Technology management based on the paradox between adoption and routinization

Fischer, S.

1993

Faculteit der Economische Wetenschappen en Econometrie

Serie Research Memoranda

Technology Management Based on the Paradox Between Adoption and Routinization

(theory and practice of Computer Aided Systems Engineering)

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Research Memorandum 1993 - 44
August 1993

vrije Universiteit *amsterdam*

Technology management based on the paradox between adoption and routinization[1]

theory and practice of Computer Aided Systems Engineering

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The management of technology is based on a crucial paradox. On the one hand, there is a need for adoption of new technology, possibly with the objective to innovate. This change in technology requires a certain amount of instability in an organization. On the other hand, there is a need for using technology in the most efficient way possible. The technology has to be standardized or routinized, which requires a certain amount of stability in an organization. The paradox between adoption of new technology and routinization of technology is central to the management of every type of technology. Based on this paradox, it is possible to identify different ways of coping with technology. In this article the paradox will be discussed in detail, and how it can be used to identify these different ways of coping with technology. Computer Aided Systems Engineering, CASE, is used as an example. Different ways of coping with CASE-technology are identified, and compared to different ways of coping with CASE-technology in practice.

1. Introduction

Numerous publications argue that the environment is becoming increasingly more complex and dynamic (Aldrich and Mueller, 1982; Toffler, 1985; Volberda, 1992). Due to these changing environmental conditions, organizations have to act in other ways than they used to act. In a description of the change in strategic issues, Ansoff shows that the critical issue for organizations has changed from focus on routinizing existing practices to managing 'weak signals' emerging from the environment (Ansoff, 1990). In order to survive and gain strategic advantage over other companies in the turbulent environment of today, organizations can respond to these weak signals by way of adopting new technology, which may possibly be an innovation. Viewed from this perspective, its seems as though organizations have moved from 'routinization' to 'adoption' as a guiding principle.

This change from routinization to adoption has an important impact on the management of technology. Technology, especially Information Technology (IT),

[1] This article will appear in the Malaysian Journal of Management Science, June 1993

plays an important role in implementing new practices in organizations. For example, IT is often regarded as an important facilitator for business reengineering, which may result in large scale innovations (Hammer, 1990). The pressure for organizations to use new technology thus forces its IT organization to do likewise. This IT organization can act as a prime stimulus for adoption of new practices in the whole organization by adopting new technology itself - what Mintzberg calls the administrative adhocracy (Mintzberg, 1983) - or by guiding the introduction of IT in the rest of the organization - what Mintzberg calls the operating adhocracy.

However, organizations can not use new technology at all costs. Given the competitive environment, a high burden is placed cost efficiency and to increase the predictability with which organizational goals and objectives can be met. When focusing on adoption of new technology, the predictability of the objectives to be attained will decrease. It is not uncommon for organizations to favor routinization over adoption. For example, with respect to IT, the still continuing software crisis (Veldwijk, 1993), and the interest in downsizing show the need for routinization, instead of the need for adopting new technologies.

So, organizations do not just face a change in focus from routinization to adoption. Routinization has remained with organizations as a guiding principle, and adoption of new technology has been added as additional guiding principle. But it seems as both these concepts do exclude each other. Routinization is directed at using technology in the most efficient way possible. Based on this concept, technology has to be standardized or routinized, which requires a certain amount of stability in an organization. On the other hand, there is a need for adopting new technology, partly or mainly with the objective to innovate. This, however, requires a certain amount of instability. The discussion above suggests that organizations face a dilemma, a choice between either control or innovation, but never both. Research has however shown that not all contradictions are dilemmas. Quite some contradictions in organizations are paradoxes, that can be solved by taking different perspectives on a problem (as is done by for example Morgan 1986) or by various other techniques (see Van de Ven and Poole 1988).

The core of management of technology is dealing with this paradox between routinization and adoption (Steele 1988). As Steele argues, nurturing and control of contradictory requirements (managing paradox) is at the centre of management of technology. There is "the need to foster a dynamic tension between reliance on conventional technology and the development of new technology to supplant it" (Steele 1988, p. 2). The highest order challenge for management, Steele argues, is to achieve a productive, continuing tension between these two. Management has to balance the "tension between the rigor, discipline and passion for stability necessary for effective operational management, on the one hand, and the change, risk taking, and innovation necessary for sustained viability and survival of the other" (Steele 1988, p. xx). So, on the one hand an

