Occupational Health and Safety Management

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1 Risk Management Principles

Risk management may be defined as the reduction and control of the adverse effects of the risks to which an organization is exposed. Risks include all aspects of accidental losses that may lead to any wastage of the organization's, society's and environmental assets. These assets cover personnel, materials, machinery, procedures, products, money, and natural resources: soil, water, energy, natural areas. Losses may result from the presence of potential harm to one or more elements of the system, either because of the interactions with other elements inside the system or with the environment outside the system. Risk is the measuring stick for this potential, which may be defined as the probability that harm will occur within a certain period.

Management as a function comprises all processes and functions resulting from the division of labor in an organization such as planning, organizing, leading and controlling. In most organizations more or less formalized management systems serve to structure, develop, and direct business processes. Systems differ with respect to branches, nature of business, company size, and human factors such as culture and policy. As firms grow in size management systems gain complexity and become difficult to use, thus resulting in domain-specific systems such as management of health, safety, environmental resources, quality or personnel. Since Health, Safety and Environmental (HSE) management have a number of over lapses and are actually practiced by the same people in an integrated manner, companies are now moving towards integrated HSE management systems as a subsystem of the business/operations management.

Risk management can be understood as an approach to reintegrate the domain-specific management systems into an integrative management concept. Many of the features of risk management are indistinguishable from the sound management practices advocated by proponents of quality and business excellence. This is reflected in standards usually based on ISO 9000, e.g. BS 7750 and the ISO 14000 series, and in legislative developments in many countries, e.g. in the EU Environmental Management and Audit Scheme (EMAS, European Union, 2001) regulation and the Control of Major Hazards (COMAH) directive (European Community, 1999) and in the USA the Risk Management Program (RMP) of the Environmental Protection Agencies. The British environmental standard BS 7750 and EMAS contributed to the development of the ISO 14000 series ‘Environmental Management Systems’ standards. Initiatives to launch an international standard on ‘Occupational Health and Safety’ (OHS) management systems have been delayed. In many countries, national guidelines give guidance on OHS management systems.

The essence of risk management is to prepare, protect, and preserve the resources of the enterprise. This approach demands analyzing the current and past operating hazard, risk, and loss-producing patterns and forecasting expected hazard, risk, and loss-operating patterns. According to Bamber (2003), risk control strategies may be classified into four main areas: risk avoidance, risk retention, risk transfer and risk reduction. Risk avoidance means the deliberate decision on the part of the organization to avoid a particular risk. Risk retention relates to the decision of the organization to meet any resulting loss from within the organization's financial resources. Risk transfer refers to the legal assignment of the costs of potential losses from one party to another. The most common approach is by insurance. The principles of risk reduction or risk control rely on the implementation of a Health, Safety and Environment (HSE) program, whose basic aim is to protect the company's assets from wastage caused by accidental loss.

The system elements to be managed include amongst others:

- health and safety of employees, suppliers, contractors, customers, and residents of the community (e.g. improvement of public health and safety),
- reliability and safety of products and services, of materials, equipment, work systems, and plants, of transport of hazardous goods,
- integrated pollution control, radiation protection, waste minimization, recycling, and waste disposal,
- sustainable management of natural resources (soil, water, natural areas and coastal zones), reduction in the consumption of non-renewable energy.

Sustainable development means the improvement in the quality of life which does not impair the ability of the ecosystem to maintain life. Managing for sustainability is predominantly based on the principles of inter-generational and intra-general equity as well as social and ecological balance (Hutchinson & Hutchinson, 1997).

The management approach of the ISO standards are based on generic management principles which are derived from different theoretical and organizational perspectives. The elements of the systems are considered to present 'best practices' of successful enterprises. They are designed to be used by organizations of all sizes and regardless of the nature of their activities. The key elements of a generic management system are integrated in the management control cycle outlined in figure 1. The cycle is based on ISO 14000 (environmental management) and on standard BS 8800 designed for an OHS management system. The key elements of such a management system are set out below (HSE, 1997):

<u>Effective OHS management</u> means developing, coordinating, and controlling a continuous improvement process by setting and adjusting OHS standards. The corporate policy is summarized in a vision, containing perspectives for the future and providing an idea of identification for all members of the organization. Policy and strategy are translated into planning processes. Both internal and external assessment methods should be used for the evaluation of a strategy's effectivity and efficiency. Regular reviews of performance based on data from monitoring activities and from audits of the OHS management system may serve as instruments.

<u>Formulation of an OHS policy</u> addresses the preservation and development of physical and human resources and reductions in financial losses and liabilities. The policy provides guidance on the allocation of responsibilities and the organization of people, of resources, communication and documentation. It influences design and operation of working systems, the design and delivery of products and services, and the control and disposal of waste. OHS policy should be aligned with people management policy to secure the commitment, involvement, and wellbeing of employees, of suppliers, contractors, and customers.

<u>OHS planning</u> is an organizational approach which emphasizes prevention and involves risk identification, evaluation, and control. Proactive planning means that hazards are identified and risks assessed and controlled according to a systematic plan, before anyone or anything could be adversely affected. Reactive planning means that measures are only considered after the occurrence of incidents such as loss-damages, accidents or deficient safety performance.

<u>Implementation and operation</u> Designing OHS-structures concerns the divisions of responsibility and distribution of formal authority, the creation of hierarchical or lean structures, the degree of self-regulation of work groups and units and the formal relations between groups and leaders. Establishing and maintaining control is central to all management functions including OHS. The allocation of OHS responsibilities to line managers, team leaders and self-managed work groups

serves as an important tool to foster the integration of OHS into the daily work activities with specialists acting as advisers.

Checking and corrective actions are the final steps in the OHS management control cycle and part of the feedback loop needed to enable the organization to maintain and develop its ability to control successfully risks. Both qualitative and quantitative measures provide information on the effectiveness of the OHS system. Learning from experience is supported through performance reviews and independent audits. This needs to be done systematically through regular reviews of performance based on data from monitoring activities and from audits of the HSE management system.

Management review is a periodic status review of the OHS management system and considers the overall performance of the OHS management system; of individual elements, and the findings of audits. The review identifies the actions that need to be taken to adjust any deviations.

Safety[1] management is more than a “paper system” of policies and procedures. An audit of the official Safety Management System (SMS) may start and end with an analysis of what is contained in the paperwork but it therefore says little about how the system is being transferred into practice. Such an analysis identifies what an organization should be doing to protect its workers, the public and the environment from harm but it does not reveal what is actually happening at the worksite and whether or not people and the environment are being protected and adverse events are not occurring.

2 Health and Safety Management

2.1 Scope and Dimensions

Recent promotion of scientific studies on safety management can be related to different events and trends (Hale & Hovden, 1998):

1. Major disasters

Several major disasters in the nuclear, petrochemical and transport industries have caused strong public concerns over the management of hazardous activities (e.g. Seveso, Bhopal, Chernobyl, Piper Alpha, Challenger, Herald of Free Enterprise, see Reason, 1990). People had trusted until then that these high technology industries had been appropriately managed by well developed safety management systems. Official reports found that root causes involved more than technical or human failures and pointed to faults in management and organization. Turner (1978) provided an analysis of “man-made disasters” and pointed beyond the technical and human factors to the organizational and cultural factors.

2. Probabilistic Risk Assessment (PRA)

As a consequence of the disasters, mandatory quantified risk assessments in the nuclear industry, followed in some countries by the petrochemical industry were required by regulators. Early PRAs

[1] The term safety is used short for "health, safety and environment" and refers to damage to hardware and environment as well as to people.

were almost exclusively technical. The Three Mile Island accident emphasized the human factor. Human Reliability Analysis (HRA) was added to PRAs. Norman Rasmussen (NRC, 1975) developed its use for process safety management at nuclear facilities.

3. Self-regulation and certification

Under the philosophy of self-regulation, i.e. those who create the risks and the pollution should be responsible for its control, regulatory emphasis in the 1970s has been changed. The central responsibility was placed on each company's management for devising, installing and monitoring its own safety management system. This led to a withdrawal of government from detailed technical regulation and close shop floor inspection of health and safety. Regulators adopted indicators for assessing how the potentialities were being used by the companies. Thus, certification, audits and other periodic assessments are used to assess company performance.

The safety management principles of the ISO standards and of the standard textbooks on safety management seem to suggest that science and industry have reasonable models of how safe and reliable organizations work. However, this is not the case. As Roberts (1990) points out, the organizational literature fails to deal specifically with either hazardous organizations or high levels of performance reliability. The standard texts on safety management, for example Heinrich, Petersen and Roos (1980), and Bird and Germain (1987) present neither specific models of the safety management system nor do they provide empirical evidence of how particular aspects of the suggested frameworks contribute to the overall level of HSE. Hale and Baram (1998) conducted a thorough literature review on HSE management and revealed a number of lines of research and isolated studies which seem to have few links with each other. They concluded that literature on SMS can be characterized, at least until the 1980s, as accumulated experience of common sense and as general management principles applied to the specific field of safety.

One of the earliest studies was that of Cohen (1977). He reviewed seven studies that dealt with critical determinants in different industrial settings. Some of the factors associated with high safety performance were: strong management commitment to safety; close contact and interaction between workers, supervisors, and management enabling open communications on safety as on other job matters; workforce subject to less turnover, including a large core of married, older workers with significant length of service in their jobs; high level of housekeeping, orderly workplace conditions, and effective environmental quality control; well developed selection, job placement, and advancement procedures and other employee support services; training practices emphasizing early indoctrination and follow-up instruction in job safety procedures; evidence of added features or variations in conventional safety practices serving to enhance their effectiveness.

Shafai-Sahrai (1971) examined 11 matched pairs of companies conducting on-site interviews and site inspections at each. Factors prevalent in low injury rate companies were senior management involvement in safety; prioritization of safety in meetings, and in decisions concerning work practice; better injury record keeping systems; use of accident cost analysis; reduced span of supervisor responsibility; spacious and clean workplace environment; and improved safety devices on machinery. Additionally, Cohen and Cleveland (1983) reported findings from a linked series of studies examining health and safety management in organizations with good safety performance across different industries. Methods included a questionnaire survey of 42 matched pairs of plants with low and high accident rates, with seven pairs of these subject to detailed site surveys. Those with lower accident rates were characterized by a strong management commitment to safety; a humanistic approach to dealing with employees, with frequent positive contact and interaction; encouragement of hazard identification by workers; better housekeeping and general plant cleanliness; presence of both informal and formal workplace inspections; greater availability and use of personal protection equipment; improved employee selection procedures; low turnover and absenteeism; and better plant environment.

Referring to these studies, Chew (1988) compared safety activities in 18 pairs of low and high injury rate companies, drawn from three Asian countries. Prevalent factors were supervisory involvement in safety activities; safety inspection; safety training; use of accident record analysis for prevention purposes; carefully applied safety rules; machine guarding; supply of personal protection equipment; and standard of housekeeping. Shannon, Walters, Lewchuk, et al. (1996) conducted a postal survey of over 400 manufacturing companies, each having at least 50 employees. The defining features of organizations with lower rates of lost time injuries included managers who perceived more participation in decision-making by the workforce and more harmonious management-worker relations; encouragement of long-term career commitment; provision of short- and long-term disability plans; definition of health and safety responsibilities in every manager's job description; performance appraisals with topics related to health and safety; and more frequent attendance of senior managers at health and safety meetings.

Finally, Shannon, Mayr and Haines (1997) reviewed 10 studies each including at least 20 separate workplaces or organizational units and using injury rates as an outcome variable. Forty-eight variables representing areas of management practices were examined. The study only listed the practices consistently associated with performance, i.e. the association was significant on one direction in at least two thirds of studies in which it appeared, and the direction of relationship was consistent for all studies:

- joint health and safety committee: health and safety professionals on the committee, longer duration of training of committee members
- managerial style and culture: direct channels of communication and information; empowerment of the workforce, good relations between management and workers
- organizational philosophy on health and safety: delegation of safety activities; active role of top management in safety; more thorough safety audits; lengthier duration of safety training for employees; safety training on regular basis; employee health screening.

Although there may be methodological weaknesses with the empirical studies (Dufort & Infante-Rivard, 1998), these studies, together with accounts of successful safety initiatives (DePasquale & Geller, 1999; Griffiths, 1985; Harper et al., 1997; Hine, Lewko & Blanko, 1999) are in some level of agreement about the ideal safety management practices. According to Mearns, Whitaker and Flin (2003, p. 644) the general themes that emerge are:

- genuine and consistent management commitment to safety, including: prioritization of safety over production; maintaining a high profile for safety in meetings; personal attendance of managers at safety meetings and in walk-abouts; face-to-face meetings with employees that feature safety as a topic; and job descriptions that include safety contracts.
- communication about safety issues, including: pervasive channels of formal and informal communication and regular communications between management, supervisors and the workforce.

- involvement of employees, including empowerment, delegation of responsibility for safety, and encouraging commitment to the organization.

