Communication and industrial accidents

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SOM-theme A: Primary processes within firms

Abstract
This paper deals with the influence of organizational communication on safety. Accidents are actually caused by individual mistakes. However the underlying causes of accidents are often organizational. As a link between these two levels - the organizational failures and mistakes - I suggest the concept of role distance, which emphasizes the organizational characteristics. The general hypothesis is that communication failures are a main cause of role distance and accident-proneness within organizations. A general classification of communication is presented, and safety communication and obstacles are distinguished. The analysis at various levels does not falsify all my hypotheses, and several dimensions of communication seem to be of interest for the safety.

1 Introduction

Many industrial processes have potentially disastrous outcomes for workers and the environment. Industrial organizations need to reduce risk because of legal obligations[1], for financial reasons and social legitimacy. Most literature dealing with occupational safety emphasizes unsafe working conditions or individual characteristics. The research to be presented in this paper relates to organizational characteristics as a cause of accident-proneness in a number of industrial organizations. Here the concept of organization relates to human activities performed to produce goods. It implies both the functions and tasks within the production, maintenance and shipping sequences of chemical industry: the primary production process. By organization I understand a group of interrelated roles; it comprises formal organization as the product of intended organization design (designed to set collective goals and make arrangements to deploy available resources to attain those goals) and informal organization as a coalition of multiple, possibly conflicting interests characterized by rules not laid down in procedures.

It is the result of a long tradition that accidents are most times studied as the result of technical - or human errors. In this paper I would like to discuss the work organization as a cause of accidents, and organizing as a risky activity. I will first define the concept of safety as a performance measure, and as a dependent variable. Because "[b]efore anything can be studied scientifically, it must be defined. This step, which sounds so easy, has been a stumbling block for accident research ever since its early days" (Hale and Hale 1972:11, Osborn and Jackson 1988:925). In this paper I would like to study the influence of communication on safety. More precise: various

[1] In western societies, organizations are faced with several laws that aim to increase safety at work. For example, the Occupational Safety and Health Act (OSHA) emphasizes regulatory standards protecting workers from health hazards on the job. Different organizations in the Netherlands have to follow different laws, which are executed by different ministries. For example, the very strict 'Mijnwet' (1810: Ministry of Economic Affairs) and the extensive but more loosely defined 'Arbowet' (1980: Ministry of Social Affairs, following the 'Ongevallenwet' from 1901 and 'Veiligheidswet' from 1934) are acts that oblige organizations to detect risks and improve safety. For a discussion of the legal and political context in other countries (esp. France and US) see: Dawson, Willman, Clinton and Bamford 1988, Dwyer 1991:22-35.

kinds of communication to cope with future events and their uncertainties (within the production, maintenance and shipping sequences of chemical industry). Research indicates that communication seems to be a potential leverage of accident-proneness (e.g. Turner 1978).

Several dimensions of communication will be measured and analyzed. In this paper I would like to introduce two classifications: a general one and another classification of communication aspects that seems especially relevant in case of accident research. These classifications do not exclude each other and all aspects distinguished by both classifications will be measured and related to (role conflict and) accident-proneness.

One speaks of risk because, in any particular instance, an accident may or may not occur; causative factors skew the probabilities of different outcomes (Graham and Rhomberg 1996:15). From an organizational perspective risk is about problems of decision-making in the face of uncertainty. Here probability cannot be calculated in a quantitative way but it can only be described in relative terms like ‘more’ or ‘less’ (proneness). This view of probability points to the main difference between the mathematical and sociological approach of risk: the concept of uncertainty. Uncertainty refers to the complexity of social reality on one side, and to cognitive limitations on the other.

Nowadays, in sociology, definitions and interpretations of risk follow the ‘uncertainty approach’. Here I adopt a broad definition from everyday English and everyday life. Risk will be defined as: ‘human activities that might cause an accident’. The words ‘human activities’ point at the role of a voluntaristic actor (or: agent) and distinguishes the concept from danger; human action can reduce or increase the probability (and size) of the damage. This definition fits closely the way in which the concept of risk is used within accident- or safety research. It only involves ‘down-side risk’: problems or accidents, and not the opportunities. Here it equals ‘accident-proneness’ (or: operational risk); which is conceived as the opposite of safety or reliability.

Based on the observation that accidents are actually caused by mistakes (e.g.: Heinrich 1959:13 Leplat 1987:133-, Reason 1990, Adams 1995:16), I will regard mistakes (including dangerous behaviour and attitudes[2]) as an aspect of accident-proneness. Of course another aspect are (near-) accidents itself. A near-accident (or 'near miss') is an incident that in other circumstances could have resulted in an accident. An (industrial) accident is a sudden disturbance within the primary process, as a consequence of unintended human action, that results in physical harm or serious damage to equipment or environment. In terms of the famous iceberg metaphor the mistakes are the part under water, the near-accidents are at the surface and the accidents are the part above the water. So, mistakes are the proximate cause of accidents and will even be regarded as an aspect of accident-proneness.

The underlying causes of accidents are organizational. As can be deduced from the definition introduced before, an organization can be seen as a structured (or: 'patterned') group of roles, or (sub) tasks, which have to be coordinated. An important aspect of coordination is probably communication. Communication is the exchange of information. It is a process of mutual adjustment that (also) goes on outside the authority structure. Various management aspects can be described in terms of (top down) communication. However, communication is a process that can take place upward, downward, and laterally throughout the organization. The hierarchical lines of communication in any organization - those networks of communication that are established by the authority structure - are supplemented by equally important lateral channels.

Management involves (mainly) regulative, or instructive, communication, while other kinds of communication can fulfill important coordination needs too. The consideration aspect of modern ('coaching') leadership, the importance to use all the available know-how within an organization, and the need to adapt to the environment point at the importance of other kinds of communication than the one consistent with the classic principles of management and hierarchical reporting relationships. These

[2]For the use of mistakes, dangerous behaviour, and attitudes as 'alternative criteria for study' see: Hale and Hale 1972:13-4

will be discussed more extensively in this paper. First I will give a rough sketch of the potential influence of communication on accident-proneness.

After his exploratory case studies of three disasters Turner (1978) concludes: "Given the emphasis upon cultural disruption in the present study, it is not surprising that the central organizing principle of this classification should be concerned with *information* and *communication*". Turner suggests that we can see modern organizations as a hierarchy of overlapping bounded decision zones. His starting point is that disasters arise from an absence of some kind of knowledge at some point. In such a situation there is a 'variable disjunction of information'. A variable disjunction of information refers to a complex situation in which several parties handling a problem are unable to obtain precisely the same information about the problem, so that many differing interpretations of the situation exist (1978:50).

