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The path of accident analysis: the traditional paradigm and extending the origins of the expansion of analysis*

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ABSTRACT
The traditional approach to accidents assumes that compliance with procedures and norms protects the system from accidents and that these events are caused by the faulty behavior of workers, which results partly from personality aspects. Identification of these behaviors can be based on comparing them with the standard "safe working practices", which safety experts are aware of ahead of time. In recent decades, new alternative views have expanded the perimeters of accident analyses and opened the way to questioning the assumption of the traditional approach to the concepts of the human being and work. These new approaches help to highlight the sterile results of traditional practices: blaming and punishing victims, recommending training, and proposing norms without changing the systems in which the accidents took place. The new approaches suggest that the traditional approach is totally worn out and emphasize the importance of operator contribution for system safety.
Key words: accidents occupational. accident prevention.

Introduction

How have accidents and disasters been analyzed through the course of history? This review exposes, summarily, a form of thinking of or organizing different approaches generated in this respect.

In the origin of the present work is the verification that a large number of analyses of accidents, conducted in the scope of enterprises and even of official agencies, are concluded in a manner to attribute responsibility and blame for what occurred to the victims of the accident or to their colleagues that operated in the vicinity (Vilela et al., 2004; Almeida, 2001; Reason, 1999). In the literature, approaches that culminate in this manner have come to be denominated the traditional or classic paradigm of security (Cattino, 2002; Dwyer, 2000).

This review seeks, among others, the following objectives: to contribute to the deconstruction of the traditional security paradigm; to furnish subsidies for the systematization of approaches currently adopted for the analysis of accidents; to supply incentives to the explicitation of assumptions adopted in practices of analyses of accidents, especially of those based on the traditional paradigm or approach; to contribute to the clarification of existent differences between positions of defenders of the *traditional paradigm* and of *systemic security*.

In a complementary manner, it intends to describe characteristics of different principles adopted in usual practices of accident analyses, so as to show that blame-attribution practices are also associated with non-utilization, or with distorted use, of principles that are being suggested in the systematization of analyses of accidents in the last thirty years. To conclude, the work shows that, more recently, the exploration of aspects of a subjective dimension of accidents benefits from the incorporation of rereading of aspects identified in data collection with the support of concepts of Cognitive Psychology, Cognitive Ergonomics, Anthropology, Systems Engineering, among others. This conceptual expansion of analysis reveals other facets of the insufficiency of traditional approaches for explaining human behaviors in work.

In a preliminary manner, it seems important to remember that a primary comprehension of the origins of and reasons for these phenomena is rooted in the beliefs that they attribute to divine will, punishment or other forms of expressing occurrences deserved by the victims. This vision has taken root in many cultures of different societies and, until today, influences said ingenuous perceptions or visions (Kouabenan, 1998).

A prehistory of analysis of accidents

Establishing a rough parallel with historical periodization, it can be defined as a prehistory of analysis de accidents arising from the contribution of Heinrich (1959), that developed a *theory of dominos,* representing the occurrence of an accident as a *linear sequence* of events or "stones". The third stone represents the occurrence of *unsafe conditions and acts* that are in the origin of the dichotomous vision prevalent in Brazil.

For some years, this was the only approach to accident causality studied by work safety (SST) and health professionals in Brazil.

This was also the understanding present in the "educative" material most frequently used, such as prevention brochures and posters, theatrical plays, etc. (Almeida, 2001). Subsequently, under the influence of ideas of the Scientific Organization of Work, two classes of causal factors in accidents have arisen that, in practice, are equivalent to the acts and conditions cited: technical factors and human factors (Neboit, 2003).

And how should these acts be identified? The most widespread practice assumes the presupposition of the existence of a correct form of work execution, called "safe", defined in legal or administrative norms and procedures. To identify *unsafe acts*, it would be sufficient for the "investigator" to compare the occurrence with this standard . And how can they be prevented? Stimulating changes in the behaviors of victims. To do this, the analyses recommend punishing inaccurate assessments, bad judgments and wrong decisions and actions, while rewarding *desired* ones. It is the strategy of the *carrot and the stick.*

This form of conceiving the accident understands the actions and omissions occurring in work as products of *conscious choices* of workers, taken in situations in which they would have different alternatives among an array of options, in conditions of absolute *control* of the situation in its course. In synthesis, the outcome of the action is used as a criterion to judge the decision taken, not considering, among others, the following aspects of the work situation: context, nature of the demands of the task, variability and history of the usual forms of execution of the work, adequacy of the "standard" in the validity of this variability, and even the associated psychic processes, for example, the stress, the incomprehensions, etc.

