tao DIGITAL LIBRARY
An international, multidisciplinary publication on organizational action, organizational change, organization and well-being. Founded by Bruno Maggi.

ERGONOMIC ANALYSIS AND ORGANIZATIONAL ANALYSIS FOR PREVENTION

ANALYSE ERGONOMIQUE ET ANALYSE ORGANISATIONNELLE POUR LA PRÉVENTION

ANALISI ERGONOMICA E ANALISI ORGANIZZATIVA PER LA PREVENZIONE•

JEAN-CLAUDE SPERANDIO
UNIVERSITÉ DE PARIS V – RÉNÉ DESCARTES

GIOVANNI RULLI
AGENZIA DI TUTELA DELLA SALUTE DELL'INSUBRIA

Abstract
The ergonomic analysis of work activities, typical of the francophone tradition, may usefully benefit from the organizational analysis that considers the well-being of the subjects of the action processes. According to the theory of organizational action, this encounter is possible: the method it proposes allows the integration of biomedical analysis and ergonomic analysis for the purpose of prevention in the workplace. A seminar of the Interdisciplinary Research Program "Organization and Well-being", with the example of an ergonomic analysis of airline pilots' activity and an organizational analysis of a work situation in large archives, shows the compatibility and the possible synergies between the two research paths.

Keywords
Ergonomic analysis, Organizational analysis, Biomedical analysis, Well-being, Prevention.

• The texts of this ebook were originally published in the journal *Ergonomia*, 1999, 12: 21-35. We thank Edizioni Moretti & Vitali for authorizing this new publication.

Ergonomic analysis and organizational analysis for prevention / Analyse ergonomique et analyse organisationnelle pour la prévention / Analisi ergonomica e analisi organizzativa per la prevenzione, Sperandio Jean-Claude, Rulli Giovanni. Bologna: TAO Digital Library, 2020.

ISBN: 978-88-98626-24-3
DOI: http://doi.org/10.6092/unibo/amsacta/6559

tao Digital Library

The TAO Digital Library is part of the activities of the Research Programs based on the Theory of Organizational Action proposed by Bruno Maggi, a theory of the regulation of social action that conceives organization as a process of actions and decisions. Its research approach proposes: a view on organizational change in enterprises and in work processes; an action on relationships between work and well-being; the analysis and the transformation of the social-action processes, centered on the subject; a focus on learning processes.

The contributions published by the TAO Digital Library are legally deposited and receive an ISBN code. Therefore, they are to be considered in all respects as monographs. The monographs are available online through AMS Acta, which is the institutional open archive of the University of Bologna. Their stable web addresses are indexed by the major online search engines.

TAO Digital Library welcomes disciplinary and multi- or inter-disciplinary contributions related to the theoretical framework and the activities of the TAO Research Programs:
- Innovative contributions presenting theoretical or empirical analysis, selected after a double peer review sprocess;
- Contributions of particular relevance in the field which are already published but not easily available to the scientific community.

The submitted contributions may share or not the theoretical perspective proposed by the Theory of Organizational Action, however they should refer to this theory in the discussion.

ISSN: 2282-1023
www.taoprograms.org – dl@taoprograms.org
http://amsacta.cib.unibo.it/

Pubblicato nel mese di dicembre 2020
da TAO Digital Library – Bologna

Ergonomic analysis and organizational analysis for prevention

Introduction

The Interdisciplinary Research Program "Organization and Well-being" dedicated its 19th seminar, held in 1998 in Bologna, to a reflection on the possible complementarity between the ergonomic analysis of work activities, typical of the francophone tradition, and the organizational analysis oriented towards prevention, conducted according to the theoretical and methodological choices on which the O&W Program is based.

The analysis of work activities, as is well known, characterizes different ergonomic contributions of francophone origin and tradition, to which the O&W Program has always paid particular attention. Numerous seminars have hosted scholars from research centers and laboratories belonging to this tradition, involving them in the debates promoted by the program's activities. However, the 19th seminar was aimed at a particular objective: to observe two work analysis methods, both aimed at prevention, but disciplinarily different, to reflect on the differences and possible synergies. The ergonomic analysis of work activities, in fact, was essentially born from a meeting between physiology and experimental and cognitive psychology, while the analysis of work action processes proposed by the theory of organizational action, and conducted according to the method of organizational congruences that derives from it, is also based on an interdisciplinary meeting, but which concerns the social disciplines.

Is complementarity possible, and how can it be expressed? The interpretation of the work process can benefit from the convergent contribution of the analysis of social action regulation on the one hand and of physiological and cognitive regulation on the other hand. The theory of organizational action includes the well-being of the subjects involved in the processes of action; the method of organizational congruences allows a direct encounter with

biomedical disciplines and has, in fact, always been adopted by occupational physicians and prevention operators. A similar encounter is possible with the ergonomic analysis. The ergonomics of the francophone tradition showed, at the end of the twentieth century, new attention to the organizational aspects of work situations: this was the focus of the 30th Congress of the Société d'Ergonomie de Langue Française, chaired by Jean-Claude Sperandio, in Biarritz in 1995.

The reflection proposed by the 19th seminar of the O&W Program significantly recalls a moment of relevant interaction between two fields of study and research, clearly distinct but open to discussion and to the possibility of collaboration. A re-edition of the contributions discussed in that seminar therefore seems appropriate. They were originally published in 1999 by the journal *Ergonomia*, the first Italian journal dedicated to ergonomics - active for about a decade - founded by Enrico Moretti in 1993 with a rich program open to multidisciplinary debates, research results, calls for projects, as well as to the ergonomic study.

