

Modelling Sociotechnical Change in IS with a Quantitative Longitudinal Approach: The PPR Method

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Abstract:

The following article suggests a critical realistic framework, which aims at modeling sociotechnical change linked to end-users' IT appropriation: the "archetypal approach". The basic situations it includes (the "sociotechnical archetypes"), and the possible appropriative trajectories that combine them, together with three propositions linked to the model, are developed. They are illustrated by means of a case study describing the implementation of an e-learning system within a French university. The paper then presents an instrumentation of the theoretical framework, based on a quantitative longitudinal approach: the Process Patterns Recognition (PPR) method. This one draws mainly on Doty, Glick and Huber (1993, 1994) who propose to evaluate the distance between organizational archetypes and empirical configurations by means of Euclidean distance calculus. The adaptation consists in evaluating the distance between appropriative trajectories (embodied by series of theoretically specified vectors) and empirical processes linked to the implementation of computerized tools in organizations. The PPR method is then applied to the same organizational setting as the one related to the case study. It validates the relevance of this type of a research strategy, which makes it possible to model sociotechnical dynamics related to end-users' IT appropriations.

Keywords:

Technology-organization interaction; sociotechnical process modelling; Process Patterns Recognition; critical realism; Structuration; methodology of research; longitudinal methods; e-learning.

INTRODUCTION:

TOWARDS QUANTITATIVE PROCESSUAL APPROACHES?

The study of the organization-technology relationship is hardly a new topic in the social sciences. From the first research forays into the sociotechnical school by Trist and Bamforth (1951) to Orlikowski's structurational model (1992, 2000), Lin and Cornford's contribution (2000) Callon and Latour's Actor Network Theory and Alter's (1986, 1995) innovation sociology in the French-speaking community, many theoretical frameworks have been developed in this perspective. With regard to Information System research, they draw either on static quantitative approaches, or on more longitudinal qualitative techniques (Choudrie and Dwivedi, 2005; Pinsonneault and Kraemer, 1993). But in spite of Giddens' (1984) invitation not to "wield a methodological scalpel" towards quantitative approaches, Archer's (1995) open view on methodology or a broader discourse in most methodological research about the use of innovative quantitative techniques (assumed to be compatible with a more emergentist perspective, see for instance Thietart, 2001), quantitative processual research is extremely rare in IS (Kaplan and Duchon, 1988; Choudrie and Dwivedi, 2005). "Process measures" (Kaplan and Duchon, 1988) are thus lacking in most IS research. This has led us to a very challenging research question:

How could one make sense quantitatively of sociotechnical dynamics from a processual perspective?

The current IS literature is not very helpful on this. Among the few longitudinal strategiesⁱ in IS, techniques based on surveys have been used for more than fifteen years. Most common

implemented techniques with a longitudinal orientation are multivariate techniques such as log-linear models, probit and logit models, Markovian approaches along with other linear formulations (Venkatesch and Vitalari, 1991: 126) or other simpler descriptive techniques. Numerous works have taken an interest in a technology acceptance evolution (like Hu, Clark and Ma, 2003), or in the evolution of computer tools' diffusion (like Mustonnen-Ollila and Lyytinen, 2003 and 2004) by means of more or less complex statistical models. Beyond a classic paradigm that could be labeled 'assimilationnist' (based on Roger's (1995) theory of the diffusion of innovation), several frameworks have been applied quantitatively to specific forms of organization-technology interactions. If some of these works used the same kind of techniques as those previously mentioned (like Chaomei and Roy, 1996), others, less frequently, opened the way to other longitudinal techniques linked to recurrent cross-sectional studies (often focused on a single variable, i.e beliefs, adoption, acceptance...) or structural analysis. From a structural perspective, Burkhardt and Brass (1990) or Barley (1986, 1990) can be mentioned. Barley, notably in his study of CAT scanners as "occasions for structuring", used longitudinal data collection centered on direct observation of interaction scripts between technicians and radiologists. Nonetheless, the complete set seems to put aside the interpretive aspects of a critical realistic approach and of many other processual approaches (structuration, Actor-Network theory, innovation sociology...). Moreover, it is hard to see how to apply this research strategy to the case of network technologies (for which direct observation of interactions is somewhat difficult). Adopting a recurrent cross-sectional perspective, some researchers have also tried to develop specific quantitative approaches (see Karahanna, Straub and Chervany, 1999 or Hu, Clark and Ma, 2003). Nonetheless, most research in this case focuses on single variables (adoption, beliefs, acceptance...) and do not instrument a broader processual framework.

With regard to longitudinal content analysis like Desanctis and Poole (1994) application of Adaptative Structuration Theory, quantitative techniques have been used for the coding of interactions and their evolutions. But if they made it possible to follow actors' interactions, these methods had two limitations. They were weak on behavioral aspects, and made it hard to generalize any trend for a whole social system (Desanctis and Poole's techniques were applied to experimental groups).

Following the previous criticisms, the quantitative longitudinal approach that has been chosen for this research thus corresponds to a different research strategy, which is labeled here a "Processual Patterns Recognition" (PPR) method.

The model linked to PPR is based on an "integrative" approach" in the broadest sense, i.e. research aiming at overcoming some classic dichotomies (actor-structure, holism-methodological individualism, structuralism-hermeneutics, IT use-IT structure, etc). Integrative approaches are based on several sociological theories, in particular that of Giddens (1979, 1984), but also of Bhaskar (1989), Archer (1982, 1995, 2003) or the works of Bourdieu (1972). All these perspectives have some common points: they kindle our interest in reconsidering IT as an interpretatively and instrumentally flexible object. They also re-visit actor's status (neither a determined element nor a totally autonomous agent) and demand that researchers look at technology-organization interactions as a vast structuration process. More precisely, they emphasize "practice" (and thus IT use) as the driver of the reinforcement or transformation of social structures. Since the early eighties, several works in organization theory and information systems have applied integrative frameworks. Among the very first studies implementing an integrative perspective (mainly structural) the work of Barley (1986), Desanctis and Poole (1992, 1994), Orlikowski and Robey (1991), Orlikowski (1992,

2000), Walsham (1993) or even Bouchikhi (1990) in the French-speaking world can be included. More specifically from a critical realistic perspective, Barley (1990), Dobson (1999, 2000, 2003), Carlsson (2003) can also be mentioned. Here, the analysis will be focused on a critical realistic perspective: the archetypal approach.

First, the archetypal approach is introduced. It is illustrated by means of a case study about the implementation of an e-learning technology in a French Economics and Management faculty. Then, a specific quantitative processual device (the PPR method) is worked out and applied to the same organizational setting as that of the case study. Lastly, some contributions, limitations and perspectives are suggested for this research.

A THEORETICAL BASE: THE ARCHETYPAL APPROACH

First, the integrative model is introduced. It will serve as a theoretical framework for the quantitative longitudinal method developed in the first part. The two fundamental elements of the archetypal approach will thus be presented: sociotechnical archetypes, and the appropriative trajectories that put them together. Then, three proposals about the deployment of trajectories will be put forward.

