IT-adaptation challenges in the process industry: an exploratory case study

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Abstract

Purpose – This paper seeks to identify and explore critical challenges for the process industry in information technology (IT) infrastructure integration and adaptation.

Design/methodology/approach – An exploratory case study was conducted at a paper mill and their main IT-vendor. Using a qualitative approach eight semi-structured interviews were carried out with representatives from both organizations.

Findings – The paper identifies four critical challenges in the integration and adaptation of IT-infrastructure in the process industry: integration as an ongoing process; maintaining stability in the installed base; locking the right stuff in; and balancing user value, continuity of production and compatibility.

Practical implications – Given the centrality of IT infrastructure in today's process industries, the importance of dealing with these challenges must be emphasized. The four challenges identified in this study are of such a complexity that they can only lend themselves to the evolutionary strategy. Such a strategy is in concert with the sensibility towards risk found in the paper industry.

Originality/value – This paper contributes by building on and expanding IT-infrastructure literature, as a result of exploring IT-adaptation challenges in process industry organizations. The findings also provide managers with a valuable insight into recognizing and handling these challenges.

Keywords Integration, Communication technologies, Paper industry, Sweden

Paper type Research paper

1. Introduction

For contemporary organizations the dream of managing their use of information technology (IT) through the establishment of an IT strategy, and aligning the IT infrastructure with existing business strategies, has seldom come to be realized. Practical evidence of integration of large-scale IT infrastructure in complex organizations show that the integration process does not follow a rational and waterfall-like process (Hanseth *et al.*, 1997). While managerial handbook recipes imply that IT infrastructure are highly malleable and enabling, and can be deployed by means of a rational decision-making process by the management this perspective to IT strategy has been criticized for undermining the role of organizational and social issues (Ciborra, 2000; Knights *et al.*, 1997).

This paper builds on the idea that large-scale IT infrastructures deployed in an organizational setting should be characterized as "infrastructures" rather than "tools" because their deployment is often constrained by an installed base. An installed base

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can be defined as the interconnected practices and technologies that are institutionalized in the organization (Rolland and Monteiro, 2002).

The purpose of this paper is to identify and explore critical challenges for the process industry in IT infrastructure integration and adaptation. As an example of a process industry, the study presented in this paper is focused on IT integration in an organization in the paper and pulp industry. The paper builds on a growing literature on information infrastructures (Ciborra, 2000; Hanseth *et al.*, 1997; Star and Ruhleder, 1996), and in particular the picture painted in this literature of IT infrastructure as stable rather than flexible, as they have been recognized as hard to change due to the inertia of the installed base (Monteiro, 1998).

The remainder of this paper is outlined as follows: First, we present a theoretical framework we argue is a useful perspective on IT integration, in the following section the case is presented. In the fourth section, we suggest four critical challenges that organizations in the process industry need to address. In the concluding section we, discuss the implications of our study, for the process industry and for future research.

2. Theory

The question of what comprises the key object of study in IS research is as important as it is continuously discussed (Avgerou *et al.*, 2004). One possible explanation to the apparently elusive key object is that it changes, or evolves, over time due to technical innovations and innovative ways of using technology. The convergence of information and communication technology (ICT) is one example of a relatively recent technical and social innovation which has challenged the incumbent key object concept in IS research. It reflects not only the convergence of technologies, but it also captures the growing integration of hitherto different systems. This does not mean that the idea of systems as the key object is rendered irrelevant, but at least it broadens the reach and scope of the research arena. The change in perspective implies we should reconsider several fundamental concepts (coupled tightly with the incumbent notion).

Replacing (information) system with (information) infrastructure as a fundamental concept has been proposed as a way to build a theory more useful for approaching the change in the characteristics of technology and our way of using it (Hanseth *et al.*, 1997). Infrastructure as a concept captures the integrated nature of the technology and suggests a perspective allowing us to approach questions of, e.g. design, strategies and methodologies not possible with system as a core concept.

