole activity.

We do not outline in this work a complete methodology for managing the development of systems that closely tied to the core of a company, such as e-Business for supply chain management. On the other hand, our retrospective understanding of the whole project suggests that the nature of the critical points faced across project advancement is primarily due to social interactions and to the evolution of actors perceptions and expectations about themselves and the others.

The development of an e-Business solution posed two serious problems: preservation of variety and integration with legacy systems and practices. The architecture chosen was suitable for addressing these problems, but it was only through the participatory development process that the actual system took shape.

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