In a situation with a variable disjunction of information, several groups are involved and because each person has access to different information, each constructs different 'theories' about what is happening and what needs to be done. Communication is not only needed to solve uncertainty, but also to avoid a variable disjunction of information. So, communication might help to resolve "the negotiation of the social validity of the information" (Stinchcombe and Heimer 1985:19).

Essentially the 'communication approach' suggests that role senders communicate expectations of behaviour to the focal person: a role. These expectations are perceived by the focal person with varying levels of role conflict and ambiguity. In his description of the 'role perception transactional process model for organizational communication-outcome relationships' Schuler (1979) explains that although this model may appear to imply causality, it should be viewed as a bi-directional, reciprocal, or transactional model. High role conflict will cause the focal person to either withdraw from the relationship or actively confront (communicate with) the role senders to reduce the role conflict or ambiguity. Withdrawal reduces still further the opportunity to acquire information, and a vicious cycle can be created. Schuler found that (perceptions of) various kinds of communication were negatively correlated to role conflict.

The more complex an organization the more important the integration of sub-tasks becomes. Communication is needed to prevent the development of false hypotheses. As Weick points out (1993:187-8): “it is largely through good communication and overview that the existence of false hypotheses can be detected and diagnosed”. Especially during high-tempo operations there is a need for close reciprocal coordination and information sharing (La Porte and Consolini 1991:30-7). Fulk and Mani (1986) and Roberts and O’Reilly (1974-1:205) assume that especially communication from lower to higher members (‘upward communication’) in the hierarchy is vital. Simon (1997:211-4) states that in particular informal communication is important for the socialization of goals.

Communication is important for individual employees to learn from others, for socialization and coordination within the organization, and for adaptation of the organization to the (changing) environment. Especially in more complex work environments it is of great importance to learn from practical experience. But as Carroll (1995:175) states: “In high-hazard industries, complexity, tight coupling, and invisibility make safe operation and learning from experience particularly difficult”. The learning process should involve the exchange of ‘best practices’, incident reviews, etc. The High Reliability Theory (e.g. Roberts 1993) emphasizes the comprehension of complex technologies by means of learning processes. While Normal Accident theorists (e.g. Perrow 1999) suggest that the learning process is handicapped by technical uncertainties and political barriers (Lagadec 1997).

Communication has long been credited as a prime factor in the attainment of organizational performance (e.g. Katz and Kahn 1966, Greenbaum 1974). Each of the disaster inquiries examined by Turner (1978:100-1) “revealed a complex and varied pattern of misunderstandings, ambiguities and failures of communication .. It seems reasonable to suggest that there will be some kind of relationship between increasing difficulty in information-handling and increasing likelihood of failures of communication accumulating in such a way as to lead to the incubation of a disaster”. By distinguishing communication as a separate category that involves “the quality or absence of communication between the various regions, departments or employees” Groeneweg (1994) also indicates that communication is a main source of accidents.

Other researchers who pointed to communication as a determinant of accident-proneness are Neuloh et al. who showed that accidents due to poor communication could occur even in groups where there was no internal discussion, and Winsemius who discussed breakdowns involving lack of forewarning (in: Hale and Hale 1972:62-3).

2 Role theory

As stated, mistakes are the proximate cause of accidents and will even be regarded as an aspect of accident-proneness. Because the underlying causes of accidents are often organizational, the link between individual- and organizational level demands a theoretical description. For this description there are roughly two potential approaches: (1) the Human error approach that looks at mistakes from out of an epistemological point of view (various kinds of irrationality as a cause of mistakes), and (2) role theory which puts more emphasis on the organizational characteristics.

Because of the dominant role of mistakes in the accident-causation process it is a common approach to study individual limitations (or 'irrationality') as a source of accidents. Because of its focus at individual limitations this 'human error approach' is sometimes popularly referred to as 'train and blame ideas'. In a methodological sense (ir)rationality is also a problematic concept to explain human errors. How can I observe the phenomenon? An instrument to measure various kinds of rationality is unknown. In a field study it is very difficult to observe mistakes, but it will be even more difficult to observe various kinds of cognitive (ir)rationality. The main problem of an experimental situation is its limited external validity, it is impossible to replicate precisely the conditions that people face in the real world, their historical experience, and other contextual factors.

Role theory[3] and especially the concept of role distance constitute an alternative mediation between the large- and small-scale worlds. Roles serve as the

[3]Role theory can be compared with the more narrow 'adjustment/stress theory' and 'goals/freedom/alertness theory'. The first one postulates that people who are not adjusted to

boundary between the organization and the individual, and represent the expectations of both. In the work of many authors (e.g. Goffman 1961, Merton and Nisbet 1966, Berger and Luckmann 1966:96, Simon 1997:230) role reveals 'the mediation between the macroscopic universe of meaning objectivated in an organization and the ways in which these universes are subjectively real to individual employees'. The main reason to suggest role to link both levels is the (relatively to the human error approach) strong emphasis on organizational characteristics instead of (cognitive) characteristics of the worker.

Because people fulfill such a large number of positions, and roles, few people get completely involved in any given role. Role distance deals with the degree to which individuals separate themselves from the roles that they are in (or the degree to which an individual embraces a given role). Role distance represents conditions of not knowing what to do, the extent of authority to do it, or incompatibilities as to what to do for whom (Schuler, Aldag and Brief 1977); it consists of role conflict and ambiguity (Kahn et al. 1964). Role conflict describes a situation in which actors are required to play a role which conflicts with their value systems or to play two or more roles that conflict with each other (Van Sell, Brief and Schuler 1981). Role ambiguity is uncertainty regarding what is expected on one's job (House and Rizzo 1972:479)[4].