As noted by Walsham, quoted by Angell and Ilharco (2004), theory is "both a way of seeing and a way of not seeing". This paper does not argue that a theory of infrastructure is the right or the only one, but rather that it is a useful perspective which makes it possible to see important aspects of the world we aim to explore in this paper. Aspects that are undetectable or uncapturable when using a systems perspective. The quote from Walsham also highlights the impact a changed perspective can have for management. How IT is regarded by the actors controlling the organizational means is an important factor in how you can manage difficulties.

2.1 Infrastructure

As indicated above, changing our understanding of our object of study in IS research – and the concepts we use to name and frame it – has widespread ramifications and makes it necessary to reconsider our other concepts, not necessarily rendering them obsolete (but rather understand how we can define them in the new conceptual context). The notion of system should not be replaced by infrastructure, but be redefined by it. Systems development, planning and control are still useful concepts but need to be seen as being implemented into a lager context of infrastructure, with very different strategies and mechanisms. The development, planning and control of systems thus need to be adapted.

(Information) infrastructure evolve over long time and cannot be built "from scratch" rather the new or changed elements is always fitted into the previously existing infrastructure – the installed base, which strongly influences how the new elements can be designed or used, i.e. how it (the infrastructure) can be improved.

The concept of (information) infrastructure can be characterised as a shared, evolving, open, standardized, heterogeneous installed base. It comprises a shared resource for a community as opposed to the idea of technology and applications as individual tools assumed by the traditional view on information systems. An infrastructure is the shared resources, materials, facilities a community draws upon/ uses when performing an action (Hanseth *et al.*, 1997; Hanseth and Braa, 1998).

An infrastructure evolves continually rather than are designed "once and for all" at the end of a development project. It evolves through conscious and unintended actions carried out by a number of different actors. It is open in the sense that it lacks clearly definable borders. New users, new applications, new linkages can be added at any given time – hence the development (evolution) is a never ending process.

As a foundation for communication and coordination, (Ciborra, 1993) standardization plays a major, but by no means simple/trivial, role in the concept of infrastructure (Hanseth, 2002). Standardization makes infrastructures an economically viable option whereas the alternative, bilateral agreements, soon becomes both time consuming, expensive and in large networks unmanageable to coordinate. This does not mean, however, that the use, development and consequences of a standard is a straight forward process.

"Standards describe the structure of an infrastructure whether they are deliberately designed or emergent" (Hanseth, 2002). The assumed universal properties of standards are only so in an abstract sense, removed from use and practice. When implemented, standards become locally embedded, making them unique and non-universal, and can thus never be used to create order (in the way usually assumed). Rather, order can only be created locally (order seen from a specific perspective), implying that order from one perspective constitutes disorder from another. As noted by Angell and Ilharco (2004):

> The dominant belief is that with "proper control procedures" we can impose order. This a complete misunderstanding of the human condition. Control doesn't create order, quite the contrary. Order is systemic and may have come about in the complexity of human actions (specifically the feedback of interactions with the environments), but not necessarily from human intent. Order must emerge first, and this order tolerates control. Only by the concession of that order does the consequent control impose structure and stability. Don't confuse order with structure and stability, don't confuse cause with effect.

Hanseth and Braa (2001) emphasize that standards do matter, as argued above, although they are not solely universal. Though being locally adapted they retain certain universal aspects. They are local and universal at the same time – local universals. They do reduce disorder, but can never be used as a means to eliminate incompatibility and redundancy. Managing disorder can, and must, be done by other means; gateways, *ad hoc* patches, duplications, etc. accepting to live and inventing ways to cope with disorder.

Infrastructures are also heterogeneous, in many regards (Hanseth, 2002). They include components of different kinds – technological and non-technological (such as human, social, organizational, etc). Secondly, layers of infrastructure are built upon each other, creating multi-layered heterogeneous dependencies. Furthermore, the sub-infrastructures can be based on different versions of the same standard or be overlapping in terms of functionality offered.