The two contributions concern, respectively, ergonomic analysis and organizational analysis. The presentation of each analysis is followed by a comment proposed from the point of view of the other analytical orientation.

The first contribution concerns the activity of airline pilots. The author is Jean-Claude Sperandio, at the time Director of the Laboratoire d'Ergonomie Informatique of the Université de Paris V - René Descartes. The analysis is carried out with a flight simulator used to train pilots, which allows representing different flight situations, failures, and inconveniences that can cause accidents and disasters. The crews' decisions in coping with high-risk conditions and the pilots' reactions to the prescriptions imposed by the automated systems of the aircraft are analyzed.

The second contribution concerns the handling of paper material in large archives. The author is Giovanni Rulli, a surgeon specialized in occupational medicine and hygiene and preventive medicine, belonging to the direction of the territorial health services of the North-West of Lombardy. The analysis

highlights the organizational choices that may originate postural risk for the spine and uses procedures from the biomedical field to determine this risk. It also allows envisaging various organizational choices that can avoid the risk present in the work situation analyzed, including - thereby anticipating what will be achieved several years later - the scanning of documents and the digital management of archives. Thus, it highlights the possibility of primary prevention, not only of protection and risk reduction, as in the traditional intervention on musculoskeletal disorders.

The comment to the first analysis is by Giovanni Rulli: it shows how the analysis of the organizational process in which the pilots' activity is immersed can be the natural integration of the ergonomic analysis. Jean-Claude Sperandio comments on the second analysis, highlighting the compatibility and possible synergies of the organizational and biomedical study of Giovanni Rulli with the ergonomic analysis of work activities.

TAO Digital Library

Ergonomic analysis of airline pilots' activity

Jean-CIaude Sperandio, *Université de Paris V - René Descartes*

Introduction

Ergonomics developed in the francophone tradition (Ombredane, Faverge, 1955; Daniellou, 1996; Sperandio, 1996; Wisner, 1997) insists on the need to link every ergonomic intervention to a precise analysis of the work, *i.e.*, of the tasks and activities of the operators and machine users, with systematic observations and interviews, in the workplace. However, some cases do not allow direct field-observations of the work situation, mainly when the aim is to study the behavior and the mental and cognitive processes of operators faced with technical or organizational accidents. Usually, these accidents are too infrequent to be observed in the limited timeframe of an ergonomic analysis. Furthermore, any scientific study's elementary condition is the reproducible nature of the findings on a representative and relatively large population. In such cases, an experimental simulation, when it is technically possible and when it is sufficiently representative of the reality, *i.e.*, of real work in usual conditions, is an ideal solution and often the only one that can be adopted. In the particular case of air piloting, very realistic flight simulators have been used for a long time, particularly for the professional training of pilots.

The analysis presented here, conducted with Arona Aw (1997), has adopted a *full flight* simulator, which is capable of precisely simulating the cockpit and the exact reactions of the aircraft to the pilots' controls; it is also able to perfectly reproduce failures and technical accidents, and to simulate communications with air traffic control. The resemblance to reality is almost perfect, also according to pilots used to pilot simulators; they know that it is not a real flight, but they accept to behave in a habitual way. It should be noted that these simulators are approved by the air authorities, exactly as the aircrafts.

We used an Airbus A320 simulator, since the European manufacturer Airbus was a partner in this research, which has been funded by the French Ministry of Transport (Directorate General of Civil Aviation) as part of a research program on "human factors" in aeronautics. The A320 aircraft was chosen because it is a typical example of new-generation aircrafts, also called *glass cockpits*, whose main characteristics are a high level of digitalization, automation, and piloting aids. In particular, this denomination refers to the presentation of all information on cathode screens, instead of the classic quadrants, according to the flight phases and the tasks in progress. Before this research, a similar one was conducted by Arona Aw on conventional aircrafts (DC10s).

Since the purpose of this contribution is neither to teach how to pilot a modern aircraft, nor to go into the details of the research and the results, we will discuss the links between ergonomic analysis and organizational analysis, focusing on the complexity of the work. Ergonomics is not only concerned with improving equipment, workplaces, and the environment; it is also concerned with the organization of work and work systems. However, if ergonomics has been based since its origins on physiology and psychology, has been harvesting knowledge and methods from these sciences and developing new knowledge and new methods adapted to the problems of human work; it is however necessary to underline that the organizational aspects have not been taken into consideration with a similar level of competence. This gap stems in part from an insufficient culture of ergonomists in this field of study, but also from the fact that very few organizational researchers are interested in ergonomics.

Origin of the research

The initial goal is to investigate the effectiveness and the interest of LOFT (Line Oriented Flight Training) training for airline pilots. Professional pilots' training generally begins on small planes to obtain basic pilot licenses, first with visibility, then without visibility. It requires following specific training for all types of commercial aircraft, usually delivered by the aircraft manufacturer or

by the airline company, and hours of training up to the professional licenses. Then, airline pilots participate in periodic training activities to keep their qualification (recurrent training), to learn some new guidelines, but mainly to train themselves to deal with accidents of varying severity and frequency.

While the basic training is primarily focused on individual learning (for the license), the purpose of the LOFT, considering that an airliner is piloted not by a single pilot but by a crew of two or three individuals, is focused on the development of the resources of a full crew. This training emphasizes crews' interactions, especially in the face of unforeseen events, not just serious ones, particularly when the solution is not based on a learned procedure. In this sense, it has been developed the concept of CRM (Cockpit Resource Management).