Learning one's role in the organization and within the work group, and resolving issues of role distance (role conflict and role ambiguity) has been found critical in individuals' success in organizations. Role conflict and ambiguity are associated with low performance. Many dysfunctional consequences of role conflict and ambiguity in complex organizations are reported: tension, turnover, dissatisfactions, anxiety, a greater concern with own (vs. work group) performance, and lower performance (Gross et al. 1958, Kahn et al. 1964, Rizzo et al. 1970, House

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their situation or integrated with it, will be liable to have more accidents. The goals/freedom/alertness theory postulates that people have accidents because they were not alert to their true situation, and that this lack of alertness was the result of a lack of involvement in their work, brought about by being told exactly what to do and what not to do (Kerr in: Hale and Hale 1972:15-6)

[4] An aspect of role ambiguity that seems of special interest in case of safety is 'overview'. Overview of all activities is whether employees have a profound knowledge about all (relations between) the activities within an organization.

et al. 1972, Beehr et al. 1976, Schuler et al. 1977, Schuler 1979). The only dysfunctional consequence not studied yet seems accident-proneness. With few exceptions, research on role distance has investigated or assumed their dysfunctional effects on individual and organizational performance. However, about the relation between role distance and accident-proneness two general hypotheses can be formulated.

Little attention has focused on the possibility that ambiguous or conflicting roles may contribute to organizational performance and may, in fact, be necessary if organizations are to adapt to changes in their environments. This idea, as found in critical and feminist theory (Ritzer 1992), is based on the view of organizations as "information-processing systems which enact and respond to complex, dynamic, equivocal environments in pursuit of multiple, conflicting, ambiguous goals" (Van Sell, Brief and Schuler 1981:62). Role distance would sensitize occupants of boundary-spanning roles to conflicting information and environmental uncertainty. According to this view role conflict and ambiguity are the tools "by which organizations provide their members with the discretion to respond to new information and to pursue sequentially a set of conflicting out necessary organizational goals" (Weick 1979).

Role distance describes the influence of organizational characteristics. I expect that less role distance will lead to fewer mistakes because of better execution and integration of sub-tasks. Based on literature it is also possible to formulate an alternative hypothesis about the flourishing (negative) influence of role distance on accident-proneness. In a methodological sense role distance is a much less problematic concept than 'irrationality'; there are well-known and validated instruments to measure role conflict and ambiguity (these will be discussed later). However studies about the multiple determinants of role distance are still very rare. My general hypothesis is that communication is a main source of role distance and, more important, a main cause of accident-proneness.

3 A general classification

Here I would like to present a general classification of communication that can be distinguished both analytically and in time and place, and relate this to role distance and accident-proneness.

In role theory concepts like integration and socialization point at the importance of communication. According to this approach (a lack of) communication (or information) is not treated as a cause of accidents, it just did not prevent them from happening. Complexity, uncertainty and interdependence increase the need for communication and the amount of information that must be processed during the course of a task performance. Communication has roughly three aims: socialization of goals (Turner: intentions; Simon: identification), integration of the divided parts of the organization, and adaptation to the environment. Socialization is a process, which links organizational goals with personal needs (e.g. Simon 1997:284-95). Integration is a process, which links the various sub-tasks to each other. Socialization and integration are processes through which individuals change from outsiders to functioning members of an organization.

To fulfill the needs of integration, socialization, and adaptation to the environment, a chemical plant needs several kinds of communication. There are three main moments of communication at a chemical plant: the working permits, the toolbox meetings, and the coffee/lunch breaks. The communication around the working permits relates to individual workers who get their instructions from the plant manager. It involves special (safety) measures for working in exceptional situations, with fire, in enclosed spaces, on a scaffold, etc. During the toolbox meetings representatives of all departments on a plant (production, maintenance, contractors) discuss the work that should be done. The plantmanager makes sure that everyone understood their role in the extensive planning, the various activities are coordinated, and new ideas or problems are discussed. During the coffee/lunch breaks the employees mainly discuss private interests and topics that are not directly task related.

The three moments of communication can be distinguished (roughly) not only in time and place, but also analytically. Based on the work of Greenbaum (1974), Roberts and O'Reilly (1974/1) and Schuler & Blank (1976), I classify the three moments in theoretical terms. The communication surrounding working permits involves *regulative or instructive communication* (or, control and command function within the hierarchy). This 'communication network' involves directions from the supervisor (about 'routine' tasks) and detailed reports from the subordinate. It refers to the quality of communication consistent with the classic principles of management and hierarchical reporting relationships, and especially the instructions that enable subordinates to properly execute their individual tasks. It always involves task-relevant information a supervisor and a subordinate receive from each other.

The toolbox meetings can be described as *informative or innovative communication* (the ideational and linking function). This communication network strives to ensure the adaptiveness of the organization to varied internal and external influences and is concerned with problem solving, adaptation to change, strategy, new idea processing, and integration of sub-tasks. Some examples are suggestion systems, brainstorm sessions, and participative problem-solving meetings (like toolbox meetings).

The informal communication during coffee or lunch breaks can be labeled *integrative communication* (the ideological/enculturation and linking function). This communication network is concerned with feelings for self, associates and work, and is directly related to employee morale. Some examples are informal scuttlebutt, the 'grapevine', and praise. Here, it also involves horizontal communication between members from different departments and organizations. If successful, it socializes employees so they identify with the organization in which they work, and contributes to integrating sub-tasks. If not, conflicts will flourish and these conflicts cause an accident-prone situation.

The correlation between organizational communication and performance depends upon the kind of performance, as well as the particular dimension of communication and its relationship with role conflict. For instance, Schuler and Blank (1976) show how satisfaction is correlated positively with informative and integrative

communication, and negatively with regulative communication (and disturbing factors). This example suggests that not all dimensions of communication will be highly related to safety performance (especially if they are not strongly related to role conflict). Here, it is hypothesized that different dimensions of communication exhibit different correlations with (role conflict and) accident-proneness, though these correlations are all expected to be negative. For instance, more regulative/instructive communication will lead to (less role conflict and) less accident-proneness.

4 Safety communication and obstacles

In literature 'risk communication' often refers to the (external) communication between the organization and the public (e.g. Chess et al. 1992, Lundgren et al. 1998); it involves relations with mass media, the environmental focus, products liability and consumer participation. In this study risk communication relates to communication within organizations. Particularly important in case of safety research is communication about (near) accidents and (perceived) risky situations; safety communication. It is possible that an organization knows a lot of regulative, informative and integrative communication, but only focused on productivity, environment, or employee well-being. So, it is important within these dimensions of communication that safety is addressed explicitly. For example whether people discuss safety regularly with their superiors or colleagues, or whether it makes sense to report dangerous situations.