An extensive review on the literature dealing with internal management system of organizations was provided by Hale and Hovden (1998). Literature on risk management at the national or industry level dealing with regulation, standard setting, risk policies, enforcement, and the management of individual workplaces and work groups was excluded. These concern notably participative management studies and studies of high reliability organizations, which concern themselves with on-line management of risk, as opposed to the off-line concern with management structure found in much of the literature. Not included are studies of safety analysis and information systems in companies or of feedback of safety performance as a method of safety improvement (Kjellén & Larsson, 1981; Saari & Näsänen, 1989; see review in Komaki, 1998).

The review summarized its findings using a management classification scheme proposed by Bolman and Deal (1984). The four frames represent four different perspectives of an organization:

- Structural topics emphasizing organization, information systems and procedures, hierarchy, rules and how goals are achieved in analogy to quality assurance.
- Human resource factors focusing on human needs, motivation, commitment, competence, participation and motivation.
- Political factors relate to/ dealing with control authorities, responsibility, power, allocation of resources, negotiation and conflict.
- Symbolic topics emphasizing values, culture, role playing, metaphors, heroes.
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<u>1. Structural topics</u>

Associated with success in developing internal control systems were measurable goals and standards, competence in organizational development and access to external expertise and available resources. Positive relation to low accident rate or good environmental performance were found for availability of financial resources, problem solving approach, stable workforce, safety training systems, good communication channels, good coordination and centralization of safety control, specialist safety service in the company, good records, a small span of control for, and time to plan by supervisors, presence of accident reporting and analysis system, evaluation and review systems. Many studies advocate systems for deviation control, modeled on quality management systems. On the subject of rules, procedures and formalization the studies are most contradictory. Some of the NIOSH studies (Smith, Cohen, Cohen & Cleveland, 1975) have shown the positive value of well-defined and detailed rules in stable, predictable situations, others in the same series showed no discrimination effect of good rules on safety performance; while still others (see e.g. Rasmussen & Batstone, 1991) have warned of their negative effect especially in on-line management of complex, dynamic technologies. The difference would appear to relate to the type of organization studied or the state of development of its system of rules.

<u>2. Human resource factors</u>

The human resource factors have been reasonably well researched. Positive relations with safety performance were found for the following topics: participation, empowerment, and encouraged innovation; participation, group norms, leadership style, feeling of control, efficacy, autonomy, social policy, quality of work life, and career progression.

In the area of communication these emphasize the content and quality of the communication as opposed to the structural aspects of communication channels.

3. Political factors

Company profitability and availability of resources were found to be positively related to high safety in two studies but unrelated in a third. Inconsistent results were found for absence of incentive payment schemes for production and presence of safety incentive schemes. Sanctioning of violations was related to high accidents.

Unclear results were obtained for the role of discipline as opposed to counseling. Openness to criticism, good labor relations, low stress and low grievance rates were all related to low accident rate. External pressure from regulators and the presence of an "order-seeking" management (as opposed to crisis management) were related to good performance. The importance of good industrial relations, openness to admit mistakes and criticism, and a constructive, rather than disciplinary approach to violations has been reasonable supported.

4. Symbolic factors

Top management commitment and real visibility in that commitment are found several times positively related to safety. Supervisor's and individual commitment, importance of safety as a value, safety attitudes of co-workers and work as a source of pride were positively related to safety performance. The evidence of safety promotion is inconsistent.

In their summary of the literature review Hale and Hovden (1998) concluded (p. 9ff):

- The field of safety management is young, and not yet adequately based on empirical studies. A considerable amount of the state of the art rests upon expert opinion and the analysis of case studies. An exception is the safety climate research.
- There has been an overemphasis on the structural aspects of management; the rules, responsibilities, formal hierarchies, plans and social policies. In contrast too little attention has been paid to the internal issues of human resources, of coping with potential conflicts and power-plays within the organization, of different perceptions and objectives among the various parties in the organization, and of integrating the values and commitment of all parties concerned.
- Literature is dominated by studies carried out in large organizations, often with a very considerable investment in sophisticated defense-in-depth management systems in safety and environment. It has led to the idea that safety management systems must be rule-bound and rule dominated. Audit systems, certification regimes and regulatory checks reinforce this view with their search for indicators which can be easily detected and proven.

Hospitals, research organizations, small innovative companies such as designer and information technology companies or simple conventional small companies have different structures, means of coordinating their activities, and of setting and monitoring their standards, which sometimes hardly overlap with those of large organization. Many do not rely for their normal management control on extensive explicit rules, but much more on competence and communication. Existing assessment techniques are not very well equipped to measure these.

The survey reveals the lack of research on the dimension of organizational learning and change. Studies of the Berkeley School (Roberts, 1990; Rochlin, 1996) on high reliability organizations is work considering on-line management of dynamic processes enclosed within military command and control cultures, not the robustness of safety management systems in companies being subject to the sorts of reorganization in the wide-open business environment.

2.2 Leadership

Occupational health and safety has not been recognized by academics as a managerial and organizational research domain (Fahlbruch & Wilpert, 1999). Less than 1% of organizational research published in top journals has focused on occupational safety, a situation that has not changed for more than two decades (Barling, Loughlin & Kelloway, 2002). Contrary to the academic neglect safety management has been practiced successfully worldwide by a great number of enterprises for decades. Policies, strategies, procedures and practices of excellent enterprises have been reviewed by business consultants, safety practitioners and academics (Johnson, 1975; Heinrich et al., 1980; Bird & Germain, 1987; Hale & Glendon, 1987; Hoyos & Zimolong, 1988; Zimolong, 1997; Zimolong & Elke, 2001).

2.2.1 Role of Managers and Supervisors

For the last decades, businesses have continuously reorganized in order to cut costs, improve productivity, and remain competitive. As a result, there has been a proliferation of management delayering in order to move responsibilities to those people carrying out the operations and to focus on team working. Teams can be managed in different ways: by supervisors, team leaders, or self managed (Vassie & Lucas, 2001). A supervisor, who is considered to be the accountable manager of the team, is responsible for planning, organizing, and controlling the members of the group, but will often not undertake any work within the group. In contrast, a team leader is normally not accountable for the work but relies on leadership skills to motivate and coordinate the work of others and facilitates their self-development. A team leader is often a working member of the group. Where a work group has no team leader, the team becomes self-managed. Surveys conducted in Britain and Germany (Cully, Woodland, O'Reilly & Dix, 1999; Windel & Zimolong, 1998) found that 60 – 80% of the workforce worked in teams. However, in both countries, only 3% worked in self-managed work groups.

In strongly hierarchically structured organizations, senior management defines organizational policies, from which in turn strategic goals and means of goal attainment are derived. Procedures provide tactical guidelines for action related to these goals and means. There is a continuous process of adapting policies to internal and external requirements and subsequently adapting internally strategic goals, procedures and practices. In delayered organizations, the policy development process may be characterized as a ping-pong process; i.e. as an active exchange process across the levels of the organization. On the operational level lower management, i.e. supervisors and team leaders execute procedures by turning them into practices. From this perspective, senior managers are concerned with policy making and the establishment of procedures to support policy implementation. On the other hand managers do execute actions, which should be in alliance with policies and procedures, however often fail to comply with procedures.

Upper management generally indicates their safety support indirectly. They establish priorities for policies, procedures and goals, set production schedules that may accommodate safe operations, and they control the incentives for complying with those priorities (e.g., compensation, rewards, discipline). Group leaders indicate management support for safety more directly than do higher level managers. They monitor compliance with higher management's policies, and they provide feedback to employees regarding the adequacy of their behaviors. Management policy and practice often sent inconsistent messages. Inconsistencies result from comparison of officially declared safety aims and goals with actual practices. For instance, if management is perceived as willing to set aside safe practices to meet production goals, employees are likely to attribute management's support for safety as paying lip service. This could lead some employees to conclude that cutting corners will be rewarded, or at least not be punished.

Thompson, Hilton, and Witt (1998) explored three factors that might be strongly influencing perception of policy-practice incongruence: goal incongruence, i.e. confusion over safety goals and the significance of competing organizational goals such as timeliness and customer orientation; organizational politics of "not sending disagreeable messages to management"; and manager fairness, i.e. perception that elevated safety concerns might not be given a fair hearing. Authors tested a model that linked management support, safety perceptions, and self-reported safety outcomes. Confirmatory Factor Analysis results indicated that organizational politics was related to perceptions of upper management support, which in turn influenced perception of work place safety conditions. Supervisor fairness influenced perceived supervisor support for workplace safety, which in turn influenced perceptions of workplace safety compliance. Finally, upper manager support for workplace safety was also found to influence perceptions of supervisor support.

There has been done little empirical research to understand how managers on different levels of hierarchy including supervisors, team leaders and self-managed groups promote workplace safety. The role of management and leadership and their influence on safety performance have been analyzed by comparing organizations with high and low rates of injuries and/ or absenteeism (Hofmann, Jacobs & Landy, 1995; Zohar 1980, Shannon et al., 1997; Zimolong, 2001a, Mearns et al., 2003), by analyzing accident- and breakdown-rates (Reason, 1990; Feyer, Williamson, and Cairns, 1997), by case studies from the process-industry (Hofmann et al., 1995), or by the examination of correlations between organizational characteristics and safety-oriented and health-promoting behavior (Dunbar, 1975; Butler, Ferries & Napier, 1990; Hofmann & Stetzer, 1996; Zohar, 2002a,b).

Safety management practices of upper management were studied by Mearns et al. (2003). Authors conducted safety surveys on 13 offshore oil and gas installations in separate years and compared safety management practices with safety performance rates. Data on safety management practices were collected by questionnaire from health and safety manager of each participating company or business unit, or the asset manager for each installation. Appropriate indicators have been identified in different industries (Blackmore, 1997; Fuller, 1999; Hurst et al., 1996; Miller & Cox, 1997; Lee, 1998). The items were thematically organized in line with the HSE (1997) classification of management practices. Safety performance data represented among other indicators the official accident and incident rates, and the proportion of individually reported accidents. In both years, the following practices were consistently negatively associated with the rate of lost time injuries:

- policies for health and safety;
- organizing for health and safety;
- Management commitment, and management involvement;
- health promotion and surveillance;
- health and safety auditing.

Overall scores of safety management practices were associated with lower accident rates in both years. Probably due to small numbers, only health promotion was significantly related to the injury rate in both years. In total, proficiency in safety management practices was associated with lower official accident rates and fewer respondents reporting accidents. Some results showed inconsistent outcomes for the two years including significant positive coefficients that contra-indicate certain practices presumed favorable. For example, management commitment was positively associated with the rate of dangerous occurrences in the first year.

The influence of individual senior managers on the safety behavior of supervisors was investigated in a study by Zohar (2002b). Intervention takes place at the level above target behavior, that is, on the level of direct superiors of the subordinate. This is a cross-level approach whereby processes introduced at one hierarchical level influence a lower subordinate level. Zohar (2002a) conducted a leadership-based intervention study in a maintenance center of heavy-duty equipment. Line supervisors received weekly personal feedback concerning frequency of safety related interactions with subordinates. Feedback was based on repeated episodic interviews with subordinates concerning the cumulative frequency of their safety-oriented interactions. Immediate superiors (section managers) received the same information and used it to communicate high safety priority. Results indicated that supervisory safety practices changed over a short period from a baseline rate of 9% to a new plateau averaging 58%. This change, in turn, resulted in significant decrease of minor injury rate.

The moderating effect of assigned safety priority by the direct superior indicates the importance of managerial goal setting and feedback. A leader whose immediate superior emphasizes safety will be more concerned with safety issues than he/she would have been otherwise. Even though leader roles entail considerable discretion, the expectations communicated by an immediate superior will influence leader's practice. As a consequence, leader's emphasis on safety issues is an interactive function of personally assigned safety priorities derived from the interaction with group members, and externally assigned safety priorities by upper management.

Research has primarily focused on supervisors as role models for promoting safety awareness and supporting safe behavior (Mattila, Hyttinen and Rantanen, 1994; see review in Komaki, 1998). Effective group leaders - for example line supervisors, team leaders - continually provide training and goal setting (antecedents), and feedback and incentives (consequences). A series of field studies conducted by Komaki and colleagues (Komaki, Barwick & Scott, 1978) revealed two primary attributes of effective supervision: performance based monitoring and timely communication of consequences. Effective supervisors monitor work in progress, particularly through work sampling (i.e. direct observation) and act accordingly. This practice clarifies both supervisory directives and expectations (i.e. antecedents) and behavior-outcome contingencies. For example, Bentley and Haslam (2001) compared safety practices of supervisors of high and low accident rate postal delivery offices particularly with respect to slip, trip and fall accidents. Supervisors from low accident rate offices appeared to have improved performance with respect to quality of safety communication, dealing with hazards reported on delivery walks, and accident investigation and remedial action.

Behavior safety is often at odds with other performance aspects, particularly speed and productivity. As a consequence, leader's effectiveness will be strongly influenced by his/her skill and willingness to deal simultaneously with competing goals and practices and to communicate safety commitment and practices to his/her followers. Results of the study by Hofmann and Morgenson (1999) indicated that quality of relationships between group leaders and their superiors (i.e. leader-member-exchange-LMX level) predicted injury records in workgroups through the mediating effects of safety communication, i.e. frequency of raising safety concerns with a superior and the leader' s declared commitment to safety.