A crew's potential is not simply the sum of individual skills, but also by the type of cooperation and relationships that are established between the members, particularly in two-pilot crews, in which both pilots have the same qualification. They alternate to the plane's controls. Even if the lead is attributed to the pilot having higher hierarchical status, who is not always the most experienced with the specific type of aircraft, or the most senior in age or in the company. Conflicts may then arise, in particular, in case of problematic situations. Therefore, the interest of the LOFT does not concern the learning of basic procedures, but the training of crews to collectively solve accidents. Indeed, pilots are well trained to solve major accidents (engine breakdowns, electrical or hydraulic accidents, fires, etc.), but these are very rare; on the contrary, they are not trained to cope with less severe accidents, which are not uncommon. Therefore, our analysis concerned the behaviors aimed at solving accidents that are, on average, frequent and not severe, consistently with the data of a research conducted by Arona Aw on the statistics of the accidents recorded on this type of aircraft.

Methodology

The full flight simulator of the Airbus A320 allows realistically simulating a large number of accidents during full or partial flights. The main difficulty is to create a coherent scenario by incorporating in a single flight all the accidents interesting to the experimenters. Each accident is chosen with some precise hypotheses on the expected behaviors and on the reasons that the pilots may have for hesitating or making mistakes. A solution, however impossible due to the time, cost, and availability limits of the simulator and the pilots would be to multiply the experimental scenarios, but this could cause other methodological problems to homogenize the experimental conditions.

We chose to simulate a full flight in real-time, from the initial flight preparation by the pilots to the shutdown of the engines, from a French airport (Marseille) to another airport in a neighboring country in Europe (Brussels): so the flight time is not too long, without being too short. During this flight, the pilots do their job as usual. They are dressed in uniform, are in radio contact with the air-traffic control, and make the usual announcements to passengers. Several accidents or problems occur during the flight: small errors in the data of the flight plan to be detected and corrected during its preparation, failure of the meteorological radar, new constraints imposed by air-traffic control to the altitude during the ascent phase, ambiguous technical alarm, partial failure of the autopilot, sudden strike at the airport of destination with the following diversion to another airport (*e.g.*, Paris-Roissy), temporary unavailability of the landing runway that imposes to land on the take-off runway (rare procedure, but imposed by the control tower when the landing runway is not available), and finally a mechanical problem which disturbs the balance of the plane, without preventing the landing. These latest accidents happen quickly. All this, far from resembling a movie that accumulates catastrophes, represents, on the contrary, an almost routine flight, during which such accidents are plausible, even if they induce a heavy workload.

The simulator records all information, alarms, commands performed by pilots, and all verbal communications exchanged. Furthermore, for the

experimentation, four front and side cameras are installed to record the pilots' behavior, who can then, after the flight, observe and comment on their behavior during the flight's critical phases.

Results

Fifteen crews (composed of two pilots) skilled for this type of aircraft, from a French airline, simulated this entire flight; all of them experienced exactly the same experimental conditions, and all managed to complete the mission of reaching the final destination. This is the first result.

Each pilot sought a solution to the various accidents, adopting "personalized" behaviors, not always optimal in terms of workload but guaranteeing safety as the main criterion. The details of the results would be too long and too technical to be described here, but we can highlight that they show the difficulty of the crews' work in case of accidents, given the complexity of modern aircrafts and the opacity of the automatic systems. And this happens even if the automation of certain functions, highly developed on this type of aircraft, aims to reduce the pilots' workload, at least when everything works smoothly, as is the more general case.

Automation is only partial, and human supervision of the automated functions remains a core activity. The crews have to resume the control of the aircraft in case of ineffectiveness of the automatisms and to find the solution to accidents or problems that occur, however infrequently; the most significant difficulty is to diagnose the nature of the accident and its cause. In this regard, our results showed some gaps in training and onboard documentation regarding rare and minor failures, and some difficulties with the interface that displays information on the screens. In addition, various constraints external to the aircraft, such as the congestion of airspace and airports, increase the crews' workload.

Among the numerous factors revealed by the work analysis, two factors appear critical: time constraints and prescribed procedures.

The crews have to manage several kinds of times and the related time constraints (Aw, Sperandio, 1998):

- the intrinsic technical time of the aircraft, called "system time", which defines several incompressible segments, from the beginning of the preparation for the flight to the end, considering that this time does not end with the landing of the aircraft;
- the time of the operational management of the aircraft, called "prescribed time", which defines other incompressible segments imposed by the airline or by airline regulations;
- the time of air control (ATC - Air Traffic Control), more urgent than ever due to the saturation of space and airports;
- the time of the commercial mission, called "passenger time", which requires departing at the scheduled time and, above all, arriving at the announced time, knowing that this depends on several external parameters, in particular the clearances by the ATC, the technical verifications of the aircraft and the efficiency of airport operations.

The accumulation of these temporal pressures has a significant influence on the workload of the crews. Compliance with procedures is also a factor of workload (although at the same time a safety factor). The piloting activities are indeed specified by checklists that must be systematically read and followed carefully to comply with the official guidelines during the flight and in case of accidents. Strong time constraints, on the one hand, written and imposed procedures, on the other hand, typically make piloting a very constrained job. Of course, differences can be noted between the prescribed tasks and the actual work - a topic usual to ergonomists - but they are minor when compared to those that can usually be observed in any job, not just in industrial settings.