The installed base thus heavily influences how new element can be implemented, and is more accurately defined as an actor in its own right than a tool (to be used at will by other actors) (Hansteh, 2002). In this regard, it is both the material to be shaped (changed, improved or extended) and, at the same time, an actor largely appearing to be outside of the designers and users control. Infrastructures are highly interdependent, complex and extremely difficult to control and manage.

The installed base increases its force over time as it gains momentum, growing ever larger and more complex. This is, within network economics, described as a self-reinforcing process of increasing returns and positive feedback, network externalities, path dependency and lock-in (Hanseth, 2002).

As the installed base grows it attracts more complementary products and makes the standard cumulative more attractive as well. This makes it more attractive to new users, which in turn means more adoption and a larger installed base, and so it continues. This mechanism in infrastructures and networks, is (sometimes) called increasing return and is created by network externalities.

Externalities come about when an actor in a market (or infrastructure) affects another without being paid in compensation. Externalities can create positive or negative effects. Second-hand smoke disease for non-smokers is an example of a negative effect, while standards can be seen as an example of a positive effect. Positive network externalities has been used in studies IT-adoption (Zhu *et al.*, 2006) where positive externalities have been the focal point. In this study, we focus primarily on negative externalities as they need to be handled successfully in order not to disrupt production.

Path dependence can be seen as an effect of positive feedback from a network externality. This means, in a sense, that choices made early on (conscious or not), or events (often seemingly irrelevant) can turn out to have significant effects later on, e.g. the standardization of the QUERTY keyboard layout, or the need for backward compatibility in new versions of technology or software.

Increasing returns and path dependence sometimes lead to another effect – lock-in. Lock-in means that, when adopted, a technology is hard or impossible to replaced by a competing technologies. As the installed base, and its standards, grows, the switching costs to a new technology or standard increases. This is in many respects a coordination issue, as the individual cost often is relatively small (but of course, not really an option if the rest of the market sticks to the old standard or technology). The coordination efforts and switching costs required to break a locked-in infrastructure are huge.

As they diffuse, the infrastructures gain momentum, a characteristic shared with standards (Hanseth, 2002). This process is aptly illustrated by Grindley (1995) see Figure 1.

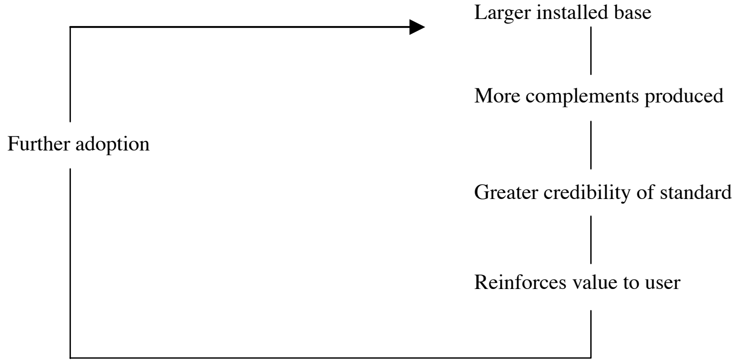

Figure 1.
Standards reinforcement mechanism (Grindley, 1995)

When applied to infrastructures, diffusion means that the number of elements in the infrastructure grows.

3. Case

The purpose of this paper is to identify and explore critical challenges for the process industry in IT infrastructure integration and adaptation. In this section, we present the main outcome of our empirical study at SCA – a Swedish based multi-national organization in the paper and pulp industry, and their main IT-vendor ABB (ABB has, e.g. supplied the control system for the mill).

3.1 Methodological considerations

This study is based on an interpretive epistemology (Orlikowski and Baroudi, 1991; Walsham, 1993), using a single in-depth case study create better understanding of the design and use of IS in an organizational context. Yin (1994) defines a case study as an empirical inquiry that investigates a phenomenon within its own context, using multiple sources of data collection. Yin suggests that a case study is a form of inquiry that does not necessarily depend on ethnographic or participant observation data but that other more "mediated" access to the case also can be valid.