The technical fragility of this approach would not be sufficient; its diffusion shows it to be associated with practices that aggravate its consequences such as attributing blame to the victims, which would inhibit effective practices of prevention.

A traditional approach of analysis of accidents

In the periodization proposed herein, initiation of systematization of the process of analysis of accidents is characterized by structuring the auxiliary practice of a policy or system of managing security and health of the workplace (SGSST), divided into four stages, shown in Chart 1. The arising of proposals of analysis systematization modifies these stages, in general, expanding the perimeter of the investigation.

Chart 1. Stages of systemization process for analysis of accidents

1.) Preparation of analysis, definition of event to be analyzed and its consequences;

2.) Analysis *per se* with correction proposals and written report;

3.) Implantation of corrections and their accompaniment; and

4.) Feedback from the system with update based on lessons learned in the analysis.

Nevertheless, structuring of the process with these four stages does not represent effective rupture with the essence of the model described above. The essence of the *approach* or *traditional paradigm* of security was summarized by Dwyer (2000) and Cattino (2002) in the following characteristics: a) improvement in levels of Health and Safety will be followed with technological improvements, disciplinary sanctions, reinforcement of the creation of new norms and controls derived from actions of specialists; b) the human being is an unreliable part and is the origin of unsafety into systems**;** c) the error is seen as a "failure" or "defect" originating from negligence of operators.

Other authors refer to this approach as *anticipationism* (Hood & Jones, 1996), to emphasize the fact that the risk factors that can originate an accident or disaster are considered to be known *a priori*. This knowledge is reflected in the instruments used in analysis of accidents that take the form of verification lists or *checklists* of "causes", to be used by safety teams.

The analysis practices that result in attribution of blame to victims are shown to be profoundly influenced by the ideas presented up to this point. Chart 2 begins with a summary of the notion of accident and of paths assumed by the analysis in accord with this approach.

Chart 2. Conceptions of accidents and their characteristics		
Conception:	**Notion of accident:**	**How are findings interpreted and analyzed?**
Traditional	Simple phenomenon with linear causal structure. Result of non-fulfillment of safety norms or prescriptions with origins in individual aspects. Model centered on the person's behavior or psychological state. Behaviors are explained by stimulus-response model	Describe the lesion (final event) and its origins. Compare behaviors and technical factors with "the correct way to do or be," considered to be the previously known standard and described in norms and prescriptions. The custom is to adopt a checklist without exploring interaction between factors. Differences identified between worker actions and standards are assumed to be "causes". Causes are explained as problems of workers. The system is saved. Prevention is based on punishment of undesirable behaviors and rewarding of desirable ones.
Model of change analyses.	Significant change in the situation with the accident compared to the situation without the accident. The change can be of technical or human components or a product of interaction of components. Assumptions about origins of behaviors are not explicit.	Analyze accident and identify what changed and the system conditions that permitted the origins of the changes. The origins of changes must always be sought in the plural. The recommended standard for identification of changes is the real work, and not the norms and prescriptions of the enterprise. Reasons of conditions that originate changes must always be sought up to the level of "causes of causes," so as to evidence managerial or organizational origins of the accident.
Model of release of energy or barrier analyses	Accident such as encounter between exposed person and released energy of potential danger present in the system. Assumptions about origins of behaviors are not explicit	Describe the elements of the model. Identify the forms of energy (dangers) involved in the accident, and explore all types of barriers capable of stopping the development of the accident, throughout the accident process, from the system origin to minimization of the consequences suffered. Absence of failures and barriers tend to be interpreted as signs of failure of the work security subsystem.

In safety situations characterized by elevated rates of accident occurrences associated with classic problems of Safety Engineering, the adoption of this model was shown to be useful as an auxiliary tool of safety policies.

First steps of perimeter extension of analysis of accidents

Preparing the process and expansion of targets of analyses

The periodization proposed herein takes as its conductive thread the stages of the model described in the previous item. In the first steps of their expansion, the stage of *preparation of analyses* comes to include definition of safety policy with diverse components, one of which is the subsystem of analysis of accidents. In these systems there comes to exist the previous definition of human resources and materials to be utilized, such as structuring of *information systems* that serve as a base for the definition of priorities to be addressed by safety teams, etc.

The events to be analyzed are also reviewed. In the case of Brazil, systems maintained in the anterior stage become attached to the legal concept of accident centered in the notion of the existence of victims linked to the enterprise according to the specific type of work contract. In the first steps of expansion the importance of detection and eventual analysis of other types of *adverse events* was discussed as incidents, quasi-accidents and material losses as an auxiliary tool of a safety policy.

