A cybernetic theory about computer interfaces and human factors within a framework of technological innovation

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1. Introduction

This paper is based on the following postulates taken from a book recently published by this author (Sáez-Vacas, 1990(1)):

a) technological innovation in a company is understood to be the process and set of changes that the company undergoes as a result of a specific type of technology;

b) the incorporation of technology in the company does not necessarily result in innovation, modernization and progress;

c) the very words "modernization" and "progress" are completely bereft of any meaning if isolated from the concept of complexity in its broadest sense, including the human factor.

Turning to office technology in specific, the problem of managing office technology for business innovation purposes can be likened to the problem of managing third level complexity, following the guidelines of a three-level complexity model proposed by the author some years ago (Sáez-Vacas, 1983).

Lastly, managing complexity is an application of one of the main principles of Cybernetics, the Law of Requisite Variety (see Ashby (1956), Beer (1985), Mélêse (1979) and many others).

2. A new theory on office automation

Both Sáez-Vacas (1983) and Flood (1987) incorporate in their respective investigations on complexity the interaction between the organized complexity of artificial systems and

the disorganized complexity of man and society (Sáez-Vacas) and the complexity of homo sapiens introduced by human activities (Flood).

Office automation produces artificial systems --office systems-- for which Sáez-Vacas recently developed a complete theory (Sáez-Vacas & Alonso, 1989) (Sáez-Vacas, 1990(1)) based on the aforecited three-level model (1983). The automated office is an anthropotechnical system in which we find three levels of complexity.

To provide the framework for the subject of this paper, below we are furnishing a very brief general summary of this theory.

This theory is synthesized in the diagram shown in Figure 1. The world of offices and technology comprises four dimensions and three hierarchical levels: for example, the three levels of crescent complexity in the office automation dimension are, starting from the bottom, the Tool Box (i.e., various tools such as word processors, electronic sheets, graphic programs, data base packages, etc., devoted to individual activities), the Office Technological System (in which the above tools are, technologically speaking, interconnected and integrated) and the Office Information System.

In this paper we are interested in focussing our attention on the role of the human and social factors, i.e., the fourth dimension, which, in turn, encompasses three different levels: the individual, the group and the organization. In relation to this dimension emerges the word "conviviality."

In the early 1970s, Ivan Illich was the first to coin the term conviviality (Illich, 1973). In his view, there are three requirements a tool must meet to be considered convivial: it must be efficient without diminishing personal autonomy; it must refrain from creating masters and slaves; and it must expand the radius of our personal actions. Thus, convivial is the best term for describing what office automation must be.

The third level of complexity in its broadest sense arises with the development of what are called in Figure 1 Social Factors and is therefore a consequence of the complex meshing of humans, office processes and technology within office automation dimension. This gives rise to the notion of conviviality as a requirement for the evolution of this kind of system (and for meeting the cybernetic law of requisite variety, applied here to complexity). In the above three principles of conviviality no advice is found concerning productivity, applications, organizational structures or management methods. The principles only point out what the relationship should be between the user and the tool, whoever and whatever they may be.

We propose applying these rules, or principles, to all the levels identified in office automation. Office automation, like any other tool, must be at the service of the