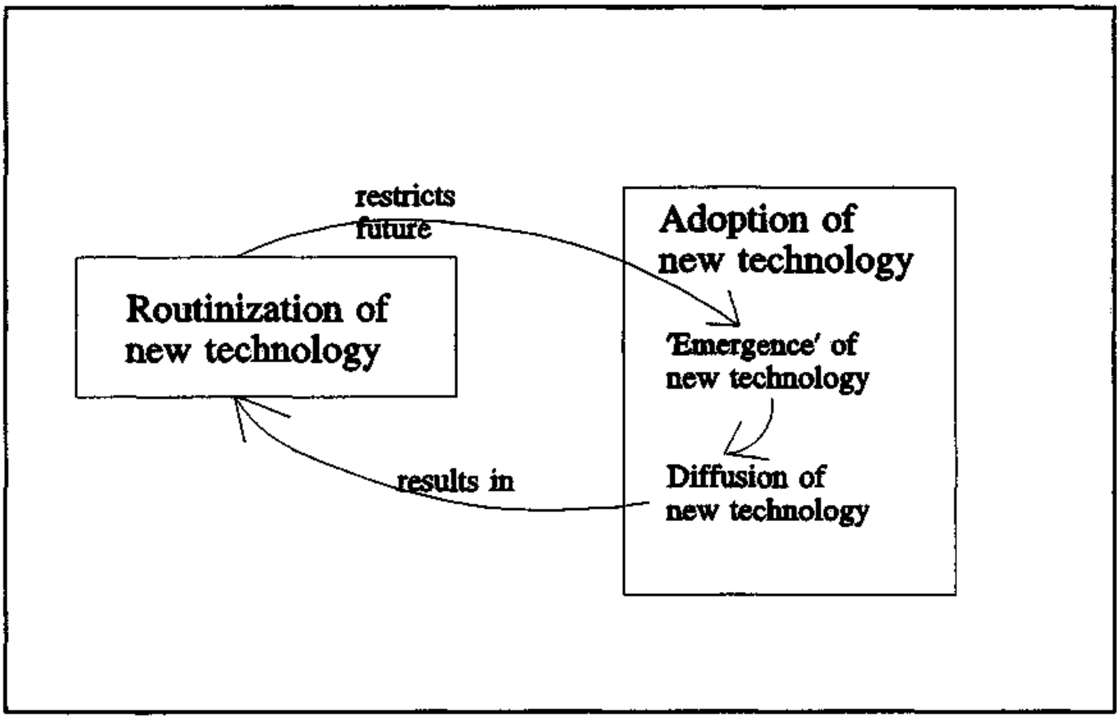

Figure 1. The dynamic interplay between routinizing existing technology and adopting new technology

organization needs to try to use technology currently in use in the best way possible, to make it a *routine* technology. On the other hand, it continuously has to be aware of the potential of new technology, and how to incorporate or *adopt* this technology in the organization.

In this article we will take a first step towards describing the management of IT based on this paradox. First, in section 2 the components making up the paradox will be discussed in detail. We will then show, in section 3, how this paradox implies that there are different ways of dealing with information technology. CASE-technology will be used as an example in section 4 to describe the different ways of dealing with IT. Next, based on empirical research in The Netherlands, section 5 discusses different ways of dealing with CASE-technology in practice. Finally, section 6 compares the findings of dealing with CASE-technology in theory and practice, and arrives at several research implications.

2. Describing the paradox between adoption and routinization

Recalling section 1, Steele formulated the paradox between adoption and routinization as the "tension between the rigor, discipline, and passion for stability necessary for effective operational management, on the one hand, and the change, risk taking, and innovation necessary for sustained viability and survival of the other" (Steele 1988, p. xx). As Steele discusses, this tension will always exist. The matching of contradictory objectives is the essence of management of technology, Steele argues that it even is the essence of management in general. So, routinization is associated with rigor, discipline and stability, and adoption with risk taking, change, and innovation. When translating these terms into the metaphors that Morgan describes - the metaphors of organization as machines, organisms, brains, cultures, political systems, psychic prisons, flux/transformation, and instruments of domination (Morgan 1986) - we can immediately identify routinization and adoption with two different metaphors. The stability and rigor of routinization is typical for the perspective of organizations as machines, whereas the change and risktaking of adoption is characteristic for the brain metaphor.

When we consider the notion that the paradox between adoption and routinization is in a sense a tension between two opposing metaphors, we can more easily understand why problematic situations occur when copying existing practices (see for example Card 1991). Such situations emerge because people tend to view and act only from one typical perspective. For example, management accounting kept its mechanistic view of the world from the 19th century, and was not able to change this perspective (Johnson and Kaplan 1988).

With the help of the metaphors of organizations as machines and organizations as brains, we can easily identify several concepts that make up the paradox between adoption and routinization. Therefore, it may be useful to briefly discuss these metaphors, as Morgan describes them.

The mechanistic metaphor

When organizations are regarded as machines, they usually are called bureaucracies. Morgan remarks that in essence, nearly every organizations is bureaucratic, because "the mechanistic mode of thought has shaped our most basic conceptions of what organization is all about" (Morgan 1986, p. 22). Morgan cites two major sources of the mechanistic metaphor: the theory of Max Weber, and a group of theorists and practitioners from Europe and America. This last group was the founding farther of classical management theory and scientific management. A typical classical theorist is for example Fayol, who formulated the management task as consisting of planning, organizing, coordinating and control (Fayol 1916). The structure the classical theorists advocated was one in which strict authority and top-down control seem to dominate (Morgan 1986, p. 27 and 28). The major advocate of scientific management is of course Taylor, of which Morgan says that "he fused the perspective of an engineer with an obsession for control" (Morgan 1986, p. 28). But, as Morgan argues, Taylor was only part of a larger development that focused on the mechanisation of life generally.

What can be concluded from this short discussion of the machine metaphor is that there is one central concept that characterizes routinization: the concept of *control*. Control is a guiding principle for both scientific management and classical management theory.