2.2.2 Transactional and Transformational Leadership

Several recent studies have suggested that transformational leadership is associated with better safety records (O'Dea & Flin, 2001; Zohar, 2002a). Hofmann and Morgeson (1999) showed that the relations in 49 dyads between leader-member exchanges and occupational accidents were mediated by safety communication and safety commitment. This is consistent with results of other studies that show that the effects of transformational leadership on performance are mediated by different aspects of employee morale, such as organizational commitment, trust in management, and fairness (Jung & Avolio, 2000). Hence, transformational leadership is characterized by value-based and individualized interaction, resulting in better exchange quality and greater concern for welfare (Bass & Avolio, 1997). It affects critical subordinate attitudes and work-related outcomes such as satisfaction with leadership, work performance, and consolidated business unit performance. Barling et al. (2002) tested a model linking safety-specific transformational leadership to occupational injuries. Results of the study provided strong support for the mediation model linking safety specific transformational leadership to occupational injuries through the effects of perceived safety climate, safety consciousness, and safety related events. A second study replicated and extended this model by role overload.

Transactional leadership, the other global dimension, concerns planning and organization of tasks and getting people trained and motivated to do actions more reliable and efficiently. Transactional supervision influences safety due to effective monitoring and rewarding practices, which are needed to maintain reliable performance during routine job operations. On the other hand, transformational leadership role relates to development and motivating people to commit themselves to more challenging goals. As noted by several authors (e.g. Bass, 1990; Bass & Avolio, 1997), the relationship between the two is that of augmentation, i.e. transactional supervision provides reliability and predictability, and transformational leadership provides better motivation and development orientation. That means that effective managers must excel in both.

The transactional role of managers was further subdivided into constructive, corrective, and laissez –faire dimensions (Bass & Avolio, 1997). Constructive leadership implies an intermediate level of concern for members' welfare. Leaders must identify needs, desires, and individual capabilities in order to offer motivationally relevant rewards. Transformational and constructive dimensions often merge into a single factor due to such individualized considerations (Avolio, Bass & Jung, 1999). Corrective leadership (i.e. management by exception) mainly includes error detection and correction based on monitoring of subordinates' performance in relation to required standards. This results in poorer, non-individualized interactions. Finally, laissez-faire leadership implies the lowest level of concern for members' welfare, i.e. non-leadership or disowning supervisory responsibilities despite rank in the hierarchy.

Zohar (2002a) studied the influence of transformational and transactional leadership on safety behavior of group members. The setting was the same as described in Zohar (2002b). Leadership was measured with the Multifactor Leadership Questionnaire (MLQ-5X-Revised: Bass & Avolio, 1997). Results indicated that transformational and constructive leadership were highly intercorrelated, as was the passive role of corrective leadership and laissez-faire. Transformational and constructive leadership predicted injury rate, while corrective leadership provided indirect, conditional prediction. Although corrective leadership failed to predict injury rate directly, it could be predicted with a two-part linkage: corrective leadership predicted climate, which then predicted injury rate. Leadership effects were moderated by assigned safety priorities of superiors and mediated by commensurate safety-climate variables. The type of interaction depended on leadership dimensions. Climate perceptions, transformational and constructive leadership, and assigned priority of superior were significantly correlated with injury rate in the expected direction.

The fact that the effects of leadership dimensions on injury records varied depending on assigned managerial priorities is important for an efficient safety management system. Depending on departmental policies and the relative priority of competing goals, supervisors monitor some performance aspects closely while paying less attention to others. In the case of unfavorable safety priorities, highly corrective supervisors seem to actively monitor speed, quality or productivity, but neglect safety deviations. Thus, assigned safety priorities of superiors are particularly important to reinforce safety priorities of supervisors with corrective or laisser-faire leadership styles. Zohar (2002a) argued that improved transactional supervision enhances performance reliability of shop-floor employees, transformational qualities should result in incremental effects, particularly under high production pressures. This augmentation implies that leadership-based intervention should be expanded to include both leadership factors.

Leadership styles must be placed into the context of policies, structure and underlying culture of organizations. Simard and Marchand (1994) illustrated the influence of what they call “micro organizational factors” on safety initiatives. Their results showed that a participatory leadership style shaped the propensity of workgroups to take such initiatives. Participatory involvement of supervisors was significantly associated with accident prevention activities and lost-time accident rates. In other types of organizations with a different workforce such a type of leadership and its effect on safety performance may be less effective. Probably, leadership style and safety performance is a product of the underlying culture.

2.3 Safety Culture and Climate

2.3.1 Definitions and Relations

Research on safety climate emerged from studies on organizational culture and climate. The construct of organizational climate refers to shared perceptions among members of an organization with regard to organizational policies, procedures and practices (Reichers & Schneider, 1990; Rentsch, 1990). Climate is a multidimensional construct that covers a wide range of individual assessments of the work environment. These assessments may be directed towards general dimensions of the environment such as leadership, roles, and communication or to specific dimensions such as the climate for safety or the climate for customer service (James, James &Ashe, 1990).

The concept of safety culture has largely developed since the OECD Nuclear Agency (1987) observed that the errors and violations of operating procedures occurring prior to the Chernobyl disaster were evidence of a poor safety culture at the plant and within the former Soviet nuclear industry in general (Pidgeon & O’Leary, 2000). Safety culture has been defined as “that assembly of characteristics and attitudes in organizations and individuals, which establishes that, as an overriding priority, plant safety issues receive the attention warranted by their significance (IAEA, 1986). Safety culture is important because it forms the context within which individual safety attitudes develop and persist and safety behaviors are promoted. Pidgeon (1991) considers culture as a system of meanings and defines culture as the collection of beliefs, norms, attitudes, roles, and practices shared within a given social grouping or organization. Turner et al. (1989) characterizes safety culture as the set of beliefs, norms, attitudes, roles, and social and technical practices that are concerned with minimizing the exposure of employees, managers, customers, and members of the public to conditions considered dangerous or injurious. According to Pidgeon (1991) a "good safety culture can be characterized by three attributes: norms and rules for handling hazards, attitudes towards safety, and reflexivity on safety practice" (p.135). When industrial and national cultures are also embraced, organizations may be considered as sub-cultures within societies. Safety climate may reflect employees' perceptions of the organization's policies, procedures, and practices concerning safety and helps employees to make sense of the priority accorded to safety within the organization (Barling et al., 2002).

The relationship between safety culture and climate is unclear and considerable confusion exists in the literature about the cause, the content and the consequence of safety culture and climate (Guldenmund, 2000). Referring to the culture concept of Schein (1992), who conceives climate as a reflection and manifestation of cultural assumptions, Guldenmund suggested the following definition: "Safety culture is defined as those aspects of the organizational culture which will impact on attitudes and behavior related to increasing or decreasing risk" (2000, p. 251). Hence, safety climate is considered as a manifestation of safety culture in the behavior and expressed attitude of employees.

Most definitions of safety culture invoke shared norms or attitudes so that the level of aggregations is considered to be the group. Group-level climate perceptions reflect shared patterns of practices rather than isolated supervisory actions (Zohar, 2000). Some authors assert that safety culture is only being assessed when the attitude object is the organization (Cabrera & Isla, 1998).

Zohar (2000) suggests regarding climate perceptions as a relatively stable pattern of actions in contrast to individual actions. For example, if managers and workers emphasize speed over safety, this may result in safety violation actions or in dangerous work activities. The focal issue is the overriding priority of production versus safety, derived as a conclusion from frequent individual observations and/ or conversations. Managers, particularly supervisors act as a role model, reflecting in individual role episodes overall emphasis or de-emphasis on safety issues.

The link between organizational climate and specific safety climate was studied by Neal, Griffin and Hart (2000). Results from 32 work groups in a large Australian hospital indicated that general organizational climate exerted a significant impact on safety climate, and safety climate in turn was related to self-report of compliance with safety regulations and procedures as well as participation in self-related activities within the workplace. Safety climate was found to operate as a mediating variable between organizational climate and safety performance, while the effect of safety climate on safety performance was partially mediated by safety knowledge and motivation.

Over 30 studies using safety climate questionnaires have been published so far (Glendon & Litherland, 2001). Flin, Mearns, O'Connor & Bryden (2000) and Guldenmund (2000) have summarized most of them in an approach to identify key factors of safety climate. Flin et al. (2000). found that the number of factors varied between 2 and 19 in the studies they reviewed, while Lee and Harrison (2000) extracted 28 factors from their analysis. However, if the same questionnaire was applied in different settings or even in similar organizations, different factor structures have been found (Brown & Holmes, 1986; Dedobbeleer & Beland, 1991; Coyle, Sleeman & Adams, 1995). One explanation for the difference observed is the variety of questionnaires, samples and methodologies used in different studies. Glendon and Litherland (2001) argue that labeling of factors play an important role. In most cases, factor analysis is applied to derive one-dimensional factors. This methodology relies extensively on researcher discretion, in particular in factor labeling. It seems possible that more similarities exist between factor structures than is apparent from the comparisons conducted to date.

The number of dimensions of safety climate remains disputed, although recurring themes across safety climate surveys include management commitment, commitment of leaders, supervisory competence, priority of safety over production, and time pressure (Elke, 2001b). Flin et al. (2000) reported three main factors: management/supervision, safety system, and risk, also frequently emerging were work pressure and competence. It might be well assumed that factors of safety climate and culture not only differ between subunits and organizations, but also between industrial and national culture (Ludborzs, 1995).

Conceptual confusion may arise in differentiating the concept of safety management from safety culture and climate. Kennedy and Kirwan (1998) assert that "safety climate and safety management are at lower levels of abstraction and are considered to be a manifestation of the overall safety culture" (p. 251). In this sense the safety culture is reflected in the strength of the SMS and the safety climate. Mearns et al. (2003) take the view that safety management practice is an indicator of the safety culture of upper management. More favorable safety management practices are expected to result in improved safety climate of the general workforce, and vice versa. Examination of safety management practices should be considered an adjunct to the assessment of safety climate within an organization. From a functional point of view, safety culture represents an implicit control system in the form of a socialization programme. It is a value-based system based upon the organization's mission, values, business details, customers and the expectations of the employees.

2.3.2 Safety Climate and Performance

Various studies have revealed that safety climate factors can predict safety-related outcomes, such as accidents or injuries (Zohar, 1980, 2003; Brown & Holmes, 1986; Dedobbeleer & Beland, 1991; Dejoy, 1994, Niskanen 1994; Hofmann & Stetzer, 1996; Diaz & Cabrera, 1997; for an overview: Glendon & Litherland, 2001). Factors of safety climate emerge as predictors of unsafe behavior or accidents in numerous structural models (Brown, Willis & Prussia, 2000; Cheyne, Tomas, Cox & Oliver, 1999; Thompson et al., 1998; Tomas, Melia & Oliver, 1999) and non-linear models (Guastello, 1989; Guastello, Gershon & Murphy, 1999). Neal et al. (2000) found that safety climate influenced self-reported components of safety performance. Cheyne, Cox, Oliver and Tomas (1998) using structural equation modeling (SEM) revealed that safety activity was influenced by five safety climate factors as antecedents: safety management, communication, individual responsibility, safety standards and goals, and personal involvement. Workplace hazards and the physical work environment were also components of the model. Results of SEM approaches support the notion of Hoffmann and Stetzer (1996) that the influence of safety climate upon safety performance is mediated through the work conditions and environment.

An expected negative correlation between a positive degree of safety culture and accident and injury rates as well as a positive correlation with safety-oriented actions can also be confirmed (Zimolong & Stapp, 2001; Barling et al. 2002). Inconsistent results revealed the before mentioned study of Mearns et al. (2003). Safety climate surveys were conducted parallel to management practice surveys on offshore oil and gas installations in separate years. Installations were assessed on their safety climate, safety management practice and safety performance. Results indicated:

- Differences between installations in their accident rates were reflected in differences in safety climate scores,
- Favorable safety climate at installation level was not consistently associated with lower proportion of employees experiencing an accident; not consistently with lower official accident reports either,
- Favorable safety climate at individual level was associated with a lower likelihood of accident involvement.

There were inconsistent results for the expectation that installation safety climate predicts the proportion of respondents reporting an accident on each installation. This expectation was only confined to year one, not to year two. Likewise, involvement in health and safety decision-making was significantly associated with injury rate in year one, not in year two. The safety climate scores were also expected at the individual level as predictors of self-reported accidents. The discriminant function exceeded 68 % correct classifications. However, as Mearns et al. (2003) admitted, this value is not high and there was little consistency in the set of best predictors.

What are the antecedent factors that promote a favorable climate? Hofmann et al. (1995) denote the individual attitudes and behaviors noticeable in safety climate as the micro-elements of an organization, which themselves are determined by macro-elements of the SMS and practices. Safety philosophy of upper management, attitudes and behavior permeate down through the levels of organization to the workforce. As a consequence, research has focused on supervisors as role models for promoting safety awareness and supporting safe behavior (Mattila et al., 1994). Involvement of the workforce in safety decision-making has also received attention (Simard & Marchand, 1994). Several studies identified various procedure based criteria through which employees could assess the relative priority of safety, resulting in organizational-level perceptions (Brown & Holmes, 1986; Coyle et al.,1995). These criteria include non-productive investment in safety technology (e.g. protective devices, safety inspections) or practices of personnel management (safety trainings; safety related incentive-system).