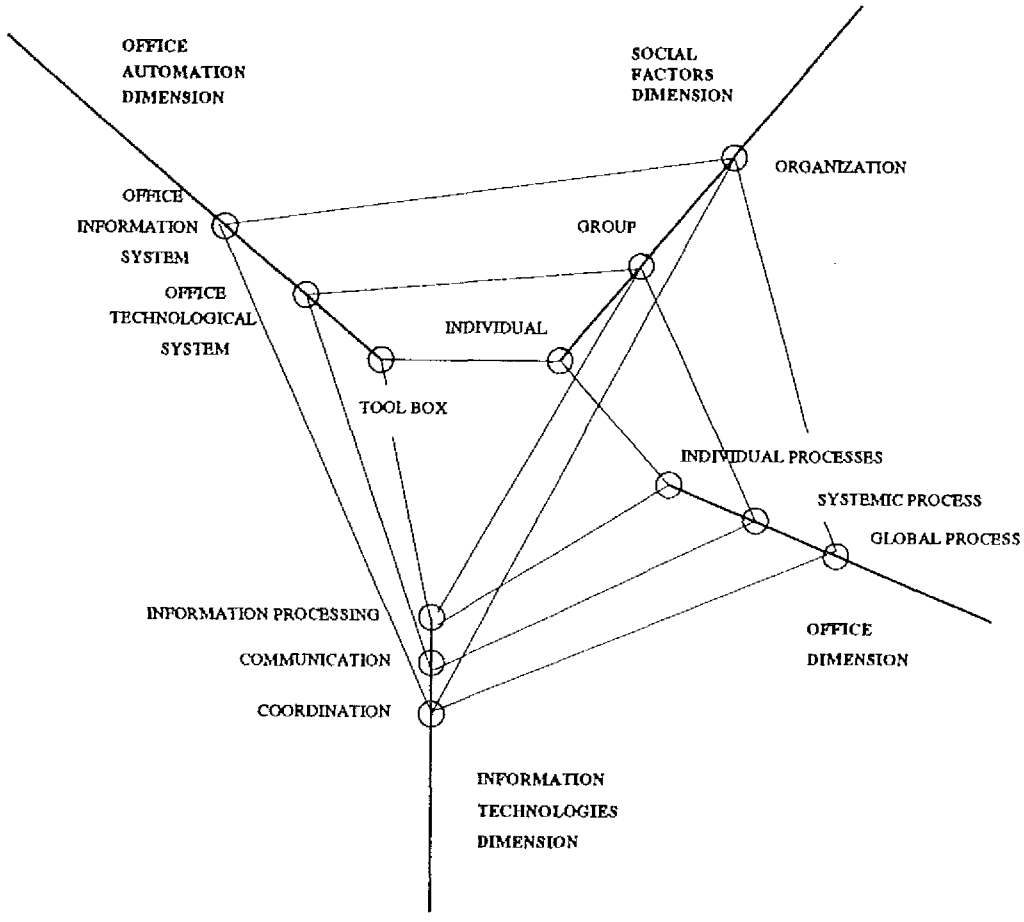

Figure 1

individual, not the other way around. To achieve this, we normally need to know what we want to do, how it will be done and who is going to do it. Some of these questions have been answered through the distinctions made in Figure 1; this Figure shows us how to structure our knowledge of Office Automation, Technology and Organizations. But this would merely involve a conceptual exercise if we do not try to go further. And for this

reason we are introducing a new understanding of these distinctions through the complexity/conviviality tandem.

With a hierarchy like the one proposed here, we can ensure that the right balance is established among all levels, at the same time that the levels at which complexity must be considered become easier to identify. The first level is the individual level, which is perhaps the best known, given that most people work at this level, making it the only level that exists in the minds of many. However, not until recently was it recognized that it is more interesting to focus on group work. Not too long ago groups worked with individual tools, and the individual had to struggle with the complexity generated by the lack of balance. This situation disrupted not only the work of the individual but also the work of the group as a whole.

Individual tools used in a group environment do not enhance efficiency; nor do they respect personal autonomy. It is therefore necessary to think in terms of an Office Technological System as the proper tool for group work. For this same reason, the individual tools used by the work group, where the primary need is actually communication, to process information creates an undesirable dependency on the elements providing that communication. The solution is, again, the Office Technological System, whose main goal, after all, is to support work group communications.

The third rule, that of expanding the personal radius of action, can only be met if the tool works at the appropriate level. The radius of action of the work group is very different from that of the individual. If individual tools are used within the context of the work group, their impact will be felt at the individual (and lowest) level; however, they will not alter the group's radius of action. As a result of a discrepancy between expectations and the final outcome, instead of expanding, this radius may actually diminish.