The anthropological concept of culture often involves values, beliefs, and roles. If communication (e.g. about safety) fails, people tend to refer to a 'blame culture' (e.g. Douglas 1992, Furedi 1997: culture of fear, Hofmann and Stetzer 1998: a negative safety climate, Tombs 1991: victim blaming). People are often ashamed or afraid to be punished and because of that the learning effect (the feedback) of the safety system is not optimal. For example, in one of the organizations under study the employees referred to the first aid room as 'the courthouse'. However, in literature the concept of blame culture seems to be used in a very loose way and to refer mainly to

norms, attitudes, and practices. This narrow meaning almost equals ‘obstacles’ or at least many consider communication obstacles a cultural element. Obstacles refer to communication disturbing factors. I prefer obstacles because it does not suggest an insight in the profound values of people, it does not imply that an undesirable situation cannot be changed in the short term (as culture does), and no valid instrument to measure blame culture is known.

In practice, people should always realize that a mistake does not have to be wrong; to err is human. Here the distinction that Groeneweg (1994:23) makes between human error and human limitations is relevant; or the similar distinction that Rochlin (1993:25) point out between errors and mistakes. An error is blameworthy, in a decision environment rich in time and low in ambiguity. Mistakes are maybe finally wrong, but they are in some sense rational decisions. Within the limits imposed by certain conditions and constraints ‘they had good reasons to choose this wrong solutions since ..’. Here an error means an error in a normative sense, it is morally wrong; it equals vandalism and terrorism. I assume a motivated, and non-suicidal, agent that has good (cognitively and morally) reasons to think what he thinks, or to do what he does.

Instead of blame culture I would like to refer to these communication disturbing factors simply as obstacles (Schuler: distortive communication; Roberts and O’Reilly: gatekeeping). This dimension of communication describes communication which conveys suppression or filtering of information and lack of a cooperative, problem solving orientation in the organization. It may at best provide only limited amounts of information for task demands and at worst provide incorrect information. Edmondson (1996) found that the willingness to discuss mistakes openly is a primary influence on detected error rates. The willingness is influenced by the shared perceptions of how consequential it is to make a mistake, and the perceived openness of the supervisor. The findings provide evidence that the detection of errors is influenced by organizational characteristics. Schuler (1979) hypothesizes that (perceived) distortive communication is positively related to role conflict. Especially if the obstacles involve information about the environment I expect that there will also be a correlation with accident-proneness that role conflict can not account for.

Thus, besides a general classification of communication, in this chapter I have also introduced safety communication and obstacles. Contradictory to the general dimensions, the last two can be distinguished only analytically, and not in time or place. Safety communication involves communication about safety, mistakes, and accidents. Obstacles refer to the frequency and quality (or even possibility) of communication, or 'communication disturbing factors'. I expect a high collinearity between the two; both safety communication and absence of obstacles make it possible to learn from mistakes and accidents or near-accidents in the past. And, just like the general dimensions of communication, these are needed to construct a correct image of the main risks within an organization to avoid fatal misunderstandings. I formulated the general hypothesis that different dimensions of communication exhibit negative correlations with accident-proneness (and role conflict). So, I expect negative correlations between accident-proneness and obstacles, regulative, integrative, informative, safety communication. To test these five hypotheses I need to measure accident-proneness, role conflict, regulative, integrative, informative, safety communication and obstacles.

5 Field study

For a useful contribution, I need to study complex and tightly coupled organizations that can be characterized as 'high risk'. Because of these characteristics I chose the chemical industry as object of study.

The research was executed within eight organizations. A field study during a shut-down, within one of the eight organizations under study, consisted out of participating research and interviews. The main goal was to do observations to obtain an inward view of the production process, the course of a shut-down, the main tasks of the various functions and departments, the coordination process during toolbox and other meetings, etc. Beside this, within six of the eight organizations, more than twenty interviews were conducted with plant managers, safety officers and other key-persons.

Because of statistical reliability, a questionnaire approach was finally chosen. Based on the analyses of Tripods and Soat, interviews, and scales derived from literature (e.g., Miller 1991), survey items were formulated for the chemical industry. The measurement scales of the items are mostly five-point Likert scales (strongly agree ... strongly disagree). In May 1999 this survey was sent to all employees within the production, maintenance and shipping sequences within organizations A-H, and their staff. The respondents were operators, different types of engineers, shippers, support staff, supervisors, etc. Four hundred and thirty-six employees cooperated in the research (56% response). The response can be qualified as relatively high, especially within safety research we can assume that respondents often hesitate, because they are afraid to be blamed or punished. Probably this phenomenon explains part of the 44% non-response, besides the fact that the employees are asked to complete questionnaires very frequently by their organization.

The eight organizations can be described by some simple indicators (table 1). At first sight the most startling numbers are the ratio between executive and non-supervisory staff within organization D, and the one between production and maintenance within organization A. The last ratio could be explained by the fact that the maintenance department of organization A was actually working within three organizations (A, C and G).

Table 1: Characteristics of the survey respondents

Organization	A	B	C	D	E	F	G	H	Total population
Response %	56	60	72	39	65	52	65	76	56
Response #	44	36	29	81	52	83	36	75	436
Production*	21	26	21	45	41	55	29	54	292
Maintenance	20	8	5	30	6	23	5	15	112
Other**	3	2	3	6	5	5	2	6	32
Supervisory staff	15	13	12	41	15	30	13	27	166
Non-supervisory staff	29	23	17	40	37	53	23	48	270

Organizations A - H are organizations within Dutch chemical industry and they operate around various processes related to the exploration of gas, and the production

of base - and functional chemicals. They are, as a joint venture or as a full daughter, part of multinational companies. To preserve confidentiality, these organizations will not be described in more detail.

6 Measurement

For measurement eight scales were used. Accident-proneness consists out of two aspects. Four items measured (near-) accidents and the employees' general opinion about the safety within their organization, e.g.: 'How many accidents did you witness within the last three years?', 'Were you involved yourself?', and 'Employees often have to do their work under dangerous circumstances.' (total score: 0 - 17). Another six items measured mistakes and risk-taking behaviour (by colleagues), e.g.: 'many employees don't have enough skills to fulfill their task in a safe way', and 'many employees push their luck too much' (total score: 0 - 16). The accident-proneness scale is an equal weighted combination of the two subscales (Crombach's Alpha = .7513; N 434, total score: 0 - 33). (For development and validation of this measurement device see Van As 2000).