The metaphor of brains

The concept of adoption is less visible in the discussion of the metaphors of Morgan. It tends to reappear in various metaphors, particularly the metaphors of organizations as organisms, brains and psychic prisons. The last metaphor is focusing on barriers of adoption, not on the adoption process itself, and is thus a necessary metaphor when discussing the context of the paradox between adoption and routinization. The metaphor of organizations as organisms also mainly focuses on the context in which adoption takes place. It is outside the scope of the article to discuss the context in which the paradox takes place. The metaphor of organizations as brains is the most suitable to characterize adoption of new technology, and deals with the view of organizations as self-organizing systems. First of all this metaphor deals with autonomy, that is self-organizing, as opposed to control. The concept of self-organization immediately brings us to the concept of learning and innovation. Morgan discusses the distinction between single-loop learning and double-loop learning. He characterizes single-loop learning as the simple process of learning, and double-loop learning as the process of 'learning to learn'. From this viewpoint, the tension between routinization and adoption is a tension between single-loop learning on the one hand, and double-loop learning on the other hand. "For example, many organizations have become proficient at single-loop learning, developing an ability to scan the environment, to set objectives, and to monitor general performance of the system in relation to these objectives. This basic skill is often institutionalized in the form of information systems designed to keep the organization 'on course'" (Morgan 1986, p. 89). This description of single-loop learning clearly is a description of the process of routinizing existing practices. Since learning to learn means learning new practices, Morgan makes little distinction between innovation and (double-loop) learning[1]. Innovation is often associated with two other concepts, entrepreneurship and creativity (Couger et. al. 1990). We can add these two concepts to arrive at five concepts that characterize adoption of new technology: autonomy, double-loop learning, innovation, creativity, and entrepreneurship.

Identifying the components making up the paradox

The discussion of the metaphors showed six concepts that are useful to describe the paradox between adoption and routinization: control, innovation, learning, autonomy and creativity. In order to define each of these concepts, we will first discuss important literature on each of these concepts.

The concept of control

It is difficult to discuss control because there is an extensive body of literature on control, emerging from different research disciplines, usually with a different focus. Table 1 gives an overview of some of the more important literature in the field of control. Some of the better known authors in the field of control are

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[1] This is clearly visible in the index of the book of Morgan. The term innovation has no single references except for barriers and need for innovation. With respect to innovation, Morgan makes reference to learning.

Author	Date	Focus
Aldrich, Mueller	1982	changes in environmental selection criteria, one of them is control
Alexander	1991	control in multi-divisional firms
Anthony	1965	management control process
Anthony	1975 and further	management control systems
Boland	1979	control with versus control over
Eisenhardt	1985	control as part of organizational design
Hofstede	1978	ineffectiveness of current management control, alternatives
Hofstede	1981	typology of management control
Johnson, Kaplan	1987	ineffectiveness of current management control
Mintzberg	1983	planning and control as a coordination mechanism
Merchant	1985	measures of control
Orlikowski	1991	impact of IT on control in organizations
Ouchi	1977	relationship between control and structure
Ouchi	1979	typology of control
Snell	1992	strategy versus control
Storey	1985a	combining control theory in management studies and sociology
Storey	1985b	levels and circuits of control
Thompson	1967	typology of control

Table 1. An overview of control literature relevant for describing the adoption/routinization paradox

Anthony, Hofstede, Ouchi, Storey, and Thompson. Anthony for example, in 1965 published his classical work called "Planning and control systems - a framework for analysis". In this publication he introduces the well-known distinction between strategic planning, management control and operational control. Strategic planning is defined as the process for deciding on objectives of the organization, on changing these objectives, on the resources used to attain these objectives, and on the policies that are to govern the acquisition, use, and disposition of these resources (Anthony 1965 p. 16). Anthony discusses the importance of distinguishing this type of planning from planning in control activities, which is much more routine. He distinguishes two control activities, management control and operational control. Management control is defined as the process by which management assures that resources are obtained and used effectively and efficiently in the accomplishment of organization's objectives. Operational control is not concerned with these management activities, but with the actual performance of activities. The control of these activities is called operational control, and defined as the process of assuring that specific tasks are carried out effectively and efficiently.

Another important work on control stems from the contingency theory of Thompson (1967). Based on the contingency paradigm, Thompson argues that different types of control seem to be suitable for different organizational settings. Thompson makes a distinction between two dimensions: knowledge about cause/effect relationships and standards of desirable performance. The former can be either complete or incomplete, the latter can be either crystallized or ambiguous. Based on these two dimensions, four different types of control can be identified. When knowledge about cause/effect relationships is incomplete, and standards of performance are ambiguous, control can only be exercised based on *input*, that is, the qualifications of the workers, such as education. When complete knowledge exists about cause/effect relationships exists, it becomes also possible to use another type of control, control based on *behavior* of workers. When standards of performance are crystallized, it is possible to exercise control based on *output*. When both knowledge is complete and standards are ambiguous, any type of control is possible.

The framework of Thompson is used by numerous authors in the discipline of organization studies. Interesting contributions to the concept of control, based on Thompson's framework, are made by Ouchi (1977, 1979) and Hofstede (1981).

Apart from the discipline of management studies, another discipline in which research of control is carried out quite often is the discipline of sociology. Storey (1980, 1985a, 1985b) has made several contributions to the concept of control. The focus of research is different from research in organization studies, in that the object of study is the social impact of control, whereas in organization studies the focus usually is the type of control that can be exercised in a given situation.

Literature suggest three dimensions of control that can be identified:

- the focus of control: whether control is directed at activities, or at human beings.
- measures of control, along with the tightness/looseness with which these measures are applied.
- the process of control, that is, the evolution of control in organizations, through time, with respect to other types of control, with respect to other organizational units, and among different levels of analysis.

Based on these three dimensions, we can easily see two islands in the field of control. The first island is the field of control in management studies, which mainly focuses on the first two dimensions. The other island is the field of sociology, which mainly focuses on the third dimension. Storey (1985) is one of the few authors to be aware of the separate fields of study. He suggests that the concept of management control can be a useful concept to integrate the fields of study.