The pilots must demonstrate their capability to make the appropriate decisions in due time, but the organization - that is, the airline, the official services, etc. – monitors the meticulous compliance with procedures and regulations. The consequence of these permanent prescriptions leads the pilots to be very scrupulous, at such a point that, in case of accidents or problems,

they first look for the appropriate procedure in the on-board documentation, which is always considered to be the source of the solution. This is not always true, the problem may be ambiguous, or the documentation may not consider it. During our simulation, the search for the solution in the on-board documentation was observed with almost all the crews, as it usually happens.

However, in this way, the pilots lose or at least risk to lose, the skills necessary to analyze the problems and define the best solution by themselves. In complex systems, it is not possible to know, predict, and prevent all possible problems and accidents, contrary to what is often claimed. For the crews, the risk is therefore to find themselves in situations in which the required documentation and procedures are lacking and to waste precious time instead of immediately engaging in the personal elaboration of the solution to the problem.

Compliance with the prescribed rules is absolutely necessary because the non-compliance with these procedures causes too many accidents, injuries, and disasters. Nevertheless, the opposite is also true. It should not be overlooked that the pilot skills are not merely related to knowing how to maneuver an aircraft in the air, but include the management of the interaction between air-ground elements that have to be continuously taken into account. Indeed, each aircraft is an element in interaction, not always foreseeable, with many others. It is important that the crews, just like many years ago, still retain a certain degree of freedom to independently resolve the unforeseen events for which they do not have a precise solution prescribed by their training. On the contrary, airlines and aircraft manufacturers, as well as aeronautics in general, civil or military, tend to make the pilot of modern aircrafts, especially of the higher automated ones, lose the innovative skills of their job, for laudable safety concerns and to the benefit of a perfect discipline.

Training must establish a sufficient "compromise", in a sense proposed by Amalberti (1996), between an excess of prescriptions, incompatible with the complexity of piloting modern aircraft, and an excess of autonomy, also incompatible with this complexity and with that of the current aviation system.

Paradoxically, despite all the prescriptions and the strict control of the compliance and aviation regulations, or perhaps precisely because of all these prescriptions, in dangerous situations, it is ultimately the crew, and sometimes only the captain, that have to take the critical decision.

Comment by Giovanni Rulli on the analysis proposed by Jean-Claude Sperandio

There are several aspects of complementarity between the path of ergonomic analysis of the work of the francophone tradition and the organizational analysis with the method of organizational congruences, that is, according to the theory of organizational action. These aspects emerge from Jean-Claude Sperandio's contribution, and I will try to highlight them.

From the very beginning of the text, it appears clear that the intent of the francophone ergonomics is, first of all, to analyze work as it manifests itself, in the field, in the attribution of the tasks to the subjects who work, and to precede a precise analysis of work to the ergonomic intervention. Observation and verbalization, *i.e.*, the collection of information from the subjects at work, are the fundamental descriptive tools of the method illustrated by Jean-Claude Sperandio: the same elements (and the collection of documentation) are essential descriptive tools for the organizational analysis for prevention proposed by the "Organization and Well-being" research Program, according to the method of organizational congruences.

This modality of analysis, even if without emphasis, is different in the anglophone ergonomics. In this latter, in fact, the object of analysis, and therefore of understanding, is not the work as a social, organizational, cognitive and action event, but rather the specific encounter between techniques and acting subjects, with the aim of higher possible compatibility between human beings and techniques, certainly from a safety and health perspective, not only in terms of effectiveness and efficiency but according to a clear technical predetermination.

The organizational analysis for prevention proposed by the O&W Program can offer an important contribution to the ergonomic analysis through an analytical description and interpretation that leads to identifying the organizational choices whose "pathogenicity" can then be assessed thanks to the consolidated tools adopted by ergonomics, physiological and psychological. However, the tradition founded on the analysis of physiological and psychological aspects does not exhaust the understanding of the work situation: in this sense, Jean-Claude Sperandio notes the lack of organizational insights. The analysis conducted according to the method of organizational congruences can validly fill this gap, allowing to identify the elements of *organizational constraint* (potentially dangerous conditions) worthy of physiological, psychological, clinical, polytechnic interpretations.

The simulation of flight situations is also compatible with a multidimensional work analysis, especially if we consider this form of experimentation to represent "typical work situations", without totalizing claims. The simulation is particularly suitable for pinpointing exceptions, unforeseen situations, where particular variability is highlighted. The organizational analysis interprets this path as a manifestation of the need for change in the piloting process and pays attention to verify the changes in the process induced by new training interventions.

The behaviors considered as "not optimal" have been related to deficiencies in training, in on-board documentation, in the presentation of information on cathode screens (including the "non-visibility" of certain aircraft automatisms), in the conditions of the airspace and the airport. In this way, various inconsistencies inherent to the entire piloting process were highlighted, undoubtedly attributable, thanks to the contribution of the organizational analysis, to specific relationships between institutional, technical, and structural aspects of the piloting process. This is a field where an analytical review of the process of action is conceivable, to allow interpreting the sources of these forms of constriction from an organizational point of view, and consequently to propose alternative choices of objectives, structuration, techniques.

