Factors Influencing Successful Implementation of Computer Based Technologies in Knowledge-Intensive Activities

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The mission of the paper is to make a contribution to increasing the understanding of implementation process of Computer Based Technologies (CBTs) in “knowledge-intensive activities”, i.e. the activities that are mainly based on high technical and professional skills. A model of the organizational aspects influencing the implementation process, developed on the basis of the literature and the authors’ research, is presented. On the basis of this model, the authors studied the implementation process of CBTs in software production activities of eight Italian firms, representative of industrial and service sectors. From the discussion of results of the study, implications both for the theory and for the management of the implementation process are derived.

In recent years Computer Based Technologies (CBTs)\(^1\) have become commonplace in every organization, bringing significant modifications, especially in “knowledge-intensive activities”, i.e. the activities that are mainly based on high technical and professional skills. These activities often occur in such fields such as management consulting, software production, research centers, engineering companies, etc.. In such firms individual knowledge has more importance than other inputs; for this reason they are labeled with the term “knowledge-intensive firms (KIF)”. Exceptional and valuable expertise dominates ordinary knowledge within the KIFs and the widely shared knowledge is exceeded by personal and idiosyncratic knowledge (Starbuck, 1992). CAD\(^2\) (Computer Aided Design) systems are the most relevant example of information technologies in engineering activities, because of their widespread use and the considerable investment of many companies in them, especially for the development of new products (Robertson and Allen, 1993; Adler, 1989). The greatest use of these technologies is in supporting mechanical design and engineering, but in the last few years they have also been applied in new fields. CASE (Computer-Aided Software Engineering) is an example of applications of information based technologies in the software development process. Generally, all these technologies promise to offer companies large improvements in flexibility, innovation, efficiency and responsiveness to customer needs.

Generally, the implementation of CBTs in knowledge-intensive activities promises to offer companies large improvements in flexibility, innovation, efficiency and responsiveness to customer needs. Nevertheless, the achievement of such results is not easy: in several cases these technologies have not delivered the benefits the managers expected (Majchrzack and Salzman, 1989; Robertson and Allen, 1993).

The most recent evidence shows that the successful implementation of Computer Based Technologies is as much an organizational as a technical change. However, the mechanisms through which these technologies are successfully implemented are not identified (Orlikowski, 1989; Geisler, 1991), because the implementation of information technologies in knowledge intensive activities involves particular
problems concerning the autonomy of professionals. Professionals appreciate the importance of their autonomy whenever the firm demands their services to absorb unpredictable variations of the current environment. New technology plays an ambiguous role in this autonomy (Weick, 1990), because it can be considered either as a threat to the professional’s position or as an opportunity for the professional to update his competence. In the first case the new technology reduces the perceived autonomy, while in the second case the new technology amplifies the perceived autonomy.

Both at the theoretical and at the operational level, it is unclear how these technologies can integrate or partially substitute the individual expertise and how managers can reduce the resistance of professionals to the new technology, by enhancing the possibility of rebuilding a new autonomy.

For all these reasons, the study of organizational change around Computer Based Technologies is becoming increasingly important, at both the theoretical and the managerial level. At the theoretical level, models are needed which, taking social and organizational factors into account, can explain the use and impact of CBTs (Majchrzack and Salzman, 1989). At the managerial level it is important to identify and manage the factors that influence the implementation process (Orlikowski, 1989) and, in particular, to understand the relationship between the use of CBTs systems and the company’s performance (Robertson and Allen, 1993).

This paper shows the results of a study on implementation of CBTs in eight Italian firms which are representative of industrial and service sectors. The methodological approach is based on a dynamic model, developed by the authors. The model points out the cyclical character of the implementation process and allows the misalignments between the opportunities offered by these technologies and the results achieved to be identified.

From the results of the study, implications both for the theory and for the management of the implementation process are derived.

**Implementation of CBTs in Knowledge Intensive Activities: Managerial Issues**

Several studies (Adler, 1989; Badham, 1989; Brooks and Wells, 1989; Friesen and Orlikowski, 1989; Lee, 1989; Robertson and Allen, 1992, 1993) have pointed out that the effective implementation of information technologies in knowledge intensive activities requires significant changes in the organization. As a consequence, managers have to understand the social and organizational dimensions of the implementation process and to plan adequately the changes in organizational dimensions (culture, structure, processes, etc.) (Majchrzack and Salzman, 1989).