The study consist of eight interviews with actors from the paper and pulp organization and the vendor, respectively. The methodological considerations in this study have been guided by the basic idea that the actors who deal with IT integration, evolution and adaptation in their everyday work possess relevant knowledge concerning our study. This is an interpretative study where by the use of semi-structured interviews we have strived to generate relevant data. Difficulties, challenges and important aspects of successful integration have been the focal matters of the interviews. Each interview lasted for approximately an hour, and was subsequently partially transcribed. Case studies have a long history of use in fields such as organization studies and management studies. There are multiple definitions of case study research and it covers a wide range of research methods, from single in-depth case studies to multi-site, multi-method studies.

A central difficulty with qualitative research is that the methods of analysis are not well formulated (Miles, 1979, p. 590). It is typically described that themes or patterns "emerges" out of the data material, but this process of emergence is hard, if not impossible, to describe. It is clear, however, that the researcher's personal and theoretical biases play a central role in this process. In order not to override the interpretations from the side of the organizational members, we felt it necessary to start out with interpretations close to their world, and at a later stage move on to more theory informed interpretations. As Gummesson notes, the aim of case studies is not "a superficial establishment of correlation" but to reach a fundamental understanding of structure and process (Gummesson, 1988, p. 79).

Generalization is important for both qualitative and quantitative approaches, albeit in fundamentally different ways. As noted by Yin (1994) qualitative case studies can only be generalized from by means of analytical generalization, i.e. a generalization to a expand existing literature rather than generalization to a wider statistical population.

3.2 SCA

The process industry is, and has been, a part of society where technology constitute an important part of the production process. A significant change today is the transformation from industrial, mechanical, technology to IT. Still major actors in the economy organizations in the process industry are sought after clients for every major IT-vendor. When discussing the question of what reasons there are for integrating the different elements in the production process several reasons are articulated by representatives from both buyer and vendor, most of which have to do with being cost-effective: process rationalization or automation aimed at reducing the work force, optimizing production and planning by streamlining processes.

Other reasons include ideas of gaining strategic advantages through integration, and increased traceability. There are also external demands from customers and suppliers, who wants to make transactions more efficient, influencing the increased digital transformation and integration. Yet another reason is the tightly regulated environmental legislation which basically necessitates the ability to measure all sorts of variables at any time:

> . . . it used to be that every system was sort of an isolated island, but that became too expensive and made maintenance very difficult [. . .] it is important to be able to see if the mill is standing still, then maybe I don't have to produce so much steam here, I can slow my rate down a bit and when the mill starts up again I can pick the pace up again, those kinds of things are really important when trying to optimize the whole factory [. . .] I mean, if the mill operates independently and lets say, have a problem with filling the tanks or pulp and we continue producing [steam] at the same rate then we have to close down the whole factory, it's much better then if we slow down production to match the mills rate – if we slow down we don't have to shut down production (systems manager SCA).

The IT architecture at SCA consists of several different, but interconnected layers. Closest to the actual production you find the field elements. These include motors, fans, vents and such that can be monitored and regulated. The input and output units used to accomplish this are also counted as belonging to the field element layer. Typical examples of field element processes are keeping track of the temperature in a motor, or indicators signalling when a product arrives at a certain point in the production line. The layer above the field elements consists of process stations collecting the data generated by the field units. Considering that every one of the field units can generate over 100 different parameters, the level of complexity is even at this level significant. The data are then sent to the next layer, servers, which in turn distribute it to operator stations and on to high-level systems such as production planning, maintenance systems or a business system.

The respondents working for the vendor emphasise the significant role of the technology already in use at the organization implementing a new system, and that the easiest thing for them clearly would be building everything from scratch, preferably using the same vendor for everything of course:

> . . . the industries have invested quite a lot in [information] systems for a number of years now [. . .] some systems are very old, some new and that, naturally, poses a problem when integrating. One problem you have to face is making the new [system] talk with the old, and that can be quite complicated (sales person, ABB).