Time stands out as a crucial element: it appears insufficient with regard to various prescriptions (time pressure) and with regard to emergencies that arise (urgency). The pilot's activity is "paced" by the execution of *the checklist*, both in ordinary and emergency conditions. It should be noted that, for the airlines, the definition and compliance with procedures represent essential elements of evaluation, and therefore a driver for the "engagement of the agents" (if the terminology of organizational analysis is adopted). Time is always a crucial element in the analysis according to the method of organizational congruences. In particular, it allows highlighting the inconsistencies between the assignment of tasks and the assigned execution times.

In this aspect, the analysis presented by Jean-Claude Sperandio paves the way for synergistic study, in particular concerning the adoption of autonomous decisions, that is, the exercise of *autonomy*, not just *discretion*. What autonomy can we refer to? To that concerning the attribution of responsibility, a management task, or that inherent in the global decision-making process? In the latter case, the possible contribution of the organizational analysis to the proposed ergonomic analysis emerges clearly. Through organizational analysis, it is possible to design the decision-making process, taking into account the objectives of the process in a conscious way, also envisaging a new need for training, centered not only on piloting simulation but also on the more general dynamics of the crew decision-making process. For example, new training courses could focus on the ability to identify the discriminating elements between the pursuit of alternatives of prescribed choices and the exercise of autonomy for approaching complex problems, or the ability to share decision-making processes. Finally, the ergonomic analysis can benefit from the organizational analysis results on the so-called "near misses". Thanks to these contributions, it would be possible to try to reconcile prescriptiveness and autonomy in the complexity of the modern piloting process.

Organizational analysis for prevention in the handling of paper material in large archives

Giovanni Rulli, *Agenzia di Tutela della Salute dell'Insubria*

Introduction

Many European Union Directives on health and safety in the workplace (89/391/EEC and following) suggest considering the whole work situation starting from its conception. Therefore, the analysis and design of work appear to be closely connected with the prevention process, and the evaluation of risk conditions at work is the first step for a complete identification of prevention measures. The evaluation required by the Community Directives must be exhaustive and based on explicit scientific criteria (Maggi, 1997). It must show the relationships among: risk conditions regarding the work situation, risk onset, risk possibility and probability, possibility of damage, possibility of eliminating risks (prevention), possibility of risk reduction (protection). The European Union directives on health and safety at work do not appear to be aimed at a simple "quantification" of the risk (intended as the probability of specific degrees of damage) but are oriented towards a complete and continuous work analysis. This analysis must include the evaluation of the *possibility of risk onset* to identify analytical levels of prevention and protection intervention.

The goal of francophone ergonomics is to understand work in order to transform it, and organizational analysis can provide an important contribution to this goal by allowing extensive preventive actions. This point of view invites researchers and workers to reflect on the inadequacy of the probabilistic model based on the need for direct relationships between causes and effects, and to pursue instead the investigation of the possibility of risk (Maggi, 1984/1990; Rulli *et al*., 1997), where the participation of workers is implicit, both to understand and to plan the work process.

What does the analysis of work processes for prevention require? First of all, it is necessary to highlight some of its most crucial aspects (Maggi, 1997):

a) *the well-being process*. The evolution towards an idea of well-being as a process that can be perfected (Rulli, 1996) presupposes that we do not limit the analysis to epidemiological standards, but to focus on preferability standards, concerning the expectations of the populations and the perspectives of prevention. From this point of view, it is necessary to avoid both deterministic investigation procedures (where the individual is subjected to technical choices) and indeterministic ones (where an organizational project of the work is not recognizable).

b) *the work process*. The work process is the result of choices, decisions, and actions. Organizational choices are choices of objectives, coordination and control (structuration), and technical choices. They are interdependent, and none of them can be regarded as merely subordinate to the others. It is possible to evaluate the relationships between these analytical levels in the workplace, highlighting the elements of incongruence regarding the objectives of the work process, tasks and their relationships, conditions of places, materials, means, coordination and control of individuals, techniques, etc. Thanks to these peculiar characteristics of the analysis, alternative choices are conceivable for every aspect of the organization to reduce incongruences, which are potential conditions of hazard. In this series of analytical and interpretative steps, knowledge of ergonomics' principles must be extended to aspects of work design, based on the awareness of the importance of conceiving work in terms of process.

c) *primary prevention*. The object of prevention is not only the worker involved but the entire work process. The analytical vision of the process is the only useful for primary prevention, while synthetic description practices, which do not highlight and do not sufficiently discriminate the specific organizational contributions, can only lead to secondary or tertiary prevention interventions. Epidemiological knowledge is extremely useful but not sufficient because it focuses on the damages to explain the risks (intended as the probability of

damage onset). Primary prevention requires knowledge of the relationships between organizational choices and the possibility of risk. Furthermore, primary prevention requires an in-depth knowledge of the alternatives of choice in the work process to evaluate the risk conditions that each organizational choice can imply.

d) *assessment of risk conditions*. It is the evaluation of the possible relationships between choices, decisions, actions, and the consequences in terms of risks and damages. It suggests not waiting for the probability (or worse, certainty) of the presence of risks and damages, especially when the exposure is variable or when it is difficult or impossible to identify specific cause-and-effect relationships (Rulli *et al*., 1996).

An example of analysis

A case study of a work process can usefully serve as an example. It concerns manual lifting actions by single operators. The analysis aims to identify alternatives of choice of objectives, coordination and control, and technical knowledge. The aim of the analysis is to determine the postural risk for the spine. The evaluation also adopted the NIOSH model (Waters *et al*., 1993) but analyzed the broad set of choices, decisions, and actions that can involve a postural risk for the spine, up to the point of proposing alternative organizational choices oriented to primary prevention. The analysis focused on the work in the archive of a large Italian insurance company. The description is based on direct observation of the work, the acquisition of information through interviews and consultation of company documentation, and the video recording of work situations.