Archetypes and trajectories: some elements for sociotechnical modeling

The archetypal approach is a synthesis of various works built on an integrative perspective, and especially on Archer's (1995) critical realistic approach and Giddens' (1984) structuration theory. A sociotechnical archetype is the long-lasting state of a sociotechnical system, more precisely *a long-lasting action-structure configuration*, described by concepts and dimensions of the integrative perspective previously introduced. Sociotechnical archetypes are stylized descriptions of what can happen when a new technology is implemented. It is suggested distinguishing four kinds: regenerated, neutral and disrupted archetypes. All four correspond to social dynamics linked to IT use and represent a specific state of the role system and its interactional scripts (cf. Barley, 1986, 1990). The four archetypes can be presented in the following manner:

	General action- structure configuration	Status of uses	Roles and resource system	Examples
Regenerated (R)	Actions change structures	Transform the role system	Unstable, questioned	The implementation of a CAT scanner can result in significant changes in physician-technician interactions. Radiologists can add their own comments and advice through the diagnosis (Barley, 1986).
Neutral (N)	Actions reproduce and reinforce structures	Either: Do not exist (innovation is not used); Reproduce and indirectly reinforce the role system (with or without improving the efficiency of the sociotechnical system); Aim explicitly at maintaining the role system	Stable. Existence of a <i>status quo</i>	Intranets' uses can reproduce the very boundaries they are supposed to overcome. People may go only on the websites devoted to their departments. They can also make private jokes and use local jargon on their forums (de Vaujany, 2003).
Disrupted (D)	Actions and structures are in tension	Reproduce, transform or interrupt the functioning of the role system by creating political or psychological tensions. In the case of an interruption, the disrupted situation is an archetype <i>per se</i> .	Unstable	The implementation of an ERP can result in various political tensions within the organization, in particular between consultants, managers, IT staff and employees. Besides, the acceptance of the new processes included in the software may be extremely stressful for employees (Lemaire, 2003).
Catalyzed (C)	Actions related to ICT accelerate or impede other actions	Uses accelerate or inhibit trends related to non-technological fields	Unstable	Some employees may use an Intranet in a transversal way (whereas others do not). Nonetheless, people may have already started adopting compartmentalized behaviors before. The Intranet then only accelerates an exogenous trend (de Vaujany, 2003).

- **Table 1: The three sociotechnical archetypes.**

In the case of a regenerated (R) situation, the role system of the organization experiences a gradual transformation, which has a certain durability. Normal interactional scripts are modified by the use of the new tools. Each one's role, resources and beliefs are changed by the implementation of the new technology.

In the neutral situation (N), the same phenomenon can be observed (reinforcement of social structures), but associated with two different dynamics. In the first, reinforcement of those social structures supported by the role system is linked to the routinal reproduction of the same interactional scripts. Reproduced actions become more and more legitimate and more and more integrated under different reflexes. This is what Orlikowski and Yates (2002) explicitly considered as a possibility with regard to temporal structures. The reinforcement of social structures is therefore an "unintended consequence of action" in Giddens' (1984) sense of the termⁱⁱ. In the second (where a more extended or open role system can be assumed, i.e. one which is in competition with other sub-systems), the reinforcement of social structures results from more intentional strategies, i.e. ritual-based maintenance of social structures (see Giddens, 1984; Bourdieu, 1972; Archer, 1995). Bourdieu (1972, p 116) thus remarks that in the case of Kabil tribes, "each group of agents tends to affirm its existence by continuous maintenance of a privileged network of common relationships, which integrate not only the set of genealogical relations maintained in a working state (called here usual relatives), but also the set of non-genealogical relationships that can be mobilized for more (material and commercial?) needs (called here usual relations)." This can also be found in some uses of e-mail systems, such as when a manager regularly sends messages to colleagues in order to maintain a certain 'warmth' in his/her professional network.

In the third situation, the disrupted archetype (D), tension can be either psychological or political (de Vaujany, 2003). Thus, disruption can be linked to actors' performance anxieties regarding new tools. Technology is here a disruptive object in actors' routines. In Giddens'

(1984) terminology, it can be said that the "ontological security", the actors' feeling of continuity, is broken. In other cases, tension is more political and inscribed in the properties of the role system. Incompatibilities can emerge in the course of interactions (Archer, 1995). Resources are allocated in a disruptive manner. Interactions evolve within sub-groups in a discordant way as compared to usual interaction modalities. The system is in tension. This situation can be superimposed on the two previous archetypes (R and N). It can also be an archetypal situation per se. This situation corresponds to an interruption of processes related to the role system. The role system is neither transformed nor reproduced. It is partially or globally suspended.

Lastly, in the fourth situation, i.e. the catalyzed archetype, technology appears less structuring. ICT uses are a category of actions among many others that will accelerate or impede changes related to non-technological fields. From this perspective, technology use will not be a factor of change. A broader, exogenous, change takes place within organization, and ICT-related practice will be a potential catalyzer. Recent works (see de Vaujany, 2003) have shed light on these configurations, such as in the case of Intranet or e-mail systems that sometimes accelerate a decompartmentalization of the organization that began before the implementation of the technology.

To expand on our system, some "appropriative trajectories" can be considered at this stage. They are possible combinations of archetypes. 'Integrativist' literature suggests two kinds, which may be supplemented by a third one. The starting point of this exploration is an article published by Orlikowski in 2000. In this paper, she suggests that, in many situations, the appropriation process of IT does not stop with a definite sociotechnical routine, but on the contrary takes the form of continuous "improvisations" and "re-inventions" of the technology. She thus aligns her model with other works like those carried out by Ciborra (1997, 1999, 2000, 2001), which insist on the recurrent muddling through of actors, who regularly rebuild

the technology, whether interpretatively or instrumentally. In order to compare Orlikowski's and Ciborra's improvisational vision and the classic model to which they aim at reacting to, it is suggested using archetypes. Before, a third trajectory ("catalytic") is put forward. It is more processual than the previous ones, and corresponds to those situations where technology continuously either inhibits or catalyzes change or reinforcement processes, which are exogenous to the technological field. It thus combines a row of catalyzed situations in a continuous way.

Finally, the three possible trajectories (applied to an overall sociotechnical system or one of its sub-units) can be described by means of the following table:

	Balancing-point dynamic	Improvisational dynamic	Catalytic dynamic
Archetypal sequence	N-D-R(-N)	R1-R2-R3	C1-C2-C3
Archetypal coherence	High	Low	High
Nature of change	Alternative and quick	Continuous and slow	Continuous and slow

• **Table 2: Comparison of three appropriative trajectories**

The balancing-point dynamic deserves some explanations. Ultimately, it describes a type of a "creative destruction" process well known by economists (see Schumpeter, 1942, 1975: 82). Innovation implies a process of destruction of former routines before new ones emerge. Other sub-trajectories can also be put forward. They imply a more harmonious social innovation in use, without any single stage corresponding to a disrupted situation (de Vaujany, 2003).