Conviviality is key both to technological innovation itself and to the successful implementation of technology in work environments. It is important that human factors/conviviality also be considered an aim of support technology. Two very well-known aspects of conviviality are user-friendly interfaces and ergonomics, both of which are certainly important, though Human Factors play a much fuller role. Even the concept of user friendly must be enlarged to encompass groups and organizations.

3. Offices systems are human activity systems

The remainder of this paper will focus on the third complexity level, which is where technological innovation processes unfold. Integrating office technology into a company leads to non-structural problems which are difficult to express if oversimplication is to be avoided. One notable aspect of these problems is that by participating in the system, designers and implementers inevitably become immersed in the very process of change.

This type of systems does not come under systems engineering but belongs to what Checkland (1981, p. 111) calls human activity systems, consisting of a number of activities linked by some principle of coherency. Such systems encompass both those fuzzy types of problems that must be tackled by company managers and many even poorer defined social problems. The nature of their complexity is multidisciplinary and, in the case of office automation, technological and socioeconomic; this is why offices systems should be approached as human activity systems. In other words, we are facing a very special type of theoretically systemic problem.

This approach towards office systems, however, has been practically non-existent in research and writings. Strassmann (1985) states that between 1960 and 1985 approximately 95% of the reference works on office automation dealt only with its technical side. Hirschheim's book (1985) and very few others have provided an interesting change in focus and a good example of that remaining 5% of reference works.

4. The basic structure of the third level of complexity

To examine this level of complexity, we use the classical technique of "divide and conquer," hypothetically breaking this level of complexity down into three simultaneously intervening sub-levels (see figure 2) presented below:

a) the complexity, strictly speaking, of office technology;

b) the complexity of the relationship between the human organization (the company as an organized system) and office technology;

c) the complexity of the relationship between the human factor (as individual components of an organization in which jobs are assigned) and office technology.

The three categories of complexity, illustrated in the graph by two ovoids and a circle, represent to us many other types of variables, all of which must be concommitantly controlled when automating a company.

5. The complexity of office technology

The complexity of office technology is viewed one way by the company's managing director, another way by a company clerk and yet another way by an office technology expert, just to cite a few of the agents involved in the innovation process. Nevertheless, from every perspective the complexity of office technology is not only vast but greater than the average complexity (in variety, forms of control) of any organization and its members. This situation is negative for companies because it does not meet the law of variety which states that the variety of the control system --in this case the organizational

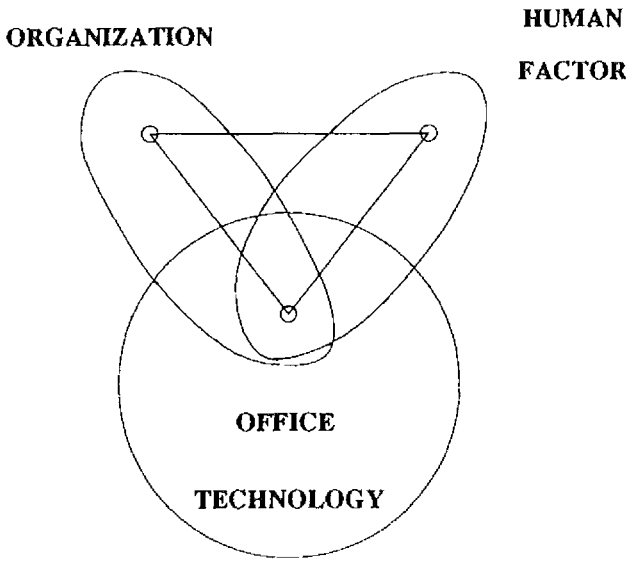

Figure 2

structure of the company-- must be equal to or greater than the variety of the system being controlled, a role which in this case is played by office technology. Otherwise, the system as a whole is unstable.