The *method of organizational congruences,* derived from Bruno Maggi's theory of organizational action (Maggi, 1984/1990), has been adopted for the analysis. The main steps of this method are:

a) the *choice of the process to be analyzed*, basing on the objectives of the investigation (efficiency, effectiveness, consequences on the well-being of workers, environmental protection, etc.);

b) the *description* of the objectives of the process analyzed, of the structure of the technical actions and their development, of the technical choices adopted;
c) the *interpretation*, *i.e.*, the assessment of the congruences between institutional, technical, and structural choices that govern the analyzed process, and the identification of the elements of organizational constraint induced by the organizational choices.

The *desired objectives* of the investigated process are the archiving of insurance documents (in three main groups: traffic accidents, management documents, other accidents), any periodic consultations, and the final destruction of documents after a certain period of time.

The *coordination and control of the technical actions* are represented by: a) the storage of documents in shelves or drawer units of variable height between 20 and 210 cm from the ground, after their daily arrival in boxes of about 20 kg each (the current archive consists of more than 13 million documents); b) the search and consultation of about 14,000 documents per year; c) the stacking in containers to send the documents for pulping, after 5 or 10 years. These actions take place simultaneously in the process, for variable times during the different moments of the day.

The *coordination and control of the development of the technical actions* can be briefly described as follows: the subjects involved are 35 males, usually with medium-low professional level; the manual lifting of loads is carried out in open space offices (8 floors of 400 m^2 each), at different times from 8.00 to 17.00, using hands, trolleys, small stools, ladders, ladders with platforms, automated shelves; the workers involved benefit from a special "allowance", and their training takes place through coaching.

The *technical knowledge* required by the actions described, in order to achieve the desired objectives, is variegated and concerns the nature of the documents and the overall process of consultation, of planning of the position of documents on shelves or in drawer units, of using of support equipment, and the use of lifting methods aimed at avoiding accidents and musculoskeletal problems.

Interpretation

By evaluating congruences and incongruences between these analytical categories, it is possible to identify the elements of *organizational constraint* and the possible conditions of risk for workers' well-being.

For to the purpose of our analysis (the prevention of spinal disorders), we only highlighted the conditions of risk of musculoskeletal accident or disorder (also through the application of the NIOSH criteria and its "lifting indexes" LI) (Waters *et al.*, 1993).

Table 1 shows the list of some technical actions carried out manually, assessed with the NIOSH criteria, and the relative "lifting indexes" (LI).

Table 1. List of technical actions, assessed with NIOSH criteria.

Technical actions	Manually lifted weight	Starting height of lifting movements	Final height of lifting movements	LI for adult male
(Manual) lifting of document boxes from trolleys to tables	20 Kg	20 cm	90 cm	1.32
(Manual) lifting of document boxes from pallets to shelves (middle levels)	20 Kg	10 cm	140 cm	1.40
(Manual) lifting of document dossiers in automatic shelves	5 Kg	90 cm	70 cm	0.50 *
(Manual) lifting of document dossiers from tables to multiple drawers (upper levels)	5 Kg	90 cm	170 cm	0.30
(Manual) lifting of document boxes from tables to upper shelves	20 Kg	90 cm	210 cm	∞

* In some cases, the horizontal displacement may be of 65 cm or more, with LI = ∞

The tasks do not have associated movements; they are carried out in a standing position, with adequate load holding (with two hands), good foot-ground friction, favorable microclimatic conditions, adequate recovery times between the different tasks. In particular, the departure and arrival heights of the movements have been indicated, "multiplier" elements with greater relevance in the composition of the total LI (ratio between the weight actually lifted and the recommended weight limit).

The main elements of organizational constraint highlighted by the interpretation of the relationships among the various analytical categories of description were:

- conditions of hazard (crushing, falling, etc.) related to the lifting of loads that are not always stable, to the use of trolleys, small stools, ladders, ladders with platforms, automated shelves, with characteristics that do not respect ergonomic principles;
- repetitiveness of simple actions, which nevertheless require attention;
- need for knowledge on the whole process and the planning characteristics of the storage of different types of documents;
- need for knowledge on the available support tools (equipment, robotic shelves, etc.);
- need for large spaces for storage;
- need for a large number of removals and periodic consultations of documents, in several actions varying over the different days;
- incongruous heights of storage in shelves or drawers;
- manual handling of loads (especially boxes of documents) with lifting rates often higher than the recommended values and with variability in the number and frequency of actions;
- need for exclusively male personnel, without handicaps;
- lack of training projects on the process and any aspects of prevention of spinal disorders.

It is possible to propose alternative choices in order to prevent and reduce spinal disorders, for example:

- acquisition of new tools (such as ladders and stools with hydraulic or electromechanical lifting systems) in order to facilitate the handling of boxes of documents;
- reduction of the dimensions of boxes and storage heights;
- promotion of training activities focused on the risks associated with handling loads and the importance of correct lifting actions (back school, etc.);

- identification of specific moments of the day dedicated to handling and limitation of the frequency of lifting activities;
- definition of a detailed health surveillance program.