Moreover, the balancing-point dynamic encompasses two symbolic thresholds particularly difficult to cross before the emergence of a practicable innovation. The first corresponds to the move from routine to change. It embodies the inertia of the sociotechnical system as regards innovationⁱⁱⁱ. The second epitomizes the difficulties to move from apprehension to acceptance of innovation in use. The implementation of a new tool may initially be greeted by wary tension, which must be overcome in order to reach a harmonious regeneration.

Therefore, the two thresholds embody symbolic gates that, if not crossed, will lead the sociotechnical system back to its initial state.

Some broad complementary propositions linked to the archetypal approach

Beyond the appropriative trajectories described, some propositions concerning the deployment of sociotechnical process and end-users' IT appropriation can be put forward. In the literature, three main propositions come to the fore. First, in accordance with Barley (1990), who was inspired by Nadel's work (1957), **the transformation of social structures will first involve a change in "nonrelational" aspects of the role system.** "Relational" roles imply an "alter ego", another person who has a complementary position in the social order (Barley, 1990): a mother and her child, a creditor and his/her debtor, a professor and his/her student, etc. Conversely, non-relational roles imply a more local and less institutional construction. Barley notices: "when introduced into a work setting, new technologies initially modify tasks, skills, and other nonrelational aspects of roles". Besides, it seems that contexts **where technology displays a high degree of "procedural" (i.e. technical) or "rule-setting" (i.e. social, related to norms of use) restrictiveness^{iv} will be more likely to lead to a quick and coherent change in the role system** than those where technology is less restrictive (de Vaujany, 2003). Appropriations will thus produce or reproduce social structures according to the level of rigidity (i.e. restrictiveness) of initial sociotechnical structures (Desanctis and Poole, 1994). It can thus be reasonably assumed that the computerization of some French abbeys is less likely to induce relational changes than the adoption of new IS systems in SMEs with a more recent history and role system. Lastly, it seems also that **appropriation drivers will be explicit in a phase of transformation of an organization's social structures.** Users will be more reflexive than in routine stages. Barley and Tolbert

(1997) thus suggest that the modification of an institution is likely to involve a more conscious choice than its subsequent reproduction.

To illustrate this archetypal approach, a case study will be suggested. It is based on the implementation of an e-learning system within a French university.

AN ILLUSTRATION OF THE ARCHETYPAL APPROACH: THE CASE OF AN E-LEARNING SYSTEM IMPLEMENTATION

First, the general history of the e-learning system implementation in a French university will be presented. Then, relevant appropriate trajectories will be put forward.

The case study as a set of archetypal situations

The following case corresponds to the implementation of an e-learning system within a French university of Management and Economics. Called a "Virtual Office" ("bureau virtuel" in French), the software was intended to supplement real-time education. The principle of this system, an open-source software, is simple: each student, when he or she logs on to the system (by means of a web browser), sees on the screen the very courses he or she is attending. Interestingly, the appearance of the virtual office is likely to be different from one student to another. The registration of a given course site depends on the teacher, the administrator or super-administrator of the system. In order to simplify the registration procedures, each student is included in a "step code" ("code étape") with five numbers, which makes it possible to register a whole group into the system at once. The functions of the

system are: "Documents", "Forums", "Agenda", "Announcements", "Groups", "Tests", "Discussion", "Course Introduction", "Hyperlinks", and "Assignments". Each of these tools can be activated or deactivated by the teacher in light of his or her needs and interests. He or she can add links to self-developed sites or html pages.

The implementation of the software was conducted by a specific commission at the university in charge of ICT devoted to teaching and gathering different "Virtual Office delegates" for each faculty. It is as one of these delegates and member of the ICT commission that I followed the overall project (and all its management components). Retrospectively, it is suggested that the history of the virtual office at the university can be divided into four main stages.

Stage 1: Initial installation of the system within the university (2002-2003)

The experiment truly began within the Medicine and IUT^v faculties of the university. Instigated by two teachers of the university, a first version of the system was implemented in 2002. The support of the Dean of the Faculty of Medicine was as strong as it was official. In a few months, the sheer number of platforms was remarkable. Most teachers of the medicine faculty, sometimes under the pressure of students, used what then named "the virtual office". In June 2003, more than 300 sites were developed, most of which used many of the advanced functions of the software.

Stage 2: Launch of a first basic version in the Management and Economics faculty: a 'confidential' software (June-October 2003)

The first attempt at introducing the system in the Management and Economics faculty dates back to early 2003. After a presentation of the software, a lecturer in charge of a master's program elected to use the system for his degree. After a general presentation to faculty members in May 2003 the dean decided to offer a version of the software to his students. After an initial period of work during the summer and the first two weeks of September, a dozen sites^{vi} were launched in a sub-component of the faculty (IUP, graduate vocational training in business studies). Then, several problems arose. The list of students included in the step-codes was not always accurate. Besides, several errors had been made by teachers in the registration process, resulting in erroneous enrolments. Many students did not find their login and password on their student card (the same used for their university e-mail account) required for authentication on the site. Finally, and primarily because of poor communication about the tool, some teachers chose not to use the new tool. The software thus initially remained little known and used. The number of business students using the software was very low (less than 50%); connections were limited as well (between three and five a day in October) for the administrative portal.

Basically, the training and communication concerning the new software were insufficient, mainly because of a lack of resources. I managed to train only ten permanent staff lecturers and three administrative agents in the use of the virtual office. Communication was also unsatisfactory. It was limited to a public notice presenting the tool in late September. Therefore I decided in late October to distribute an instructional guide for the software within the Faculty of Management.

At this stage, a neutral situation seems to dominate. Either the system is not generally used, or it is appropriated in an extremely reproductive manner. Teachers use it as a

continuation of their courses. According to these perceptions, it is also rather marginal, not related yet to the core of their department's communication tools.

Stage 3: The initial and increasing use of the software by permanent lecturers of the IUP (November 2003-January 2004)

It was actually in late November and December that the Virtual Office began to take off within the faculty. The bulk of the installation problems with the step-codes (due to unpaid fees) were solved. More than 15 sites were set up within a month by permanent lecturers of the IUP. Three community sites were also put at the students' disposal: a "general culture space", a "foreign students' space" and a "research portal" devoted to academics. The problem of the reluctant faculty members was also resolved. I began to notice the students turning instinctively to the Virtual Office for administrative information. The first part-time lecturers' sites were also set up after I got in touch with them and organized individual presentations of the tool (in total, a dozen).

The number of connections skyrocketed. In the case of the administrative portal of the IUP alone, connections moved from 3-5 a day to 30-40 a day on average. This portal alone accounted for half of the online activity at the Faculty of Management. The administrative portal of other components of the Faculty (for those with one) experienced more difficulties (notably the one linked to the Department of Finance). Except for its Master's program, the Economics department had no portal and courses on the Virtual Office were still marginal.