Expansion of analysis *per se*.

Rethinking the analysis: to find blame or to seek prevention?

With regard to analysis of events *per se*, important contributions appear, of which the following deserve to be highlighted (Almeida, 2001; Johnson, 2002; 2003; Livingston, Jackson & Priestley, 2001): a) explicitation of differences of objectives between analyses directed toward *identification of those responsible* and those that aim to *identify causes* and subsidize *prevention practices* of accidents with similar aspects; b) explicitation of notions of *analyses of changes* and of *analyses of barriers* as fundaments of accident analyses, and the appearance of techniques based on these principles, isolated or in association. The notion of *assumed risk* expands the frontiers of this approach; c) explicitation of *strategies of formulation* and of *choice criteria* of preventive measures to be recommended and implemented.

With respect to objectives of the analyses, it becomes evident that, when a team limits the search to those *responsible* or *blamed*, the process tends to be restricted to the vicinity of the consequences of the event. In the jargon of the area, the search is restricted to the identification of *direct causes* of the accident. Finally, the less that is known about the accident, the greater the probability of a conclusion that results in attribution of cause and responsibility to operator error. Also it is possible to verify that, the more complete the analysis, the greater the probability of identification of other types of causal factors and of limits of the prior conclusion.

One of the definitions adopted for *direct* or *immediate causes* of an accident is "the most obvious reason for which the adverse event occurs". Beyond these, there are also *basic or root causes*, and the *underlying* or *contributive causes*. *Root causes* are events, failures that give origin to all the rest. They are of a managerial nature, such as planning or organizational failures. The *underlying causes* are less obvious organizational or systemic reasons for the origins of accidents. For example: the non-realization of pre-use inspection of a machine, on the part of supervisors, or an increase in production pressures (Health and Safety Executive, 2004).

The reasons for the adoption of this differentiation among types of causal factors are not very clear. Despite this, its utilization gained great diffusion, being incorporated into different techniques of analyses of accidents. Nevertheless, although the necessity for exploration of the origins of human behaviors indicated as *immediate causes* of an accident is explicit, studies show that the interpretation of these findings continues to be based on the same conception of the human being adopted in the traditional paradigm (Vilela et al., 2004; Baumecker, 2000; Llory, 1999).

How should these analyses be structured? Since the primordial ones, a list of questions appears that should be responded to in the analysis: *What? Who? When? Where? How? Why?* Additionally, multiple forms of organizing an analysis have appeared. The most widespread adopt the model of *sequence of events* mounted as a Chart that begins, to the right, as consequences of the accident, for example, the lesions suffered by the victims. Close beside comes a list of *immediate causes*, followed by, more to the left, a list of *underlying causes* and, finally, at the extreme left of the Chart, a *root cause*. Some models work with the idea of a list of root causes.

This model of analysis tends to be complemented with *lists* of each of the groups of causes, so as to "help" the analysis team in its work. The lists of causes are not merely innocent tools in support of prevention. Despite being elaborated with the best of intentions, they internalize a worldview of safety strongly influenced by *presuppositions* of the *traditional approach*. Security norms, practices prescribed or specified, services orders, the presence of technical devices that can be used as measures of protection or *barriers* to release of different energy flows during an accident etc., tend to be adopted as *standards of comparison* with the actions identified in the accident. The verification of differences tends to be taken as proof of identification of the accident *cause*. It deals with a model of *anticipatory* inspiration, that is revealed to be useful if evidencing material and environmental conditions and also of behaviors indicated as associated with increase in the risk of accidents. The highlighted actions and omissions tend to be judged per se. Their occurrence and, at times, the mere supposition of occurrence are interpreted as proof of operator failure, implicating judgement of his *responsibility* and of his *guilt.*

Adoption of analyses of changes, barriers and concepts like system, activity and their components, rules of logic etc., in new techniques of analyses of accidents, aids in systematizing them at the same time in which it expands the perimeters of these investigations.

Change Analysis

In accord with the notion of *analysis of changes,* if the system were to function in the same manner as in a *normal situation* or one without accidents, these would not occur. The occurrence of an accident always demands the appearance of some *change* or *variation* in functioning of the system without accidents. As a consequence, to analyze an accident is to identify these *changes* and the conditions of this system that permitted its origins (Binder, 1997; Monteau, 1979).

