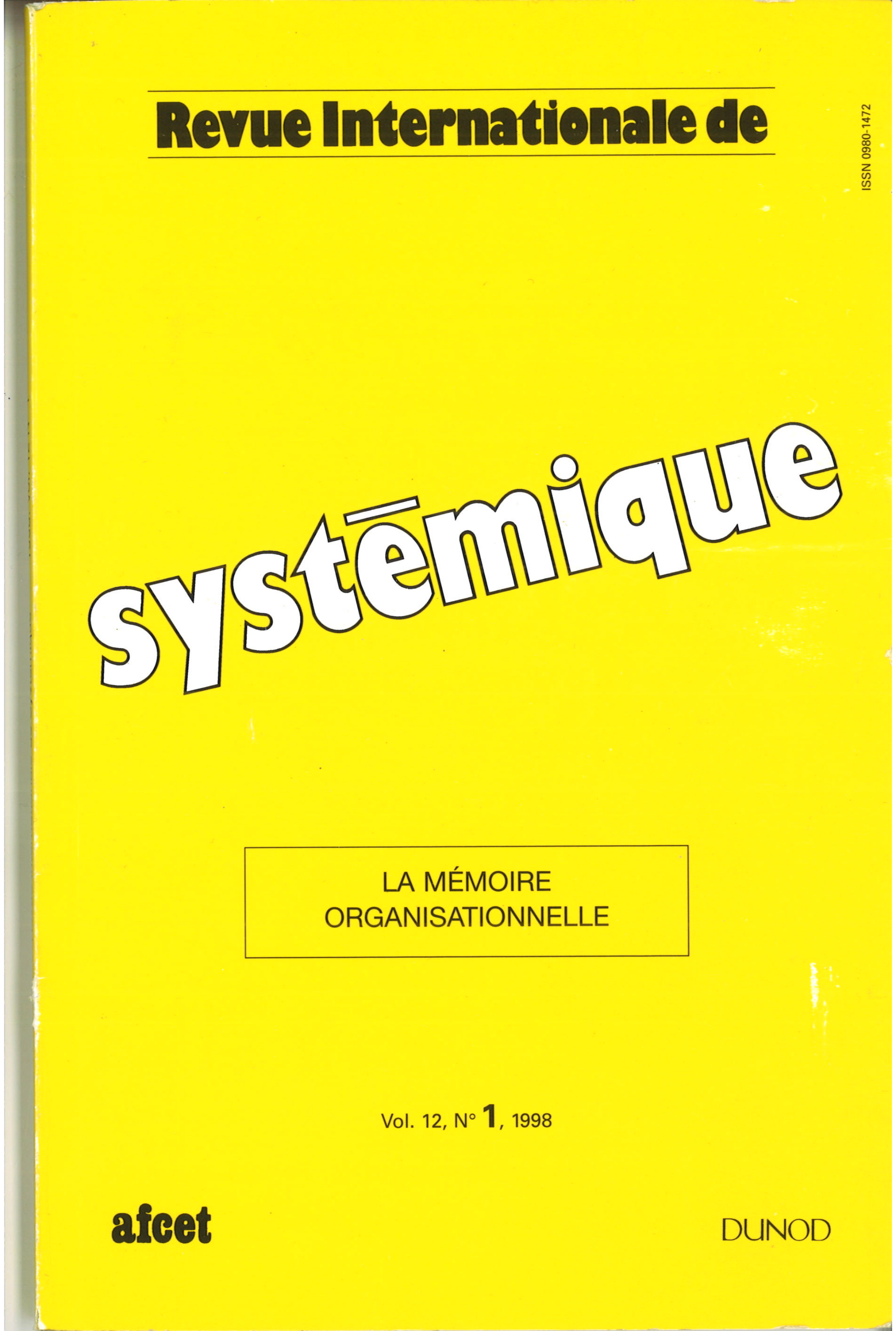

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Organizational memory, cognitive artifacts and routinization: suggestions from a field-study