In the IUP, however, lecturers (especially those heavily involved in the department) promoted the virtual office during their courses. Concrete uses were nonetheless limited to the most basic functions of the software (documents, hyperlinks, course presentation, assignment). But

the tool gradually gained adherents among the teachers. In our own courses, I did my utmost by mentioning interesting exchanges on the various forums in order to foster student interest. As for the students, feedback was generally positive. Indeed, it could be noticed that the number of registered people was not representative of the actual number of users. Several students frequently shared the same password and login. A student thus wrote on one of our questionnaires: "most of the time, I do not connect with my own login password". On the whole, users appreciated having online much of the information they had previously had to request from the secretaries (scheduling, grades, addresses, internal rules, etc). Forums received their first contributions and soon many students had signed on. On the whole, the virtual office has been a means for students to achieve a fundamental goal of the IUP: autonomy. Some students thus began using the tool to exchange ideas about a case study or a report. In the case of certain decentralized departments (60 km away from the main site), the development of an administrative portal relieved a part of the loneliness they had felt before. At this stage, administrative agents were also relatively satisfied with the new tool, which simplified some of their tasks. Students called less to ask for information concerning schedule changes or course information.

Finally, multiple re-invention processes, i.e. 'innovation in use', can be noticed for this third period. The tool, initially conceived as an educational resource, became an administrative tool, a research support network, and a device devoted to a specific course of the IUP (in this last case, strongly modular and frequently improvised by teachers ("cours de methode") devoted to the management of trainees). Nonetheless, the broader sociotechnical dynamics clearly relates to a **catalyzed situation**. The "Virtual Office" is more a way to accelerate a pre-existing trend: the growing autonomy of most students, particularly in the case of the IUP. It is a way to find information autonomously, to get in touch directly with the

professor they want to discuss with, or to get some professional information related to jobs in the continuation of the course.

Stage 4: Growth of a community of practice and first steps toward institutionalization in the Faculty (February to June 2004)

During the fourth and last period of the study, the Virtual Office experienced a progressive 'institutionalization'. Several appraisals of the software's distribution were made during the regular meetings of the 'steering committee' every two weeks. Significant information concerning the IUP department was regularly relayed online with the 'Announcement tool'. The first official participations took place. The dean of the IUP committed himself more strongly, and even participated in forums dealing with course features. A procedure to systematize feedback about courses was implemented by an administrative agent of the decentralized department. This was accomplished in the form of a book free to students, in which they could make their remarks, which were then relayed by the secretary. The first official meeting between the whole the faculty and the computer analysts responsible for the software was held. A general evaluation of the Virtual Office was also made for the annual meeting of the IUP department (in early June 2004) along with the management committee of the institute. A "permanent working group" in charge of the virtual office and e-learning technology within the faculty was established.

During this period, it could also be noticed that more advanced functions had been appropriated by teachers (such as the group tool and various types of online exercises). The last permanent teachers not involved in the project finally established sites. Nevertheless, some departments in the faculty (such as Economics and Finance) still displayed very low usage of the technology.

From late March (perhaps because of the positive reports distributed), the level of daily connections to the portal exploded to approximately 50 a day. Students automatically turned to the virtual office for newer and newer types of information. The number of contributions to forums was so high that I was compelled to delete some old topics in order to better organize the site. I also began to notice the first tensions in discussions concerning education and faculty organization. Nonetheless, it was decided not to interfere in the discussion between students and to give the exchanges complete freedom.

On the whole, the situation was far from ideal. Several students of the IUP, from then on regular users of the tool and increasingly more demanding, voiced their criticisms. They regretted that too many lecturers used their site as a sort of "PowerPoint garage" and wished that they had more sites at their disposal, notably with regard to resource management, and more up-to-date information (especially with regards to classroom assignments). Moreover, some regretted the lack of involvement of several lecturers of the institution. For the other departments in the faculty (in particular Economics), this fourth period initially grew rather slowly. Several sites were set up. In the management area, I also developed an administrative portal for the final course of study still not online (the "CAAE").

At the end of this fourth stage, the faculty seems clearly to be experiencing **a catalyzed situation**. In spite of some "bricolages" (more related to a better efficiency than new modus operandi), the system's uses are mainly **catalyzers** of exogenous trends related to non-technological fields (in particular in the case of the management department).

Overall appropriative trajectories related to the case

Finally, the same sociotechnical dynamic can be found in this case study as the one suggested by Lin and Cornford (2000, p 9) for the implementation of a groupware technology within

their university: "We see an almost casual deployment of technology attracting increasing attention, and slowly developing a profile within the university. The debate around the system moves from the individual to the informal (team), and then into the main management structures." Gradually, the virtual office became institutionalized within the different departments (especially for the IUP) thanks to the middle-management of the faculty (particularly the directors of various BA or Ms courses and permanent lecturers). The increase in use of the tool has been progressive (ten sites in December 2003 for the IUP and 65 in late June 2004) and the structure of the system has been both modified and redirected, indeed more towards student-administration interactions (which is a somewhat astonishing result for a system initially designed for educational purposes).

From the archetypal approach perspective, **the catalytic trajectory clearly makes sense of the situation.** It seems that most e-learning-related practice either reproduce (sometimes more efficiently) usual teaching or administrative habits. On the other hand, some other actions (related to administrative portals and some teaching sites) more clearly accelerate exogenous trends (towards more autonomy).

Now the archetypal approach has been illustrated through the classic case study research strategy, it is suggested to apply and test the model in a different way. In the continuation of the research question suggested in the introductory part, a quantitative processual approach (PPR) will be worked out. It will then be applied to the same organizational setting as that of the French university. But will it lead to the same conclusion? Will it be a way to specify some statements related to the case study?

FROM THE CASE STUDY TO THE PPR METHOD:

A NEW WAY FOR SOCIOTECHNICAL MODELLING?

The starting-point: the works of Doty, Glick and Huber

The idea of evaluating the Euclidean distance between the appropriative trajectories of our model and empirical processes came through the reading of Doty and Glick (1994) and Doty, Glick and Huber (1994). These authors wanted to evaluate the relevance of frameworks and hypotheses drawn from Mintzberg (1979, 1983) and Miles and Snow (1978). Dissatisfied with the usual appraisal techniques, Doty, Glick and Huber took those specific to the field of psychology (see Cronbach and Gleser, 1953), thus enabling them to assess the degree of proximity between an individual's or group's real profile (in the form of scales integrated in a vector) and their theoretical profile (also represented by a vector representing a set of psychological features, see Cronbach and Gleser (1953).