What is the definition of a *normal situation* or *comparison standard* necessary for the identification of *changes*? In the traditional approach, the definition used most often refers to a restricted concept of *deviation*, understood as "every action or condition that is not in accord with the norms of work, procedures, legal or normative requisites, system requisites of management, good practices, etc., that can, directly or indirectly, bring damage to the person, to the environment, or to one's own property or to that of a third party, or a combination of these" (DuPont do Brasil, 2003).

Discussing change analyses, Johnson (2002) affirms that the different standards can be taken as an *ideal condition*: descriptions contained in documents, such as routines, step-by-step, operational norms ("guidelines"), contracts, accords or conventions; safety norms etc., according to the case. An *ideal condition* also could be that which *existed before the accident*. This distinction is considered important because in the origins of an accident could be "*inadequate practices maintained for much*" time. In these circumstances, the focus of analysis should be much more on the reasons for the presence of these practices.

From the operational point of view, the conduction of analyses based on this principle tends to show differences in relation to choice of *comparison standard*. In the case of the *tree of causes* technique, it is recommended that the safety team adopt as the *standard* the knowledge of the routine or *habitual situation* of work, that will be compared with the findings of the *situation present in the accident*, in a manner to permit the *identification of variations* (Binder, 1997; Monteau, 1979).

Applying current language concepts of Ergonomics, in these methods emphasizes that the comparison standard would be the *real work*, the *activity*, and not the *prescribed work* (Guérin et al., 1997). More recently, Rasmussen (1997) refers to these same concepts using the expressions *established practices* and *specified practices*.

For practical reasons, techniques of analyses based on this notion, like the *tree of causes* method, recommend the initiation of reconstruction of the event by its ultimate happenings. The existence of an injured worker or of a damaged product is an easily identifiable change that serves perfectly the proposals of this type of analysis (Binder, 1997; Monteau, 1979).

One of the differences established by the use of this notion in accident analysis practices is the emphasis of explication of what really happened, instead of more reports that explained the occurrence with the indication of a supposedly unexecuted norm or rule, or of an action that was not carried out by workers, or even of non-existent protection that should exist, etc.

In traditional analyses, "error" is defined as deviation in the performance of a sequence of actions in relation to that *prescribed* or *specified*. As a consequence, starting from the result known after the accident, they easily identify "errors" of this type. For example, the lack of a relief valve in a system that exploded, a lack of a bodyguard in scaffolding from which a worker fell, etc. When this type of analysis concludes with identification of these aspects, it comes to disallow the identification of what and how it exploded, or of the reasons associated with the fall of the worker, or even of the motives for which there was no bodyguard long before the accident. When these aspects were neglected, the spaces for more effective prevention practices are narrowed.

This approach introduces into the system a discussion on the *stop rule* to be adopted in analyses. In practice, the process leads the team in search of *causes of causes*, and so on, successively. The *changes* identified associated with *rules of logic* are utilized as a guideline for elaboration of *diagrams* of changes having occurred and of the "causes" of their origins. Each of the aspects represented aims for the continuity of the design and so on, successively. Subsequently, the scheme is completed with the representation of habitual conditions of the system that participated in the accident. One of the manners of doing this is to associate an analysis of barriers with an analysis of changes.

Taken seriously, this process flows into the identification of managerial practices and choices of diverse subsystems, and even of the high hierarchy of the enterprise, habitually not discussed by the security team, whose exploration can represent a potential source of embarrassments in the organization. In enterprises that are not prepared to accept such questioning, they tend to be restrained and the analyses tend to be concluded in early stages of the questioning process.

Sometimes they explore *aspects of a technical dimension* involved in the accident, countering the presupposition of methods of analyses that consider enterprises as open socio-technical systems (Lima & Assunção, 2000).

Chart 2, already presented, includes a summary of the notion of an accident and of forms assumed in techniques of investigation based on analysis of changes.

Barrier Analysis and Assumed Risk

In accord with the notion of *analysis of barriers*, the accident always involves the release of an *energy flow*, potentially dangerous, that was controlled by *barriers,* or preventive measures, existent in the system. Eventually, the system could not have the indicated barriers, even to contain that energy temporarily. The *barrier analysis* consists of identification of the energy forms released in the accident and of the reasons that explain their release. Emphasis is placed on exploration of *barriers* that existed or should have existed in that system and in evidence of the potential contribution of each one of them in that scenario. Could one barrier that was not present have avoided the accident or minimized its consequences? In the affirmative case, how can its absence be explained? Did some existent barrier fail? Why? And so on, successively.