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ORGANIZATIONAL MEMORY, COGNITIVE ARTIFACTS AND ROUTINIZATION: SUGGESTIONS FROM A FIELD-STUDY

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Résumé
L'organisation accumule et reproduit des compétences qui sont souvent décrites comme des répertoires de connaissances face à des problèmes récurrents. Le papier propose des suggestions issues d'un terrain empirique dans une communauté comportant un réseau de techniciens. En particulier on analyse le rôle des artefacts techniques dans l'émergence du processus de routinisation. Ces supports techniques incluent de la connaissance organisationnnelle, structurent l'activité et renforcent le processus de routinisation.

Abstract
Organizations accumulate and replicate competencies that are often described as a repertoire of solutions to recurrent problems. The paper unfolds some suggestions stimulated by a field study in a community of network technicians. In particular, it is analyzed the impact of cognitive artifacts in the emergence of routinization. Artifacts embody organizational knowledge, structure the activity and reinforce the routinization.

INTRODUCTION

A growing community of students are strongly supporting the idea that organizations can be conceived as repertoires of resources and competencies, following Edith Penrose's (1959) pioneering approach. Organizational knowledge (Kogut and Zander, 1992; Spender, 1997), competencies (Winter, 1987), capabilities (Dosi, Nelson and Winter, in press), routines (Nelson and Winter, 1982) are only some of the main concepts developed to understand how organizations do what they do (Kogut and Zander, 1996), what are the sources of competitive advantage (Barney, 1991), what makes the difference among com-

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peting organizations (Amit and Schoemaker 1993, Teece, Pisano, Shuen, 1996).

One of the first and most quoted intellectual efforts to define the processes by which organizations accumulate and replicate their knowledge is due to Nelson e Winter and their evolutionary theory of the firm (1982). Organizations are conceived as actors that solve problems. As a result of this problem solving activity organizations learn and develop a repertoire of solutions, procedures, practices that are applied over and over to face recurrent problems. Nelson and Winter call routines these solutions as they tend to be repeated across the time, they are evoked in a quasi automatic way without a previous phase of rational analysis and evaluation of alternatives and consequences, they are often not articulated and carry elements of tacit knowledge.

Organizations develop a variety of ways to accumulate and record their competence. Organizational knowledge is stored in individual memories where "reside all the knowledge, articulable and tacit, that constitutes individual skills and routines, the generalized language competence and the specific command of the organizational, and, above all, the associations that link the incoming messages to the specific performances that they call for" (Nelson and Winter, 1982:104). Moreover, organizational knowledge is stored in artificial memories, such as documents, data bases, manuals, books of standard operating procedures. Finally, organizational routines are another kind of artificial memory; routines are a mean to store tacit knowledge that cannot be codified and recorded in a physical *locus*. Routinization is based on the repetition of patterns of behavior evoked by particular conditions. Trough a process of remembering by doing, organizations accumulate a repertoire of routines that act as a memory of organizational competence.

The paper moves from this perspective and unfolds some observations stimulated by a field study. I spent seven months in the field observing a community of technicians who are in charge for the maintenance of a cellular phone network (see section 2). I focused my attention on the processes of accumulation and diffusion of competence within the community. Most of the paper is devoted to the description of two incidents (section 3 and 4) that I use to understand how routinization takes place. Such micro-level of analysis allows me to trace some elements and dynamics that characterize the routinization (section 5). In particular, the development and the use of cognitive artifacts affect the routinization and play a critical role in the accumulation of competence. Cognitive artifact is a concept developed by Don Norman (1991, 1993) who emphasize the role played by tools we use to represent and know the world that we experience.

The data I used to describe the incidents come from my field notes written at the time of my participant observation, unstructured interviews, analysis of internal documents, discussions with the technicians. As usual, a case study is a sample of one, itself and I will not try to suggest any generalization. Still, the detailed description of a context suggests to consider and hypothesize some "hidden" dynamics that other research may explore further.