The strategy suggested by the authors for testing the theories of Mintzberg or Miles and Snow corresponds to a three-step methodology:

(1) Theoretical specification, i.e. the building of vectors which are supposed to represent the ideal types and which will be the benchmark for the study (for instance, the configurations originally put forward by Mintzberg). Doty and Glick (1993) suggest that three techniques can be adopted by the researcher: the author's specification itself, the specification by an expert or a panel of experts on the theory, and the placement of archetypes on a continuum^{vii} or the use of empirically specified ideal-types. Doty, Glick and Huber clearly preferred the first possibility. Indeed, the second technique applies to rare cases where the typology can be inscribed in a continuum. The third, implying the use of real organizations corresponding to the ideal-types, will sometimes erase the initial richness and relevance of ideal-types.

(2) Working out of empirical vectors from surveys returned from a vast number of organizations.

(3) Testing of the hypotheses linked to the contingency model. For instance, in order to appraise the Mintzberg model, Doty, Glick and Huber tested three propositions. First, that the more an organization looks like an archetype, the more coherent it will be and thus the more effective. Second, that the more an organization looks like the archetype implied by the level of complexity and stability of its environment, the more effective it will be. And last, that the more an organization looks like the hybrid form implied by its environment, the more effective it will be.

Explanation of the longitudinal technique of Euclidean distance calculus

After reading Doty and Glick, it was decided to take their research technique and adapt it to the archetypal approach, which supposed a more longitudinal tool than the one used previously. This work of adaptation resulted in three separate theoretical sequences (corresponding to appropriative trajectories), divided into three sets of vectors integrating scales (ranging from 1 to 5).

The balancing-point trajectory (sequence N-D-R):

	T1	T2	T3
N	5	1 or 5	1
D	1	5	1
R	1	1 or 5	5
C	1	1	1

• **Table 3: The balanced trajectory**

In this case, T1 (the first coherent archetypal phase) is dominated by neutrality. The second stage (T2) can be related to various possibilities. Either disruption alone can dominate the system, or it can be mixed with neutral or regenerated situations. Then, at T3, regeneration goes through before new forms of routines are related to the sociotechnical system.

The improvisational trajectory (sequence R1-R2-R3, i.e. R at T1, R at T2 and R at T3):

	T1	T2	T3
N	1	1	1
D	1	1	1
R	5	5	5
C	1	1	1

• **Table 4: The improvisational trajectory**

The catalytic trajectory (sequence C1-C2-C3):

	T1	T2	T3
N	1	1	1
D	1	1	1
R	1	1	1
C	5	5	5

• **Table 5: The catalytic trajectory**

It can also be suggested that this dynamic can be specific to an organization's sub-components. Stakeholder 1 may experience a catalyzed situation while Stakeholder 2 may be more involved in an improvisation dynamic. Factorial analysis and standard deviation calculus may be useful to appraise the general coherence of the sociotechnical trajectory under study.

Usually, distance appraisal is based on Euclidean distance calculus. Cronbach and Gleser (1953, p 462) have suggested the following techniques to appraise similarities between profiles:

Symbol and proponent	Procedure	Type of comparison	Remarks
D (Osgood-Suci, 1952; Cronbach et Gleser, 1952)	Distance measure	k (also k-1, k-2)	A general formula
CRL (Pearson, 1928)	Distance measure for standardized variates	k	
rp (Catell, 1949)	Transformed distance measure for standardized variates	k (also k-1)	Convert D to a scale from 1 to -1
Q (Stephenson, 1950)	Product moment correlation across variates	k-2	Symbol Q used here instead of r for clarity
Rho (Spearman)	Correlation across scores ranked within a profile	k-2	
Tau (Kendall, 1948)	Based on rank arrangements	k-2	Highly correlated with rho
r pa	Based on tally of similarity of slope along profiles	k-2	Estimate of tau based on partial data

• **Table 6: Main techniques to appraise similarities between profiles.**

In order to adapt the method proposed by Doty, Glick and Huber (based on a classic distance approach D) to the processual perspective of the archetypal approach, the following indicators can be worked out: a Total Effective Vectorial Distance (TEVD), a Total Potential Vectorial Distance (TPVD) and four Appropriative Proximity Indices (API). On the three periods, the Total Effective Vectorial Distance can be calculated as follows:

$$TEVD = \sqrt{\sum_{i=1}^3 \sum_{l=1}^3 (X_{i1j} - X_{i1k})^2}$$

With X_{i1j} : value at T_i on the line 1 of vector j , which corresponds to real appropriative states for T_i , and X_{i1k} : value at T_i on the line 1 of the vector k , vector treating the theoretical appropriative states for T_i .

For the TPVD calculus, the method is the same except, in the place of $\frac{V_i}{V_j}$: $\frac{V_i}{V_j}$: value at T_i on line l of vector r , the vector condensing the appropriate states is opposite those of the theoretical vector $\frac{V_i}{V_j}$.

In the continuation with Doty and Glick's method, an API can be worked out using the following formula:

$$\boxed{A P \frac{V_i}{V_j} E T E V P T} \quad \text{With } 0 \leq API \leq 1.$$

Lastly, an important problem remains: that of the division of the different phases, which will compose unitary vectors. How will the various stages that constitute the mean vectors be distinguished and then archetypal change isolated? The following rule will be followed: a significant change between two parameters (for instance R_2 compared to R_1) validated by a mean comparison test (see Lesard Monga, 1993; Mbengue, 1999) will characterize an archetypal change (see appendix A.5).

Modelling suggested for the sociotechnical system under study

It has been decided to follow a cautious two-step operationalization strategy. First, and in continuation with a critical realistic perspective as proposed by Archer (1995), agents categories have been distinguished within the role system under study (a university of Management and Economics): students, teachers and administrative agents. Then, the research was centered on three axes of interaction: students-teachers, students-students and students-administrative agents. Finally, three dimensions helped us to generate our first set of items: interactions in the classroom and interactions outside the classroom, interactions within

and outside the institution, and interaction with the teaching process (i.e., preparation and assessment of courses). In the end, four sub-constructs have been worked out for R:

- Student-teacher interactions in the classroom (R S-T-C), which deal mainly with relational and intra-institutional aspects;
- Student-teacher interactions outside the classroom (R S-T-OC), dealing with less relational aspects, either intra or extra institutional;
- Student-student interactions in or outside the classroom (R S-S), treating non-relational aspects, whether intra or extra-institutional;
- Student-administrative agent interactions (R S-A), dealing with nonrelational aspects, intra or extra-institution.

For the first three axes, a set of items was developed. They treated the various stages of the teaching process. The idea was the following: if the set made a concrete system (good factorial validation and internal consistency), then the theoretical trajectories proposed as referential in our first part would be maintained. However, should the set not be maintained, it will be necessary to come back to the theoretical specification work.

At the end of this first logico-deductive work, the research resulted in an initial list of items associated with a scale ranging from 1 to 5, which corresponded to respondents' level of agreement: 'Strongly agree' for 1 and 'Strongly disagree' for 5 (see appendix A.1).