For these reasons, as Geisler states (1991), the following questions become increasingly significant: “… how should these technologies be linked or networked with existing technologies and processes? how should we evaluate the performance of these technologies? what are the problems associated with the application, adoption, adaptation and usage of these technologies and how can we resolve them?…” (p. 291).

The recent literature on managerial facets of computer based technologies has pointed out several issues that influence the effectiveness of the implementation of these technologies:

- the perceptions of the management about the technologies and their capabilities: different perceptions of CBTs will lead to different use of the systems (Majchrzack and Salzman, 1989; Weick, 1990; Robertson and Allen, 1992, 1993);
- the expectations managers have for the CBTs. When managers view these technologies primarily as a machine to enhance productivity they tend to adopt a minimalist approach to organizational change. When managers view CBTs as a means to increase the individual’s efficiency, these technologies “became a catalyst for needed organizational change” (Majchrzack and Salzman, 1989 p.177);
- the “technological frames” (Orlikowski and Gash, 1991), that is “the set of assumptions, meanings, knowledge and expectations that people use to understand the nature and role of technology in organizations” (p. 4).
- the user’s interpretation of the technologies and the social interests and motivations in using them (Goodman et al., 1990; Orlikowski and Gash, 1991; Tyre and Orlikowski, 1992; Lewis and Seibold, 1993);
- the relationships between technologies and the user’s environment (Leonard-Barton, 1988; Meyer and Goes, 1988; Majchrzack and Salzman, 1989);
- the modifications in social relationships within project teams (Orlikowski, 1989; Brooks and Wells, 1989);
- the number and variety of interventions on organizational aspects (such as skills, training, changes in procedures, structure, organizational culture, etc.). In several cases, as Majchrzack and Salzman (1989) state, the perspective of managers is that implementation of information technologies “requires only little organizational change” and that “these organizational change will naturally follow the technological change” (p. 174). Nevertheless CBTs are more likely to achieve their intended benefits when managers take organizational and social aspects of implementation process into account (Brooks and Wells, 1989);
- the linking of organizational changes with the technical changes, without which the benefits of the new technologies will not be achieved (Adler, 1989);
- the explicit strategy of implementation followed by the firm, i.e., as Friesen and Orlikowski (1989) state, the way in which “the manner, timing, and phases of diffusing” of the new technologies are introduced and clearness in “delineating the role to be played by the automated aids, the system
Almost every issue is related to perception and expectation of people involved in the implementation process. Indeed the result of the implementation process is related to several environmental and personal factors. The identification of the role these factors play in the organizational context is fundamental both in evaluating the adoption of the technologies and in managing the implementation process. Managers have to understand how each factor influences the process and try to reinforce their influence in facilitating successful implementation.

**A Dynamic Model of Computer Based Technologies Implementation**

In order to identify the key factors of the implementation process of CBTs in knowledge-intensive activities we developed (Capaldo et al. 1993a, 1993b) on the basis both of the literature and our research (Raffa and Zollo, 1988, 1992, 1994), the model presented below. The model integrates the several issues influencing the implementation process in a general pattern of analysis from which researchers and practitioners can derive operational tools to evaluate the implementation process (Figure 1).

According to this model, the initial results of the adoption of Computer Based Technologies are different from the opportunities perceived by the management: between perceived opportunities and real results some misalignments exist. It is not easy to identify the factors which determine them. This is due, above all, to the fact that these technologies have an impact on the skills and tasks of professionals producing unpredictable reactions from them. In fact CBTs play an ambiguous role (Weick, 1990) in the perceptions of professionals because they are viewed either as a threat to their autonomy or as an opportunity for the professional to update his competence.

The perception and the interpretation of these misalignments play a central role in the implementation: the way in which the managers interpret these misalignments leads to different paths of implementation. According to their perception of misalignments managers try to reduce them by modifying factors such as professional skills, organizational structure of the company, organizational structure of the development process, work organization. During this correction process other opportunities are perceived which introduce other misalignments. In this way we have a series of cycles, which are characterized by specific perceived opportunities, perceived misalignments, interventions and so on. Therefore, the implementation process has a dynamic and cyclical nature. Consequently, the different perception of the opportunities and misalignments among the firms brings about different implementation paths and results.