Figure 3 attempts to synthesize the elements which foster office technology complexity and no doubt represent intrinsic common barriers that the current state of technology itself paradoxically raises against technological innovation.

We could analyze each one of these elements, but, to avoid lengthening this paper unnecessarily, we will leave this analysis partly up to the reader's intuition. Various chapters of the afore-cited book (Sáez-Vacas, 1990) address this matter. Here we will simply give a brief overview:

At the level of computation (or Information Processing - see Figure 1), the variety of computing capacities and properties encompasses machines ranging from personal computers of various families and capacities to mainframe computers, including in between all types of mini-computers and an ever-growing assortment of working stations. As far as memories are concerned, there exists all types of technology, be they 5" 1/4 or 3" 1/2 diskettes and recording tape or optical CDs, not to mention all the complementary apparatus. Turning to software, what technician is capable of getting a handle on the

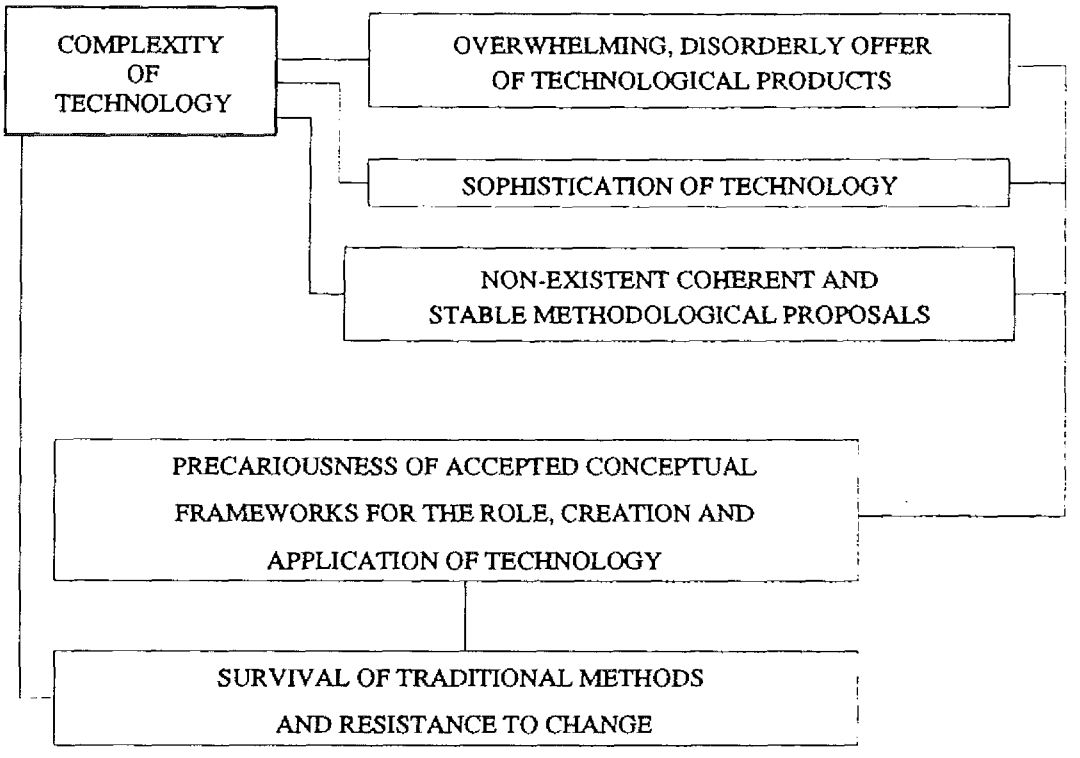

Figure 3

confusing array of available programs, which vary from those that resolve simple, specific office functions to those of the ever-richer group of integrated packages?

At the level of communication technology, the perspective is equally overwhelming and, to a certain extent, too broad intellectually. We have local networks operating with highly diverse technical systems, long-distance network connections, new generations of PABX telephone exchanges and already emerging are integrated digital service networks and future IBCN networks.