As a conclusion to this preliminary phase of the empirical work, it is possible to expand on some quantitative techniques made for this study. The goal of this research was not to adopt a positivist stance; this would have been incoherent with the theoretical positioning of our model. In view of the fact that our theoretical framework shed light on the possibility of a co-existence of different archetypes or trajectories within the same sociotechnical system, more importance was thus given to internal consistency and convergent factorial validation (relative

to the discriminatory one). Besides, the scales and the items they include stressed the sub-dimensions (multiples) of the archetypes instead of the usual reformulations of questions. Lastly, the whole methodological device was used with a more comprehensive than explanatory objective.

First results of the PPR at T1: refinement of scales and some initial trends

Parallel to the participatory-research mentioned in the case study section, the implementation of the e-learning system in the French university has been an opportunity to apply the PPR method suggested in the first part.

The sampling was made of approximately 40 users^{viii} representative of the 400 students in all departments of the Economics and Management Faculty:

- An "Institut Universitaire Professionnel de management" (IUP), ten years old. It numbers approximately 320 students pursuing BA and MA degrees and 80 teachers (permanent and part-time);
- An "Institut de comptabilité et de finance" ("Institute of Accountancy and Finance"), more recent, with 80 students.

For the first observation period T1 (in December 2003), convergent and discriminatory factorial analysis along with Cronbach Alpha (see appendix A.1, A.2 and A.3) incontrovertibly confirmed the relevance of our four sociotechnical archetypes R, N, D and C. For T1, the situation was largely dominated by a catalytic phenomenon (see table 3 below).

	Phase 1	Phase 2	Phase 3
Actual measures linked to vector V1, V2 and V3	R=2,64, N=2,83, P=1,53 and C=3,17	R=2,6, N=2,89, P=1,48 and C=3,14	R=2,59, N=2,39, P=1,37 and C=3,34
Theoretical measures for a balanced trajectory 1	R=0, N=5, P=0 and C=0	R=0, N=0, P=5 and C=0	R=5, N=0, P=0 and C=0
Theoretical measures for a balanced trajectory 2	R=0, N=5, P=5 and C=0	R=5, N=0, P=5 and C=0	R=0, N=5, P=0 and C=0
Theoretical measures for	R=0, N=5, P=0 and C=5	R=5, N=0, P=0 and C=5	R=0, N=5, P=0 and C=0

a balanced trajectory 3			
Theoretical measures for an improvisational trajectory	R=5, N=0, P=0 and C=5	R=5, N=0, P=0 and C=5	R=5, N=0, P=0 and C=5
Theoretical measures for a catalytic trajectory	R=0, N=0, P=0 and C=5	R=0, N=0, P=0 and C=5	R=0, N=0, P=0 and C=5

- **Table 7: Measures (ranging from 1 to 5) of archetypal situations within the Economics and Management Faculty.**

The tool had thus a very moderate structuring effect. **Regeneration** (see appendix A 4.1) **mainly involved student-administration interactions** (which is broadly convergent with the case study). From the students' perspective, the Virtual Office is not very disruptive, either from a psychological or from a socio-political point of view (P=1,53).

From T1 to T5 (January^{ix} to May 2004): implementation of the PPR method

As shown in table 4, the Appropriative Proximity Indices demonstrated that the three trajectories of the archetypal approach (catalytic, balanced and improvisational) co-exist in this case.

	Calculus	Results	Classification by descending order
API BP 1	EVET= 9,37 EVPT= 17,3	45,8%	4
API BP 2	EVET= 9,42 EVPT= 17,3	45,5	5
API BP 3	EVET= 8,87 EVPT= 17,3	48,7%	3
API C	EVET= 7,68 EVPT= 17,3	56,1 %	1
API I	EVET= 8,83 EVPT= 17,3	49%	2

- **Table 8: Appropriative proximity Indices from T1 to T3**

Nevertheless, the catalytic trajectory seems to be more present than the other two (API for the catalytic trajectory was 56.1%, whereas it was 49% for the improvisational dynamic and 45% for the balanced one, as seen A.6.2). The survey thus broadly confirms the trends

advanced in the case study. The Virtual Office is a tool that primarily changes the flow of academic and administrative information about the IUP (classroom assignments, due dates, regulations for exams and reports, grades, etc). Eventually, **it can be noticed that the software had not really resulted in a significant decrease in administrative workload** (as suggested first at T2 by R S-A scores). Only one out of 3 administrative agents confirmed that the technology makes it easier for them (they receive fewer queries about IUP's administrative documents on file, less direct or phone questions about IUP's current events, etc). For the other two, the situation is more or less unchanged.

In the educational area (R S-T), the situation is rather neutral. Intra and extra-classroom interactions are scarcely modified by the technology (perhaps because the model was insufficiently centered on the tool's potential added values: tests used for self-evaluation, groups, forums concerned with the preparation of case-studies, etc). In accordance with the fact that the catalytic trajectory is most pronounced, the tool mainly served as a catalyst for that IUP project started long before the arrival of the virtual office: namely, the development of student autonomy. Through project groups, the open-mindedness of teachers, and the specific nature of the interactive and modular education, students are incited to be individually responsible as soon as they enter the IUP.

Lastly, this research clearly confirms the first two propositions raised in the first part. Over this one year and a half period, the system has led mainly to changes related to non-relational aspects of roles. R S-A interactions are thus more structures than R S-T ones. More over, this system corresponding to a low-level of restrictiveness is not appropriated in a very coherent way. Various sub-trajectories and archetypal situations co-exist (see A.4). With regard to the third proposition, the case and the PPR method do not make it possible to confirm or refute the statement.

DISCUSSION: CONTRIBUTION, LIMITATIONS AND PERSPECTIVES

At this point, some implications, limitations and extrapolations of this work can be raised. It seems that several contributions can be related to this research. First, from a methodological perspective, **the fieldwork confirms the feasibility of the PPR approach**, and its complementarity with more qualitative techniques (such as participatory research). Then, from a theoretical standpoint, the creation of new models has expanded the archetypal approach. Some obscure points concerning N and R have been defined precisely. Neutrality truly seems to be more than the simple opposite of a regenerated sociotechnical state (see A.2, A.3 and A.4 appendices). Moreover, disruption from a psychological point of view seems inherent to a system with disruption from a political point of view (particularly for the case studied). In the field of education, this work enabled the expansion and refinement of models specific to graduate studies. Factorial analysis made it possible to consider that there are logically four dimensions in the interactional system under study: student-administration, teacher-student in the classroom, teacher-student outside the classroom and student-student. The student-teacher interactions outside the classroom are the most problematic to study.