This proposition does not really appeal to those investing in IT though, who rather express a wish not to become too dependent on any one vendor for different reasons. This leads to a heterogeneous collection of systems and units and makes integration a more difficult affair. Even relatively small changes, e.g. replacing a control or field unit, can end up being difficult. The new part (due to the rapid development of IT) is almost always an updated version with new (and supposedly improved) functionality. The choice of either downgrading the new component to match the one being replaced, or trying to implement the new functionality by adapting the installed base then has to be addressed. How to choose between the two is not often obvious. Minimizing the disturbance in the production process is often the most important factor in these decisions.

Another important aspect of integration, emphasised in our study, is ascertaining the validity of the data generated. The main problem in accomplishing this resides not in describing the functionality or construction but in correctly indexing the new component. Indexation is not an inherently difficult task, but the amount of post makes it in some cases monumental. As some parts of the infrastructure are (in terms of IT at least) rather old and lacking in documentation the process becomes more like detective work than anything else:

> If we are to integrate a maintenance system where the motors are numbered A-Z and on to AA-AZ, etc. we cannot just insert our system which names the objects in numerals, e.g. 1-9999. [. . .] this is where the adaptation comes into play. One cannot ask the client to – lets say we are putting in a new control system and integrate it with their business system – ask them to rename all their stuff in the business system . . . all posts in their data base, like a million posts. It becomes unmanageable. [. . .] It is not realistic to believe that you somehow will rename a motor in the documentation in the layers and systems – so what you end up with is often something like translation tables of some sort. That's not fun to work with (systems engineer, ABB).

In order to handle this complexity the new system can be tested in a simulated environment (a software-based simulation testing the component or systems behaviour in certain situations), this is done primarily because shutting down production to run tests on the actual site is not an option. This kind of testing prevents a lot of initial errors, but not all. It is only when implemented an in use it is possible to detect the actual consequences of the new part or system.

Maintenance is a recurring theme in our study. We would like to differentiate between the following three categories of maintenance: software, hardware and machine. Software maintenance has traditionally been seen as an activity only pertinent to the computers in the organization. Recently, due to the fact that virtually all the machinery in the organization is integrated by use of IT of some sort, maintenance is practically ubiquitous encompassing everything from business system to field units. Almost all components in the mill and the rest of the factory contain some form of CPU and software, all of which demand maintenance:

> . . . integration demands intelligence in all components, i.e. a CPU, a kind of firmware. Earlier it was just our control systems [. . .] Today every little component, be it a small switch or I/O unit, has some sort of intelligence making them subjects of upgrading and maintenance. [. . .] Maintenance is different today (project manager, ABB).

When problems arise in intelligent components it typically is to be found in the software. The rapid development rate in the IT-industry means that the lifespan of many components today is very short, not seldom under a year. Even though the new components adhere to standards, the vendors cannot guarantee 100 per cent compatibility. This can in some cases mean that new software is downgraded. This makes software maintenance an important issue. From the vendors point of view one problematic aspect of this situation is that their customers are not used to paying for this sort of "abstract" maintenance. The customers, however, mean that their primary objective is stability and simplicity.

Hardware maintenance also poses a challenge for the organization, again not least due to the rapid rate of development, but also due to significant changes in the way the vendors work today. Earlier most large vendors produced everything in-house and could supply spare parts from their own stock. Recently 3rd party suppliers develop most of the components used by the larger vendors. This change has had an impact on vendors and their customers:

> Our old systems were Unix-based and we produced the cards ourselves. Then you could keep the same machine, just produce, say, 10 card per year. But now we are in the hands of HP, IBM & DELL and when they change their series we've got to make it work on them too. That's a challenge. The customers notice this too. Often they buy the same machine to make maintenance easier, they are familiar with them and have stocked up on spare parts. Then they ask for an operator terminal, same as they bought a year and a half ago. But then we have to tell them HP has discontinued the 4100, now it's called 4200 containing SATA-discs instead. Then they have to buy two terminals, one to run and one spare [. . .] They don't need faster computers, SATA having faster internal bus won't make them happier, they don't need USB. It just has to work. But that's not what makes the IT-world go round (project manager, ABB).