Both these fields of study can provide valuable contributions to describing the paradox between adoption and routinization of technology, by carefully describing the way in which routinization is effectuated in organizations. Management studies shows us how control can be realized (operationalized) in an organization, sociology makes us aware of the process of control. From the process of control we can learn that different types of control cannot always be chosen by free hand: the type of control changes through time (Aldrich and Mueller 1982), structure, uncertainty or other contingencies may determine control (for example, Ouchi 1977, Snell 1992), and different controls can exist at the same time, resulting in a less clear or pure for of control than might be expected (Storey 1985).

The concepts of innovation, learning, creativity, autonomy, and entrepreneurship

From the discussion of the metaphor of organizations as brains it was concluded that there are five major concepts that characterize adoption of new technology in an organization. These are the concepts of innovation, creativity, (double-loop) learning, entrepreneurship and autonomy. To get a full understanding of the paradox between routinization and adoption, it is necessary to have a better understanding of each of these concepts.

Similar to the concept of control, there is an extensive body of literature on innovation. Rogers (1983) made a review of over 2000 publications on innovation. But, also similar to control, there is few literature that relates the concept of innovation to IT. This can be concluded from (Walsham 1991), who shows that few IT researchers have look at the metaphor of organizations as brains.

Authors that are well known in the field of innovation are Drucker, Mintzberg, Quinn, and Van de Ven. Some of these authors have also discussed the concept of entrepreneurship. With respect to creativity, reference can be made to Amabile and Couger. Major streams in organizational learning emerge from publications of Argyris and Schön, March, and Senge. Of the five concepts, the concept that is least discussed is the concept of autonomy. We will make reference to a discussion of Walsham. Table 2 gives an overview of literature on each of these concepts, which may be considered relevant for this.

Several conclusions come to mind when reviewing literature in the fields of innovation, creativity, and their related concepts. First, compared to the routinization aspect of the adoption/routinization paradox, the body of terms related to adaption is much larger. In the former section, only one concept was

Author	Date	Comments
Amabile	1985	social psychology of creativity
Amabile	1988	the relationship between creativity and innovation
Argyris, Schön	1978	single-loop versus double-loop learning
Couger	1990	creativity in IS research
Drucker	1985	entrepreneurship and innovation
Gluck	1985	incremental versus big-bang innovations
Maidique	1980	champions of innovation
March	1991	incremental learning
McKee	1992	organizational learning
Mintzberg	1979, 1983	structure and innovativeness
Quinn	1908, 1985	strategic change, related to innovation
Roberts, Fusfeld	1981	structure and innovativeness
Rogers	1983	diffusion of innovations
Senge	1992	generative learning
Ven, van de	1986	management of innovation

Table 2. An overview of innovation/learning/creativity/autonomy literature relevant for describing the adoption/routinization paradox

discussed, the concept of control, whereas in this section five concepts were discussed: autonomy, creativity, entrepreneurship, innovation, and learning. But contrary to the separation of research fields with respect to the control concept - the separation between organizations studies on the one hand and sociology on the other hand - the research field on adaptation seems to be less separated. Most of the concepts discussed in this section are presented together, as can be concluded from Morgan (1985), Gluck (1985) and Van de Ven (1986).

Second, it can be concluded that the large amount of concepts makes discussions of the adaption concept rather confusing. Quite often the various concepts are not clearly defined, resulting in terms to be used interchangeably, without much distinction.

Third, in response to the second conclusion, the relationship between each of the concepts can be made more clear by discussing the focus each of these concepts have. Creativity, autonomy, and entrepreneurship are often oriented towards the individual level, towards the individuals involved in the adaption process, and the qualities or characteristics these individuals should have. The field of research on innovation is mainly directed at technical aspects (Van de Ven 1986), not at the social and organizational aspect. Organizational learning can add to the body of research on innovation by addressing these latter aspects. But one should be aware that organizational learning is directed at organizations becoming more reflexive, at organizations constantly reconsidering their own frames of reference (Huysman 1993). So, organizational learning is not specifically directed towards innovation. Organizational learning can be regarded as a necessary precondition to arrive at innovation, but not all organizational learning activities are directed towards innovation.

The discussion of the adoption and routinization aspect allows us to describe the paradox between these aspects more clearly. To achieve this, the various concepts discussed will have to be synthesized. This synthesis will be focus of the next section.

Defining the concepts

Several concepts were discussed that characterized the paradox between adoption and routinization. These concepts were identified using the idea of metaphor, as discussed by Morgan (1985). With the help of the work of Morgan, it is easy to identify the metaphor of machines with the routinization aspect of the paradox, and the metaphor of brains with the adoption aspect. Using these metaphors, we arrived at five concepts that make up the paradox: control for the routinization aspect, and innovation, learning, creativity, entrepreneurship and autonomy for the adoption aspect. Each of these concepts was discussed. Based on this discussion, we can arrive at a set of definitions for each of these concepts. These are presented in table 3.

The discussion of the concepts allows for the paradox between adoption and routinization to be described more carefully. The number of different concepts characterizing the paradox suggests that it is better to classify the paradox than trying to define it. When some concept is difficult to structure, a common approach is to describe the concept based on *questions*. This classification approach is typical for linguistic studies and is also applied in Artificial Intelligence research (for example, Weigand 1989, Minsky 1975). Such an approach does by no means guarantee completeness, but it results in an intuitively logical and orthogonal collection of primitive features (Boogaard et. al. 1993). A classification of the paradox shows the different dimensions into which the paradox can be broken down, and the concepts that are related to each of these dimensions. This not only offers the opportunity to arrive at a 'richer' description of the paradox, but also allows the paradox to be observed more clearly in practice.