Safety climate may possibly have a mediator function between leadership and safety-oriented behavior (Hofmann & Morgeson, 1999; Simard & Marchand, 1997; Zohar, 2002b).

The mediation role of safety climate was supported in a study of restaurant employees (Barling et al., 2002). Safety-specific transformational leadership predicted injuries through the effects of perceived safety climate, safety consciousness, and safety related events. A second study replicated and extended this model by role overload.

Results of the study by Hofmann and Morgeson (1999) indicated that quality of relationships between group leaders and their superiors (i.e. leader-member-exchange-LMX level) predicted injury records in workgroups through the mediating effects of safety communication, i.e. frequency of raising safety concerns with a superior and the leader’ s declared commitment to safety. Both these mediators are related to safety climate, i.e. they provide behavioral and declarative evidence for workers to assess supervisory concern for their safety and the importance of safe behavior.

Outcomes on the effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups (Zohar 2002a) indicated that leadership effects were moderated by assigned safety priorities and mediated by commensurate safety-climate variables. Climate perceptions, transformational and constructive leadership, and assigned priority of superior were significantly correlated with injury rate in the expected direction. Transformational and corrective leadership were correlated with one aspect of climate perception, namely preventive action. Similarly, corrective and laissez-faire leadership and climate correlated negatively with this type of climate perception.

3 Organizational Control of Hazard and Risk

3.1 Planning and Controlling for Safety

Safety management efforts have traditionally been directed at the prevention of repetitions of accidents that have already occurred. Strategy has concentrated on reactive prevention rather than proactive prevention. Measures to control hazards have been based on information derived from detailed accident investigations. Assessing risks and devising preventive measures without the help of accident data is difficult: it involves assessing the probabilities of a wide range of unwanted outcomes. A hazard-effect control plan must be developed and maintained to cope with all the hazards and adverse effects detected. Range of measures has focused almost exclusively on the errors made by people who were involved in accidents, not the managers and engineers whose errors may have created a climate and a physical environment where failures occur more likely or more serious. Unsafe acts create conditions where further unsafe acts may lead to incidents or accidents. The remote errors by managers and designers have been described by Reason (1987a) as latent or decision failures, and the errors performed by people directly at risk as active failures.

Proactive safety management must address the following distinctive elements of the accident causation process:

- Multi-causality of accidents: Accidents happen as a result of a chance concatenation of many distinctive causative factors, each one necessary but not sufficient to cause a final breakdown (Reason, 1987a).
- Active and latent failures: Active failures are events which have an immediate adverse effect. In contrast, latent failures lie dormant in an organization for some time only becoming evident when they are triggered by active failures: unsafe acts, and unsafe conditions. The dichotomy stresses the importance of management responsibilities for safety and draws attention to the scope for detecting latent failures in the system well before they are revealed by active failures.
- Different modes of human errors: According to the framework of Rasmussen (1983) human errors may be triggered on different level of awareness. Skill-based errors involve ‘slips’ and ‘lapses’ in highly practiced and routine behavior; rule-based errors are mismatches between a situation and the required actions to be taken; and knowledge based errors occur simply due to missing information or wrong inference. Violations, sometimes referred to as ‘risk taking’, may occur when people deliberately carry out actions in a way contrary to a known or unknown rule. The success of training programs depends on the nature of the errors likely to be made.

Risk management and safety management are both allied to the system safety approach. Similar disciplines are the total quality management and the environmental management systems, which are based on the same considerations, but work with different operational processes and objectives. Quality management systems are designed to detect and correct deviations from quality standards. This principle is known as the deviation concept in safety sciences (Kjellén, 1984). Hazards are defined as deviations from a standard or ideal situation. They will lead to damage of the system elements (human, equipment, material) and/ or to the system's environment (water, soil, air, people), if they are not prevented, discovered and corrected.

The overall objective of system safety is the reliability of functions: The system is to work the way it was planned and nobody should be harmed by an accident, toxic substance or malfunction. The term system is used to clearly describe defined activities, processes, and equipment during the lifetime of the system (Hoyos, 1992). Events such as exploding spray cans, magnesium burning on dumps for weeks or chlorofluorocarbon (CFC) that goes up into the atmosphere are examples of the need of a total system management of safety. First, systems were regarded as systems with their sub-components; soon the systems of humans-machines and the extension of the term to organizational systems with the sub-components human, group, organization, methods and processes were included. According to Bird and Loftus (1976), the stages associated with system safety are as follows:

1. The pre-accident (proactive) identification of potential hazards.
2. The timely incorporation of effective safety-related design and operational specification, provisions, and criteria.
3. The early evaluation of design and procedures for compliance with applicable safety requirements and criteria.
4. The continued surveillance over all safety aspects throughout the total life-span - including disposal - of the system.

Depending on the objective of the system, each system will have a series of phases, which follows a chronological pattern. The overall life-span of a manufactured product may comprise the following phases: conception and planning; design and engineering; use/ operation; modification and maintenance; demolition and disposal. Each of these phases can be further subdivided. The risk management of HSE for an organization must consider all phases of the life cycle of the plant or facility it exploits and the goods and services it delivers. Each phase is an activity which must be managed safely in its own right and which must feed forward into subsequent phases and have a feedback loop in order to facilitate organizational learning processes.

Insert fig. 1 Risk assessment and effect management through life cycle of business activities. Process consists of four steps: identify, assess, control, and recover. Hazards are interpreted as deviations from standards. Four generic life cycle phases – design/planning, operation, modification/maintenance and demolition - are shown from left to right. For the operation phase, the normal, deviation and rescue phase is exemplarily depicted.

This concept is illustrated in figure 1 taking into consideration the life-span of a system (Zimolong & Hale, 1989). The model emphasizes that hazards built into a technology or activity and the preventive measures to eliminate and control them are largely conditioned by the decisions made in the planning and design phase of the activity. The life cycle phases are shown horizontally, the control and rescue measures are placed vertically: the elimination, reduction and control of hazards as well as the limitations of the consequences of damage.

During the operational phase, the system may move from time to time outside the defined parameters or standards. The flexibility and built-in controls of the socio-technical system, i.e. of personnel, organization and technical protective measures, normally allow the system to return to normal operation, and no near miss, break down, or accident is experienced. In the overwhelming number of industrial settings, however, only a few of the deviations are discovered and effectively controlled. The system remains in an unstable situation. This state may last anywhere from seconds to months, years and lifetime. During this time, deviations might be detected by the operator, maintenance and repair personnel, safety inspector, or a safety audit team. If no recovery actions are taken and the defenses are inappropriate for this very case, the latent failures eventually turn into active failures which suddenly become potent with some conditions which are harmless in themselves (Reason, 1993). Now only secondary protection measures to contain or divert the energy that was accidentally released are appropriate measures to limiting damage to less important system elements. Examples are safety goggles to guard against foreign objects, fall arrest harnesses to stop fall, and hard hats to protect against falling objects. Further damage reducing measures are rescue actions that limit the time of exposure to harmful energy, for example, disconnecting the current in electrocution cases or washing off the caustic chemical, administering timely first aid and proper treatment by the rescue system.

System safety essentially is planning for health and safety. The process includes establishing performance standards by which to measure and assess the HSE policy, the organizational arrangements for developing and maintaining it, the physical controls needed to meet the requirements of the performance standards (hardware control), and the systems and procedures required by the performance standards for managers, supervisors and other employees (software control).

The British Health and Safety Executive (HSE, 1998) provides a framework for identifying key areas in the operational phase of a system for which performance standards are important. First stage control includes the elimination and reduction of hazards and risks entering the organization. Performance standards cover the physical resources (i.e. workplaces, materials and substances, plants), the human resources (recruitment, selection of personnel and contracting organizations), and the information related to health and safety, risk control, and positive health and safety culture. Second stage control eliminates or minimizes risks arising inside the organization. Performance standards cover hazards and risks arising from premises, plant and substances, procedures and people. Third stage controls minimize risks outside the organization arising from work activities, products and services. Performance standards are required to control these risks including both organizational procedures and the control of specific risks.

3.2 Origins of Deviations

From a safety point of view, hazard represents a source of energy with the potential of causing immediate injury to personnel, and damage to equipment or structure. Employees are further exposed to diverse toxic substances, such as chemicals, gases or radioactivity, some of which cause health problems. Unlike hazardous energies, which have an immediate effect on the body, toxic substances have quite different temporal characteristics, ranging from immediate effects to delays over months and years. Ozone is a good example. It causes inflammation along the entire respiratory tract. This is like sunburn deep in the lung. For people with asthma, it increases sensitivity to allergies, frequently requiring hospitalization. Often there is an accumulating effect of small doses of toxic substances which are imperceptible to humans.

The harmful effects of health hazards, such as hearing loss, cancer, liver damage, silicoses are regarded as illnesses. However, back pains, may result from improperly designed chairs, headaches from poor ergonomic layout of VDT work place. This exceeds the traditional view on accidents. Consequently, controls are not always identical: the prevention of contact or its reduction to a level where no harm is done is valid only for hazardous or toxic materials, whereas illnesses resulting from poor design requires ergonomic standards, planning and sometimes complete re-installation of the working system. Under the total loss approach, accidents are taken as undesired events that result in harm to people, damage to property or loss to process (Bird & Germain, 1987). They include not only those circumstances which actually cause health problems or injury, but also every event involving damage to property, plant, products or the environment, production losses, or increased liabilities. The severity of an injury that results from an accident is often a matter of chance.

Insert Table 1 Some forms of possible health hazards

It depends upon many factors, such as dexterity, reflexes, physical condition, the portion of the body injured; as well as the amount of energy exchanged, what barriers were in place, whether or not protective equipment was worn. The 'no injury' incident or 'near miss' often has the potential to become events with more serious consequences. Analysis of the more frequently occurring property damage incidents and the near misses provides more information for guidance in the work of prevention and clearer understanding of the causes of accident problems.

Several studies have been undertaken to establish the relationship between serious and minor accidents and other dangerous events (Bird & Germain, 1987; HSE, 1997). In industry, the pyramid of accident ratios is used by many companies, which is a statistical ratio between the number of fatalities, injuries, no-injury accidents and incidents. It is by no means a causal relationship, i.e. preventing all minor injuries would not result in the prevention of all serious or fatal accidents. The actual ratios in different pyramids differ significantly, indicating the problem of reliable measurement and different ratios for different locations.

Traffic studies conducted by means of Traffic Conflicts Technique have clearly proved different ratios of fatalities, injuries and conflicts (incidents) at various types of intersections (Zimolong, 1981). Not surprising, at least to the expert, is the result that apparently dangerous looking traffic-light-regulated junctions have a vast amount of conflicts. The ratio of conflicts to accidents equals 1,170:1. "Safe" looking nonsignalized urban junctions have a smaller ratio of 470:1. At "safe" junctions conflicts turn into accidents three times more often as compared to signalized junctions (Erke & Zimolong, 1978). Most accidents happen because people commit active failures, which are called "unsafe acts". Not wearing safety glasses is one example. In terms of system safety, unsafe acts and unsafe conditions are substandard practices and substandard conditions, i.e. deviation from an accepted standard or practice. A vast number of substandard conditions involve poor ergonomic design of machine, equipment and the work environment.

It is essential to consider these practices and conditions only as symptoms, which point to the latent failures (Wagenaar, Groeneweg, Hudson & Reason, 1994) or basic causes behind the symptoms (Bird & Germain, 1987). Incidents usually start with relatively insignificant and common failures of design, operating and maintaining of equipment, with human errors or degraded performance. In combination with circumstances and the reactions of equipment and people, hazards can be released and escalate to cause injuries or damage to environment and assets. The equipment failures and exacerbating circumstances themselves are also generally the result of human failures long before the incident e.g. during design, construction and planning. Human failures may also have a long history of bad habits and wrong work methods which were not corrected and of procedures which were not enforced. The interactions are complex between equipment, people and surrounding environment.

The prevention of unsafe acts and conditions to minimize incidents will be quite troublesome if their systemic nature is overlooked. They are not random events, but logical and systematic consequences of psychological states. Examples are lack of attention, haste, inexperience, reasoning errors, and misperceived risk. Psychological states are again not random events. They are caused by latent errors related to managerial and organizational failures and omissions; errors that were made long before the accident, and which have been present all the time. "Haste may be caused by any one of the following: too rigorous planning, a reward system that stresses speed, lack of personnel, frequent breakdown of equipment, a motivation to complete more than the normal portion of work, exceptional emergencies that had never been foreseen" (Wagenaar, Souverijn & Hudson, 1993, p. 159). In all these examples the cause of haste is a latent failure that has been present for a long time. Telling people not to be hasty is pointless. Haste can only be prevented by removal of latent failures that cause haste.

Various substandard practices relate to the deficiencies in communication and information between functional units of the company. Equipment and materials which are inadequate or hazardous will be purchased if there are no adequate standards, and if compliance with standards is not managed. Poor work process layouts and interfaces will be designed and built if there are no adequate standards and compliance for design and construction. Equipment will wear out and produce products with quality deficiencies, create waste, or break down and cause property damage, if that equipment is not properly selected, used, and maintained (Timpe, 1993).