However, a more specific comment is necessary about the incongruence between the process' desired objectives (storage and consultation) and the related structural and technical choices. In fact, most of the manual handling of loads is directed towards logically oriented storage to facilitate quick and easy consultation of documents. Automated shelves were installed in order to facilitate the removal of documents, based on their previous insertion. These choices show that this type of archive's logical interpretation is not different from that used for spare parts or raw materials warehouses. However, the orientation towards the problems of manual handling of loads should not be limited to automation, mechanization, support of actions, or optimization of the actions themselves in terms of duration, frequency, applied force, or in any case to the modification of the multipliers impacting on the lifting ratios, etc. It should extend to reflection on the purposes of the storage process and the "nature" of the archived "matter". Alternative choices based on the storage of information rather than paper sheets would undoubtedly be more congruent in this case. One choice could be document scanning, another, even more advanced, the acquisition of selected information (in view of subsequent uses) through the use of predefined document templates. These last choices, which are different from the simple automation or mechanization of operations, would make it possible to avoid:

- the interpretation of the storage of documents as the storage of everyday objects;
- the growing need for additional space (which occurs with the increase of stacking heights);
- the need for extending the use of robotic electromechanical shelves, which is a first alternative to the simple manual handling, but always inspired by the same principle of handling materials, not information;

- the continuous withdrawal and re-insertion of documents in order to provide the information requested by central or peripheral offices;
- the constraint on the selection of male personnel, without any disability;
- finally, the same manual handling of loads.

This choice would also allow to immediately make requests for data necessary for statistical purposes, even for marketing planning, while now these evaluations are only possible through a complex collection of data from different sources. However, such a choice must be carefully made, in order to foresee the consequences on the different technical knowledge required, on the overall costs, also in terms of reduction and especially of reconversion of the workforce, on the need for confidentiality and identifiability of data, on the new and different training needs.

This example of analysis shows that any program to improve health and safety conditions can benefit from simple interventions (on materials or health surveillance), but must not lose its capability to understand the complexity of the elements that determine the global work context. Furthermore, the possibility must always be envisaged to act radically on the objectives of the processes and on the articulated ways to achieve them, thus defining a hierarchy of interventions and their consequent planning. Thus the organizational analysis can contribute not only to the identification of the risk (as the probability of the occurrence of damage) and of the exposure (doses, times, etc.), but especially to the explanation of the complex aspects of the choices that can determine the possibility of a risk for the well-being of workers.

Comment by Jean-Claude Sperandio on Giovanni Rulli's analysis

The analysis conducted and presented by Giovanni Rulli could be considered as an ergonomic one. The subject of this analysis - the consequences of handling heavy loads in terms of risk of *work-related musculoskeletal disorders* (*WMSD*) - is a central topic of current medical-physiological ergonomics. One of the consequences of the increase observed in such disorders is the development of ergonomic studies devoted to this topic and of the attention paid to the

complaints of workers, not only workers involved in heavy physical work but also those who work in offices, especially if sitting in front of a computer.

WMSD is also a relevant subject in contemporary occupational medicine. The point of view of occupational medicine is primarily concerned with the early diagnosis of these WMSDs, the necessary treatments, and the possible consequences of any possible incapacity in filling some jobs. The point of view of ergonomics is complementary: the adaptation of workplaces, tools, and methods to avoid any risk (or at least to reduce the risk) of WMSD, both in corrective and preventive ergonomics. Therefore, Rulli's analysis may be interesting to ergonomists, even to those who are solely or primarily interested in physiological aspects.

Nevertheless, according to the theory and method proposed by Bruno Maggi, Giovanni Rulli adopts an organizational analysis. This line of research is perfectly convergent with ergonomics. Indeed, when we focus (in the sense of conceiving or modifying) on the technical means of work, we focus or should focus (in the sense of moving, adapting) on the organization. If the consequences are not studied and taken into account, several signs of inability to adapt quickly appear. Reciprocally, an organization cannot be conceived or modified without considering the technical means, the physical or social environment, the characteristics of the people, etc.: they are two always connected areas of every innovative process. Hence, an organizational solution that would have been successful here may fail elsewhere if the social and material conditions are different. Similarly, any technical change that does not include a process of (re-)organization is doomed to failure. The many failures in ill-ordered operations for introducing information technology in enterprises are an example of this.

Giovanni Rulli underlines the conflicts that arise between the criteria adopted for archiving documents and those adopted for consulting documents. In fact, the two criteria, arranging documents to fit the available space better or to make them easily accessible, imply two different strategies. It is necessary to consider the nature of the objects (shape, size, weight, possible incompatibility

with other nearby objects) and the logic of their research and use. Several other criteria connected with the possible hazards for operators must also be taken into account, particularly when objects are heavy and may induce a risk of WMSD.

I would now like to comment on the proposed changes indicated by Rulli to prevent and reduce the risk of WMSD. I change the order of the discussion:

- acquisition of new tools to support the work of handling heavy loads;
- reduction of the dimensions of boxes and storage heights;
- identification of the specific moments of the day dedicated to the handling of paper materials and limitation of the frequency of lifting operations;
- promotion of training initiatives to teach correct lifting operations;
- definition of a health surveillance program.