To measure role conflict and ambiguity items are used based on the conflict and ambiguity scales developed by Rizzo, House and Lirtzman (1970, also: McLaughlin 1986:494) and the identification and commitment scales developed by Van Veldhoven and Meijman (1994). In case of role conflict, 9 questions are asked about conflicts at the level of individual tasks (Likert scales, Alpha = .7949; N 450, total score: 0 - 40). E.g. 'Do you have to do your work in another way than you would like to?' and 'Often I have to do unnecessary work'. To measure role ambiguity, 12 items were included about ambiguities at the level of individual tasks (Likert point scales, Alpha = .8253; N 420, total score: 0 - 48). E.g. 'I know exactly what my duties are' and 'I know how I'll be evaluated'.

To measure regulative/instructive communication only four items were used. I based them on the audit of organizational communication from Greenbaum (1974) and the communication items from Schuler and Blank (1976). These are about

directives from superiors, and reports from subordinates on task related topics (Likert scales, Alpha = .6517; N 446, total score: 0 - 16). E.g. 'I am required to report detailed technical information to my superior' and 'Every day I receive directives about what to do'.

Informative/innovative communication on the other side is less structured and less tightly related to the task as regulative/instructive communication is. It relates to problem finding, problem resolution, generating ideas, etc. To measure this kind of communication fifteen items were used based on the audit from Greenbaum (1974) and items from Schuler and Blank (1976), and on the OPRA98 audit[5] (Likert scales, Alpha = .8681; N 420, total score: 0 - 60). E.g. 'Communications flow both up and down', 'Feedback about P&Is is the rule rather than the exception', and 'In our organization colleagues inform each other regularly about successful practical experiences and projects (best practice)'.

To measure integrative communication seven items were used, based on the communication items from Schuler and Blank (1976) and items about communication between different departments from Georgopoulos and Mann (1962). These are about information that is not immediately relevant for the own task, and communication about intersecting activities (Likert scales, Alpha = .6748; N 443, total score: 0 - 32). E.g. 'I get enough information about the problems within my organization' and 'When I am in trouble, it is easy to visit my superior'.

In order to measure safety communication I used ten items, derived from the interviews. These refer to the possibility and frequency of communication about safety, and dangerous situations (Likert scales, Alpha = .7626; N 435, total score: 0 - 40). E.g. 'If it is about safety, they never ask my opinion' and 'It is useful to report risks (near-misses, etc.)'. As stated, the obstacles involve communication disturbing factors in general, and the consequences for the individual employee in particular. These disturbing factors were measured by thirteen items, based on the 'Upward Communication Behaviour Scale' of Roberts and O'Reilly (1974-1) and Distortive Communication items of Schuler (1979:280). This more general scale measures a

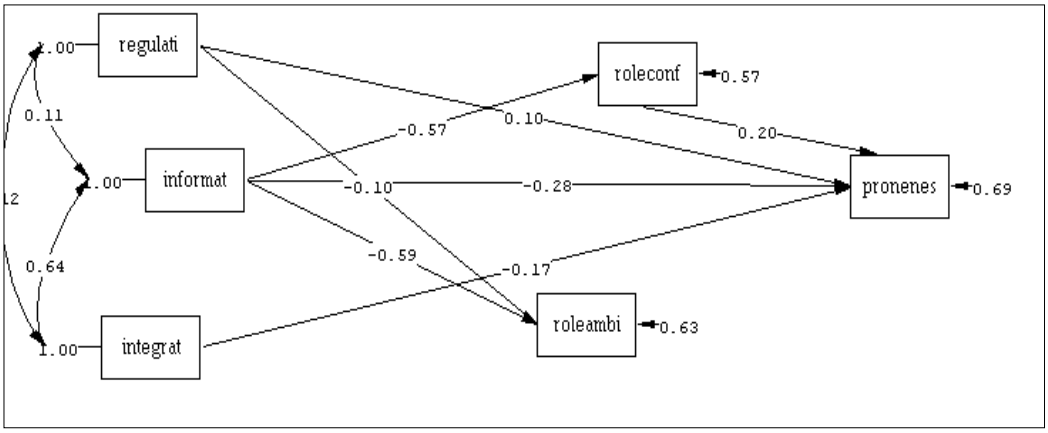
[5]Pilot survey 'Order management Proces Audit' (OPRA98) by P.Post, University of Groningen.

degree of information distortion and suppression (Likert scales, Alpha = .8414; N 431, total score: 0 - 52). E.g. ‘If a project or task is going badly, it would be better to keep it quiet’, ‘In order to get a job done it is necessary to make it appear more urgent than it really is’ and ‘It looks as if employees have something to say, but in reality they have not’.

7 Analysis

The data can be analyzed at two levels: (1) A quantitative analysis at individual level, and (2) an analysis at organizational level based on the quantitative data combined with more qualitative data. At individual level the data will be analyzed by path analysis. Path analysis is an extension of multiple regression. Its aim is to provide estimates of the magnitude and significance of hypothesized causal connections between variables. The standardized coefficient ßeta makes it possible to compare different regression coefficients. These represent the relative importance of each variable. First role conflict and ambiguity scores are compared to the accident-proneness score. Subsequently scores on regulative, informative and integrative communication are compared to the accident-proneness and role distance scores (figure 1).

Figure 1: Path model of communication, role distance and accident-proneness



Method of Estimation: Maximum Likelihood; (indicators of model without role ambiguity:) Chi-Square = 6.99; df = 1; P-value = 0.030; R^2 accident-proneness = 0.31; R^2 role conflict = 0.42; RMSEA = 0.084; AGFI = 0.94

Clarification of measures and indexes: R^2 is the relative amount of variance of the dependent variable (accident-proneness) explained or accounted for by the explanatory variables. The Chi-square (X^2) is probably the most frequently used test of significance in social science. It can be considered a measure of overall fit of the model to the data. The chi-square is a badness-of-fit measure, therefore, chi-square statistics should be non-significant. A small X^2 corresponds to good fit and a large X^2 to bad fit. Zero X^2 corresponds to perfect fit. The Chi-square tends to be large in large samples if the model does not hold. To reduce (elimination is impossible) its dependence on sample size a number of goodness-of-fit measures have been proposed (Jöreskog and Sörbom 1993:122-) based on the computation of the degrees of freedom (df).