This makes managing spare hardware parts problematic, e.g. skyrocketing the cost of keeping their own spare parts, and not being able to get guarantees from the vendors:

> We can't just guarantee. Much of what we now have is based on 3rd party suppliers, servers, network-stuff, etc. In the computer world decides to change from USB 1.1 to USB 2.0, then it's out of our hands. You just have to tell the customer that all your spare parts are practically worthless. The hunt for new technology would slow down considerably if the customers were to decide (project manager, ABB).

Machine maintenance is in itself not an integration challenge, but closely connected to problems of keeping information valid in the infrastructure. Recently all maintenance performed on machines has to be manually recorded into the maintenance system, something which not always work. This makes it difficult to coordinate upgrades or changes in the other systems as machine maintenance sometimes mean changes in functionality or performance are made.

This study has not been focused on one particular IT integration project, rather we have tried to explore what issues, problems or difficulties the involved actors have experienced in dealing with different aspects of integration. The interviews have yielded interesting, if perhaps somewhat tentative, insights into the everyday intricacies of IT integration. In the section that follows we will elaborate on these insights.

4. Discussion

In this section, we discuss the case finding in relation to the theoretical background to get a identify and explore critical challenges for the process industry in IT infrastructure integration and adaptation.

4.1 Integration as an ongoing process

Viewed from the perspective of our theoretical framework, all of the problems, difficulties and issues the different actors in the study point out or discuss, indicate that a major challenge for the company in question is to view integration as an ongoing process and not as isolated instances or projects limited in time or scope. In order to devise ways of dealing with many of the issues raised by the actors in this study, the organization needs to adopt a of useful way of thinking about these issues.

We propose that viewing integration as a process of infrastructure development is useful in this regard. Infrastructures are never built from scratch or isolated from the environment. Processes change, people are replaced, new customers and partners are added, standards evolve, etc. continuously in an organization contributing to changing the circumstances for integration. The installed base, of technological and non-technological actors, will dictate what improvements or changes are possible and it is therefore quite important to consider when conducting, what is labelled, integration projects. Since, ICT permeates the entire organization, it could be argued that almost every change could have important consequences in regards to integration.

4.2 Maintaining stability in the installed base

Infrastructure within the process industry consist of many interconnected layers and has a high degree of complexity. This implies that it is difficult, if not impossible, to predict (or even detect) all consequences of a change in the infrastructure. The challenge is maintaining stability in the installed base in spite of continuous change and evolution. The installed base is stable in the sense that it is difficult (practically impossible) to replace due to its size and complexity. But, importantly, since the layers and elements in the infrastructure are interconnected and interdependent, it is at the same time fragile in the sense that one faulty part or incorrectly indexed table can do substantial damage and cause all kinds of problems. This is a very serious issue when considering the cost of halting production for even a few minutes, let alone a day or more.

The transition from traditional industrial technology to being permeated by IT is an important factor for the process industry in this regard. The challenge of maintaining the installed base is significantly different when dealing with integrated IT. If a cogwheel malfunctions, you only have to consider its direct environment (number of cogs needed, diameter, etc.) when replacing it, but since almost all parts today has software and some sort of CPU and is interconnected to the rest of the infrastructure (process planning, maintenance, etc), it poses a problem of a different magnitude. The situation would not be as problematic if identical parts were readily available, but that is not often the case. The rate of evolution in IT is such that hardware and software products have, in industrial terms, a very short lifespan and (identical) spare parts are often impossible to buy.