These are five ergonomic proposals that all have an evident organizational dimension. Acquiring new means involves a choice of materials that will inevitably impact the choice of human resources, that is, on the choice of people and their qualifications. Rulli noted that the staff is exclusively male and free from disabilities because physical strength is required. Let us see what happened in some companies after introducing automated machines and, more generally, of technical means able to reduce the need for physical efforts: the scale of the aptitudes required to operators has changed. Women and older or weaker men or those with minor disabilities, who were previously excluded, become able to do the job. For example, in the past, women were excluded from the airline pilot profession because the manipulation of the controls of older generation aircrafts required a certain physical strength, not recognized to women. However, with the electro-hydraulic assistance available in modern aircrafts, physical strength is no longer a decisive capability criterion. The same happened to the drive of large trucks. The introduction of information technology has dramatically changed the skills required for various professions: less physical strength but more intelligence, less manual dexterity but more

ability to handle symbolic information. However, automation is not without consequences on employment levels, unemployment, and wages.

The organizational dimension of the second proposal (reducing the size of the boxes and the storage heights) is evident; I will not insist on it. The chronophysiological and chronopsychological dimension is implicit in the proposal to identify specific parts of the day dedicated to the lifting activities and to limit the frequency of these activities. It has long been known that the frequency of accidents at work can be reduced through an adequate limitation of the length of working time. This effect is well known and is also observed outside the work situation, for example, at home or on the roads, particularly among road haulers, especially at night. Considering the WMSD, the effect of the heaviness of the loads and the work duration has been proved.

The need for specific training for lifting loads is at the boundary of ergonomics. With an excess of optimism, ergonomics postulates that a well-designed system should not need specific training or particular techniques for selecting workers; however, the generalization of this criterion is utopian. Postures and gestures have great importance on the onset of WMSDs; the correct movements must be learned. In this case, replacing inefficient or dangerous empiricism with adequate training is a fundamental organizational choice.

The definition and application of a health surveillance program for WMSDs is another fundamental organizational choice, but it can be observed that companies that have an advanced vocational training policy also have an advanced health policy, and vice versa.

Finally, Giovanni Rulli proposes a relevant reflection on the possible decrease in the volume of documents archived by adopting optical scanners or even a computer generation of documents. This choice presents several technical difficulties, costs, and drawbacks but can actually change the nature of storage problems. For example, it can limit the lifting of heavy boxes but also increase the speed of consultation, facilitate the transfer of documents between distant workplaces, etc. As Rulli pointed out, we need to look at the protection

of workers as well as the long-term benefits for users. Certain paper documents have been preserved for centuries; what about data stored on computer media?

However, I would like to conclude with a well-known story: a boss orders his subordinates to destroy a stock of old documents, which have become useless with information technology, but not without recommending making backup photocopies of these documents because, with the information technology, you never know!

References

AMALBERTI R.
1966 *La conduite des systèmes à risques*, Paris: Presses Universitaires de France.

AW A., SPERANDIO J.-C.
1997 L'étude Archimede III: le *Full Flight Simulator* comme support de formation et de recherche sur le comportement humain dans le pilotage des avions de nouvelle génération, in *Recherche, Pratique, Formation en Ergonomie. Evolutions et interactions dans un contexte social, économique et technique* : 439-447, Lyon : Actes du 32° Congrès de la Société d'Ergonomie de Langue Française.
1998 La dimension temporelle dans le pilotage et l'exploitation des avions *glass-cockpits*, in *Temps et travail* : 371-378, Paris : Actes du 33° Congrès de la Société d'Ergonomie di Langue Française.

DANIELLOU F. (ED.)
1996 *L'ergonomie en quête de ses principes*, Toulouse: Octarès Editions.

MAGGI B.
1997 Analisi e progettazione del lavoro per la tutela della salute. L'orientamento innovativo del d.lgs. 626/94, in Montuschi L. (Ed.), *Ambiente, salute e sicurezza*: 323-350, Torino: Giappichelli; 1998 ed. fr., Analyse du travail et action pour la santé. Une double innovation résultant d'innovations normatives, *Informations et Commentaires. Revue Internationale de Sciences Sociales Appliquées*», 103: 35-44.
1984/1990 *Razionalità e benessere. Studio interdisciplinare dell'organizzazione*, Etas Libri: Milano.

OMBREDANE A., FAVERGE J.-M.
1955 *L'analyse du travail*, Paris: Presses Universitaires de France.

RULLI G.
1996 La formazione per la prevenzione e il d.lgs. 626/94. Un'esperienza nel settore dei servizi, in *Formazione per la prevenzione, Metodo delle Congruenze Organizzative e d.lgs. 626/94*, Quaderni del Programma di Ricerca "Organization and Well-being", Torino: Tirrenia Stampatori.

RULLI G., CRISTOFOLINI A., BIANCO R., GARRINO L., MAFFEI L., MUSSANO R., MAGGI B.
1996 Analisi organizzativa del lavoro ospedaliero: identificazione degli elementi di costrittività e ipotesi sulle loro relazioni con il benessere degli infermieri, *La Medicina del Lavoro*, 86, 1: 3-15.

RULLI G., GRIECO A., BARBARO M., FENGA C., GERMANO D.
1997 La valutazione del rischio negli uffici attraverso l'analisi della situazione di lavoro. Un approccio olistico, *Acta Medica Mediterranea*, 13S: 155-163.

SPERANDIO J.-C. (ED.)
1966 *L'ergonomie face aux changements technologiques et organisationnels du travail humain*, Toulouse: Octarès Editions.

WATERS T., PUTZ-ANDERSON V., GARC A., FINE LJ.
1993 Revised NIOSH equation for the design and evaluation of manual lifting tasks, *Ergonomics*, 36, 7: 749-776.

WISNER A.
1997 *Réflexions sur l'ergonomie (1962-1995)*, Toulouse: Octarès Editions.