ORGANIZATIONAL EVOLUTION AND SEMIOTICS IN COMPLEX ENVIRONMENTS: THE CASE OF THE AERIAL SAFETY

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Abstract

The effort in advanced information sy stem that many organizations have achieved to improve performance under foreseeable situations has increased organizational complexity decreasing the capacity to deal with unforeseen situations. At this respect, our research question is: what is the limit for this model of devel opment? Once reached, what are t he alternatives to improve? An explanation can be organized around semiotic. To do this, the aerial safety learning model and its collateral effects will be analyzed.

Keywords

Organizational evolution, semiotics, sense, complex environments, Ai r safety.

INTRODUCTION

In this paper we analyze the effort that many organizations have developed related to the design of the technical and structural mechanisms to improve performance of work processes. However, improvement in rules and procedures seems to *backfire* when unknown problems arise that become a barrier to the solution. Every new rule or device can be a good way to manage a planned event (Reason, 1997) but, at the same time the reaction to an unplanned one can be impeded.

As a result, the pace of improvement of many organizations has stopped or decreased. The technology-based development generates new events through unexpected interactions among parts of the system. Consequently, this kind of development decreases the capacity of the system to manage these new events. An explanation to this issue can be organized around semiotics related concepts. The concept of having to look for ways to improve from the present situation is especially relevant.

In order to study this phenomenon, we proceed as follows: In the first epigraph, we analyze briefly the evolution of information technologies and the effects produced in organizations, especially human operators' capacity. Next, we study this situation in a specific industry, aerial transportation, focusing our interest on safety related issues. Finally, some conclusions can be derived from this analysis for the future organizational evolution.

Theoretical background

Information and communication technologies together with detailed procedures have become an essential piece for organizational evolution in recent years. From this point of view, an evolving system acts as a machine that requires information gathering and processing and reflects an external reality as closely as possible. To get these representations information technologies have been very useful. At this respect, the definition from Varela (1988) of a computer as a device that manages symbols but only handles its physical shape and not its sense is relevant. This characteristic of information technologies causes a lack of capacity of systems to manage unforeseen events; therefore, those events should require human operators. However, information systems design is complex enough to make them opaque for their operators who, in many situations, do not understand the principles of its functioning.

Winograd and Flores (1987) show that "opacity of implementation is one of the key intellectual contributions of computer science" since every level of design can become independent from the one below, keeping its own logic. This issue is different in the construction of a mechanical system. The mechanical system is more complicated since every level of design has to be justified by the one below. That means that in circumstances where the required knowledge is present, a mechanical system can trace a contingency until its origin. This does not happen in a information system. The opacity of implementation of information systems breaks the logical chain among different levels of design. The hardware designer, the software designer and the operator live apart and they can become experts in their fields having no idea about the others' fields since they have become functionally independent.

When everything happens as planned, this blind-to-meaning model works fine; however, in opposite situations where unplanned contingency appears, the feasibility of dealing with it is decreased compared to the old mechanical systems. Reason (1997) explains this fact under his "SRK" model where "S" stands for Skills, "R" for Rules and "K" for Knowledge. Each character represents a level. The Skills Level is the basic and the Knowledge Level is the top in this model. An opaque system only allows its operators to reach the Rules Level since the opacity of its design makes it impossible for the operators to get the Knowledge Level.

That happens because operators cannot access to the meaning of their actions. In the field of Knowledge Management, Choo and Bontis (2002) introduced the concepts of meaning and sensemaking as important issues for the improvement and learning in organizations. In the field of Organisational Semiotics, Gazendam (2001) explains the importance of active exploration as a key to build a world model that allows its author to manage it. If the design of the system impedes that active exploration and, therefore, the access to meaning of the activity, the introduction of new features to a system could transfer capacities from the operators to the technical part of the system instead of adding new capacities.