The complexity of technology does not end with its variety and sophis-tication. Rather, it is becoming accentuated by the practices of an aggressive, brash market in which the multiplication of companies selling all types of products, tools, machines, services, solutions, etc., is creating a haze of confusion in the minds of customers. The picture is completed by the proven fact that, in general, the methodology for applying and

introducing information technology is in evolutionary terms lagging behind said technology by various generations.

The real degree of technological complexity as schematically described above is reflected in the high volume of failures, problems and resistance relating to its introduction, outside of its potential for providing the promised working advantages.

The classical argument that blames the resistance put up by humans or by an organized system for the barriers that are blindly raised to the marvels of technology is only half-true. The other half of the truth is that the excess of technological complexity, that is to say, its unsuited capacity in human terms, elicits conservative reactions and creates a void of ideas about the role, the creation and the application of technology, which fuels the vicious circle depicted in Figure 3.

6. Adapting complexities: an application of the law of requisite variety

After making the above statements, and returning once again to Figure 2, it can be asserted that, as a rule, it is impracticable for the organ-ization (or the human factor, i.e., each user) alone to bring about the change and increase in complexity necessary to rise to a level of technological requisites. The office technology industry must also be asked to meet the company partway by reducing the complexity of its products and services, at least in the area visible to the user. These two complementary strategies are reflected in Figure 4 by means of some symbols typically used by Beer to represent the mechanisms for amplifying and reducing variety (Beer, 1974, 1985), which will be discussed at some length below.

6.1. Organization versus Office Technology

It must be accepted that the organization will always have to increase its complexity if it wants to evolve, and the case we are analyzing is no exception. On the contrary, this is a special case with a superior approach, like the one described by Mélèse (1979), among others.

Some of Mélèse's ideas can be summarized as follow:

a) an organization is a system of mental representations that are difficult to separate from the environment;

b) all companies must address the problem of information from an overall viewpoint;

c) autonomy and innovation require complexity;

d) this complexity must be distributed among all the levels of an organization.

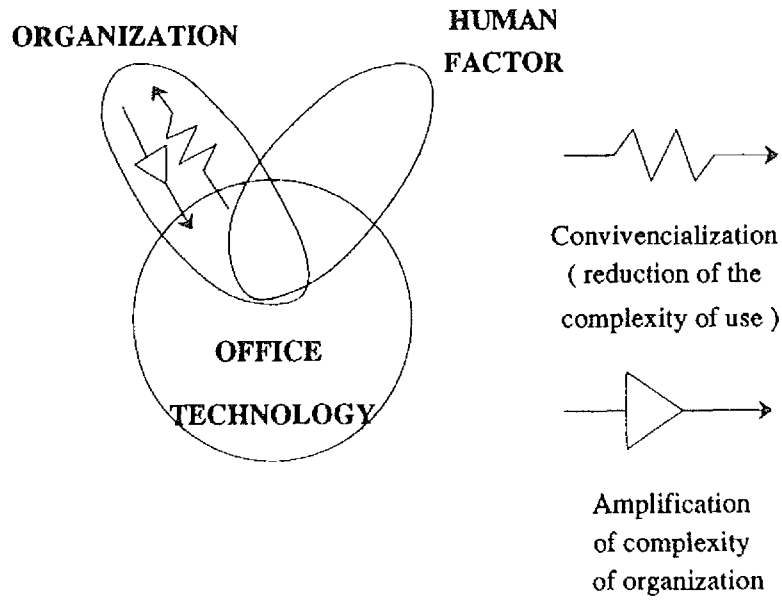

Figure 4

Let us explain. In an organization the effects of numerous "transversal systems and kinds of logic" (technological, commercial, financial, social, trade union, spacial, symbolic, etc., systems) intersect and combine and, for the most part, are determined and controlled outside of the organization, in some part of the environment. In other words, each organization is a node of the larger political-social-economic system, and this node is in turn a system whose interacting components are the mental representations of a variety of external and internal agents.