The origins of the deviations from standard are deficiencies in management and organization. Wagenaar et al. (1994) have suggested eleven types of latent failures, which have emerged on the basis of studies of hundreds of accidents and incidents. They are related to the work environment, to the individuals doing their job, and to management (see table 2). Detailed lists which cover different factors are provided in Petersen (1978) and Bird and Germain (1987).

System safety engineering involves the application of scientific and engineering principles for the timely identification of hazards and initiation of those actions necessary to prevent or control hazards within the system (Leveson, 2002). It draws upon professional knowledge and specialized skills in the mathematical, physical and related scientific disciplines, together with the principles and methods of engineering design and analysis to specify, predict and evaluate the safety of the system. Although much of occupational safety is now being recognized as being behavioral, safety engineering still has a major role in occupational safety. General topics and methods are concerned with guarding energy sources, design and redesign of machinery, equipment and processes, application of environmental standards, and establishment of inspection systems, such as statutory engineering inspections of pressure vessels, cranes and lifting machines, or electrical installations. Comprehensive coverage of those topics provides Bird and Germain (1987) and Ridley and Channing (2003).

Workplace designs that do not take ergonomic principles into account are likely to lead to an increase in errors and accidents and a decrease in safety and efficiency. Error-prone designs place demands on performance that exceed capabilities of the user, violate the user's expectancies based on his or her past experience, and make the task unnecessarily difficult, unpleasant, or dangerous. The systems approach applied to ergonomics treats humans and machines/computers as components interacting together to bring about some desired objective. The role of the individual is characterized by his/her capabilities and limitations, mainly the human sensory capabilities, the perceptual/cognitive processes and the human performance abilities. For the workplace designer or safety practitioner, reliable anthropometric data, i.e. data concerning the measurement of physical features and functions of the body are found in human factors handbooks (Van Cott & Kinkade, 1972, Woodson, 1981). Ergonomic principles for enhancing the design and safe operation of work facilities and equipment may be organized at the component, the workstation, and the workspace level including the work environment. At the component level, visual displays, various types of controls, and visually or auditory warnings are considered. Workstation designs are based on anthropometric data, which are available for designing cabinets, consoles, desks, and other workstations (Woodson, 1981; Corlett & Clark, 1995). Particularly, special considerations have been given to computer workplace design and to software user interface design (Hix & Hartson, 1993).

Overall workspace design is concerned with the integration of several work areas and how to ensure that ambient environmental conditions fall within acceptable ranges. Thermal comfort, noise, and lighting are among the most important environmental factors to assess in occupational settings. The essentially multi-disciplinary nature of the subject is covered in a number of useful chapters and books, amongst others in Grandjean (1980), Shackel (1984), and Corlett and Clarke (1995), Meister and Enderwick (2002).

3.3 Hazards and Effects Management

A vital part of safety management is the hazards and effects management (HEM) process, e.g. identifying and managing hazards and adverse effects of activities. It consists of four steps: identify, assess, control and recover. The process should be applied to current and new activities, operations, products, services and involves the assessment of HSE impacts or potential impacts on people, environment and on assets. It should include the full life cycle of the business from inception to termination (Visser, 1998). The types of risk assessment and measures to be taken are directed by the potential consequences of risks.

Most injuries result from minor hazards at the workplace. Slip, trip and fall incidents are the most common incidents when performing normal activities. Qualitative risk assessment, housekeeping rules, procedures and behavior rules, awareness programs and training are convenient measures to manage these hazards. Workplace hazard management is part of the overall HEM process. A smaller proportion of injuries results from hazardous activities, the performer of the activity or people in the immediate vicinity are the potential targets for these activities. These hazards are generic for the type of work performed; working at height, with electricity, with gases under pressure. Principles on identification of hazards and barriers to prevent progression to consequences can also be applied to these hazardous activities. Precautions to be taken are not specific for a particular location or enterprise. They can be dealt with by using procedures and checklists, adopted by the company, which may originate from the regulator, from industry or be generated in house.

HSE-critical activities in the business process are defined as the activities required establishing and maintaining the barriers along the paths that lead to major consequences. Safety Cases deal with critical operating procedures, design and engineering studies. They are communicated for guidance and reference for supervisory staff and engineers. The hazards and effects management process requires that hazards with the potential of intolerable consequences should be identified and fully assessed, necessary controls should be provided and recovery preparedness measures should be in place to take care of any potential loss of control. Two kinds of barriers are used: Measures taken to prevent the circumstance or initiating event from occurring. Recovery measures and equipment to prevent the event causing harm and damage are barriers to limit the consequences and reinstate the process. For each initiating event one or more barriers can be deployed, dependent on their effectiveness and the potential severity of the consequences. Barriers can be hardware, instrumentation, procedures, competencies etc.

Various types of activities are necessary to recognize the need for barriers, to deploy them and to keep them effective. Design activities specify the necessary hardware and equipment, inspection and maintenance activities ensure that this hardware and equipment retains its integrity and reliability, operational activities ensure that equipment is used within the defined limits of the controls provided, and administrative activities provide the necessary training, awareness and attitudes to ensure that people perform predictably in all normal and abnormal situations.

In the simplest case, workplace hazards can be identified by observation, comparing the circumstances with the legal standards and guidance. In more complex cases, measurements such as air sampling or examining the methods of machine operation may be necessary to identify the presence of hazards presented by chemicals or machinery. The complexity of many health risks means that the identification of health hazards and risks will generally require the measurement of exposure, calling for specific monitoring and assessment techniques and the competence to use them. While health risks arising from the use of substances can be controlled by physical control measures, systems of work and personal protective equipment, confirmation of the adequacy of control will often require measurements of the working environment to check that exposures are within pre-set limits. In special cases, surveillance of those at risk to detect excessive uptake of a substance, i.e. biological monitoring or early signs of harm, i.e. health surveillance, may also be necessary.

Insert Fig. 2 Determination of a risk index

Assessing risks is necessary in order to identify their relative importance and to obtain information about their extent and nature. This will help to identify where to place the major effort in prevention and control, and in order to make decisions on the adequacy of control measures. The relative importance of risks may be determined by taking into consideration both the severity of the hazard and the likelihood of occurrence. There is no general formula for rating risks in relative importance but a number of simple risk estimation techniques have been developed to assist in decision making (Bird & Germain, 1987; Steel, 1990). They involve only some means of estimating the likelihood of occurrence and the severity of a hazard. An example is given in fig. 2.

Usually the amount of harm resulting from a critical event or accident is a matter of chance. The hazard-potential can be assessed in a risk matrix. Two questions have to be answered: "What could have happened?" and "How often can the consequences occur?" Hazards - the potential to cause harm - will vary in severity. The effect is rated both in terms of injuries and damage of property. In fig. 2 the likelihood of harm is rated on a five level scale ranging from once in 5 years to more than once in a week. The cells of the matrix may contain some arbitrary risk numbers. The organization decides what kind of measures has to be taken by which kind of risk number. Health hazards, malfunctions and near accidents and even accidents can be assessed in the same way. Systems of assessing relative risks can contribute not only to establishing risk control priorities but also assist in prioritizing other activities, and ranking departments and units according to their safety levels. Hoyos and Ruppert (1993) developed a hazard potential analysis for the identification and assessment of hazards at the workplace. The Safety Diagnosis Questionnaire (SDQ) relates the hazards identified to a broad repertoire of abilities and skills that are considered the basis of hazard control by the worker.

The identification of deficiencies and deviations from standards related to managerial and organizational arrangements is usually done in an audit and review process. Some topics are for example organizational arrangements to secure the involvement of all employees in the HSE efforts, the acceptance of HSE responsibilities by line managers, the communication of policy and relevant information, the timely consideration of HSE-related standards into the planning and design process. More topics are provided in table 2 "List of basic causes of loss". Audits are normally performed by competent people, independent of the area or activities being audited. This can be achieved either by using external consultants or by using staff from different sections, departments or sites to audit their colleagues. On the basis of structured work group discussions, Wagenaar et al. (1994) integrated the employees into the review process. The authors developed a method for predicting the causal structure of future accidents on the basis of symptoms already visible. These are the failure states which are listed in table 2.

In more complex situations or in high risk systems, qualitative or quantitative risk assessments may be required by legal standards and guidance. For example, in the chemical or nuclear industry, special techniques and systems may be applied when planning a new system or major changes of an existing system.

Insert Table 2 Hazard analysis and risk assessment techniques

Hazard and operability studies (HAZOPS) and hazard analysis systems such as event or fault tree analysis have repeatedly been summed up and presented, among others by Hoyos and Zimolong (1988), and Ridley and Channing (2003). In Table 3 an overview is given on the techniques suitable for the planning and design phase of a system. Probabilistic risk assessment (PRA) is a systematic quantitative assessment of the likelihood of the levels of damage from operating industrial settings. The assessments are derived from combining the likelihood of occurrence of hardware and human related errors. One well-documented application of a procedure to obtain human error probability estimates is THERP (Swain & Guttmann, 1983). Other methods, such as the human cognitive reliability model and the maintenance personnel performance simulation model have been discussed by Svenson (1989). Recently new techniques have been developed, amongst others the Dynamic Reliability Technique, which identifies the origin of HEPs in the dynamic interaction of the operator and plant control system (Cacciabue, Caprignano & Vivalda, 1993), A Technique for Human Error Analysis (ATHEANA; Cooper, Ramey-Smith, Wreathall, et al. et al., 1996), and the Cognitive Reliability and Error Analysis Method (Hollnagel, 1998). Reviews on current trends in reliability analysis, systems and cognitive engineering are given in Giesa and Timpe (2000), Wickens and Hollands (2000), Leveson (2002), Strauch (2004).

Swain and Guttmann (1983) recommend the following procedure to conduct a PRA:

1. Dividing up of the tasks in subtasks and elements;
2. Analysis of possible failure with the help of a fault or event-tree;
3. Determining the probabilities of faults for the corresponding task-element from a data base or through subjective estimation;
4. Computing of the reliability of tasks or frequency of failures with the rules of probability calculus.

The most difficult problem still remains the availability of data. A number of attempts have been made to collect human reliability data (Miller & Swain, 1987). Sometimes expert judgment is calibrated in some way, for example, through psychophysical methods such as rating, ranking, or magnitude estimation, or through analytical methods such as SMART (Edwards, 1977) or MAUD (Humphreys & Wisudha, 1983). Research has shown that experts are liable to errors of judgment in just the same way as lay-persons, especially when they are forced to go beyond their experience (Kahneman, Slovic & Tversky, 1982). Zimolong (1992) conducted an experiment which compared three different estimation techniques, including an expert ranking and a decision aiding technique (SLIM, Embrey, 1987) and THERP. A satisfactory match between estimated and empirically derived human error data was yielded only for THERP for routine tasks. The application of SLIM and ranking led to a mis-match between estimated and actual HEPs. At present, no reliable technique for the quantitative assessment of error probabilities is available.

The challenges for safety management are to devise appropriate indicators of operational and economic impact and to be able to attribute types and amounts of operational and economic impact on formulated strategies and activities. Active monitoring systems provide essential feedback on performance before an accident, ill health or an incident happens. The methods involved in monitoring ongoing safety strategies and activities vary widely, ranging from periodic checks of compliance with performance standards, to relatively straightforward tracking of training and education services delivered, to checking on how hazardous exposures are controlled. Monitoring can include serious re-examination of whether the needs of the safety strategy and related projects as originally intended still exist, or it may suggest modification, updating, or revitalization. Reactive systems monitor accidents, ill health and incidents. Securing the reporting of serious injuries and ill health generally presents few problems for most organizations. However, the reporting of minor injuries, other loss events, incidents, and hazards requires special efforts and attention and creates difficulties in most organizations.

Most companies are set up to measure accountability through analysis of results. Monthly accident reports at most plants suggest that the supervisor and manager should be judged by the number and cost of accidents that occur in his/ her department. Petersen (1978) strongly emphasized that they should be judged by what they do to control losses. Numerous techniques have been introduced for guiding and measuring accident prevention efforts of supervisors and line managers (Bird & Germain, 1987).

An alternative approach to measuring and evaluating the efficacy of safety management is the use of safety related financial/ economic performance ratios. These ratios are performance indicators that are used to show the strategic value and operating leverage, i.e., the ratio of the percentage change in operating income to the percentage change in operating costs associated with safety management efforts (Imada, 1990). The direct costs of accidents can be determined by using one of the suggested models, for example by Veltri (1990) or HSE (1993). Models disclose the direct costs of accidents and the economic impact on cost-volume-profit performance standards and profitability potential of the company. The indirect costs of accidents are difficult to calculate, chiefly, because no suitable model for verifying any results in reliable and valid ways has been developed. However, Grimaldi and Simonds (1989) presented an uninsured cost model that provides a reasonable measure for determining uninsured costs of accidents.