Although, in safety practices, the notion of *technical barriers* of protection would be better known, the *analysis of barriers* adopts a more inclusive comprehension. Thus all types of possible *barriers* must be explored. For example, the definition of criteria for purchases of materials or for intervention decisions in cases of detection of failures in the functioning or management of a determinate subsystem; training implementation; development of practices to stimulate the creation of a culture of security; the (non) contracting of specialized counselors; restrictions on overtime hours, etc.

From a practical point of view, different forms of conducting *analyses of barriers* appear. The method *management oversight risk tree* (MORT), developed in the 1970s by Johnson (1975), begins with an organization of the temporal sequence of events, so as to identify the different energy flows released in the accident. They are represented in the initial column of the Chart, beside which is the specification of agents or materials vulnerable before the release of that form of energy. The third column of the same Chart must be filled in with barriers known as protections capable of avoiding the flux, diminishing the quantity of energy released or minimizing consequences for living organisms or vulnerable materials (The Noordwijk Risk Initiative Foundation, 2002).

Another form of conducting *analysis of barriers* is associated with development of *models of accidents*. The models tend to adopt graphic representation of elements present in an accident. The model of Dumaine (1985) defines accident as an *encounter* between a *susceptible living organism* and *energy* released from *potential danger* present in the system. It also includes *factors unleashed* from the energy release that had been previously controlled in the system and *factors generating* the presence of potential *danger*. The analysis seeks to identify barriers known as protectors capable of avoiding the *encounter*, the appearance of *factors unleashed* from the energy flow, the generation of *danger*, etc. Many *checklists* used in analyses of accidents are inspired by the notion de *analysis of barriers*.

The notion of *barriers* is adopted by Reason (1997) in the *organizational accident* model, which denominates *active errors* the contribution of human behaviors to the release of energy flow occurring in the accident. According to him, the analysis must be extended to the search for *causes of causes*, in other words, of so-called *latent* or non-proximal reasons for accidents that, in general, are managerial or organizational.

Taking this model as a reference, it can be said that the principal difference between the traditional and *systematic* approaches is the fact of the former continuing to insist on the idea that the principal causes de accidents are the human behaviors situated in proximity to the outcome of these events, in other words, the "unsafe acts" or *active errors* of the victims.

Supported in concepts such as those described above, the analyses tend to assume determinate systematization, although the degrees of liberty of the team in the conduction process would be relatively elevated, explaining differences in conclusions of analyses of the same type of event, by different teams that use the same technique. Another source of differences in results of analyses is in the degree of mastery of the technique and in the conception of the accident on the part of members of the teams. The form in which each understands notions of the accident, of analyses of changes and of barriers, of the open sociotechnical system, of human behaviors in the system etc., influences the conclusions of the analysis.

One of the basic differences between *analysis of barriers* and *analysis of changes* is that the latter is shown to be more refined with information collection practices based on open-ended questions. In this manner previously unanticipated reasons can be identified and foment discussion about their eventual role in the origins of an accident. Furthermore, to conduct a search of the *causes of causes* and decide on the *endpoints* of the analysis, the team must discuss and explain the reasons associated with the choice of these points. In the analysis of barriers, the list of causes tends to overlap. In turn, realized as a complement to analysis of changes, the analysis of barriers can contribute to an expansion of analysis and indication of other prevention strategies.

Another concept that comes to be associated with these two is that of *assumed risk* or *residual risk*. It deals with risk identified in previous analysis and assumed after technical evaluation. The decision to assume it is conscious, for example, because the adoption of corrections would be impractical. The authors involved in this type of decision need to prove that it was taken in a satisfactory manner (The Noordwijk Risk Initiative Foundation, 2002).

Considering that systems must be conceived incorporating *analyses of barriers* based on the most current scientific knowledge; and that, at the same time, from its conception to installation and operation these systems pass through *changes* that need to be considered in SGSST, so as to avoid losses and accidents, the idea grows that the *acceptable risk* in the operation of any system is that associated with aspects that cannot be controlled with the resources offered in light of more current knowledge.

In other words, the systems need to demonstrate that they stem from the best and most current practices and prevention tools for the control of dangers and risks. To do this, they would also be assuming the risk of occurrence of unanticipated and uncontrolled events with these better resources: the *assumed* or *residual risk* of the system. Among these uncontrollable risks, are those still unknown, such as those associated with unexpected interactions between system components that, in the majority of situations, present mutually independent behavior.