Summarizing, our model expresses the implementation process as a series of paths, whose characteristics are different according to the company’s perception of the opportunities offered by the new technologies and of the nature of misalignments between opportunities and real results. From the point of view of the model, each path is described in terms of four main variables: perceived opportunities, perceived misalignments, interventions, perceived results. Following this approach, we applied the model to eight Italian firms, representative of industrial and service sectors. The results of the study are presented in the next paragraph.

**Empirical Evidence**

**Field of Research**

The field of our research was the implementation process of CASE (Computer Aided Software Engineering) technologies in software production.

We studied eight different organizations, including independent small firms and software development groups within large corporations. The main characteristics of these firms are described in Table 1.

The variety of organizational problems related to the adoption of CASE systems is an excellent laboratory to analyze the managerial factors which are involved in imple-
mentation of CBTs in knowledge-intensive activities. In fact, the implementation of CASE technologies modifies the activities of all the actors involved in the software project, from the customer to the system operator, generating a variety of organizational problems such as displacement of existing personnel (which affects first the work organization and then the technicians both in their activities and in their professional profiles), and disruption of social relations among project team members (Orlikowski, 1989). As these problems recur in the implementation of other Computer-Based Technologies, such as CAD systems, the results of the study of CASE technologies is representative, in general, of the Computer Based Technologies implementation process. In addition, there is a great interest in the study of CASE technologies implementation. In fact, despite the technical services and advantages offered by CASE, the difficulty in industrializing the software development process has disappointed many users, limiting the spread of this technology in the world of business (Souza, 1991; Loh and Nelson, 1989). The reasons for this limited spread are not clear because “the mechanisms through which CASE tools are successfully implemented are not identified, because of the lack of empirical data on the organizational effects of using automated means to develop systems” (Orlikowski, 1989; p.1) and “little is understood about what are the options, what are the problems, what are the implications of deploying CASE tools” (Friesen and Orlikowski, 1989; p.2).

Methodology

To study the implementation process of CASE technologies we adopted the model described in the previous section. It is not easy to evaluate the elements expressed by the model, because of the difficulties in analyzing the several factors that come into play. This suggests that we should limit the application of our model to the qualitative aspects of the implementation process. To detect them we carried out semi-structured interviews with project managers and personnel involved in software process development for each of the firms of the sample. All interviews took place from 10 to 18 months after the adoption of CASE technologies, from 1991 to 1993. We adopted semi-structured interviews to obtain as much depth and variety of data as possible. The interviews explored a variety of themes relating to general company issues, opportunities for adoption of CASE technologies, problems related to the implementation and ways the management faced them. The authors complemented the data collected by interviews with the results of project records and documentation analysis, on-site observations and informal social contacts with members of software development process teams.

Results

The data collected were grouped under these following themes: perceived opportunities, perceived misalignments, interventions, perceived results.

In Table 2 the meaning associated with each theme and the different typology of responses are shown. The results indicate the complexity and the variety of the implementation process. Generally, the different perceptions of the opportunities and misalignments among the firms bring about different implementation paths and results. Nevertheless, some common features can be highlighted:

- the most common perceived opportunity is the improvement of product quality (3 firms), followed by innovation of processes and products;
- misalignments between technology and organization are perceived as unsuitable individual skills and mismatching of existing methodologies. In some cases work organization and professional roles are considered inadequate to take advantage of CASE adoption;
- training on new technologies is the firm’s most frequent action to reduce misalignments. But the best results are achieved when management act on organizational factors, facilitating the implementation of CASE by pilot projects that are carried out by teams working together with the traditional development teams and modifying the content of