The loss of meaning makes the human operator to act under the Skill Level and Rules Level instead of using the Knowledge Level (Reason, 1997). Every new added feature could reinforce this process. Therefore, the real improvement -from a whole system scope- should be lower than expected since increases in technical capacity go together with decreases in human capacity: The technical model of development not only adds capacity to the system but also extracts capacity from one of its components transferring it to the other one. The expected effect should be drawn of this model of development: The capacities of the system that can be performed by technology are increased and the capacities that cannot be performed by technology but by its human operators are decreased.

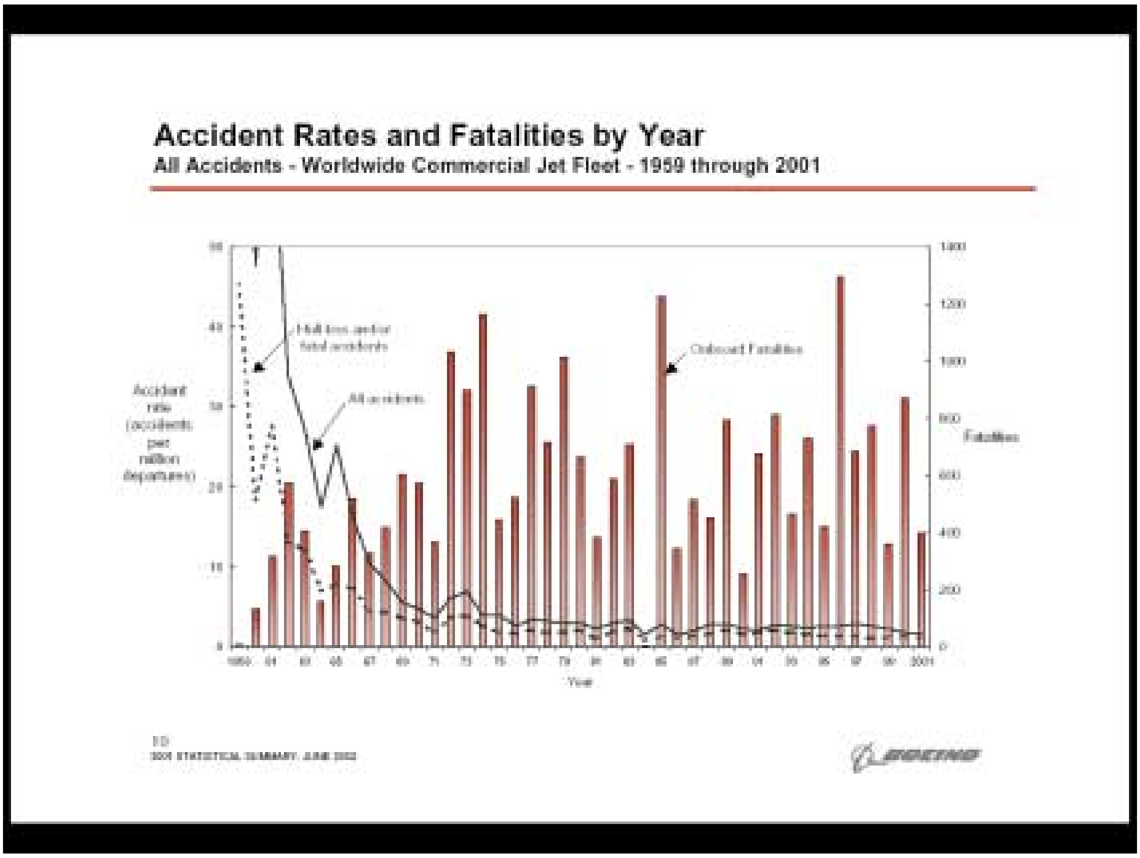
Since information technologies do not have access to the meaning but to symbols (Varela, 1988), those activities requiring access to meaning –those events representing exceptions to the general rule and not included in the system design- could have serious limitations to be performed. By the other side, actions than can be included in the system design can be performed efficiently, decreasing like that the number of errors.