There are a growing number of well-known auditing methods, i.e. an inspection of the organizations and administrative procedures on a scheduled basis to determine their safety relative to a standard criterion. Among these, the International Safety Rating System (ISRS, Bird & Germain, 1990) is widely used. ISRS is a safety auditing program for assessing the different parts of the company's health and safety activities. The safety management factors in ISRS are ranked and assigned a numeric value, based on a qualitative judgment of the relative importance of the elements. The MORT concept (Management Oversight and Risk Tree; Johnson 1980) has formed a basis for further developments of safety analyses and safety assurance methodology in industry. MORT is a logic tree that provides a disciplined method to analyzing an accident, and provides a format for safety program evaluation. The SMORT method (Safety Management and Organization Review Technique; Kjellén 2000) provides a systematic and stepwise means of unfolding relevant causal factors by starting with identification of risk influencing factors at the workplace level and proceeding through the various managerial level of the organization.

Common to the majority of audit methods used is the characteristic that they have only to a minor extent been scientifically validated (Eisner & Leger, 1988; Guastello, 1991; Rouhiainen, 1992). Methods with the exception of SMORT (Tinmansvik & Hovden, 2003) have been developed and tested through practical approaches, rather than a scientific approach. Such audit systems are largely based on the collected experience of long years of consultancy or management. As Hale, Heming, Carthey and Kirwan (1997) claim, they can give the impression of arbitrary lists of topics clustered under convenient headings which vary from one instrument to another. They do not have an explicit model of management system nor do they provide an empirical based weighting system of the items or topics covered. It is not clear whether they are too detailed or not complete enough. Even the merits are unclear. As an example, Eisner & Leger (1988) very much questioned the assertion that the application of the ILCI audit instrument for the mining industry was the primary cause of the accident reductions faced in South African mines (International Loss Control Institute, 1990).

4 Individual Control of Hazard and Risk

4.1 Hazard Perception

Most of the safety and health related hazards in industry cannot be eliminated, reduced or minimized. People have to perceive, detect and control hazards and dangers if confronted with them at work. In case of individual control of hazards, this requires careful analysis of hazards as well as what it takes to control hazards. The perception of hazards is essential to the subsequent phases of action in hazardous situations: personal risk assessment, decision-making and selection of the appropriate protective, and/ or preventive action.

Saari (1976) defines the information processed during the accomplishment of a task in terms of the following two components:

- the information required to execute a task and
- the information required to keep existing risks under control.

For example, a construction worker perched on the top of a ladder, who is required to drill a hole in the wall, has both to keep his balance and to automatically coordinate his body-hand movements whilst drilling a hole; a driver searching for route information ahead simultaneously adjusts distance and speed of his own car relative to the vehicles in front of him. In both cases hazard perception is crucial to coordinate body movement to keep hazards under control whereas conscious risk assessment only plays a minor role, if at all.

Not all hazards are directly perceptible to human senses. Examples are electricity, colorless, odorless gases such as methane and carbon monoxide, x-rays and other forms of radioactivity, and oxygen-deficient atmospheres. Their very presence must be signaled by devices which translate the presence of the hazard into something which is recognizable. Most of the toxic substances are not visible at all. Ruppert (1987) found in an investigation in an iron and steel factory, in municipal garbage collecting and in medical laboratories that from 2230 hazard indicators only 42% were perceptible to the human senses. 22% of the indicators have to be inferred from comparisons with standards, for example, an increase in the noise level coming from the press of the garbage truck indicates the risk of being hit by particles bursting from the container. Hazard perception is based in 23% of cases on clearly perceptible events which have to be interpreted with respect to knowledge about the type of hazardousness, e. g. a glossy surface of a wet floor indicates slippery conditions. In 13% of reports hazard indicators can only be retrieved from memory, for example, current in a wall socket can only be made perceivable by the proper checking device. There are also situations where hazards exist which are not perceivable at all and cannot be made perceivable at a given time. One example is the risk of infection when opening blood samples for medical tests; another is the risk of material falling down from scaffoldings at construction sites. The knowledge that hazards exist must be deduced from one's knowledge of general principles of causality or acquired by experience.

The results demonstrate that the requirements of hazard perception range from pure detection and perception to elaborate cognitive inference processes of anticipation and assessment. Delayed or accumulating effects of health hazards, e.g. toxic substances are likely to impose additional burdens on individuals. Cause and effect relationships are sometimes unclear, scarcely detectable, or misinterpreted. In Table 3 a list of requirements on perceptual processes of hazard detection and perception is presented based upon studies of 391 work sites in industry and public services (Hoyos & Ruppert, 1993). Experienced raters had to assess all hazards at a particular site which resulted in 2373 hazards identified (Hoyos, 1995). On the average, people have to cope with six perceptual and cognitive demands per hazard in order to control the risk at work. They include visual recognition, selective attention, auditory recognition and vigilance. As expected, visual recognition dominates auditory recognition. About three-quarters of the hazards have to be detected visually, in only 21.2% of the cases it is by auditory detection. In more than half of all hazards observed, people had to divide attention between task and hazard control, for example, observing crane movements while working at construction sites. This is mentally strenuous and likely to be error prone. Even more alarming is the findings that in 56% of all hazards employees have to cope with rapid activities and responsiveness to avoid being hit and injured, e. g. by sudden sidestepping to avoid an oncoming vehicle.

Insert Table 3 Detection and perception of hazard indicators (after Hoyos & Ruppert, 1993).

Insert Table 4 Prediction and evaluation of hazard indicators (after Hoyos & Ruppert, 1993).

Table 4 shows the cognitive demands of anticipation and assessment which are required to control hazards of the worksite. The core characteristic of all activities summarized in this table is the requirement of knowledge and experience to cope with hazards. It emphasizes the need of establishing signs, warnings, introducing personal counseling, training and qualification efforts. As Hoyos, Bernhardt, Hirsch, and Arnhold (1991) have demonstrated, employees have little knowledge of hazards, safety rules and proper personal protective behavior. In some cases (16.1%), perception of hazards is supported by signs and warnings, usually, however, people rely on knowledge, training and work experience. It is without doubt mandatory to improve the indication of hazards and risks by warning signs and labels. The use of labels and warnings to combat potential hazards, however, is a controversial procedure for managing risks. Too often they are seen as a way for manufacturers to avoid responsibility for unreasonably risky products. Obviously, labels and warning signs will be successful only if the information they contain is read and understood by members of the intended group of people. Frantz and Rhoades (1993) found that 40% of clerical personnel filling a filing cabinet noticed a warning label placed on the top drawer of the cabinet; 33% read part of it, and no one read the entire label. Contrary to expectation, 20% complied completely by not placing any material in the top drawer first. Lehto and Papastavrou (1993) provided a thorough analysis of findings pertaining to warning signs and labels by examining receiver, task, product, and message-related factors. The editorial work of Wogalter, Young and Laughery (2001) on “Human Factors Perspectives on Warnings” covers a selection of articles on warnings and hazard communication since 1973.

4.2 Personal Risk Assessment

Personal risk assessment refers to the decision-process as to whether and to what extent the individual will be exposed to hazard; for instance, working on a high scaffolding, or driving a car at high speed. It seems people must decide in the face of danger. However, people doing their jobs on a routine basis rarely consider these hazards or accidents in advance: they run risks, but they do not take them. Much of the time there will be no conscious perception or consideration of hazards as such. "The lack of safety consciousness is both a normal and a healthy state of affairs, despite what has been said in countless books, articles and speeches. Being constantly conscious of danger is a reasonable definition of paranoia" (Hale & Glendon, 1987, p. 41).

There is a wide variety of interpretations of the terms "risk". On the one hand, risk is interpreted to "mean probability of an undesired event". It is an expression of the likelihood that something unpleasant will happen. A more neutral definition of risk is used by Yates (1992), who argued that risk should be perceived as a multidimensional concept that, as a whole, refers to the prospect of loss. Technical risk-assessment usually focuses on the potential for loss, which includes the probability of the loss occurring and the magnitude of the loss in terms of death, injury, or monetary costs. Lay peoples' sense of risk depends on more than the probability and magnitude of loss. It may depend on such factors as potential degree of damage, as well as on dimensions such as the unfamiliarity of the consequences, the involuntary nature of exposure to risk, the uncontrollability of damage, and the biased media coverage. The feeling of control in a situation may be a particularly important factor (Slovic, 1987). A different research direction has addressed emotional reactions to risky situations. The potential for serious loss generates a variety of emotional reactions, not all of which are necessarily unpleasant. There is a fine line between fear and excitement. Again, a major determinant of perceived risk and of affective reactions to risky situations seems to be a person's feeling of control, or lack thereof. As a consequence, for many people, risk may be nothing more than a feeling (Trimpop, 1994).

The overwhelming evidence that people often make poor choices in risky situations seems also related to inappropriate risk assessment. In particular, research on judgment and choice has shown that people have methodological deficiencies such as in understanding probabilities; negligence of the effect of sample sizes; reliance on misleading personal experience; holding judgments of fact with unwarranted confidence, and misjudging risks. People are more likely to underestimate risks if they have been voluntarily exposed to risks over a longer period, such as people living in the neighborhood of reservoirs facing the risk of flooding; or in areas where earthquakes are not uncommon. Similar results have been reported from industry. In a field study (Zimolong, 1985) 153 members of six occupational groups mainly from the building industry and auxiliary building trade, amongst them carpenters, tile layers and construction workers rated the frequencies of falls resulting in minor injuries, and in serious/ fatal injuries, respectively. Ratings were carried out for eight different work sites: ladder, scaffolding, roof, building under construction, etc. Estimates were compared with frequencies based on fall accident statistics. The results clearly indicated a job specific underestimation or overestimation of the frequencies. As can be seen from fig. 3 there is a mis-match between the risk as subjectively assessed and as objectively measured.

Insert fig. 3 Subjective risk estimation of accidental falls from various work sites. Columns depict positive percent figures (overestimation) and negative figures (underestimation) of specific workplace risks. Assessments were made separately for eight different work sites including ladder (l), scaffolding (sc), roof (r) and stairs (st). (From Hoyos and Zimolong, 1988, p.175)

Generally spoken, employees underestimate high-risk activities and overestimate low-risk activities, however, underestimation of risks is ruled by the exposure time to the specific risk. For instance, carpenters and painters frequently use ladders, and they considerably underestimate the risk of accidental fall. Tile-layers typically underestimate the risk of fall from roofs, whereas scaffolding assemblers obviously seem to believe that falls from scaffoldings will never happen to them. Actually, it is the most frequent cause of minor and severe injuries. Shunters, miners, forest and construction workers all dramatically underestimate the riskiness of their most common work activities if compared to objective accident statistics. They tend to overestimate, however, obvious dangerous activities of other fellow workers when required to rate them.

Unfortunately, expert's judgments appear to be prone to many of the same biases as those of laypersons, particularly when experts are forced to go beyond the limits of available data and rely upon their intuitions. Research further indicates that disagreements about risk will not disappear completely when sufficient evidence is available. Strong initial views are resistant to change because they influence the way that subsequent information is interpreted. New evidence appears reliable and informative if it is consistent with one's initial beliefs, contrary evidence tends to be dismissed as unreliable, erroneous, or unrepresentative (Nisbett & Ross, 1980). When people lack strong prior opinions, the opposite situation occurs - they are at the mercy of the problem-formulation. Presenting the same information about risk in different ways, for example, mortality rates as opposed to survival rates, alters their perspectives and their actions (Tversky & Kahneman, 1981).

Most of the personal risk decisions in every day life are not conscious decisions at all. People are not even aware of risk. Most of our daily behavior is automated and runs smoothly without continuous attentional control and conscious risk-taking. Reason's GEMS (1987b) model describes how the transition from automatic control to conscious problem-solving takes place when exceptional circumstances arise or novel situations are encountered. In normal work routines, however, conscious risk assessment and decision-making is just not present. Therefore, it cannot be argued that people's way of evaluating risk is inaccurate and need to be improved. The notion that the acceptance of risks, identified after the occurrence of accidents, is the primary cause of the incident does not take into account that in most cases no conscious risk assessment was undertaken. In research as in practice, less attention has been paid to the conditions in which people will act automatically, follow their good feeling, or accept the first choice that is offered (Wagenaar, 1992). Contrary to these findings, there is a widespread acceptance in society and among safety and health professionals that risk-taking is a prime factor for causing mishaps and errors. In a representative sample of Swedes aged between 18 and 70 years, 90% agreed that risk-taking is the major source of accidents (Hovden & Larsson, 1987).

Preventive activities in order to cope with hazards comprise amongst others: planning work procedures and steps ahead; regular checking of equipment and material for defective parts; the provision of adequate storage; selection of safe work procedures by means of selecting proper material and tools; setting appropriate work pace; inspection of facilities, equipment, machinery and tools. The most frequent protective measure required is the usage of personal protective equipment (PPE, Hoyos & Ruppert, 1993). Together with the correct handling and maintenance it is by far the most important requirement in industry. There are major differences in the usage of PPE among companies. In some of the best companies, mainly in the chemical and mineral oil industry, the usage of PPE approaches 100%. In contrast, in the construction industry, safety representatives have problems even in attempts to introduce particular PPE on a regular basis. Is risk perception and assessment the major factor which makes the difference? Again, this is doubtful. Some of the companies have successfully enforced the usage of PPE, which then becomes habituated, e.g., the wearing of safety-helmets. They have established the "right safety culture" and thus have subsequently altered personal risk assessment. Slovic (1987) in his short discussion on the usage of seat-belts shows that about 20% of road users wear seat-belts voluntarily, 50% would use them if it was made mandatory by law and beyond this number, only control, incentives and punishment will serve to improve the automatic usage. Thus, it is important to understand what factors govern risk perception. However, it is equally important to know what the company can do to change behavior and, subsequently, how to alter risk perception.