<table>
<thead>
<tr>
<th>Firms</th>
<th>Firm’s characteristics</th>
<th>Industry type</th>
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<tbody>
<tr>
<td>Firm 1</td>
<td>Small, single product software firm. 10 employees</td>
<td>Software production</td>
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<tr>
<td>Firm 2</td>
<td>Large firm in the aerospace sector. 32,000 employees. 42 EDP centers and 1000 software employees.</td>
<td>aerospace</td>
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<td>Firm 3</td>
<td>Large company, producing and maintaining custom software. 1700 employees. 1600 technicians.</td>
<td>Software production</td>
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<td>Firm 4</td>
<td>Large company, producing projects on commission. 400 employees.</td>
<td>Software production</td>
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<tr>
<td>Firm 5</td>
<td>Firm producing software systems for telecommunications. 200 employees.</td>
<td>Telecommunication</td>
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<td>Firm 6</td>
<td>Small firm producing telecommunication services.</td>
<td>Information and communication services</td>
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<tr>
<td>Firm 7</td>
<td>Entertainment and information services; 13,000 employees. 100 EDP workers, with highly specialized professionals.</td>
<td>Credit</td>
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<tr>
<td>Firm 8</td>
<td>Credit institution with an EDP Department and 200 EDP workers, with highly specialized professionals.</td>
<td>Credit</td>
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### Table 2: Themes and typologies of responses

<table>
<thead>
<tr>
<th>Perceived opportunities</th>
<th>New product development</th>
<th>Product quality</th>
<th>Standard</th>
<th>Productivity</th>
<th>Innovation</th>
<th>Market (M) Customer satisfaction</th>
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<td>Development process (D)</td>
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<td>(D) Innovation</td>
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<td>Perceived misalignments</td>
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<td>Technicians (T)</td>
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<td>Organizational environment (O)</td>
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<td>Inadequate culture</td>
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<td>Organizational changes</td>
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<td>Inadequate tools</td>
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<td>Customers (C)</td>
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<td>Inadequate culture</td>
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<td>Results</td>
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<td>Product (P)</td>
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<td>(D) Maintenance</td>
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<td>(D) Process Improvement</td>
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<tr>
<td>(D) Productivity</td>
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<td>(D) Personnel savings</td>
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<td>(D) Research Center</td>
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<td>(D) Pilot project</td>
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<td>Personnel hiring</td>
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<td>Pilot project</td>
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Table 3: Classification of the results of the research
The implementation process cannot only be explained by considering the technological/organizational environment interaction but also by introducing other variables, such as customers and suppliers which influence the implementation process. Sometimes the customer’s organizational and technological environments are not able to grasp the advantages offered by new technologies. In other cases the difficulties in technology implementation are due to the need to establish strong dependence ties with CASE suppliers.

Table 3 shows a classification of the results for each of the eight firms. Furthermore, the results show two phases of the implementation process. In the first phase a gain in productivity, due to the reduction of development time, is the most important result perceived by the management. At the end of the first cycle both the technology and the firm’s organization are different from the beginning, and new opportunities and misalignments are perceived. When firms become aware that not only the technical aspects are important to appropriately manage CASE, they start to change from a technological strategy to one based on marketing. In that way the product customization, the process differentiation and the development speed are considered as part of a marketing strategy, sometimes explored by pilot programs. Only during the second cycle are firms able to exploit the potential value of CASE. This second cycle has not been completed, and the result of the whole process is still uncertain. The different adaptation cycles between technology and organization are summarized in Figure 2.

One of these adaptation cycles is presented in Figure 3.

Conclusions and Implications

The goal of this paper was to make a contribution to increasing the understanding of the opportunities and misalignments related to the implementation process of Computer Based Technologies in knowledge-intensive activities. The model discussed in this paper meets this need. The application of the model has enabled us to study in depth the problems related to the implementation process. In addition, the model has shown its validity as a general pattern of analysis from which managers and consultants can derive operational tools to identify the key factors of the implementation process and to manage the organizational changes that can facilitate it in their organizational context. These reasons, together with the variety of the type of organizations in which the model was applied, encourage us to attempt to derive from the results some general implications both for the theory and for the management of the implementation process of Computer Based Technologies. We are conscious that theoretical issues and the implications for managers are intimately linked and it is difficult to separate them. Nevertheless we prefer, for greater clarity, to discuss these topics separately.