A CASE STUDY: A COMMUNITY OF NETWORK TECHNICIANS IN A NEW BORN TELECOMMUNICATION COMPANY

Omnitel is a private company that provides a service of wireless communication in Italy. The company has been commercializing the service since the end of 1995 and in less than six months Omnitel built a cellular network based on GSM technology by installing more than 600 transceiver stations; at the beginning of 1998 the transceiver stations are over 2000.

To manage such a fast-growing network, composed by hundreds of stations spread all around the country, Omnitel hired more than one hundred skilled technicians with previous experience in the telecommunication field. They are organized in teams, and they are in charge for the stations installed over a defined area.

Technicians' charge covers installations of new transceiver stations, upgrades, maintenance and the trouble fixing of the working stations. They are supposed to face a variety of problems and situations that implies some sort of expertise with many different domains, such as digital cellular telecommunication, electronics and electricity and air conditioning systems. Accumulation and diffusion of technical competencies was a critical issue as soon as the network has started working for the following reasons:

a) there was a gap between technicians' skills and the *spectrum* of required competencies; first, GSM is an innovative digital technology and most of the recruited technicians had no previous experience with it; second, as a newborn company Omnitel lacked of direct experience, habits, rules; standard operating procedures and artificial memory devices were in the process of definition and did not cover all the information and documentation needs.

b) the strategic relevance of technical competencies; in fact, a reliable network is one necessary condition to compete in the market. Network reliability depends on Omnitel's ability to accumulate and replicate technical competencies.

During the first months technicians used to work together in small groups; later on, they spread over and started working alone. Each technician was given a car, some equipment (spare parts, instruments, tools), a cellular phone, and a portable computer; he had everything he needed in the every-day activity.

An analysis of network technicians' daily work shows that they spend most of their time in the field and used to go to the office very seldom (once or twice a week). The technicians' activity is coordinated by a team leader who schedules the team's work, interact with the supervisor and the other technical departments.

Even though the technicians often work alone, they have frequent interactions with the other members of the team. They frequently call each other (they spend over 20 hours a months in cellular phone calls) and they share stories, problems, ask for suggestions and for meeting. They sometimes meet for lunch and they share news and stories; they talk about their own or others' experience, such as "odd" troubles they were (or were not) able to fix, gossips. Moreover, they use to assist each other when they undertake new activities; they schedule the job in a convenient time, meet at the transceiver station and work together. As they have cellular phones it is extremely easy to them to schedule and rearrange these meetings, if something unexpected happens. Other times expert technicians help other team's members trough the phone.They often need just a value of a parameter or few hints to interpret alarms, to use a special measure instruments, to choose a good restaurant for lunch. Therefore, even though the technicians work most of their time alone they look for interaction both face-to-face and by phone.

ROUTINIZATION AND COGNITIVE ARTIFACTS

Routinization is the process by which routines emerge and become relatively stable patterns of behavior. Routines are not actually stored in physical place, still they are an essential part of organizational memory. The following incident describes the design and introduction in the every-day life of a cognitive artifact; my point is that introduction of cognitive artifacts strongly affects the routinization and have consequences on accumulation and diffusion of organizational competencies.

Temperature simulation tool

Surprisingly, the unreliable components of the stations were the more traditional technologies, namely the air conditioners and the electronic device

which connects the transceiver stations to the network. The first ones, the air conditioners are a vital component of the stations as to work properly GSM equipment needs stable climatic conditions and it suffers either too hot or too cold temperature; the stations are endowed with two temperature sensors (internal and external) and five climatic devices (two air-conditioners, two fan units and an electric heater) that are controlled by an electronic unit (see figure 1).