It is clear that one aspect of the difficulty of the problem resides in that having this node evolve in terms of organization, information and communication in order to follow the evolution of the environment requires equipping it with a variety of ways to perceive, associate and combine numerous dissimilar variables.

Office technology forms part of the external technological system, as well as of the commercial, social, trade union and other systems. Strictly speaking, it is a typically organizational technology, for it sets out to process messages, ideally all those messages

of the company and all communications passing through the organization. Moreover, we know that it even leaves its mark on the cognitive and emotional behavior of individuals.

We believe that the previous paragraphs, though abstract, have made apparent the great difficulty, generally much greater than that customarily acknowledged in reference works, involved in doing what must be done: namely, in raising in a coherent manner the level of complexity of the organization, and not only because of the major comparative increase in strictly technological complexity analyzed in section 5.

At the same time, it is a fact that the functional variety and the capacity of office tools grows unchecked. Consequently, it seems essential for the office technology industry and other technological agents to take the steps necessary to reduce the degree of visible complexity of their products and services. The meeting point between these two sets of actions is established by the law of variety.

In short, simultaneous actions must necessarily be taken on two complementary fronts for innovation to actually take place.

For the sake of example, below we provide an idea of the panoply of different general strategies that could be adopted by each company as well as by the technological industry. The reader will readily know which of these strategies will broaden and which will reduce variety.

a) each company, for its part, must:

- design, transform and explain its organization in keeping with the new tools, converting its classical bureaucratic structure into a "more pliable" and decentralized structure;

- select and train its personnel, giving priority to such characteristics as personal initiative, self-management, a sense of timing and coordination and an interest in learning the workings of the company and the environment in order to take on more fullfilling jobs;

- devote the amount and type of training necessary to teach each office technological application/function, depending on the degree of complexity (the three-level model could serve as a general guide);

- make the conviviality of hardware and software viewed as a whole a primary criterion for making decisions about office technology material purchases;

- organize an in-house human technical assistance network to resolve all the personal difficulties users encounter during the learning process.

The last three aspects form part of what we call "organizational convivialitization."

b) some of the many options the office technology industry has in its hand to contribute to this process include:

- strenghthening the naturalness of man-machine interfaces;

- advertising its offer of products and services with less fantasy and more emphasis on how said offer can solve real organizational problems;

- selecting and not overmultiplying the functional options of these products;

- developing or promoting the development of sociotechnical methodologies for applying office technology;

- simplifying technical language when possible.

6.2. **Individuals versus Office Technology**

The foregoing equally applies on a small scale to each individual of the company or user of technology. The general technological innovation process can be broken down into as many microprocesses as there are users, subject to the personal reactions of each user and the winning or losing situation created for the user by the changes that accompany technology. To a large degree, said microprocesses are cognitive in nature.

From a cybernetic viewpoint, each microprocess is designed to provide the user with a technological office tool that amplifies (symbolized by the triangle) his capacity to relate on an information basis with his organization and his socioeconomic environment (see the second part of Figure 5). The upper part of Figure 5 depicts the step prior to reaching this state, involving the application of mechanisms governed by the law of variety, namely:

(a) A reduction in variety (as perceived by the user) of the technological office tool = good user interfaces + organizational convivialization.

(b) A broadening of the very complexity of the user in relation to the functionality of the tool = learning, training or recycling.

The equation expressed in the above Figure naturally takes into account the fundamental role of the organization in guiding and catalyzing the cognitive processing symbolized in the amplifier (b), an aspect already addressed above among the strategies ascribable to companies.