Browne and Cudeck suggest using Steiger's Root Mean Square Error of Approximation (RMSEA) as a measure of discrepancy per degree of freedom for the model. Based on practical experience Browne and Cudeck (in: Boomsma 1998:Ch.18-13) state that the RMSEA will be zero if the model fits exactly, a value of about 0.05 or less would indicate a close fit of the model in relation to the degrees of freedom, a value of about 0.08 or less would indicate a reasonable error of approximation, and it would not be correct to employ a model with a RMSEA greater than 0.1. AGFI is the Adjusted Goodness of Fit measure, and should be greater than 0.95. To decide whether a postulated model fits (as compared to no model at all), the X^2 and AGFI are suggested. To take into account that the model does not hold exactly in the population the RMSEA is most interesting.

Within my analysis, the P-value of the Chi-Square shows that the overall fit of the model to the data is weak (almost significant). The same conclusion can be drawn from the AGFI that is less than 0.95. However, the RMSEA value is not higher than 0.1, so this measure still permits me to draw some preliminary conclusions. The analyses at individual level (figure 1) show significant correlations between most concepts. The analysis of role distance shows a significant relationship between role

conflict and accident-proneness. However, partly due to collinearity, no significant correlation could be found between role ambiguity and accident-proneness. Role ambiguity does not seem to contribute to the model.

Especially informative/innovative communication is strongly correlated (resp. -.34 and -.65) with both role conflict and accident-proneness. However, regulative-/instructive and integrative communication are not correlated with role conflict and only weakly (and in case of regulative/instructive communication even positively!) correlated with accident-proneness.

I cannot explain why role conflict does not account for the influence of these kinds of communication; the positive correlation of regulative/instructive communication is contradictory to the hypothesis. On second view, the minor influence of regulative/instructive communication is not surprising, after the findings of the minor (and also positive) influence of the related concept of task specification (Van As 2001). The minor influence of regulative/instructive communication indicates that directives and reports on task related topics have only a limited value to avoid accidents.

Because there are only eight organizations under study, a reliable statistical analysis is difficult at organizational level. If possible I will try to interpret the data at this level in a more qualitative way. To analyze the data at organizational level, I calculated the average score on accident-proneness, role conflict and ambiguity for each organization. At the organizational level the relationship between role conflict and accident-proneness is less clear than at the individual level. As we can see in table 2, the differences at organizational level are not spectacular. The most surprising scores are role conflict of organizations A and D. The high score on role conflict of organization A could not be interpreted by the high score of the maintenance department. The score of this department was expected to be high because this department operates within three organizations. However, without maintenance the score would be even a little higher (9.4). This points at a surprising result: the relatively low score of maintenance workers on role conflict (only within organization

D the maintenance department knew more role conflict than production). Apparently uncertainty as a work characteristic does not have to be correlated with role conflict.

Table 2: Accident-proneness, role distance and communication (means)

Organization	A	B	C	D	E	F	G	H	Total
Accident-proneness	9,9	10,7	11.0	11,1	12,3	12,3	12,9	13,4	11,6
Role conflict	9,2	8,2	9,3	9,8	9,1	9,2	9,0	10,8	9,6
Role ambiguity	19,6	17,5	16,7	19,7	15,5	17,2	17,6	19,1	18,1
Regulative/instructive comm.	7,1	7,9	8,0	8,0	8,0	7,7	8,2	7,6	7,8
Informative/innovative comm.	42,5	42,8	41,2	39,0	39,6	40,3	40,9	37,6	40,0
Integrative communication	19,5	19,7	18,8	18,9	18,4	18,6	18,2	17,1	18,5

So analyzed at the organizational level (table 2) the scores indicate that role conflict seems to have some influence on accident-proneness. This influence is not all decisive, but the analysis confirms my findings at the individual level. I conclude that role conflict has some potential to explain the first step of the accident-causation process and role ambiguity does not contribute to the model. So overall role conflict can be seen as an intermediate variable, which means that I have two 'dependent' variables to relate communication failures to.

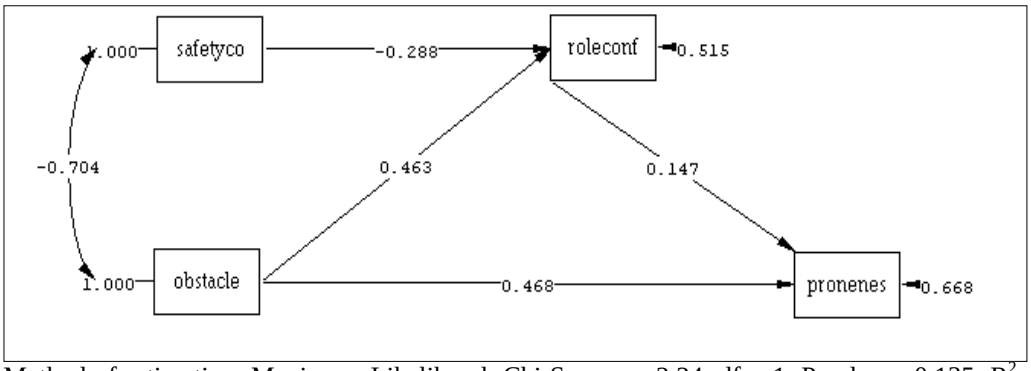
In the eight organizations under study, working permits were used and issued in the same way, the same kind of toolbox meetings were held, and the coffee/lunch breaks were also quite similar. In view of safety, communication was mentioned by most (interview and survey) respondents as the most important organizational failure. Because of this appraisal, I did not expect spectacular differences except, of course, a higher score for less accident-prone organizations; closer to organization A. At the organizational level, my conclusions drawn from the analysis at individual level were relatively confirmed (Table 2).

Based on the analyses, I can now conclude that regulative/instructive communication is not greatly important for safety and at the individual level there is even an indication that it correlates positively with a more accident-prone organization. On the other hand, integrative and especially informative/innovative communication are important in reducing accident-proneness. The scores of

organization H (37.6 and 17.1) seem to indicate that it is especially important not to communicate less than a certain minimum.

Safety communication and obstacles:
Now scores on safety communication and obstacles are compared to the accident-proneness and role conflict scores (figure 2). Because role ambiguity does not contribute to the model, this aspect of role distance was not involved in the analysis anymore.

Figure 2: Path model of safety communication, obstacles, role conflict and accident proneness



Method of estimation: Maximum Likelihood; Chi-Square = 2.24; df = 1; P-value = 0.135; R^2 accident-proneness = 0.32; R^2 role conflict = 0.49; RMSEA = 0.052; AGFI = 0.98

The analysis at individual level shows significant correlations between role conflict and both safety communication and obstacles. The high collinearity between the communication aspects was expected because these two aspects are analytically separate, yet empirically strongly interlinked. Also a strong correlation was found between obstacles and accident-proneness (and a high percentage of explained variance; R^2 accident-proneness), a correlation that role conflict can not account for. Surprisingly enough safety communication does not seem to be directly correlated with accident-proneness.