A classification can be described along several dimensions: 'what' - the objective

Concept	Definition
Control management control operational control	 the process by which management assures that resources are obtained and used effectively and efficiently in the accomplishment of organization's objectives (Anthony 1965) the process of assuring that specific tasks are carried out effectively and efficiently (Anthony 1965)
Innovation	the implementation of a creative idea (Amabile 1985)
Organizational learning single-loop learning double-loop learning	 learning to detect and correct errors from existing practices learning to detect and correct errors in existing practices themselves
Entrepreneurship	innovation is the means by which the entrepreneur either creates new wealth-producing resources or endows existing resources with enhanced potential for creative wealth (Drucker)
Creativity	on order for something to be creative it should be 1. (perceived as) new or unique, 2. have value, 3. and the task responded to should not be algorithmic (based on Amabile 1985)
Autonomy	lack of (especially behavioral) control

Table 3. Definitions of the concepts characterizing the adoption/routinization paradox, and their underlying dimensions

of the activity - 'how' - the means by which to realize the objective - 'who' - the type of agent needed to initiate the activity - and 'when' - characteristics of the recipient of the activity. It is quite straightforward to relate each of the concepts we discussed - that is, control, innovation, creativity, learning, autonomy, and entrepreneurship - to the dimensions of classification. The first step is to break down the classification into the routinization aspect and the adoption aspect. For each of these aspects, the dimensions can be described. What results is table 4.

The 'what' dimension describes the objectives that are to be realized. On the one hand, an organization will want to achieve control; input control, behavior control, output control, or any combination of these. However, striving for institutionalizing such a process results in a tension with another process an organization wants to implement. This process is innovation, defined as the process that results in the implementation of creative ideas in organizations.

The 'how' dimension clarifies the way in which the objectives control and innovation are realized. Control can be realized by focusing on single-loop learning, innovation can be realized by focusing in double-loop learning. Literature is less clear on the kind of persons involved in the adoption/routinization paradox. Only the role of entrepreneur, often seen as critical for innovation, is discussed by authors as Drucker (1985) and Couger (Couger et. al., 1990). The same remark can be made with respect to the 'when' dimension. Literature is

Classification aspect	ROUTINIZATION	ADOPTION
WHAT HOW WHO WHEN	control single-loop learning - - -	innovation double-loop learning entrepreneurship autonomy creativity

Table 4. A classification of the adoption/routinization paradox

not clear on the characteristics of the recipients, that is, the potential users of technology, for both the adoption and routinization. For adoption two characteristics are mentioned and were discussed in this chapter: creativity and autonomy. For the routinization aspect, the characteristics are less clear.

Based on this classification, it is possible to discuss how management of technology can take into account the paradox between adoption and routinization. This results in several ways of dealing with technology, and is the subject of the next section.

3. Identifying different ways of coping with technology

"My overall approach has been to foster a kind of critical thinking that encourages us to understand and grasp the multiple meanings of situations and to confront and manage contradiction and paradox, rather than to pretend that they do not exist" (Morgan 1986, p. 339). This passage forms one of the main conclusions of the work of Morgan. Like he argues, we can conclude that we cannot refrain from facing paradoxes. Cameron and Quinn (1988) argue that fundamentally, a paradox is just a mental construct. It exists only in the thoughts and interpretations of the individual.

Several authors discuss ways of dealing with paradoxes. Morgan himself believes in taking different perspectives or metaphors on a phenomenon to understand the complex world around us. Van de Ven and Poole (1988) search in a quite different direction. They identify four different ways of coping with a paradox (Van de Ven and Poole 1988):

- live with the paradox and try to make the best of it.
- clarify connections between different levels of analysis.
- take the dimension of time into account.
- adopt new concepts to address the paradox.

The first solution is not really a solution to dealing with paradoxes. Although it may look appealing, the ignorance for the paradox does have its price. It may result in just the problems the organization wanted to solve by dealing with the paradox. This leaves the three other options for dealing with the paradox of routinization versus adoption. With respect to managing technology, the difficulty for organizations is not so much just adopting new technology or just controlling it once it is in use. Every technology will go through process of adoption and a process of control. The difficulty lies with combining the capacity for control and for adopting new technology *at the same time*. So, the third possibility, taking the time dimension into account, is also not a likely alternative, since this solution implies that one horn of the paradox is assumed to hold at one time and the other at a different time (Van de Ven and Poole 1988, p. 24). Consequently, in dealing with technology, addressing the paradox between adoption of new technology and routinizing existing technology, can only be realized by either taking into account different levels of analysis, of by adopting new concepts to address the paradox. The last section introduced several concepts that characterized the paradox. We will combine these concepts with the idea of levels of analysis to show how the paradox can be addressed.

Markus and Robey (1986) stress the importance of using different levels of analysis. They make the distinction between micro, meso and macro levels of analysis. The paradox between adoption and routinization can be addressed by taking into account both micro and macro levels of analysis (see Fischer et. al. 1994). For the purpose of our study, it is sufficient to focus on the macro level of analysis, the level of organizational activities. With respect to these activities, similar to Anthony (1965), we can make a distinction between managerial activities on the one hand and operational activities on the other hand. Management activities will either be controlled very tightly, based on behavior or performance, or will be controlled very loosely, to stimulate innovation. Operational activities may also be controlled tightly, more likely based on behavior than outcome, or loosely, again to stimulate innovation. So, organizations do not face an explicit choice between either control or innovation, but, based on distinguishing different kinds of management and operational activities and making a separate control/innovation decision for each, can combine different combinations of control and innovation at the same time (for a more detailed description, we refer to Fischer et. al. 1994).