Basically, this leaves the organization three options. One is to stock up on spare parts, which is very expensive and in the long run not a viable option. Another is to buy new parts and risk problems of incompatibility and unforeseen effects elsewhere in the infrastructure. A third option is to buy a new product and, if possible, adapt it by downgrading it to mimic the old part. This is sometimes a demand from the vendors, e.g. the vendor responsible for the development of the product-planning system demands downgraded software (when bought from other vendors) to guarantee functionality in the system.

Adhering to a certain standard seems to be one way of handling this situation, but standards must be adapted locally to fit into the installed base and cannot therefore be used as a means to circumvent the intricacies of integration.

4.3 Locking the right stuff in

Process industries are large and complex organizations consisting of several levels with several different actors with different needs on each level, and different computer systems and different other technological elements. Thus, they involve not only a few legacy systems[1], but also several legacy systems being part of a larger information infrastructure, consisting of elements such as work procedures, inscriptions and paper forms. Therefore, implementing the new system also involves changing an information infrastructure and the installed base.

The installed base is that which already exists; a heterogeneous network of humans and technology (Hanseth, 2002). The installed base is thus difficult to change and also very difficult – if not impossible – to control due to its complexity and interconnectivity. What the installed base is varies depending upon what kind of infrastructure you are looking at, but an important element in information infrastructure is behaviour inscribed into already existing elements.

It seems as if the deployment of IT infrastructure have lead the process industry in our case to a lock-in situation, as the existing systems are tightly integrated into the large organization and have a large installed base. This installed base is building on a vendor-specific standard – on the standard deployed by ABB in their product portfolio. The size of the installed base in the process industry makes the coordination effort and the switching cost huge, meaning that it is difficult to develop competing technologies. Lock-in are often a result of path dependency, which is that past selections have a large impact on future development (Hanseth, 2002). In our case, we can see how a technology has been adopted and gained an installed base, and we are thus faced with a lock-in situation. The strategy adapted is clearly one of a "conscious lock-in" – it is firmly believed that the key risk at hand is poor compatibility between infrastructure elements. With a conscious lock-in, in particular with investing into the ABB product portfolio, the problem of compatibility is avoided. What is not avoided, though, is the lock-in to ABB's product portfolio. Alternatives for avoiding lock in are for example to define and adopt good universal standards which means that no one is binding to a particular technology, standard can if correct used lead to flexibility.

4.4 Balancing user value, continuity of production and compatibility

The challenge of relying on a stable standard on the one hand, and resisting lock-in effects on the other, relates to the challenge of finding a balance between value for users and continuity of production and compatibility. While implementing a new system and thus changing an information infrastructure and the installed base is critical for the future survival for an IT-intensive organization, an installed base will more than often prove to be hard to change.

Needless to say the value delivered by an IT infrastructure depends on who you see as the user. The effects of IT integration will vary across the organization. For instance, while maintenance personnel will not necessarily feel that their lives are enhanced by them making explicit how much time they spend at different work tasks, such information will become valuable elsewhere in the organization. However, if the maintenance personnel will not experience any benefits at all they are unlikely to use the system to the extent they are expected to which in turn leads to poor value for other organizational members too.

Our interviews clearly demonstrate the tendency towards "downgrading" of IT infrastructure components in order to accomplish compatibility. The consequence is that the process industry pay full prize for a service not fully used. Such a consequence has to do with a strong installed base resisting change. The prize paid here is the lack of evolution of the IT infrastructure.

The value for users is thus deflated in the process of complying to the installed base by downgrading components. The challenge of finding a balance between the value for users on the one hand, and continuity of production and compatibility on the other.

5. Conclusion

The purpose of this paper was to identify and explore critical challenges for the process industry in IT infrastructure integration and adaptation. To this end we identified four critical challenges: integration as an ongoing process; maintaining stability in the installed base; locking the right stuff in; and balancing user value, continuity of production and compatibility. Given the centrality of IT infrastructure in today's process industries the importance of dealing with these challenges must be emphasized. How do we deal with them then? How do we change the IT infrastructure in a way that is feasible and desirable?