Again: in the eight organizations under study, communication was considered a main source of accident-proneness; many respondents realized the importance of these factors. One stated: "The Deming-circle improved a lot; because of that the blame culture changed into an improvement culture"[6]. Small differences could be detected; for instance, in organization A it is permitted, in cases of small incidents, to submit a one-page report, omitting the names of the people involved. According to the plant manager, this improved the willingness to report and alleviated much of the fear. In general, I did not expect sensational differences – again, naturally except for a better score for less accident-prone organizations; closer to organization A.

Table 3: Safety communication and obstacles by organization (means)

Organization	A	B	C	D	E	F	G	H	Total popul.
Accident-proneness	9,9	10,7	11,0	11,1	12,3	12,3	12,9	13,4	11,6
Safety communication	26,3	28,8	27,6	23,7	27,1	26,9	26,4	26,2	26,2
Obstacles	16,1	15,8	16,0	20,9	17,8	18,6	19,1	20,4	18,7

At the organizational level (table 3) significant differences can be detected for both variables. On safety communication these differences are contradictory to the hypothesis, between D and E, D and F, and D and H. So, the influence of safety communication seems to be falsified, the influence of obstacles not.

From the analyses above, I can conclude that the general classification seems useful in explaining accident-proneness. Informative/innovative and integrative communication especially have explanatory power, while regulative/instructive communication seems unimportant. Especially from the analysis at organizational level, I can also conclude that obstacles are strongly correlated with accident-proneness and role conflict. However, the results provide contradictory support for the relationship with safety communication, and this hypothesis seems to be falsified.

[6]The essence of the Deming approach this respondent referred to "concerns the creation of an organizational system that fosters cooperation and learning for facilitating the implementation of process management practices, which, in turn, leads to continuous improvement of processes.." (Anderson et al. in: Zhang 2001:9).

Some differences even point to an alternative hypothesis: in accident-prone organizations there is more, instead of less, safety communication. An explanation for this could be that safety communication does not prevent accidents, but accidents are the cause of safety communication. Thus, 'In accident-prone organizations there is more to talk about'. Some exceptions show that, just like the other organizational failures (Chapters 4 and 5), none of the factors is all-decisive.

8 Conclusions

In this paper I tried to analyze the influence of organizational communication on safety in chemical industry. Accidents are directly caused by mistakes, but the underlying cause is often organizational. As a link between the organizational and individual level I suggested the concept of role distance. I presented a general classification of communication, and distinguished safety communication and obstacles. I found that role conflict has some potential to explain the first step of the accident-causation process and role ambiguity does not contribute to the model.

From the analyses above I can conclude that the general classification seems to be a useful one to explain accident-proneness. Especially informative/innovative and integrative communication have explanatory power, while regulative/instructive communication seems to be unimportant. Especially from the analysis at organizational level I can also conclude that obstacles are strongly correlated with accident-proneness and role conflict. But the results provide only very modest, and even contradictory, support for the relationship with safety communication, and this hypothesis seems to be falsified. The results even point at an alternative hypothesis: in accident-prone organizations there is more, instead of less, safety communication. The explanation for this could be that safety communication does not prevent accidents, but accidents are the cause of safety communication. In other words: 'in accident-prone organizations there is more to talk about'. Some exceptions show that none of these factors is all decisive.

References

Adams, J. 1995: *Risk* (London, ISBN 1-85728-068-7)

Beehr, T.A., J.T. Walsh and D. Thomas 1976: *Relationships of Stress to Individually and Organizationally Valued States: Higher Order Needs as Moderator*, in: Journal of Applied Psychology (February, Vol.61#1, p.41-7)

Berger, P.L. and T. Luckmann 1966*: The Social Construction of Reality – A Treatise in the Sociology of Knowledge* (New York, ISBN 0-385-05898-5)

Boomsma, A. 1998: *Covariantiestructuuranalyse - 3* (Vakgroep Statistiek, Meettheorie & Informatiekunde, RuG)

Carroll, J.S. 1995: *Incident Reviews in High-Hazard Industries: Sense Making and Learning Under Ambiguity and Accountability*, in: Industrial & Environmental Crisis Quarterly (Vol.9, #2, p.175-97)

Chess, C, A. Saville, M. Tamuz and M. Greenberg 1992: *The Organizational Links Between Risk Communication and Risk Management: The Case of Sybron Chemicals Inc*., in: Risk Analysis (Vol. 12, #3, p.431-38)

Douglas, M. 1992: *Risk and Blame* (London, ISBN 0-415-06280-2)

Dwyer, T. 1991: *Life and Death at Work – Industrial Accidents as a case of Socially Produced Error* (New York, ISBN 0-306-43949-2)

Edmondson, A.C. 1996: *Learning From Mistakes Is Easier Said Than Done: Group and Organizational Influences on the Detection and Correction of Human Error*, in: Journal of Aplied Behavioral Science (Vol.32, #1, March, p.5-28)

Fong, G. and O.A. Vasicek 1997: *A Multidimensional Framework for Risk analysis*, in: Financial analysts journal (Vol.53, #4, p.1-7)

Fulk, J. and S. Mani 1986: Distortion of Communication in Hierarchical Relationships, in:M.L. McLaughlin: Communication Yearbook 9 (Beverly Hills, ISBN 0-8039-2493-3)

Furedi, F. 1997: *Culture of Fear: Risk-Taking and the Morality of Low Expectation* (London, ISBN 0-304-33751-X)

Georgopoulos, B.S. and F.C. Mann 1962: *The Community General Hospital* (New York, ISBN 0-8240-8205-2)

Goffman, E. 1961: *Encounters: Two Studies in the Sociology of Interaction* (Indianapolis, ISBN 0-672-60818-9)

Graham, J.D. and L. Rhomberg 1996: *How Risks are Identified and Assessed*, in: The annals of the American Academy of Political and Social Science (London, ISBN 0-7619-0298-8)

Greenbaum, H.H. 1974: *The Audit of Organizational Communication*, in: Academy of Management Journal (December, Vol.17, #4, p.739-54)