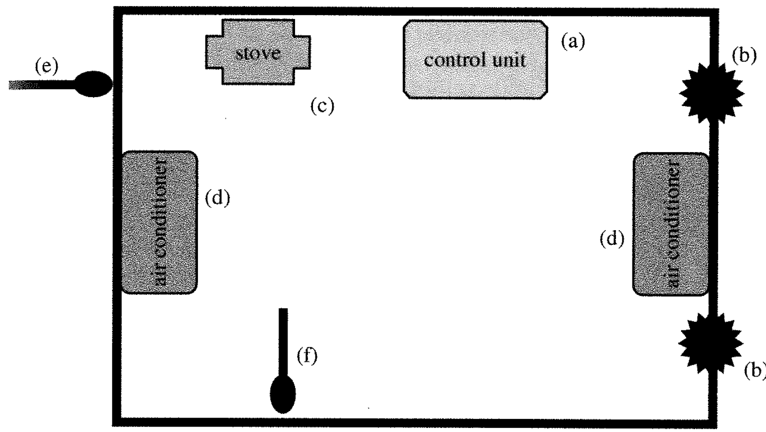

Figure 1. Components of the air conditioning system installed in a transceiver station.
Plan of a station equipped with: (a) electronic control unit, (b) two fan units that push cold air inside; (c) the stove installed only in some stations, (d) two air-conditioners, (e) external temperature sound and (f) internal temperature sound.

The air-conditioning system is a sophisticated one; it has three different types of alarms and it distinguishes among a high number of different climatic conditions and what happens in each of these states (which devices start to work and to which temperature they stop) it depends on the absolute internal temperature, the difference between the internal and the external temperature, the presence/absence of alternate electricity and eleven parameters (temperature thresholds and hysteresis levels) set by the technician (figure 2 reproduce the scheme of the system as it is explained in the manual).

Therefore, taking care of the conditioning system became one of the most important tasks of the maintenance activity; nevertheless, at the beginning Omnitel did not define any full maintenance procedure to follow and teams

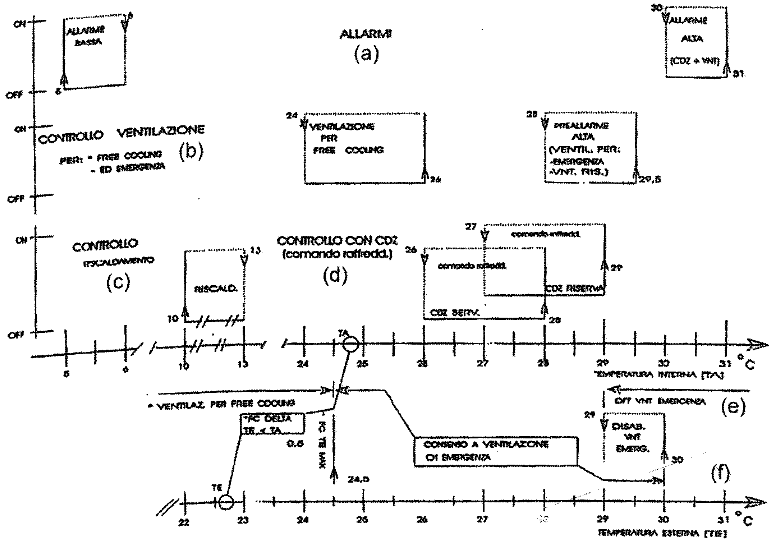

Figure 2. Scheme adapted from the manual of the air-conditioning system control unit.
It represents (a) the alarms related to the stati of too cold and too warm internal temperature, (b) the fan units; (c) the stove, (d) the air-conditioners, indicated as main and supplementary. The device status (on-off) depends on the climatic conditions of (e) external and (f) internal temperature. Nevertheless, to the same internal climatic conditions devices activation depends on the external temperature and therefore; such relationship is not clearly represented in the graph.