Implications for the theory

At a theoretical level, a crucial issue which emerged from our experience is the relationship between individual competence and Computer Based Technologies. Generally, the adoption of CBTs is suggested by the need of the firm to improve the productivity of the development process, rendering it more predictable and less dependent on the personnel turnover. In other terms, managers try to partially transfer individual skills to CBTs. In this way individual knowledge is substituted by the new technologies. This fact can give rise to resistance of the professionals to the new technologies, because professionals feel their importance as individuals and appreciate the importance of their autonomy. Furthermore, it is not easy to define the degree of substitution between these
technologies and individual skills. Literature on relationships between technologies and professional skills has pointed out that the substitution is partial and is limited by the existence of tacit knowledge.

For these reasons, at a theoretical level the following aspects need to be investigated:

- what are the specific issues on relationships between technologies and the professional’s skills in knowledge-intensive activities;
- how can the adoption of Computer Based Technologies become a source of opportunity updating the professional’s skills and enhancing the tacit capability of interpretation;
- how can the resistance of professionals to adopting CBTs be reduced by enhancing the possibility of rebuilding a new autonomy.

We are currently focusing our study on such problems. Our next paper will consider these issues. However, we would like to underline certain managerial implications of our research, which can be useful for practitioners.

**Managerial implications**

At a managerial level, the results of our research showed that the efficiency of the CBTs implementation process is strictly linked to the number, type and scale of organizational changes that the management introduce in addition to the adoption of the new technologies.

Management must be capable of evaluating the technological impact of CBTs on the various elements of the organization: procedures used within the company, professional roles, social relationships between the various professionals in the software development group. The importance of the evaluation of such elements is due to the fact that they can produce certain “intangible” costs which must be added to the explicit costs (i.e. costs of the supply of CBTs, costs of training, etc.), making the implementation process much more expensive than had been forecast. Such intangible costs are due to incompatibility with existing methodological, structural and cultural characteristics of the organization, i.e. the reduction of motivation of personnel, as a consequence of the sense of frustration than can be caused by feeling too restricted by CBTs and the need to modify the current procedures of the company to make them compatible with the new technologies.

Management must be also capable to facilitate the mutual adaptation process between new technologies and organization, by identifying and promoting the most appropriate organizational interventions.

In particular, our research showed that the success of the implementation process depends on the capability of the management to lead, in a parallel way, four different phases:

a) **unlearning**, in which professionals change their skills, removing a part of their knowledge and expertise;

b) **substitution**, in which a part of the previous knowledge and expertise of the professionals is transferred to the new technologies;

c) **individual learning**, in which professionals build new expertise around the CASE technologies to update their skills and modify their orientations. In this way the adoption of the new technologies creates new added value in skilled personnel;

d) **organizational changes**, in which new organizational structures, compatible with the higher professional value, are created.

Generally, firms are inclined to simplify the process, concentrating the support on individual learning. Individual and social implications of unlearning and learning are often ignored and also organizational aspects are not taken into account. If the phases of unlearning and substitution are not carefully managed, and organizational changes are not carried out in conjunction with them, professionals can perceive the adoption of new technologies as a threat to their skills, status, job security and work autonomy (Friesen and Orlikowski, 1989). For these reasons it is important for managers and consultants to be able to implement Computer Based Technologies not by reducing but by emphasizing specific individual expertise, identifying the necessary organizational changes and encouraging changes in professionals’ orienta-
tion with modification of reward systems and career paths.

Although the article is the result of the authors’ joint work, the subsection “Implementation of CBT in Knowledge-Intensive Activities: Managerial Issues” is awardable to M. Raff; the subsection “A Dynamic Model of Computer Based Technology Implication” is awardable to G. Zollo; and the subsection “Empirical Evidence” is awardable to G. Capaldo.

Endnotes

1 Youssef (1994) states that “the term CBTs refers to hardware-based and related software-based technologies used in designing, manufacturing, and managing all the activities to produce a product or provide a service” (p.4).
2 A CAD systems, generally defined, is a design software and hardware package which utilizes interactive computer graphics.
3 The term CASE indicates a heterogeneous group of products that aims to offer both development and maintenance tools (CASE Tools) and development integrated environments based on standard methodologies (SEE, Software Engineering Environment).

References


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