Organizations thus can manage the paradox between adoption and routinization of technology by distinguishing between different types of activities, and for each of these activities decide on the proper level of control or innovation. Based on the different types of control that Thompson (1967) identifies, we arrive at four different combinations of dealing with control and innovation. These four different control combinations characterize different ways of coping with technology, as is shown in figure 5. If few or loose control of activities exists, an organization will be oriented towards adoption of new practices (technology). This type of management of technology, which we will call *adoptive technology management*, is characterized by its focus on innovation, through a process of double-loop learning, guided by one or more entrepreneurial change-agents and by users of technology who are stimulated to be autonomous and creative.

	Routine technology management	Unit technology management	Engineering technology management	Adoptive technology management
What	performance and behavior control	performance control	behavior control	loose control
How	single-loop learning	single-loop learning	single-loop learning	double-loop learning
Who		small entrepreneur	small entrepreneur	entrepreneur
When	routinize, few autonomy	creative behavior, autonomy	creative outcome, few autonomy	creativity, autonomy

Table 5. Four different ways of managing technology

Control of activities may also be based mainly on behavior. This is typical for a situation in which work is well defined, but has quite a few exceptions (Cusumano 1991). In such a situation, the outcome of activities cannot be planned in advance, which is why performance control is not possible. A typical example of an organization in which control is mainly based on behavior and not on outcome/performance is what Mintzberg (1983) calls the professional bureaucracy. Because of the many exceptions to the activities to be carried out, skills of users of technology will have to be high and specialized. We will call the management of technology based on only behavior control *engineering technology management*, because of the importance of this high level of skill. This type of technology management is more likely to be realized by single-loop than double-loop learning, because of the tight control of behavior. Entrepreneurship, creativity and autonomy are less necessary than for adoptive technology management.

The third way of coping with technology characterizes the situation in which only outcome/performance control is exercised. This way of coping with technology is typically for ill-defined activities, with few exceptions (Cusumano 1991). Because activities are ill-defined, it is difficult to control activities based on behavior. But because their are few exceptions to the outcome of activities, control can still be based on performance. So few standardized skills exist, and the way in which activities are carried out is typically based on authority. This can only be realized in a situation of non-mass production, hence we will call this type of management of technology *unit technology management*. Like engineering technology management, this way of coping with technology is likely to be realized by single-loop learning, with a low level of entrepreneurship, creativity and autonomy.

The last way of coping with technology is the most controlled way of technology management. In situations that are stable and highly predictable, both control on behavior and performance can be carried out. This is typical for very routine technology, the mass-production type of technology. In these situations entrepreneurship, creativity and autonomy are not only unnecessary; these characteristics are prohibited for effective management of technology. We will call this type of management of technology *routine technology management*.

Note that the classification of different ways of managing technology is similar to the classification of Perrow (1967) in mass-production technology, engineering technology, unit or craft technology, and non-routine technology. However, the advantage of the classification in table 5 is that we have a far better notion of the relationship between the different ways of managing technology, by taking the adoption/routinization paradox as starting point.

We now arrived at a description of four different types of management of technology, routine, unit, engineering en adoptive technology management. This classification can be applied to any type of technology, including IT. Applying the classification to Computer Aided Systems Engineering, CASE, may be interesting because the impact of CASE-technology on organizations tends to be very high but unpredictable (Fischer et. al. 1993), thus stressing the need for careful management of CASE-technology. In the next sections, we will identify different ways of managing CASE-technology, and compare these to the management of CASE-technology in practice.

4. Different ways of coping with CASE-technology

The body of research on CASE is extensive. However, few research has been carried out in the theoretical field, and the empirical research is mainly oriented towards developing new tools (Wynekoop and Conger, 1990). In this article we want to make a contribution to the theory on CASE-technology by applying the framework presented in the former sections to this technology.

In the following, we will make a distinction between Integrated CASE or ICASE, and CASE tools. CASE tools are defined as tools that support only one or two phases of the process of developing and maintaining information systems. Literature commonly makes a distinction between Upper CASE tools and Lower CASE tools. Upper CASE tools are tools that support the analysis and design phases, sometimes planning. Lower CASE tools typically support one or two of the later, 'lower' or technical, phases of systems development and maintenance, such as design, coding and testing. When most of the phases of developing and maintaining information systems are supported by a tool, we will call such a tool Integrated CASE or ICASE.

Looking at literature on CASE, like McClure (1989), Gane (1990) and Martin et. al. (1989), the distinction between tools en integrated environment apparently is seen as suitable enough to describe CASE-technology. However, such a distinction is difficult to maintain when trying to classify CASE-technology according to the different ways of technology management. More characteristics are needed than just the level of automation that is used to distinguish ICASE from CASE-tools. In order to characterize CASE-technology and make it suitable for classification, the following dimensions of CASE-technology are identified:

- the level of automation - the major dimension used to distinguish ICASE from CASE-tools.
- the type of method of systems development used - the method can be either open, allowing for different techniques to be used to arrive at the ends, or closed, being very rigid and prescribing every action to be performed.
- type of process of development/maintenance of information systems - this can be either the traditional, sequential way of development and maintenance, or a more iterative approach, which allows for interaction of developers and end-users.
- the type of system supported by the technology - the system can be either a routine-type of system, such as administrative or transaction-oriented systems, or non-routine systems, with each functionality of a system completely different from other systems.