One of the advantages attributed to the use of these techniques is the possibility of systematization of analyses: of data collection to ascertain the impact of measures implemented. This process tends to diminish the number of unexplored aspects, of bias originated in the formation of analysis team members, and reinforces the necessity of crosschecks with the use of different information sources. Other advantages attributed to this model of analyses are: identification of patterns of accidents and of organizational aspects present in accidents. The identification of similar aspects in accidents uses a notion equivalent to that of saturation: "*phenomenon by which, past a certain number of interviews, [...] the researcher or team has the impression of not acquiring new knowledge relative to the sociological object of inquiry*" (apud Bertaux, 1980, p.205).

Chart 2 also includes a summary of the accident notion and of the paths assumed by investigations based on analyses of barriers.

Discovering the subjective dimension of accidents

Although techniques based on the theory of systems harshly criticize narrow behaviorist approaches and the reductionism of "analyses" of accidents that attribute blame to victims of these events, in many cases, they also do not respond adequately to questioning arising around the *subjective dimension* of accidents. In a certain manner, exploration of aspects of the *organizational dimension* of these accidents appears to be taken as negation of the antecedent.

The *causal tree* method (ADC), developed by psychologists in France, was criticized due to its *objectivism* (Goguelin, 1996). In Brazil, in some of its publications utilizing this method, Binder & Almeida (1997, p.751) present the technique reinforcing this characteristic *"[...] its application demands detailed reconstruction, with the greatest precision possible, of the history of the accident, registering only facts, also denominated factors of the accident, without emitting value judgments or interpretations".*

The critique of Goguelin centers on the absence of exploration of cognitive aspects, whose approach gained impetus with the development of the cognitive approach in psychology and in ergonomics. It seems important to establish the fact that, at the beginning of the 1970s, when the ADC method was developed, the utilization of concepts from the cognitivist school in studies on the work world occurred in an embryonic manner.

In the experience of the author, in many situations of use of the *causal tree* method, the lack of a distinction between *ADC tree* and *analysis* and, in particular, the lack of an explicitation of the necessity of the complementary conceptual approach of aspects represented in the scheme had contributed to the occultation of invisible aspects of work, impoverishing interpretations and conclusions of analyses.

Nevertheless, parallel to the development of techniques based on *analyses of changes*, *of barriers* and in the idea of *assumed risk*, there also appeared new forms of analyses of accidents inspired by concepts of sociology, anthropology, social and cognitive psychology, and of ergonomics of activity, indicating new paths for the collection, organization and interpretation of data relative to the origins and prevention of accidents. These contemporaneous approaches will be presented in another text.

Formulation and selection of prevention measures

The different techniques of analyses commented upon associate orientations of systematization of the formulation process and the selection of prevention recommendations. The causal tree method recommends that the participants be stimulated to suggest the *direct elimination* of determinate factors, the creation *of barriers that impede the origins* of these same factors and the *suppression of elements necessary to their origins*. Whenever possible, the initial list of recommendations should include proposals of these three types for each of the factors represented in the scheme, and also for the potential problems or factors formulated during the interpretation of the scheme. The utilization of *selection criteria* of proposals elaborated also is emphasized. Among the criteria that would assist the systematization of analysis and choice of priorities, the following stand out: 1.) *stability* of the measure in time; 2.) *additional cost* - physical, cognitive or affective - of the measure for the operators; 3.) possibility of *dislocation of risk* to other parts or even to other systems; 4.) is the *reach* of the measure - localized or capable of extending its benefits to other parts of the system? 5 is the *time necessary for its application* - immediate or does it demand long-term maturation? (Binder & Almeida, 2003)

In turn, after dividing the accident into ten phases, going from pre- to post-lesion, Haddon (1973) proposed ten types of preventive strategies, shown in Chart 3.

Chart 3. The ten accident prevention strategies of Haddon Jr.
1. Prevent the formation of potentially harmful energy present in the system;
2. Reduce or limit the quantity of energy formed;
3. Prevent the release of this energy;
4. Modify the spatial distribution of energy release starting from its origin;
5. Separate, in space or in time, from susceptible structures, live and inanimate, the energy that is being liberated;
6. Interpose a material barrier between susceptible structures and energy;
7. Modify surfaces and basic structures so as to dissipate the energy load;
8. Increase the resistance of susceptible structures;
9. Reduce losses, detect and evaluate rapidly the damage having occurred to hinder and impede its continuity and extension; and
10. Stabilize, repair and rehabilitate the lesions and losses, aiming for promotion of a return to functional pre-event "status".