introduced a variety of different practices. In particular, it was not defined what to do and how often to repeat the maintenance inspections; further, technicians had no previous experience of air-conditioners and they had no idea how to check them. Apparently, such competencies gap soon became a critical issue and the teams faced it in a variety of ways. For instance, one of the first problems to solve during the inspections was to check if the air-conditioners worked properly; in fact, during the inspections the conditioners may rest only because the internal temperature is right. In some teams technicians used to change temporarily some parameters (e.g. lowering the threshold temperature over which the conditioners start to cool); other technicians used to warm the internal temperature sound with a flame and simulate the conditions to turn on the conditioners. Nevertheless, it happened that these and other solutions were often unsatisfactory; for instance, air conditioner sometimes turned on (this means that the electric engines work) but they were not able to lower the temperature (e.g. because the pressure of the gas in the coil was not adequate). Moreover, by warming the internal sound (and leaving out the absolute and relative vale of the external temperature) it is possible to simulate and test only some possible climatic conditions. Therefore, some technicians were not able to understand whether or not the air-conditioning system of a station was properly working. Moreover, the picture that reproduces the system functioning did not help, as it did not show what should have happened in all the possible climatic conditions. It neglects that the internal temperature may be either higher or lower than the external one. During my observation in the field I met a pair of technicians who were not able to understand whether or not the controller unit of the climatic system was properly working. As the analysis through the scheme was not meaningful, they decided to separate and go to two different stations and repeat the same experiments on two different controller units. They coordinated their attempts and shared the results as they communicated by means of cellular phone during all the experimental sessions (during the process a third technician working in a third different station was involved); at the end they had the impression that the same "odd" behavior was reproduced in all the stations.

These situations show a variety of efforts accomplished by teams to acquire some competencies on an unknown technical domain. To this point the problem was very easy: to understand whether or not the air-conditioning works (diagnosis and trouble fixing are still far away). From this point of view it is relevant what happened in another team, where technicians built a physical tool to help them to simulate all the possible climatic conditions. One of them understood how the sounds send input to the controller unit; therefore, they built a device which is connected to the controller unit instead of the sounds. This way they could simulate all the conditions of internal and external temperature by turning around two knobs. Finally, they introduced a checking sheet where they marked all the situations in which the devices (the main air-conditioner, the reserve one, the fan units and the stove) start and stop to work. Building and introducing the tool and the sheet radically changed the maintenance activity. At that point it was clear what to do during the inspection visit. Some vague process was substituted by a stepped process specified in the checking sheet.

Cognitive artifacts as "priem"

The introduction of standardized tools have standardized the activity, too. In particular, the constraints posed by the artifacts (the piece of paper to mark) reinforces the routinization of a practice. The degrees of freedom (alternative ways to accomplish the maintenance) are reduced and the link between a situation and the required activity is strengthened. Lev Vigotskij (1931) provides fundamental insights to understand how cognitive artifacts affect human behavior. In general, any effort to codify all human behavior (especially the superior activities, as reasoning) in terms of a rigid stimulus-reaction scheme is poor and scarcely meaningful. Nevertheless, in the every-day life people use special devices that Vigotskij calls *priem* or *stimulus sdrestvo*, aimed to strengthen the relationship between a situation (*stimulus*) and a desired output (*reaction*). For example, one common practice used to remember to do something that we think to forget (i.e. the stimulus-reaction scheme is weak) is to make a knot within the handkerchief. This case, the knot is a physical artifact aimed to reinforce a particular behavior; in analogous way, the artifacts designed to accomplish the maintenance activity reinforce a particular sequence of actions and focus technicians' attention.

The routinization of the activity follows a phase characterized by a cognitive loop: technicians meet a problem, they discuss and develop a common representation of the situation, they activate a process of search to a generate satisficing solution. The search space is anchored to the shared problem representation and to the competence that teams own (as, for instance, the repertoire of solutions they successfully used in other situations or skills – in this case computer language programming –). First solutions often modify the initial representation of the context and open the door to the accumulation of other competence and enhance a new search step. The two different practices described in this story, the use of a lighter to warm the temperature sound and the simulator tool, rely on different representations of the conditioning system. The former focuses on absolute values of the internal temperature, the latter takes in account all the variables (internal, external temperature and the comparison between them) considered by the control unit.