Based on these four dimensions of CASE-technology, we can identify four types of CASE-technology, each corresponding to a different type of management of technology. The four different types of CASE-technology are shown in table 6. What many authors define as ICASE is in fact the traditional, sequential or iterative, and closed ICASE-technology. This type of technology corresponds best to the routine technology management, in which both behavior and outcome is controlled, and in which autonomy and creativity are prohibited. The closed character of CASE-technology ensures that behavior and outcome are controlled very tightly, although not every systems developers may be aware of this (Orlikowski 1991). CASE-technology is often supported by a menu-system, which gives users of the technology the impression that they have a choice which activities to perform. But using closed CASE, the menu-options can only be initiated in a prescribed sequence.

In addition to closed CASE, there is another type of ICASE-technology, which we will call open ICASE-technology. This type of technology corresponds to the unit technology management identified in section 3. Behavior is ill-defined, so control has to be exercised based on outcome/performance. On the other hand, systems to be developed are still routine, which suggests that the level of automation can still be very high. The only way to realize this type of management of technology with the use of CASE is by open ICASE-technology. The technology is integrated because systems are still routine, so development and maintenance can still be automated to a large extent. But since behavior is

	Routine technology management	**Unit technology management**	**Engineering technology management**	**Adaptive technology management**
Level of automation	High	Relatively Low	High	Low
Method	Rigid	Open	Relatively Rigid	Open
Process	Sequential or iterative	Iterative	Sequential or iterative	Iterative
Type of system to be supported	Routine	Routine	Non-routine	Non-routine
	Closed ICASE	*Open ICASE*	*Closed tool-sets*	*Open toolsets*

Table 6. Classifying CASE-technology based on type of technology management

ill-defined, it is not possible to use a rigid method, because a rigid method would prescribe the way in which activities are carried out. Hence, the method used should be open, allowing for different techniques to be used.

The other two types of management of technology are characterized by the fact that outcome/performance control is not possible. Translating this to CASE-technology, it means that the type of system to be developed is difficult to specify. The system to be developed or maintained is non-routine, which means that every system will be substantially different from every other type of system. As a consequence, this type of management of technology cannot rely on an integrated environment. An integrated environment can only be used when knowledge exists about the type of system to be developed. Hence, when this type of management of technology is used, the type of CASE-technology to be used has to be a set of different tools, which allows for the development and maintenance for different types of information system. These tools can be combined in different ways, with each combination of tools being specifically suitable for one type of information system. When behavior can be controlled - that is, when engineering technology management is carried out - it is possible to use a rigid set of tools, in which each tool prescribes the way in which activities have to be carried out. If even behavior cannot be controlled, the only type of CASE-technology suitable is a set of open tools. In this situation, developers and maintainers are given autonomy and creativity, in order to allow them to act in the most innovative way that is possible.

Now that we have classified different types of CASE-technology, each corresponding to a different way of managing technology, it is interesting to compare this classification to the use of CASE-technology in practice. This will allow is to make conclusions about the scope of use of CASE-technology in practice, the limitations of the current use, and possible areas for improvement. It will also show us whether the classifications of tables 4 and 5 are suitable for describing the practice of management of technology. In the next section, we will discuss use of CASE-technology in practice, and compare the results from the empirical research with the classification we derived from theory.

5. The practice of coping with CASE-technology

In this section, we will discuss empirical results from a research project that focused on the control of the IT organization. The project used triangulation to describe the control of the IT organization in detail: a comprehensive case-study at a large banking organization, a detailed case-study at 18 companies using structured interviews, and a large survey research (for a description of the total research project, including the methodology, we refer to Fischer and Doodeman, 1992). Triangulation of research results requires careful checking of the representativeness of each of the samples of study. This was realized by creating a large database on companies using CASE-technology. The data of the companies was used for both survey and interview research. Non-response was checked for the survey research.

We will use results from one part of the project, a detailed case-study research among 18 different companies in The Netherlands, to flesh out the model describing the adoption/routinization paradox. The case-study research made use of the structured interview technique to describe (1). the type of IT activities carried out in the organization, (2). the type of culture, structure, internal environment, external environment, and history, and (3). the introduction of CASE-technology in the organization (a detailed description of the research from the perspective of CASE-technology can be found in Fischer, 1993). The interviews carried out were structured according to frameworks provided in the works of Humphrey (1987, 1989), Hofstede et. al. (1992), Mintzberg (1979, 1983), and Zaltman (1977). These frameworks were used to operationalize the characteristics of the organizations, typically characteristics of culture and structure. Reliability of the research results was ensured by interviewing an average of two persons per organization, and by feedback of the interview results. Feedback was allowed at the end of each structured interview, after receipt of a comprehensive description of the research results (Fischer and Doodeman, 1992), and at a feedback session two months after completion of the project. Interviews with individuals lasted typically between two and three and a half hours.