5 Behavioral Risk Management

5.1 Scientific Foundations

Most successful behavioral programs have tried to modify the value function for safe behavior by introducing short-term rewards that outweigh immediate costs. Literature reviews reveal that most documented interventions have used the operant perspective of role behavior and the attendant ABC framework (i.e. antecedents-behavior-consequences; see Luthans & Kreitner, 1985; Stajkovic & Luthans, 1997; 2003). Mainly two kinds of antecedents were used - goal setting and training - and three kinds of consequences, namely feedback, incentive, and social recognition. Antecedents have mostly been used in combination with positive consequences of some kind (McAfee & Winn, 1989; O’Hara, Johnson & Beehr, 1985; Geller 1996).

Behavioral management is based on the behavioral model of learning, with its roots in Skinner’s operant conditioning and Thorndike’s law of effect. Learning is understood as a relatively enduring change in behavior that results from the behavior and its consequences and antecedents. Contextual and antecedent events, such as the physical and social factors of the work environment, key features of job requirement, prevailing hazards, work rules, cues and prompts of superiors set the stage for a given performance. Consequences exert the strongest influence on the rate and durability of behaviors. The main premise of behavioral management is that employee behavior is a function of contingent consequences (Bandura 1969; Komaki, 1998).

Goal setting is widely accepted as to be one of the most powerful behavioral motivation techniques. Goal-setting theory was formulated inductively largely on the basis of empirical research conducted over nearly four decades (Locke & Latham, 2002). The essential elements of goal setting theory, namely specificity and difficulty of goals; goal effects on the individual, group and organization levels; the proper use of learning; and the moderators and mediators of goals are summarized in the high performance cycle (Locke & Latham, 1990). Goal setting affects performance by directing the attention and actions of individuals and/or groups, mobilizing efforts, increasing persistence, and by motivating the search for appropriate performance strategies. Goals have a directive function. They direct attention and effort toward goal-relevant activities and away from goal-irrelevant activities. They also have an energizing function. High goals lead to greater effort than low goals. They also affect persistence. Difficult goals prolong effort. Finally, goals affect action indirectly by leading to the search for and use of task-relevant knowledge. Setting difficult, yet achievable goals, and providing performance feedback in relation to them. The goal-performance relation is mediated through the concept of self-efficacy (Bandura, 1997). People with high self-efficacy set higher goals and vice versa. They also find and use better task strategies to attain the goals. The goal-performance relationship is strongest when people are committed to their goals. This is particularly important, when goals are difficult (Klein, Wesson, Hollenbeck & Alge, 1999). Goal commitment can be enhanced by leaders communicating an inspiring vision and behaving supportively. An alternative to assigning goals is to allow subordinates to participate in decision-making. Meta-analyses of the effects of participation in decision-making on performance yielded an effect size of only d = .11 (Wagner & Gooding, 1987). Subsequently, Locke, Alavi and Wagner (1997) found that the primary benefit of participation in decision making is cognitive rather than motivational. Participation stimulates information exchange and leads to a better informational basis, e.g. on efficient task strategies.

Training is one of the most pervasive methods for enhancing the skills and performance of individuals. Over the past decades, there have been several cumulative reviews of the training and development literature. Most recent meta-analytic review was conducted by Arthur, Bennett, Edens and Bell (2003). Authors examined the relationship between specified training design and evaluation features and the effectiveness of training in organizations. Depending on the criterion-type, the sample-weighted effect size for organizational training was d = .60 - .63, which is a medium to large effect. Results indicated a substantial decrease in effect sizes from individual learning outcomes to manifestations in subsequent job behaviors and organizational performance outcomes. This decrease in effect size points to the critical issues of favorability of the posttraining environment for the performance of learned skills. Trained and learned skills will not be demonstrated if incumbents do not have the opportunity to perform them (Noe, 1986; Ford, Quinones, Sego & Speer Sorra, 1992).

In the field of safety, the development of employee’s competencies through training programs may increase the knowledge of hazards and how to control them, improve skill levels, and help develop better hazard control strategies. However, safety related training is often flawed because it is conducted in an environment where the members of the group are unknown to each other. Hence different group norms, standards and behavior emerge as compared to the original work setting. Therefore, knowledge acquired and safety attitudes developed in the training environment will not be used or reinforced by superiors and colleagues in the original work setting. Additionally, objectives and aims of the trainings are mostly unclear to the trainee and the organization, respectively. Hence superiors and colleagues do not know how to capitalize on the new skills. Personal development programs that identify health and safety needs of the employees and link those needs to strategic requirements of the organization may overcome some of these constraints.

Performance feedback is usually defined as information about the effectiveness of particular work behaviors and is thought to fulfill several functions. For example, it is directive, by clarifying specific behaviors that ought to be performed, it is motivational, as it stimulates greater effort, and, it is error correcting, as it provides information about the deviations from a prescribed standard or level. The relationship between goals and performance is complex, but goals have been demonstrated to mediate the effectiveness of feedback, while feedback has been shown to moderate the effectiveness of goals. The relationship between goals and feedback can be construed as the joint effects of motivation and cognition that control action (Guzzo, Jette & Katzell, 1985). Goals, for example, inform individuals to achieve particular levels of performance in order to direct and evaluate their actions and effort, while performance feedback allows the individual to track how well they are doing in relation to the goal, so that if necessary, adjustments in effort, direction or possibly task strategies can be made.

Feedback has the potential to function in a variety of ways: as a reinforcer when it conveys success, as a punisher when it conveys failure, and as an antecedent when it prompts or cues the conditions under which responses will be reinforced and/ or punished. Perhaps it is because it can operate in all these ways at once that feedback has been found to be an especially powerful modification technique. In a meta-analysis of psychologically based interventions Guzzo et al. (1985) found goal setting to increase performance with an average effect size of d = .12 for management by objective, and d = .75 for goal setting on productivity. They reported a mean effect of d = .35 for appraisal and feedback. Kluger & DeNisi (1996) found a mean effect size of d = .41 for feedback and performance. That does not mean, however, that feedback is less powerful than goal setting. They complement each other, and, in combination, should be far more effective than either one alone, thereby providing a powerful management tool for effecting change.

Behaviors that positively effect performance must be contingently reinforced. Contingently administered money, feedback, and social recognition are the most recognized reinforcers in behavioral management at work (Bandura, 1986). Stajkovic & Luthans (2003) conducted a meta-analysis on behavioral management studies in organizational settings. They examined whether combined reinforcement effects of money, feedback and social recognition are additive or synergistic, i.e. the combined effects are greater than the sum of the individual effects. In particular, authors found a significant main effect of behavioral management on performance (d = .47). This average effect size represents a 16% improvement in performance and 63% probability of success. The effects of the individual reinforcers on task performance was 23% (d = .68) for money, 17% (d = .51) for social recognition and 10% (d = .29) for feedback. When these three reinforcers were used in combination, they produced the strongest, synergistic effect on performance of 45% (d = 1.88). The result that financial incentives strongly affect motivation and performance was found in numerous studies (for a review see Cameron, Banko & Pierce, 2001). In a meta-analytic review carried out by Jenkins, Mitra, Gupta and Shaw (1998) financial incentives were related to performance quantity (effect size of d = .34), but not related to performance quality. Tasks had been coded into intrinsic and extrinsic tasks. Contrary to expectations on intrinsic motivation (Deci, 1971) the task type did not moderate the strength of the relationship between financial incentive and performance quantity.

It is quite clear that financial and non-financial incentives can indeed increase performance when the incentive system is properly designed. Guzzo et al. (1985) reported an average effect size for financial incentives of d = .57 with a broad confidence interval that also included zero. Authors concluded that the strength of incentive effects depends heavily on the circumstances and methods of applying them. The major findings of 24 studies which have examined the effectiveness of the use of positive reinforcement and feedback was that all studies found that incentives or feedback were successful in improving safety conditions or reducing accidents, at least on a short term (McAfee & Winn, 1989). However, there are also some constraints to be noticed. Several studies reported situations in which safety indices did not improve. For example, Hopkins, Conrad, Dungel, et al. (1986) found that training and praise improved the use of respirator usage of only one of four sprayers (gelcoaters). Apparently, respirator usage was disagreeable to the other three workers because of the discomfort and inconvenience involved. A managerial challenge is to discriminate between reinforcing qualified people versus inflating the competence perceptions of unqualified employees.

Also the question remains of whether some incentives are more effective than others. Many consequences have been found to function effectively as reinforcers for many people. Among others, these include recognition, praise, privileges, material or monetary rewards, which can be embedded within compensation or performance appraisal systems, and preferred activities or assignments. Unless used with care, prizes and awards soon begin to lose their appeal, while having one's efforts specifically and sincerely acknowledged or praised by a respected peer or supervisor will tend to keep serving as a reinforcing function. Once high performance has been demonstrated, rewards can become important as inducements to continue, but not all rewards are external. Internal, self administered rewards that can occur following high performance include a sense of achievement based on attaining a certain level of excellence, pride in accomplishment, and feelings of success and efficacy. The experience of success will depend on reaching one's goal or level of aspiration.

Another issue to consider with respect to the effects of internal incentives is the nature of the task. Hackman and Oldham's job characteristics theory (1980) states that the degree to which the work is seen as rewarding is dependent on the degree to which the task possesses four core attributes: personal significance, feedback, responsibility/ autonomy, and identity as a whole piece of work. These core attributes are growth producing, and they fulfill important needs. A review of the literature on the relation of the core attributes, critical psychological states and the outcomes supports the approach despite the fact that some issues have been risen concerning the method of asking the same people for the core attributes, psychological states and outcomes (Algera, 1990).

5.2 Behavioral Safety Programs

Behavior sampling has been successfully used by several researchers implementing behavior modification safety programs (e.g. Komaki et al. 1978; Reber & Wallin, 1984; Reber, Wallin & Duhon., 1993; Shannon, Robson & Guastello, 1999 ; Sulzer-Azaroff, Harris, & McCann, 1994; Vassie & Lucas, 2001). This method is based on randomly sampled observations of individual's behavior, and evaluating whether observed behaviors are safe or unsafe. Lingard and Rowlinson (1997) introduced their intervention on construction sites with a series of joint goal-setting meetings, leading to specific performance safety goals concerning housekeeping activities, access to heights, and scaffolding construction. These meetings were followed by publicly displayed feedback charts for eight weeks, based on observations conducted by trained observers. During that time, the gap between the baseline level and the designated goals had to be minimized.

Goal setting in a paper mill improved performance if goals were assigned by supervisors, but not if they were set by the workers (Fellner & Sulzer-Azaroff, 1985). McCarthy (1978) used a time series design to reduce the number of "high bobbins" in a textile mill. Bobbins are spindles of thread which, if not pushed down far enough, cause tangles. Introducing goals of increasing difficulty plus feedback led to a steady decrease in the number of high bobbins. When feedback was removed, the number of high bobbins increased and then decreased again when feedback was reintroduced. Saari (1987) significantly improved housekeeping in a shipyard through feedback and implicit goal setting. Employees were given a written list of correct work practices, shown slides illustrating correct and incorrect practices, and given a one-hour training seminar. The observed correct practices on the shop floor were presented with posted boards showing the performance on a quantitative index. Chhokar & Wallin (1984) used a six-stage time series design for machine shop workers: baseline, training plus goal setting, weekly feedback added, monthly feedback added, training and goal setting only, and bimonthly feedback added. Safe behavior of the employees was defined as the percentage of employees performing their jobs in a completely safe manner. They found an increase in performance which reached 95% of maximum possible safe performance, if goal setting and feedback was provided. This was an increase of 30% as compared to the baseline of 65%. Alavosius & Sulzer-Azaroff (1985) introduced feedback on safe performance in patient-transfer by staff in a hospital, thereby improving significantly proper lifting techniques.

The effects of goal-setting are applicable not only to the individual but to groups (O'Leary-Kelly, Martocchio & Frink, 1994) and organizational units (Rodgers & Hunters, 1991). A growing amount of research has been done showing positive effects of goal setting and feedback for groups. Among others, Latham and Kinne (1974) and Nadler (1979) found that specific goals led to better group performance than unspecified, vague goals. Other researchers reported (Latham & Yukl, 1975) that groups performed better if their goals were difficult rather than if they were easy. The effectiveness of task feedback in group goal setting will be maximized if feedback involves both individual and group performance information. In addition, to maximize the productivity of such teams, information and control systems should contain information on team progress and individual progress.

An instructive example of the interaction of various elements of a behavioral safety management program is the study of Komaki et al. (1978). Authors introduced goals and feedback to improve worker safety in two departments in a food manufacturing plant. The intervention consisted of identifying safe and unsafe practices, the safe practice was introduced as the desired behavior goal, a board was posted with the baseline data of safe behavior, and the departmental goal of 90% was suggested and agreed to by the employees. Thereafter, whenever observers collected data, they posted on the graph the percentage of incidents performed safely by the group as a whole. In addition to feedback, another planned component of the intervention program was for supervisors to recognize workers when they performed selected incidents safely. To ensure the participation of the supervisors, the president and the plant manager were asked to talk to each supervisor about the safety program at least once a week.