As for **the potential limitations, it seems that the overall strategy along with the archetypal approach on which it is based targets more 'weakly project-embedded' technologies than technologies strongly embedded in this stage.** Thus, the case of Enterprise Resource Planning seems different from that of e-mail systems, Intranets, groupware, e-learning tools (at least the majority) and even CAT scanners. ERP are tools whose project phase may be extremely long: between one year and two and a half years for four complete modules (Lemaire, 2003). Conceptualization and local development of the tool are followed as well by steps that can have strong structuring power. Key-users, intermediary managers,

local computer developers, editor consultants, and setting consultants are all involved in lengthy negotiations around the processes that make ERP a highly project-embedded technology. On the other hand, projects like intranets or groupware systems, with more emerging contents, shorter duration, and smaller conception perimeter, would certainly be more relevant to the trajectories of the archetypal approach and the research strategy (from implantation to t+n) that we followed. If this were to constitute a future research agenda, the archetypal approach should be adapted to apply to restrictive and strongly 'project-embedded technologies'. For the time being, the way it is formulated is close to end-users' behaviors.

Another limitation lies in the sequential logic of this work, which sticks to a monthly program. The data collection schedule may have missed an important step in the structuring process of the sociotechnical system. Here the difficulty seems to boil down to the periodicity chosen for the study. The researcher must nonetheless take into account the potential reactions of respondents to excessive reminders regarding the return of completed questionnaires. Besides, because of the multiplicity of methodologies used for this study, it was possible to keep an eye on changes in between the different data collection phases.

The third and last limitation is in the starting point of data collection for the survey. The immediate implementation of the questionnaire in October (i.e. the first month of the technology) would have undoubtedly valorized more an initial neutrality. This would have contributed to increasing the Appropriative Proximity Index for the balanced trajectory. The lack of time explains this error.

Research perspectives akin to or benefiting from this empirical study are numerous. The following represent a far from exhaustive list:

(1) In accordance with the first remark, to use the method in the project stage in order to observe a restrictive tool (like an ERP) in a virtual state. This could be a structuring object for organization. Further, it implies the dissection of two types of questionnaires: one focused

on N, D, R and C in the project phase (with specific scales) and another one centered on the post-project phase (with other items and scales for N, D, R and C);

(2) Obviously, to move from the academic world to the business world. Nonetheless, this first study seems to have been an interesting preparatory phase for more company-centered research;

(3) To couple user-focused questionnaires with others centered on communities in charge of IS management in order to work out and test propositions about IT appropriation and its associated effectiveness;

(4) To integrate Archer's most recent work (2003), notably her propositions about the "internal conversation" of actors (interacting with a technology), which would make it possible to move from a descriptive to a more comprehensive stance;

(5) To continue using the archetypal approach and to prolong its assimilation-accommodation process, i.e. to discover potential new trajectories or any possible refinements of the archetypes.

Acknowledgements

We wish to thank Claude Pellegrin, Frantz Rowe and Matthew Jones, as well as the associate editor (Rob Harris) and two anonymous reviewers for their detailed feedback on the manuscript. We would like also to acknowledge the great help of Kirsten Albertsen in the proofreading of this article.

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Appendices

A.1 Table of items^x

Codes	Questions	Status
R1	My use of the virtual office has changed my participation in the course	R S-T-C: M
R2	I think I am in a better position to understand the course since the implementation of the virtual office	R S-T-C: M
R3	The virtual office has changed the overall management of the course as achieved by the teacher	R S-T-C: M
R4	The use of the virtual office has not devolved into pre-existing pedagogical routines	R S-T-C: E in T1
R5	The virtual office enables the teacher to re-center his work on essential aspects of the course	R S-T-C: E in T2
R6	The virtual office has increased the number of interactions between the teacher and his students, notably by means of announcements, agenda and forums	R S-T-OC: M
R7	The virtual office makes it possible to extend the course beyond the scheduled time limit, and favors interactions that would not have taken place without the tool.	R S-T-OC: M
R8	The virtual office modifies the way the teacher manages his case-studies	R S-T-C: E in T2
R9	The virtual office modifies the way teachers present aspects of their course, especially theories, concepts and methods	R S-T-C: E in T1
R10	The role of teachers has been modified by the use of the virtual office	R S-T-C: E en T1
R11	The use of the virtual office leads me to ask questions I would not have raised otherwise	R S-T-C: E en T3
R12	Since using the virtual office, I get in touch with teachers I would not have tried to meet otherwise	R S-T-OC: M
R13	Since using the virtual office at the university, I got in touch with students I wouldn't have met otherwise.	R S-S-OC: M
R14	Since using the virtual office, I feel more involved in the course	R S-S-OC : M
R15	With the virtual office, I guess it would be easier to cover a course I missed	R S-T-OC: E in T3
R16	With the virtual office, I know more things about my administrative environment at the faculty	R S-A: M
R17	With the virtual office I work more continuously and more intensively with the members of my group for collective reports (strategic analysis, information systems reports...)	R S-S-OC: E in T1
R18	With the virtual office, I prepare case-studies jointly with my colleagues...	R S-S-OC: M
R19	With the virtual office, I ask the administration for less information	R S-A: M
R20	With the virtual office I succeed more easily in evaluating my work (for example via the "test" functionality)	R S-S-EI: M
R21	The virtual office helps me to stay in touch with my colleagues during the period I have to spend with my company (I must spend out of class?)	R S-S-EI: E in T1
R22	The virtual office helps me to stay in touch with my faculty during periods of alternation or during holidays	R S-A-EI: M
R23	The virtual office has changed the way I prepare the assignments given by my teacher	R S-T-OC: M
R24	The virtual office has changed the way I prepare for my exams	R S-T-OC: M
N1	The virtual office has not devolved into pre-existing routines	N S-T: M
N2	The use of the virtual office consolidates the relationships between teachers and students that existed beforehand	N S-T: M
N3	The use of the virtual office makes the role and status of the teacher even more legitimate	N S-T: M
N4	With the virtual office, the usual way to do a course is finally strengthened	N S-T: M
P1-1	I do not feel I am good enough to use this tool that looks too complicated	P S-T-OC: M
P1-2	When I use the virtual office, I feel out of my depth with its functions and contents	P S-T-OC: M
P1-3	I find my colleagues more at ease, which makes me nervous	P S-S: M
P1-4	Since the virtual office has been put at our disposal, I feel more out of my depth with the course	P S-T-C: M
P2-1	Since we have been using the virtual office, there are more tensions between teachers and students	P S-T-OC: M

P2-2	Since we have been using the virtual office, there are more tensions between students and the administration	P S-T-OC: M
P2-3	Since we have been using the virtual office, there are more tensions between students	P S-S-OC: M
C1	The virtual office has only accelerated some changes initiated before the use of the tool	C S-T-I: E in T1
C2	The virtual office has only helped me reinforce habits I had developed before my first use of the tool	C S-T-OC: E in T2
C3	The virtual office is one factor among many others that contributes to the evolution of teachers and education	C S-T-C: M
C4	The virtual office is parallel in importance to the course given by teachers	C S-T-C: M
C5	The virtual office plays a very marginal role in my understanding of the course	C S-T-C: M
C6	The virtual office plays a very marginal role in the management of the course as achieved by the teacher	C S-T-C: M
C7	I was already used to asking my teachers questions before the virtual office was implemented, but this tool has helped me do this more	C S-T-C: M

* *Key to the table*: S: students; T: Teachers; A: administrative Agents; I: institution; EI: extra-institution; C: in the classroom; OC: out of the classroom; M: maintained; E: eliminated.