Tables 7 and 8 describe the type of CASE-technology in use by each of the organizations that participated in the research. Table 7 gives a description of the type of organization and several characteristics of the CASE-technology that was

Company	Branch	Degree of automation	Rigidity	Process	Type of systems
A	Public	ICASE	High	sequential	routine
B	Banking	ICASE	Low	sequential	routine
C	Industry	Upper CASE	Low	sequential	routine
D	Banking	ICASE	Low	sequential	routine
E	Banking	ICASE	High	sequential	routine
F	Energy	Upper CASE	Low	slightly iterative	routine
G	Energy	Upper CASE	Low	slightly iterative	routine
H	Banking	Lower CASE	High	sequential	routine
I	Banking	Lower CASE	High	sequential	routine
J	Transport	Upper CASE	Low	sequential	routine
K	Transport	ICASE	High	sequential	routine
L	Public	Upper CASE	Low	sequential	routine
M	Industry	ICASE	High	sequential	routine
N	Industry	Upper CASE	Low	sequential	routine
O	Transport	ICASE	High	sequential	routine
P	Agricul-ture	Upper CASE	High	sequential	routine
Q	Public	ICASE	High	sequential	routine
R	Banking	Upper CASE	Low	sequential	routine

Table 7. Characteristics of organizations investigated

Company	WHAT type of control to be implemented using CASE	WHEN characteristics of the users of CASE after implementation	WHO existence of a charismatic change agent during the implementation process	HOW type of change due to implementation of CASE
A	performance	control	---	strong
B	behavior	autonomy	---	strong
C	loose	control	---	weak
D	all	autonomy	---	strong
E	all	control	change agent	strong
F	performance	control	---	weak
G	performance	control	---	weak
H	behavior	autonomy	change agent	strong
I	performance	control	change agent	strong
J	loose	control	---	weak
K	performance	control	change agent	strong
L	performance	control	change agent	strong
M	loose	autonomy	---	strong
N	loose	autonomy	---	strong
O	behavior	autonomy	---	strong
P	performance	control	---	strong
Q	performance	autonomy	---	strong
R	loose	---	---	weak

Table 6. Characteristics and 'creativeness' of use of CASE-technology

introduced. Table 8 describes the CASE-technology introduced using the classification of table 5. With the help of tables 7 and 8, we can assess the current focus of management of CASE-technology in practice.

Based on table 7, we can make the following observations. First, the seems to be no relationship between degree of automation and the rigidity of the method supported by the technology. ICASE-technology tends to be slightly more rigid.

The lack of relationship is similar to what was expected from the classification in table 5. ICASE-technology can be rigid as well as open (less rigid), and the same can be said for CASE-tools. There was no open lower CASE toolset, but only two companies specifically focused on this type of CASE-technology.

More striking than the degree of automation or the degree is rigidity is that the process supported by the technology is still almost always based on the traditional, sequential approach. CASE-technology allows for a more iterative type of process, but few organizations seem to strive for these kind of processes. Similarly, all organizations focused on the development of routine systems. Although the term CASE suggested automation of systems development of *routine* systems, this is certainly not necessary. CASE tools allow for the development of non-routine systems as well, as table 6 showed us.

From table 8 some other interesting conclusions can be made. The role of a change agent with charisma is just as likely to occur under routine technology management as under adoptive technology management. Under the latter type of management this person is a real entrepreneur, but under the first type of management their are people with a similar role. The reason for this is that under routine technology management the changes that occur as a result of routinizing existing technology may have just a dramatic impact as under adoptive technology management. Norms and values are not changed, but the way of control is. Once the CASE-technology is really routinized, such a person is not needed any more. Under adoptive technology management, such a person will keep to exist.

From table 8 we can also conclude that the relationship between the aspects what, when, and who is similar to what was expected based on the discussion in section 4. Sometimes the objective of CASE-technology is ensuring loose control, but systems developers are not as autonomous as would be expected from theory.

6. Conclusions

This article discussed the management of technology. Central to the management of technology is the paradox between routinization of existing technology on the one hand, which requires a certain amount of stability in an organization, and adoption of new technology, which requires a certain amount of instability. Various concepts that underlie this paradox were discussed: the concept of control, innovation, creativity, autonomy, learning, and entrepreneurship. Based on these concepts, and an identification of different levels of analysis, it is possible to show the paradox between adoption and routinization can be solved. Both control and innovation can exists at the same time, only at different levels of analysis. Based on this notion, we identified four ways of coping with (information) technology: routine technology management, unit technology management, engineering technology management, and adoptive technology management.

The discussion in this article gives an interesting contribution to current theory on management of technology. The contribution does not lie in the identification of four types of technology management - this looks similar to other typologies, such as Perrow (1967) - but in the relationship between each type of technology management. Because the identification of these different types of technology management is based on a classification of the adoption/routinization paradox, the underlying relationships between each different type of management is more clear, as well as are the pros and cons, and objectives. The four types of management show the different trade-offs made in each case with respect to adoption and routinization. Each type of management has a slightly different focus, adoptive technology management focusing meanly on adoption of new technology, routine technology management mainly on routinization. But both allow for adoption and routinization at the same time, only under one type of management one will be more difficult to realize than the other.

The theory described in the article was fleshed out using the example of CASE-technology. First, based on the theory, different ways of coping with CASE-technology were identified. These different ways of coping with CASE were compared to different ways of coping with CASE-technology in practice. First of all it showed that the theory proved to be useful to describe the way in which technology can be managed. The identification of four different ways of coping with CASE-technology is more rich than classifications of CASE-technology that existed so far. It also showed that, so far, work on CASE-technology is still very much focused on the control-side of systems development and maintenance activities. Using more techniques in one CASE environment may overcome this, but one should be aware that getting more adaptive and innovative is not only a question of technology. Management of technology does not consist only of technology, it also consists of management. Using specific tools can support the level of autonomy and creativity in organizations, but it can never enforce it. Managing technology also means managing organizational issues.

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