The appearance of *criteria of evaluation of preventive measures* aggregates another type of criticism to traditional approaches of accidents that, in Brazil, resulted almost always in suggestions for changes of behavior of accident victims and their colleagues. This type of suggestion is described as ineffective when adopted in isolation, and as presenting the lowest stability in time, above all, if not conceived with an adequate program of periodic reinforcements.

In psychology, studies appear that show other limits and fragilities of training proposals supposedly directed toward behavioral changes (Kouabenan, 1999; Rogers & Mewborn, 1976; Levanthal et al., 1965). A large portion of the proposals destined for prevention of accidents is based on *fear stimulus*. Studies show that fear or shock provoked by terrifying messages is an emotion that disperses before the time necessary for behavioral change to occur. This is one of the reasons that explains differences found among declarations of attitudes favorable to changes in behavior and effective changes of behaviors of persons interviewed after exposure to this type of stimulus (Kouabenan, 1999; Rogers & Mewborn, 1976; Levanthal et al., 1965).

The expressions *passive* and *active prevention* were utilized generically to designate, respectively, measures that demand the active participation of those involved, such as the utilization of equipment of individual protection, and measures that dispense this participation, such as automatic blocking devices that stop movements of machines when there are worker body parts nearby (Gielen, 1992; Baker et al., 1982). The notion of *safe failure* appears in association with these ideas

(Baker et al., 1982; Haddon & Baker, 1981) to indicate that the systems must be conceived so as to tolerate the occurrence of failures.

The introduction of criteria of choices of preventive measures and the emphasis placed on necessity of recommendations relative to organizational, managerial or distal causes of accidents stimulate debate about questions of a new type, for those interested in prevention of accidents and management of risks in general. Among these stands out the degree of technical and political difficulties associated with formulation of recommendations of a new type, such as, for example: exploring origins of practices of re-assignments of workers for sectors and activities in which they had never worked before; facing origins of introduction of increases of pressure of time and of production; managing risks of simultaneous and successive activities or those in which operators come across unusual situations (Binder & Almeida, 2003).

Questions appear on appropriate techniques for the approach of this new type of "risk factors" and with respect to the profile of professional formation necessary for security teams. There also appear lines of questioning on the characteristics of organizations favorable or unfavorable to the development of health and security policy advances an active and permanent manner to address this type of questions.

The response given to these lines of questioning, in marks of the traditional approach, is the exacerbation of behaviorist practices. Insisting on the idea that the principal causes of accidents on unsafe or similar acts, *behavioral security* proposals appear. Some of them refer to the necessity for changes, also, in behaviors of their managers and intermediate bosses, although in practice this aspect persists neglected.

Implantation of corrections and their follow-up

The subsystem of analysis of accidents organizes a process of evaluation of prevention recommendations originated in its activities, as well as the implementation and follow-up of the measures chosen, demanding a formal definition of flow for transaction of reports, definition of those responsible for taking decisions, for their implementation and for checking their respective chronogram.

Another important aspect is the necessity of follow-up of the impact of measures implemented in which the occurrence of accidents is referenced that include similar aspects, almost equal to those it intended to control with the measures adopted. In case this occurs, especially in a frequent manner, it is very probable that the team is faced with *signals* that permit it to think of failure of previous effort and of the necessity of reanalysis of the situation. Unfortunately, in many cases, in these hours, resistance originating from the *traditional approach* comes to the surface. The *signals* that the situation sends are interpreted as confirmation of the fallibility of the human component of the systems, presenting an opportunity for and reinforcing normative recommendations, new rules, procedures and even the punishment of "indisciplined" or "deviant" persons.

Feedback from the system

The process of systematization of accident analysis is completed with the development and implantation of practices of *feedback* from the system with the results obtained.

In the initial phases of this process, it aims to share immediate findings with the other members of the system. One of the motors of this practice is the idea of informing, at which they participated in the analysis process, the conclusions obtained so as to highlight the importance of their contributions to the perfecting of the system. In this way, it strengthens the possibility of future contributions, especially in systems that effectively implement recommendations of impact on improvement of their security and reliability and they show plenary recognition of contributions of diverse participants. Subsequently, associated with the notion of SGSST, feedback incorporates new objectives, such as that of becoming the source of updating and continuous improvement of the risk evaluations present in the system.

With the advent of the Internet, the forms used to test this *feedback* gain new possibilities and greater agility.

The development of the notion of *organizational learning*, understood as a continuous process, stimulates the recognition of the importance of this component of the subsystem of analysis and prevention of accidents, and renovates the forces interested in the expansion of the perimeter of accident analysis and of breaking with the presuppositions of the traditional paradigm.