The observation of the diffusion of such artifacts in the every-day life of other technicians suggests a further step: being able to use artifacts does not imply to share the representation or the same degree of awareness developed by the designers. The technicians who designed and built the device to simulate the temperatures developed a representation of the system and of the controller unit that is embodied in the artifacts itself. The competencies needed to design the tool are diffused and shared with the other technicians as long as they learn to use the tool. They do not need to know anything about the controller unit's scheme, as the knowledge about the system is embodied in the tool design. Therefore, people who learn to use a cognitive artifact are usually

focused on the correct sequence of actions required to get an output and they are not aware of the accumulated knowledge embodied in the artifact itself, in its shape, in its size.

Ed Hutchins (1995:96-99) provides a detailed and impressive description of these properties of the cognitive artifacts analyzing tools and practices diffused in navigation. For example, the astrolabe's shape embodies centuries of navigation experience; people who learn to use the astrolabe, inherit all the accumulated knowledge stored in the physical design of the tool, without any degree of awareness.

Routinization as a cultural process of learning

Routinization is often described as a simple repetition of every-day practices; nevertheless, a micro-level observation of the process suggests that some important cognitive implications are in order. Routinization and socialization of practices implying the use of artifacts do not require to share the same aware knowledge and the representation developed by the artifacts designers. Artifacts may be introduced and used in an automatic way with no aware representation of the embodied knowledge.

Rather, the introduction of new artifacts and the routinization of practices within a community of technicians like that one described, implies a process of socialization and diffusion of organizational competencies. Most of what we can observe as individual skills is actually a product of organizational competencies. Knowledge required to use an artifact or to diagnosize and fix a trouble is shaped as individual expertise but it is the result of a process of search, analysis, trial that are shared and socialized by the community.

ROUTINIZATION AND ORGANIZATIONAL MEMORY

Nelson and Winter suggest to look at routines organizational memory and this metaphor has been widely discussed and used trough the paper. The next incident enlightens how some forms of artificial memory (databases, and routines) may interact. The cognitive artifact described here is a piece of software developed by some technicians in order to retrieve some information. As in the previous story the artifact work as a structuring resource that enables the routinization and make available important bases of organizational memory that otherwise are neglected.

Analysis of cellular phone calls traffic in Omnitel GSM network

Omnitel GSM network is monitored all the time and an alarm system reveals new breakdowns; technical information of every call is tracked and recorded in databases; looking at these databases network technicians can infer whether the stations they take care of have some problems not seen by the alarm system. Unfortunately, such databases consist of tens pages of numbers and it is hard to filter only the interesting information; moreover, the data are stored in servers and the technicians in the field had no access to them from the field. Finally, most of the time the absolute values of the data do not mean anything and they have to been interpreted by the comparison with time series which implies getting the data from different datasets. Therefore, in many teams technicians do not even look at these database.

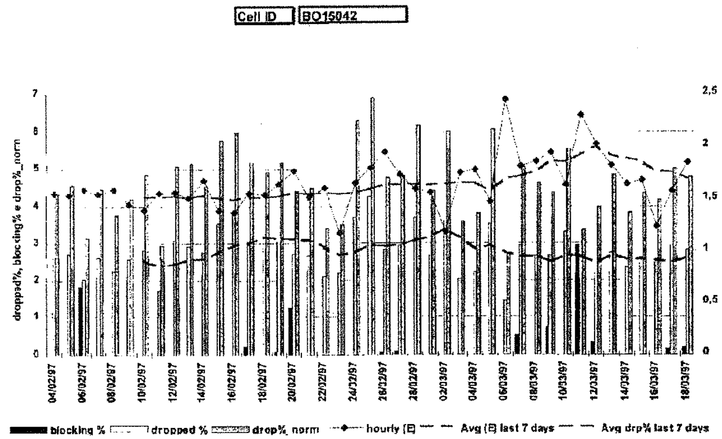

Figure 3. Graphical report based on phone calls traffic data in a transceiver station. The graph plots six different indexes of calls traffic filtered from 30 data-sets.