Hanseth (2002) has described two generic strategies for changing an information infrastructure:

(1) *Evolutionary*: slow, incremental process where each step is short and conservative.

(2) *Radical*: fast changes, a radical break with the past.

The radical strategy is difficult to implement in practice due to the role and nature of the installed base and network externalises. The evolutionary strategy, on the other hand, consists of changing a small part of the network, then making sure the newly added parts work properly. This means that the change effort is spread out over time, each step being small. In information infrastructure theory, the strategy of change and development is called cultivation (Hanseth, 2002). Cultivation requires a close analysis of the way behaviour is inscribed in the already existing elements of an infrastructure, the installed base.

The four challenges identified in this study are of such a complexity they can only lend themselves to the evolutionary strategy. Such a strategy is in concert with the sensibility towards risk we find in the paper industry. A breakdown in IT infrastructure will probably lead to a breakdown in production, which will extremely costly. To this end the evolutionary approach to changing the IT infrastructure is synonymous with a risk-management approach.

An evolutionary approach has the benefit of being sensitive towards "that which already exists" in the plant – both people and technology. We have discussed the need for a sensitivity towards technology – the installed base – in some detail. A similar sensitivity has to be addressed towards the people working in the plant and how the institutionalized professional identifies shape the work process in the plant. As noted by Rolland (2003), IT infrastructures that contradicts deep-seated local professional identity by the assumptions articulated by/inscribed in the infrastructure a feeling of "meaninglessness" and "existential anxiety" among the users. This underscores a critical risk associated with IT infrastructure projects – to balance the local with the global in such a way that empowers, rather than disempowers, local staff (Jonsson and Holmström, 2005). Such risks are characteristic for "the risk society" (Beck, 1999; Beck *et al.*, 1994). Beck maintains that "latent side effects strike back even at the centres of their production" (Beck, 1992). For the process industry, the attempts to gain better control over production processes by means of more sophisticated technologies can encounter such a side effect of the process operators feel as if they are disempowered by new technology.

5.1 Theoretical and practical implications

The results of this study also highlights the need to further elaborate upon our chosen theoretical framework. We would argue that the concepts of stability and fragility of the installed base is one such area. Another is the concept of risk and risk management. Our proposed shift from system to infrastructure as the core object of study clearly lends a different perspective on risk and risk management. The challenges we identify in this study can doubtlessly be regarded as serious risks for process-industry organizations. Creating awareness among decision makers at all levels in these organizations thus becomes an important issue. We suggest that the challenges presented above should be regarded as such, in addition to knowledge transfer. We also suggest that the infrastructure perspective sheds a different light on what knowledge is regarded as relevant, and the importance of identifying barriers to creating value from the knowledge. The challenges indicate that knowledge needed to successfully handle them not necessarily is to be found within the organization. A different relationship with the vendor could be immensely helpful in making informed decisions regarding when, and what, to lock-in, how to choose technological paths.

Chang and Lin (2007) show how organizational culture plays a pivotal role in implementing information security management. Security is an important aspect of any process industry organization due to the importance of continuous production and the high degree of systems integration. The infrastructure perspective can contribute to further elaborate on issues of information security management by highlighting the complex, socio-technical nature of IT implementation, adaptation and use. The installed base also helps to articulate why security management cannot be conducted as a once-off or isolated event in an organization, and how technological and non-technological actors both are important to regard.

The challenges also highlight the importance for management to consider IT maintenance, upgrades and adaption as an important part of IT investment. We suggest that "information systems" investment could be considered a subcomponent of infrastructure expenditure and investment, resulting in a different view of, e.g. the all-important day-to-day maintenance work that constitute significant role in the successful adaption and implementation of IT into the pre-existing installed base.

Note

1. Bisbal (1999, p. 2) states that a legacy information system can be defined as any information system that significantly resists modification and evolution.

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