A.2 Cronbach Alpha from T1 to T5 (on final scales)

	Alpha T1	Alpha T2	Alpha T3
R	0,713	0,84	0,849
N	0,54	0,567	0,55
P	0,667	0,745	0,86
C	0,589	0,525	0,633
R E-P-C	0,657	0,625	0,7
R E-P-HC1	0,45	0,657	0,58
R E-P-HC2	0,76	0,38	0,33
R E-E	0,5	0,683	0,683
R E-A	0,83	0,43	0,75

NB: R E-P-HC2 has been given up.

A.3 Factorial analyses (extract) :

Overall factorial analysis at T2 (without eliminated items, with Varimax rotation and eigenvalues higher than 1)

	Components
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Variables	1 (R)	2 (C)	4 (P)	7 (N)
R1	0,163	0,79	0	0
R2	0,250	0,65	0	0,11
R3	0,02	0	0	0
R6	0,793	0	0,21	0,23
R7	0,538	0,31	0	-0,19
R12	0,62	0,31	-0,19	0
R13	0,610	0	-0,11	0
R14	0,358	0,125	0,16	0
R16	0,68	0	0	0
R18	0,588	0,34	0,23	0,19
R19	0,02	0,15	-0,3	0,26
R20	0,05	0,65	0	0,31
R22	0,003	0	0	0,325
R23	0,433	0,27	0	0,13
R24	0,607	0,51	0,13	0
N1	0	0,125	0	0,732
N2	0,3	0,179	0,35	0,369
N3	0,15	0	0,45	0,299
N4	0	0,256	0	0,699
P1	0	-0,16	0,825	0
P2	0,2	0,29	0,786	-0,14
P3	0	0	0,655	-0,11
P4	-0,21	0,15	0,273	0
P5	0	0	0,04	-0,1
P6	-0,18	0	0,257	0
P7	0,15	0	0,2	0,11
C3	0,1	-0,09	-0,16	-0,16
C4	0	0	0	0
C5	0	-0,424	-0,15	0
C6	-0,13	-0,639	0	-0,2
C7	0	-0,2	-0,11	-0,1

A.4 Results for each scale

A.4.1 Presentation of values corresponding to sociotechnical archetypes (with the use of final scales for the five periods)

	Mean value at T1	Mean value at T2	Mean value at T3	Mean value at T4	Mean value at T5	Items in the scale
R	2,69	2,64	2,52	2,64	2,59	R 2, 3, 6, 7, 12, 13, 14, 16, 17, 18, 19, 20, 22, 23, 24
N	2,83	2,87	2,89	2,91	2,39	N 1, 2, 3, 4
P	1,53	1,48	1,56	1,4	1,37	P 1, 2, 3, 4, 5, 6, 7
C	3,42	3,17	3,11	3,15	3,34	C 3, 4, 5, 6, 7

A.4.2 Presentation of the values for T1 and T5 for all sub-constructs (on definite scales)

	Mean value at T1	Mean value at T5	Items in the scales
RE-P-C	2,467	2,32	R 1, 2, 3
RE-P-HC1^{xi}	2,76	2,42	R 7, 12
RE-E	2,395	2,35	R 13, 14, 18, 20
RE-A	3,14	3,19	R 16, 19, 22
P1-i	1,58	1,25	P 1, 2, 3, 4
P2-i	1,48	1,52	P 5, 6, 7

A.5 Results of mean comparison tests

A.5.1 General formula

Here, n is higher than 30, which makes it possible to consider samples as big and to use the following formula:

$$T_{ij} = \frac{(Y_i - Y_j)}{\left(\frac{S_i^2}{n_i} + \frac{S_j^2}{n_j}\right)}$$

With: S_i^2 : variance, Y_i : mean, n_i : number of observations. Then, in order to approximate T with T N(0,1) for $\alpha=0,05$, T=1,96

A.5.2 Results

Comparison	T1-T2	T2-T3	T3-T4	T4-T5
For R	0,45	1,07	1,05	0,43
For P	0,5	0,66	1,34	4,5
For N	0,2	0,14	0,19	0,26
For C	2,21	0,56	0,35	1,57

Thus, phase 1 corresponds to a unique vector (V1), phases 2, 3, 4 will have to be included in the same mean vector (V2), and phase 5 corresponds to a third vector (V3).

ⁱ In a broad manner, Kimberly (1976: 329) defines longitudinal research method as: "Longitudinal organizational research consists of those techniques, methodologies and activities, which permit the observation, description, and/or classification of organizational phenomena in such a way that processes can be identified and empirically documented." Miller and Friesen (1982) propose defining five types of longitudinal methods: "type 1", concerning non quantitative researches centred on a single organization, "type 2" studies focused on a quantitative multivariate analysis of a single organization "type 3" quantitative studies with a limited scope, centred on multiple organizations, "type 4" non-quantitative multivariate analysis of multiple organizations and "type 5", quantitative multivariate analysis of multiple organizations.

ⁱⁱ Orlikowski (2000) proposes two sub-situations: inertia (technology is used as a means to maintain the status quo) and application (technology is used to significantly change the status quo).

ⁱⁱⁱ See Tyre and Orlikowski (1994) on the "windows of opportunity" that sometimes occur in ICT appropriation.

^{iv} Silver (1988, p.52), restrictiveness is the "degree to which and the manner in which a [structure] restricts its users' decision-making processes to a particular subset of all possible outcomes." Thus, the more restrictive the technology, the more limited is the set of unintended (non-prescribed) actions the user can take; the less restrictive the technology, the more open is the set of possible actions during the use process (Desanctis and Poole, 1994, p.126).

^v "Institut Universitaire Technologique", i.e. brief post A-level vocational training.

^{vi} One administrative portal (including administrative information such as internal rules, conditional scheduling of reports, daily time schedules, notes, forums, etc) and eleven sites devoted to teaching.

^{vii} "An alternative theoretical approach is possible when two of the ideal-types define the endpoints of a continuum. In this special case, one ideal-type is scored as the maximum value on each relevant construct and a second ideal type is scored as the minimum value on each construct", (Doty and Glick, 1993; p 237).

^{viii} n1=54, n2=48, n3=37, n4=35 and n5=31.

^{ix} Each evaluation was carried out at the beginning of the month following the period in question. The December 2003 evaluation was thus made during the first week of January 2004.

^x Beyond the items set out in the table, the survey also included questions about respondents' profiles, frequency and forms of technology use

^{xi} At the end of T1, two different scales were built for OC: OC1 including R 7, 12 and 15, and OC2 including R 6, 23 and 24. The next phase lead us to give up the OC 2 construct.