Some industries, as aerial transportation, are risky enough to accept this development model. The improvement of many activities is decreasing performance in a few of them. If these few activities could drive to situations, important in terms of human or material losses, the basis of this model of development should be re-examined.

In the next epigraph, aerial safety is going to be analyzed in order to show how these effects happen even in industries that can exhibit a high improvement rate.

The case of aerial safety

Results in aerial safety show a successful example about the feasibility of a real improvement in very complex organizations. The figure (Boeing, 2002) illustrates the evolution of safety until the present moment:



It is especially interesting to observe that since 1975 the improvement rate has decreased. That happened in the presence of an important technological evolution in the aerial field. I f one of the factors to improve the behavior of the system has been technology and the results show a decreasing rate of improvement, another different factor should be responsible for that decreasing rate.

Reason (1990) identifies this factor by explaining that we can produce a new accident trying to a void the last one. In other words, limiting the freedom to a ct of human operators can avoid mistakes but, at the same time, can impede necessary actions. In a complex environment, there are cont ingencies where necessary actions could be unplanned; therefore, these actions should be unforeseeable and unmanageable by the design of the organization.

If human operators are allowed to act but they are part of a system that they do not fully understand, the feasibility to act is more theoretical than real since operators could not know how to act. The development of information technologies in aviation shows how this can happen: An old aircraft had many indicators requiring a human operator to g et the whole picture from multiple data sources; a new aircraft is very different, having a few multifunctional screens and giving information that the own system has integrated before. The new Boeing 747 generation has about one third of the indicators that the old Boeing 747 generation had; even more, the flig ht engineer is not required anymore in the new flightdeck.

Information technology has allowed an important improvement in the aerial industry: Automated flightdecks can be managed by less people and, at the same time, common flightdeck designs for different planes allow some crews to fly different planes with a very short time of adaptation (Airbus, 2002). Furthermore, since automation can prevent human mistakes in previously defined situations, actions can be performed near to the limits without the danger of surpassing them. Aircraft manufacturers can design fuel-efficient planes even when its design makes a plane unstable since automatic systems should impede dangerous situations.

The positive contribution of information technologies in aviation is its character of efficiency-booster. They can provide efficiency through design improvement, payroll reductions and training cost reductions due to its simpler interfaces. The not-so-good part is related to the new role of human operators and their accessibility to the real meaning of their actions.

Some accidents in new planes have shown very clearly this effect: Once the operator has adopted a passive attitude and thinks that "the system never fails", he becomes useless in situations that exceed the system capabilities –precisely those that could justify his/her presence in the flightdeck-.

Accidents like AeroPeru 603 or American Airlines 965 (Walters & Sumwalt, 2000), both in technologically advanced planes, can only be explained through an accepted passive role related to the information system. Once the information system started to give confusing indications, the operators could not take the right actions.

Both situations could have happened in old planes. The accident of AeroPeru happened because of a piece of tape that someone forgot in the outside part of the plane, giving false speed and height indications; the accident of American Airlines was due to a confusion with radio-frequencies. However, if we think about procedures in an old plane, probably, none of these accidents should have happened:

- AeroPeru 603: The situation of bad indications is analyzed even for lower licenses like glider and private pilot licenses. Any pilot knows that the solution to this problem is breaking the glass of the instrument –in the case of a plane with pressure cabin; they have to put the outside pressure too-. If these pilots didn't do that, the explanation could be easy : They never could think in their plane as an usual plane and were looking for an explanation in the information system part. Even when they started to work with basic instruments –outside the information system- getting the same bad indications, they never had the frame of mind of a glider pilot or a Cessna pilot under the same situation.

- American Airlines 965: The confusion between two radio-stations with the same frequency made the pilots getting lost in a high-mountain area. If, instead of a multifunctional screen with a keyboard, they would have a paper-made map, probably, they should not get confused and, if so, they could quickly correct the mistake.