Final commentaries

This text rescues aspects of the trajectory of accident analysis, aiming to show that, from the technical point of view, there are already elements that justify the diminution of the occurrence of analyses circumscribing behaviors of victims close to the lesions. Among these are highlighted: the appearance of notions of direct causes and basic causes; the introduction of analyses of changes, above all in cases in which the standard definition of deviation is based on real work and in which there is explicitation of *stop rules* of the analysis, and the practices of analyses of barriers used in association with models that include the exploration of the organizational origins of accidents and as a complement to analyses of changes.

The fact of concentrating on recommendations of prevention classified as *low stability* in time or isolated use of *active* measures also calls attention to the persistence of the traditional approach. In situations in which the work system remains unaltered, the follow-up of the implantation of these measures can reveal a recurrence of accidents with similar aspects, in other words, the exhaustion of the reach of these recommendations.

Unfortunately, in a large number of analyses, the identification of behavior classified as lacking continues to be interpreted as a sign of failure or low reliability of the human component of the system, capable of being corrected with punishment of "deviation". In synthesis, not even the introduction of techniques of analysis of socio-systemic inspiration breaks with the marks of the traditional approach. In some cases, analyses of this type of accidents indicate, as the "basic cause", the existence of failure of supervision of compliance to prescribed behaviors.

A recent study, elaborated at the request of the Health and Safety Executive in the United Kingdom, points out requirements of a successful incident investigation (Health and Safety Commission, 2001): 1.) A causal model that represents a system-based approach to incident investigation; 2.) Involvement of relevant individuals within the investigation; 3.) The identification of both immediate and underlying causes; 5.) The development of recommendations that address both immediate and underlying causes; 6.) The implementation of these recommendations and the updating of relevant risk assessments; 7.) Follow up to ensure that actions taken are successful in reducing the risk of further incidents; 8.) F*eedback* to relevant parties to share immediate learning; 9.) The development of an accessible database.

As can be seen, part of the limits and lines of questioning already commented upon remains absent from the list above. Nevertheless, some of the characteristics listed, such as that at number two, the updating of evaluations of risks cited at number six, and at number nine (that deals with the notion of databases as a component of a system of vigilance against accidents), already reflect aspects of a *conceptual expansion* of analysis of accidents.

What is understood by *conceptual expansion*? The expression is used to designate the incorporation of concepts in the analysis process. Its utilization opens new paths for the comprehension and analysis of accidents. With the use of concepts, starting from the same material, the analysis team can arrive at understandings vastly different from those obtained without their use.

The notion of *error trap*, developed by Reason (1997) and used by Almeida & Binder (2004), enables the identifying of tasks organized with sequences of steps that increase the chances of omissions in situations initially interpreted as lack of attention by the operators. The concepts of Rasmussen (1982), Reason (1999; 1997) and Reason & Hobbs (2003), as well as those of *activity, regulations, competencies, situated cognition, systematic migration to the accident*, indicate new routes for analyses of human behaviors in work accidents. Differently from traditional approaches, in the new approaches the accident is organizational and the origins of behaviors are sought in material and social circumstances of the work context understood as circumstances that influence the ways of psychic management used by operators in work (Vidal-Gomel & Samurçay, 2002; Lima & Assunção, 2000; Rasmussen, 1997).

This text seeks to present aspects of the trajectory of conformation of the traditional approach to accidents, indicating elements that point to limits of the conception of the human being adopted in it, and of exhaustion of its possibilities of contributions in systems that improved their security performances and that work with new technologies.

In what direction will the analysis of accidents go? The contemporary debate is shown to be divided into two great currents: *behavioral safety* versus *systemic safety*. The behavioral approach defends the idea that the principal causes of accidents are "unsafe acts" that equate to *active errors* of operators. Therefore, the English abbreviation for behavioral security programs, BS, ("behavioral safety"), comes to be used for workers' movements as an abbreviation for programs of blame attribution ("blame-the-worker safety programs").

The systemic approach contains models of accident psycho-organizational dictums and rejection of the negative idea of human error present in the traditional approach. The following gain prominence: a) the recognition of the contribution of the social or human subsystem for the safety of systems; b) the contribution of structural characteristics and of the material and social circumstances of the system, especially of responses to environmental pressures for the origins of safety and of risks in the work situation. This approach introduces new challenges to those interested in exploration of the human dimension in open socio-technical systems. Among the most important appear to be: how are situations identified in which "their" system could benefit from the use of *conceptual expansion*? How can it be known which concepts will be useful in each situation? These aspects will be reevaluated in another text.

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