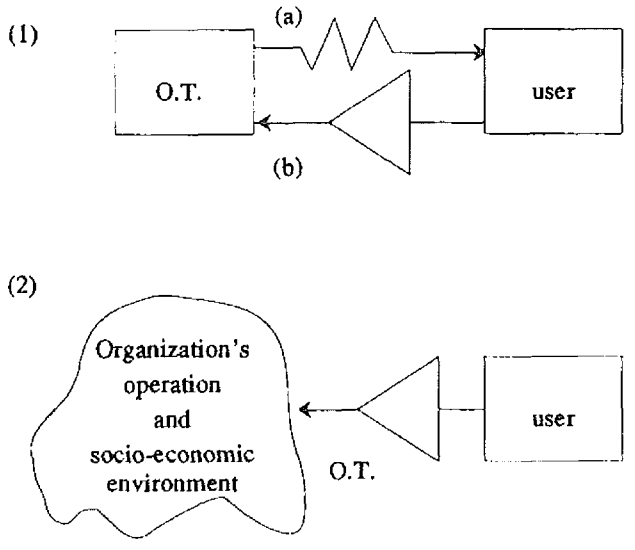

Figure 5

Undoubtedly, the table of measures proposed in this section also contains a considerable number of unknowns and problems to unveil and resolve. Though many of them are beyond the reach of companies, they can be tackled by industry or research institutions, and their solutions will enhance the feasibility of some of the above strategies.

The search for methods of teaching computer word processing to active users, designed to conceal at the outset and gradually reveal as the student progresses the functional and operative complexity of technological office tools, is only a small example of what we want to say (cf a sample of the work of J.M. Carroll, 1985). In keeping with this same desire to optimize the teaching of beginners, Sáez-Vacas and De la Torre (1991) have begun some work on commercial word processors.

Lastly, there is also room for a variety of apparently modest efforts by other agents outside of a single company, companies as a group and the technological industry, efforts which nevertheless help to improve the innovation processes within the framework of ideas described herein. A book the author has written and recent published (Sáez-Vacas, 1990 (2)) provides an example of this point. The content and structure of this book are designed to act like variety amplifiers and reducers (see Figure 3) in connection with the relationship between managers and office technology.

7. Conclusions

It has been possible to provide a wide-reaching model of office automation by means of a multidimensional theory of three levels of complexity.

It has been shown that one of its dimensions, namely that of the Human and Social Factors vector, is key to the design of office systems, since, when all is said and done, these systems belong to a very special kind of systems called "human activity systems."

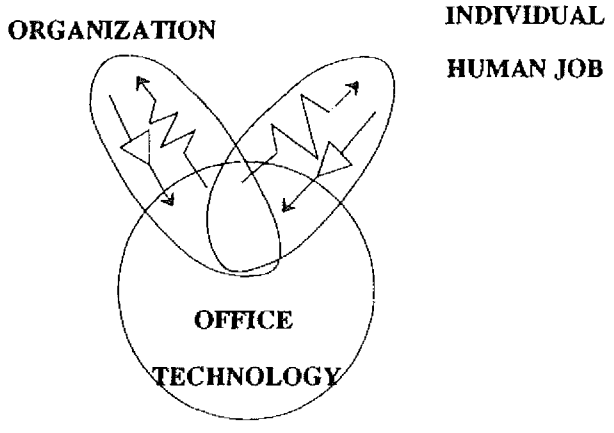

Figure 6

Thus, the three levels of complexity of the Human Factors vector constitute a decisive problem in processes to technologically innovate companies through office automation. Specifically, the third level of complexity seems to be a nucleus that should be isolated if it is to be controlled.

Indeed, once this nucleus has been broken down into three relatively different areas of complexity, an fairly complete conceptual attack, using the cybernetic law of variety, can be launched with a view to its control.

As is summarized in Figure 6, this law is a performance guide on the mechanisms for adjusting complexities, at the collective level of an organization as well as at the individual level where a single person performs his job. This second level, however, is

naturally comprised within the strategies of the first level. It is in the field of the adjustment mechanisms where there is a genuine need for research and ideas.

Controlling the third level complexity of office systems would, in the author's opinion, be tantamount to paving the road of innovation with this new technology.

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