Information technology designers have trade meaning for legibility and pay special attention to get inputs and outputs with visual representations familiar to operators coming from older systems. In this way, operators can get friendly interfaces and use to think that a new plane is similar to an old one. Likewise, the independence among design levels in information systems (Winograd & Flores, 1987) makes the transition from one plane to another easy. Different kind of planes can share identical flightdecks (Campos, 2001).

This kind of solution increases the complexity of the system, since it gives the operators an image about how the system supposedly works but that image is an output of the system and not the way internally used to perform its functions. The puzzlement between both modes –the real (logical mode) and the output received by the operator (operational mode)- gets the operator confused when a situation shows clearly the next fact: The operator has been using the operational model "as if" it was coincident to the logic model. In critical situations, this operator has to learn that this is not true.

Consequently, the expert operator becomes conscious of this fallacy through different microevents where the output of the information system does not work as expected. Baberg (2001) explains this fact through a very common joke among pilots: Supposedly, the most common sentence spoken in a modern flightdeck is: "What is doing now this bastard?" referred to the plane. Therefore, the operator learns to distrust the system –actually, its design is based on giving the operator the information supposedly required and nothing more- and gets confused and powerless if something happens making evident the contradiction between the operational and the logical mode.

Dennett (1996) uses two metaphors to illustrate the contradiction between these modes. Dennett opposes the model of an information agency to the model of a commando group. In the first model, the operator knows only the information required to perform the specific task. In the second model, the whole information about situation is given to operators since unknown events are expected and operators can be demanded to confront them.

The increasing complexity of organizations has driven to situations where operators are managed under the "information agency" model; consequently, they only receive the operational model since the logical model should be very complex to understand.

The key issue should be as follows: Which are the conditions that could convert the opacity to the meaning by the operator in a sound decision?

CONCLUSIONS: NEW CHALLENGES

The case shown in this paper is not an exception. Many organizations use advanced information systems and operators are given an operational model but not a logical one. In situations where serious contingencies are not expected, limiting the knowledge required to operators can be an efficient way to act. However, this model has an important flaw when contingencies are frequent and/or important. The kind of development that can provide efficiency to the organization can prevent human operators to become an alternative resource under unknown events.

Operators do not learn better the behavior of the system through their activity because of the incomplete knowledge they have received to perform their tasks. Learning other design levels of the system could be very far from their training and experience. Consequently, the evolution drives the system far beyond from the understanding capacity of the operator.

Therefore, operators provided with incomplete knowledge do not represent a good solution, especially in those fields where contingencies can be serious. At the same time, training and experience of these operators do not qualify them to reach a deeper understanding of increasingly complex systems. That draws a dilemma hard to escape.

The next challenge to be faced by engineers is related to this dilemma: Since full understanding of the systems by operators is difficult, time-consuming and expensive, the requirement for simpler systems is hard to meet. That is especially in those systems that deal with high-risk activities. The reasonable limit for technological design should not come from technological potential but from the level of complexity where human operators start becoming unable to execute their role as an alternative to the system.

This solution goes far beyond ergonomic issues and the idea of getting interfaces as easy as possible. The real issue is in the organizational semiotics field and the transparency requirement, especially in high-risk activities. New programming languages and new logical models are required to make systems meaningful to operators.

Rassmussen (1986) pointed out a requirement for information system designs: They had to be *cognitively run* by their human operators. In this way, these operators can be able to know at any moment the real state of the system. This requirement has been far to be met by the new technology developments. The independence among design levels (Winograd & Flores, 1986) has some advantages and the temptation to get the most from the information system is always present. However, the existence of different modes –logical and operating- has to be avoided. The "as-if" way, dismissing the access of the operators to the meaning of their actions is not enough in high-risk environments. That means working with the logical model of the systems and keeping it easy to understand for its operators. Making easier that logical model instead of hiding it is the next step in organizational development.

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