To overcome these difficulties some technicians skilled in computer science developed easy applications to filter, manipulate, and graphically represent the data. These first trials were discussed and socialized within the team; some technicians were skeptical, others gave suggestions to improve the software tool. As a result a new application was developed; each user could easily filter the data of particular stations, the data were stored in a local memory (e.g. the hard disks of portable computer) and it was possible to compare the historical sequence of datasets and represent the time series in a graphical way (see

figure 4). Nowadays this software is used by other teams' technicians which are still improving and adapting it to their needs; to these teams monitoring the calls traffic in the network has become one of the habitual job and part of the maintenance activity.

Cognitive artifacts, artificial memory and routinization

The incident of software development shows once again how the routinization gradually take place in the every-day activity trough articulated dynamics of representation, search, discovery, introduction of artifacts which embodies competencies largely ignored by the users.

Routinization takes place through the repetition of the activity in the every-day life. Remembering by doing is the expression used by Nelson e Winter (1982:99) to describe the essence of routinization. The most critical competencies are elements of tacit and procedural knowledge that cannot be easily codifies, replicated and accumulated in a physical artificial memory. Rather, they are stored as habits, practices, routines that are evoked to solve recurrent problems. The described artifact does not change the nature of the competence, the analysis of the traffic data, but it makes the process to retrieve of data more automatic, standard and easy. It works as the stimulus-mean described by Vigotskij; the activity is more structured, and easy to replicate and remember.

This incident shows how different forms of organizational memories (artificial memories like database, cognitive artifacts and habitual practices) interact and structure what an observer perceives as competent behavior.

CONCLUSIONS

At this point it is possible an reasonable to point out some lessons we can learn from the field. Routines are a fundamental form of organizational memory as they embody competencies that hardly can be codified, represented and stored in physical places. Routines emerge as a result of a process that has been analyzed through an empirical investigation in the field. In the described stories routinization is affected by the design and the introduction in the every-day life of cognitive artifacts that have a strong impact on organizational behavior.

Cognitive artifacts structure the flow of actions, embody element of accumulated competencies that become available to artifact users. Users often are not aware of the accumulated knowledge embodied in the artifact and they focus their attention on the proper way to use it (e.g. sequence of actions to perform, buttons to press, input to give).

Looking at individual's behavior it is natural to emphasize the individual dimension of expertise; nevertheless, individuals skills are often a result of social interactions. Technicians involved in the maintenance of the air-conditioning system behave according to a reliable and standardized routine which is a social product. Cognitive artifacts work as means that reinforce the routinization, define some accepted practices and constrain team experience on common bases.

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TECHNOLOGY, CODIFICATION OF KNOWLEDGE AND FIRM COMPETENCES

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Résumé

A partir de l'expérience de la codification dans la métallurgie, cet article examine la nature du savoir-faire technologique en vue d'une conceptualisation. Après avoir examiné les différentes acceptions du terme « tacite » dans la littérature économique, il présente une taxinomie des approches utilisées pour produire de nouvelles connaissances. Elle permet de comprendre la différence entre science et technologie. Les déterminants de la vitesse du mouvement de codification des connaissances technologiques et organisationnelle sont discutés et l'intérêt des compétences tacites, complémentaires des compétences s'appuyant sur des connaissances codifiées, est mis en évidence.

Abstract

Drawing upon the historical experience of the codification of steel technologies, this paper discusses the nature of technological know-how in general terms. After examining the meanings of tacitness in the economic literature, it presents a taxonomy of the approaches used in generating new knowledge, useful to understand the diverse nature of science and technology. The determinants of the pace of codification of technological and organisational knowledge are discussed and the roles both of formalized training and of tacit competences complementary to a codified knowledge base are highlighted.

INTRODUCTION

The conceptualizations and propositions advanced in this paper have been largely inspired by the recent transformations of the technological base of the steel industry, which occured under the impact of the progress achieved in electronics, the increasing provision of instruments of measurement and the broad application of computerized automation. On the one hand a few revolutionary new technologies have appeared (like thin slab or strip casting, conti-

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