Groeneweg, J. 1994: *Controlling the Controllable: the Management of Safety* (Leiden, ISBN 90-6695-106-0)

Gross, N., W.S. Mason and A.W. McEachern 1958: *Explorations in Role Analysis: Studies of the School Superintendency role* (New York)

Hale, A.R. and M. Hale 1972: *A Review of the Industrial Accident Research Literature* (London, ISBN 0-11-360895-0)

Heinrich, H.W. 1959: *Industrial Accident Prevention – a Scientific Approach* (4th.ed. New York)

Hofmann, D.A. and A. Stetzer 1998: *The Role of Safety Climate and Communication in Accident Interpretation: Implications for Learning from Negative Events*, in: Academy of Management Journal (Vol.41, #6, p.644-57)

House, R.J. and J.R. Rizzo 1972: *Toward the Measurement of Organizational Practices*, in: Journal of Applied Psychology (Vol.56, #5, p.388-396)

Jöreskog, K. and D. Sörbom 1993: *LISREL 8: Structural Equation Modeling with the Simplis Command Language* (Hillsdale, ISBN 0-8058-1442-6)

Kahn, R.L., D.M. Wolfe, R.P. Quinn, J.D. Snoek and R.A. Rosenthal 1964: *Organizational Stress: Studies in Role Conflict and Ambiguity* (New York)

Katz, D and R.L. Kahn 1966: *The Social Psychology of Organizations* (2nd edition, New York, ISBN 0-471-02355-8)

Lagadec, P. 1997: Learning Processes for Crisis Management in Complex Organizations, in: Journal of Contingenies and Crisis Management (Vol.5, #1, March, p.24-31)

LaPorte, T.R. and P.M. Consolini 1991: *Working in Practice But Not in Theory: Theoretical Challenges of "High-Reliability Organizations"*, in: Journal of Public Administration Research and Theory (January, #1, p.19-47)

Leplat, J. 1987: *Accidents and Incidents Production: Methods of Analysis*, in: Rasmussen, et al (ed.) New Technology and Human Error (Chichester, ISBN 0-471-91044-9)

Lundgren, R. and A. McMakin 1998: *Risk Communication* (Columbus, ISBN 1-57477-055-1)

McLaughlin, M.L. 1986: *Communication Yearbook 9* (London, ISBN 0-8039-2493-3)

Merton, R.K. and R.A. Nisbet (ed.) 1966: *Contemporary Social Problems* (2nd edition, New York)

Miller, D.C. 1991: *Handbook of Research Design and Social Measurement* (5th edition Newbury Park, ISBN 0-8039-4219-2)

Osborn, R.N. and D.H. Jackson 1988: *Leaders, Riverboat Gamblers, or Purposeful Unintended Consequences in the Management of Complex, Dangerous Technologies*, in: Academy of Management Journal (Vol.31, #4, p.924-47)

Perrow, C. 1999: *Normal Accidents: Living With High-Risk Technogies* (New York, ISBN 0-691-00412-9)

Reason, J.T. 1990: *Human Error* (Cambridge, ISBN 0-521-30669-8)

Ritzer, G. 1992: *Sociological Theory* (3th edition, New York, ISBN 0-07-052971-X)

Rizzo, J.R., R.J. House, and S.I. Lirtzman 1970: *Role Conflict and Ambiguity in Complex Organizations*, in: Administrative Science Quarterly (June, Vol.15 p.150-63)

Roberts, K.H. (ed.) 1993: *New Challenges to understanding organizations* (New York, ISBN 0-02-402052-4)

Roberts, K.H. and C.A. O'Reilly 1974-1: *Failures in Upward Communication in Organizations: Three Possible Culprits*, in: Academy of Management Journal (Vol.17, #2, June, p.205-15)

Roberts, K.H. and C.A. O'Reilly 1974-2: *Measuring Organizational Communication,* in: Journal of Applied Psychology (Vol.59, #3, p.321-6)

Rochlin, G.I. 1993: *Defining "High Reliability" Organizations in Practice: A Taxonomic Prologue*, in: K.H. Roberts (ed.) New Challenges to understanding organizations (New York, ISBN 0-02-402052-4)

Schuler, R.S. and L.F. Blank 1976: *Relationships Among Types of Communication, Organizational Level, and Employee Satisfaction and Performance*, in: IEEE Transactions on Engineering Management (August, Vol.EM-23, #3, p.124-9)

Schuler, R.S., R.J. Aldag, and A.P. Brief 1977: *Role Conflict and Ambiguity: A Scale Analysis*, in: Organizational Behavior and Human Performance (20, p.111-28)

Schuler, R.S. 1979: *A Role Perception Transactional Process Model for Organizational Communication-Outcome Relationships*, in: Organizational Behavior and Human Performance (23, p.268-91)

Simon, H.A. 1997: *Administrative Behavior – A Study of Decision-Making Processes in Administrative Organizations* (New York, ISBN 0-684-83582-7)

Stinchcombe, A.L. and C.A. Heimer 1985: *Organization Theory and Project Management: Administering Uncertainty in Norwegian Offshore Oil* (London, ISBN 82-00-07600-8)

Tombs, S. 1991: *Injury and ill-health in the chemical industry: decentring the accident-prone victim*, in: Industrial Crisis Quarterly (Vol5, #1, p.59-75)

Turner, B.A. 1978: *Man-made Disasters* (London, ISBN 0-85109-750-2)

Van As, S. 2001: *The Measurement of Accident-proneness* (SOM Research Report, in review)

Van As, S. 2001: Authority Structure and Industrial Accidents in Chemical Industry (SOM Research Report, in review)

Van Sell, M., A.P. Brief, and R.S. Schuler 1981: *Role Conflict and Role Ambiguity: Integration of the Literature and Directions for Future Research*, in: Human Relations (Vol.34, #1, p.43-71)

Van Veldhoven, M.J.P.M., and T.F. Meijman 1994: *Het meten van psychosociale arbeidsbelasting met een vragenlijst: De VBBA* [Measurement of Psychosocial Work Pressure by a Survey: The VBBA] (Amsterdam, ISBN 90-6365-085-X)

Weick, K.E. 1979: *The Social Psychology of Organizing* (New York, ISBN 0-394-34827-3)

Weick, K.E. 1993: *The Vulnerable System: An Analysis of the Tenerife Air Disaster* in: K.H. Roberts (ed.) New Challenges to understanding organizations (New York, ISBN 0-02-402052-4)