Following the intervention in both departments, the percentage of safe practices increased significantly. By the first week, the wrapping department of the bakery had obtained their first 100% score. During the entire intervention, no score fell below the baseline, and over half of the time, the department obtained 100% scores. Scores in the make-up department immediately rose to 100% and, with one exception, continued at this level. During the reversal phase, however, performance dropped to baseline levels (see fig. 4). Difficulties were encountered in implementing the recognition component of the intervention. Only 15% and 54% of the recognition checklists of the supervisors were turned in, respectively. Although management continued to give their verbal support, there were few indications that management was communicating their support to supervisory personnel.

Overall, some important issues of implementing a behavioral safety program can be derived from this study. A requirement analysis was performed jointly with supervisors, a difficult goal of safe performance score was suggested and agreed upon by workers, observations of critical actions prior to the intervention served as baseline level, safe conduct rules (i.e. behavioral standards) were explicitly stated, and specific feedback consisting of the weekly percentage of safe practices was publicly displayed. The fact that performance returned to baseline levels during the reversal phase indicates that the program was not sufficiently supported by employees, supervisors and management.

Fig. 4 Effects of goal-setting and feedback on safe performance in two departments of a food manufacturing plant. (From Komaki et al., 1978).

Participative approaches look more promising to ensure commitment of workers and of superiors. They include: participative goal-setting, establishment of problem solving groups, quality circles and use of group discussion techniques (e.g. Marks, Mirvis, Hackett & Grady, 1986). Participative goal setting was applied to set safety improvement goals for critical behavior in a three-shift production plant (Cooper, Phillips, Sutherland & Makin, 1994). All factory personnel, including senior management, attended their respective department's goal setting meetings. Performance feedback was presented graphically in each department on a weekly basis. The results indicate significant improvements in safety performance, with a corresponding reduction in the plant's accident rate. There was a lack of support, however, for an inverse relationship between actual safety performance and accident rates. It was found that the nature of the tasks mediates the relationship between safety performance and accident rates including such factors as time pressure, manning level, and sickness absenteeism, which created a greater time pressure for workers. Nature of the task and sickness absenteeism explained 70 percent of the overall variance on accidents. These findings further reinforce the importance of ascertaining the effects that managerial, organizational and job related variables have in impacting upon workplace safety.

An intervention program using safety circles to reduce accidents with respect to housekeeping was introduced in a Finnish shipyard (Saarela, 1990). Two main tasks were given to the small groups: identifying and eliminating obstacles of good order and safety and establishing new housekeeping practices in the department. Members of top-management and the safety organization coordinated the program and disseminated general information concerning the program. Results indicated a 20 per cent decrease of occupational accidents related to housekeeping during the intervention period and one year later after the implementation. Gregersen, Brehmer and Moren (1996) reported a study using the group decision technique to improve the commitment in safety of the drivers of a Swedish telecommunication company. Drivers met in groups of 10-15 persons to discuss general and specific problems related to safety. After the third meeting, each driver decided about his/ her own future activities to solve the safety problem in question. This was only one of the conditions in the safety program which included driver training, safety campaigns and a bonus system for safe driving. There was a significant decrease of accident rates in the experimental group which performed under the condition of group discussion, but none in the control group.

As Sulzer-Azaroff (1978; 1982) points out, safe and unsafe practices probably persist because they are in some way naturally reinforced. In addition, although there are natural punishers for committing risky acts, for example, injuries, pains, sicknesses, these are often delayed, weak, or infrequent. Most health hazards are not perceivable at all and negative consequences have to be inferred from knowledge, memory or experience with a considerable risk of drawing wrong conclusions. Safety programs often have turned to heavily emphasizing behavioral antecedents directly at the workplace. Signs, guidance, threats, incentives, goals, training, work design and ergonomic design of workplaces are among the more frequently utilized antecedents. The antecedents of risky performance frequently are difficult or impossible to control. No one can alter an individual's history of reinforcement, and modifying such conditions as hazard perception, risk assessment, or turning risky performance into preventive behavior are at best difficult.

The key practical implication from the results on behavioral safety programs is that behavioral management strongly impacts performance in organizations. However, managers have to take into account that organizational process and design problems may limit the effectiveness of such programs. Aside from the difficulties of proper installation of ABC principles into procedures, techniques, and actions, they are contingent upon the characteristics of the individual organization. They depend on function, policies and strategic goals of the organization, type of technology used, requirements of the market in terms of stability and flexibility, and socio-cultural background of employees. High reliability organizations such as in the nuclear industry require different procedures and techniques as compared to companies in the construction industry. Another managerial concern refers to commitment and durability. One possible way to ensure long term commitment of employees and superiors is to address both behavior and attitudes simultaneously by fostering active employee involvement, and utilizing feedback in long-term programs. This requires employees to become involved and actively participate in the identification of hazards, substandard practices and conditions, in the setting of goals, and in monitoring the safety performance of their colleagues. Management commitment and support are essential prerequisites to facilitate this type of safety intervention.

5.3 Human Resource Management

The last two decades have witnessed a remarkable shift in human resource management (HRM) research from a micro-analytical approach to a macro-strategic perspective. People are recognized as the strategic resource, shifting the focus of attention on linking HRM practices with business strategy and organizational performance (Pfeffer, 1994; Huselid, 1995; Paul & Anantharaman, 2003). Although the HRM-performance relationship has been proved, the linkage process remains unclear (Becker & Gerhart, 1996). Some researchers have proposed competence, commitment, congruence and cost effectiveness as intermediary variables (Beer, Spector, Lawenrce, et al., 1984). Becker and Huselid (1998) have suggested that intervening variables such as employee skills, motivation, job design, leadership and work structure link operating performance.

Management of an organization's human resources includes such activities as personnel planning, recruitment, placement, development, performance appraisal, training and competency assessment, counseling and guiding of individuals and groups (leadership), payment concepts, back-to-work programs and rehabilitation at the workplace. Such personnel systems include valid selection procedures for hiring and promotion purposes, performance appraisal and review systems to ensure that the person is measured on the right goals and standards and receives accurate feedback, effective training procedures for the development process, and labor relations that are conducive to employee motivation. Personnel development of people’s capabilities means in-company training focused on the company related targets, closing the gap between the actual state of the art and the target state through qualitative personnel planning, and supporting and realizing career planning with personnel-related targets. Contractors, suppliers, and temporary workers have to be included in the training program according to the level of risk to which they may be exposed or could cause.

With respect to safety a major purpose of the performance appraisal process is to modify behavior, to feed back information to the employee for counseling and development purposes so that the person will start doing or continue doing the activities critical to effectively performing on the job. The feedback must lead to the setting of and commitment to specific HSE goals. External and internal rewards play a significant role in getting people to accept goals and motivating them to maintain goal-relevant behavior in the long term. The key reward in organizational settings is probably not feedback but rather the consequences to which feedback leads such as recognition, praise, raises, financial rewards and promotions, privileges, material or monetary rewards, which can be embedded within compensation or performance appraisal systems, and preferred activities or assignments. Internal, self administered rewards that can occur following high performance include a sense of achievement based on attaining a certain level of excellence, pride in accomplishment, and feelings of success and efficacy.

Recently, new concepts and frameworks of HRM systems with respect to health, safety and environment have been proposed by Hutchinson and Hutchinson (1997); Zimolong (2001b); Zimolong and Elke (2001). Key elements of the systems are people management, management of information and communication, (re)design of work and technology, and management of an HSE supporting culture. Generic management activities include those of the management control loops of the ISO-standards. Up to date, the relationship between HRM practices, procedures and organizational health and safety performance has not been thoroughly investigated. Reviews on HRM literature with respect to health, safety, and environment (Zimolong, 1997; Hale & Baram, 1998; Zimolong & Elke, 2001a) revealed a number of lines of research and isolated studies on HRM topics. However, the linkage between HRM and organization’s HS performance remains a black box.

Zimolong and Elke conducted a cross-organizational study in the chemical industry to identify key practices and systems of HRM that are connected to organization’s HSE performance (Elke, 2000; Zimolong, 2000). Practices, processes and structures in HSE-related planning and design of work systems, in human resource management, in information and communication management, and in cultural aspects were sampled through interviews and questionnaires. Other topics addressed the control strategies of the human resource subsystems such as lead, training, and incentive systems, and the kind of substitutes companies have developed to maintain an efficient control loop. In total 18 plants participated, their size ranging from 200 to 1,500 employees. Managers from top to lower level (n=292), HSE experts (144) and union representatives (55) were personally interviewed. A sample of 10-15 % of the workforce responded to an HS management questionnaire. In sum 686 interviews were conducted and 1.536 questionnaires returned. The study covered excellent and poor companies, as well as firms getting better or becoming worse within a period of four years. The HS performance level of companies was measured by the frequency of lost time injuries (LTI>3 days) and ill-health related lost work days. LTI-figures were converted into relative accident rates taking into account levels of risks associated with the production of chemicals (products). The excellent group included all companies which stayed under the median of their comparable risk group for four years (range between 1.5 and 13.1 accidents per 1.000 employees). In the progress group plants improved during the last two years of the study period. They showed similar LTIs as the excellent group. In the fall off group companies got worse in their HS performance; their median was equal to the median of the overall risk group. Finally, the poor group included all plants that reported always LTIs above the median of the risk group (range from 13.7 to 125.4).

In each company the actual status of the HRM procedures and systems with respect to control strategies, recruitment, selection and placement, performance appraisal, training, leadership style, and incentive programs was raised. Members of the human resource departments documented the official use of the human resource (HR) systems. This was called the documented status of the systems. Additionally, 100 interviews with the managers of different departments (production, planning, maintenance and personnel) were carried out to compare the documented status with the systems actually in use, i.e. applied by the managers. A rather strictly defined criterion for the "practiced application" was chosen: More than 50 % of the interviewed managers of a plant had personally to confirm the regular use of a system. Otherwise it was coded as not practiced.

The most frequently documented HR systems were appraisal systems (53/31%), career development and promotion systems (53/26%), training systems (47/24%), and reward systems (40/34%). The second figure indicates the practiced systems. As expected, there is a considerable difference between the documented state and the actual application of the systems. Most differences between documented systems and systems in use exceed 20 percentage points. Organizations differ fundamentally in how they control the usage of a HR system. A complete control loop (Deming loop) has three phases: monitoring, measuring, and reviewing and taking action, if necessary. Most companies monitor the application of systems (65%), only 16% measure it, however, 31% review the outcomes. As compared to the poor group, excellent companies show a higher percentage of reviews (57/20%), but have similar figures in monitoring (57/60%) and measuring (14/0%).

Insert fig. 5 Application rate of human resource systems for the management of health and safety in excellent, progress and poor companies. Excellent management uses a combination of systems: strong leadership accountability, appraisal, and reward systems.

Leadership related to HS, performance appraisal, reward system, career development and promotion, and training systems are the most frequently documented as well as practiced applications of HR systems (see fig. 5). In general, poor companies only use one or two systems, mainly leadership, occasional appraisal or development systems. The most remarkable difference between the excellent and the poor group is the adoption of reward systems related to HS performance for managers and workers. Companies striving to improve their HS performance invest many activities into HRM systems. Application rate is higher as compared to the excellent firms.

The combination of systems creates a further distinction between the groups. Excellent companies mostly combine strong leadership accountability in HS with appraisal and reward systems. The adoption of the triad seems to be a key characteristic of the successful companies. No particular pattern of combined systems emerges from the progressing or poor group. Companies striving to get better do not yield typical patterns of HRM systems; they invest into all systems. To summarize, companies with excellent records in HS performance mainly rely on strong leadership responsibility in HS, on appraisal, and on reward systems that are combined to a "holistic HRM system". These systems not only include indicators of business performance, they also address HS indicators and performance. No stand alone or parallel management system based on HS criteria has been found. Companies of the progress group have adopted a variety of systems. Eventually they will reduce the multitude of systems to a few combined systems, which will form their typical HRM profile.

Systems have to be monitored, reviewed and changed, if necessary. Typical control strategies of the excellent companies include monitoring, reviewing and taking actions. However, it seems that some companies have developed substitution measures for superior-based control loops. One approach is the introduction of self-managed teams, whose members have managerial responsibilities for HS.

5.4. Design of Work and Technology

The outcomes of safety, health and well-being depend to a significant degree on the installation and maintenance of safe and reliable technology, as well as on ergonomic and psychosocial aspects of work design. General topics and methods of systems safety engineering are concerned with guarding energy sources, design and redesign of machinery, equipment and processes, application of environmental standards, and establishment of inspection systems, such as statutory engineering inspections of pressure vessels, cranes and lifting machines, or electrical installations (see Ridley & Channing, 2003).

Ergonomic and psychosocial aspects of work are potential contributors to the health and well-being of employees and organizations. Their health effects can also be regarded as contributors to work motivation, or work performance. From an ergonomic perspective, the design of the environment, workstations, tasks, work organizations, and the tools or technology should reasonably accommodate the employees' capacities, dimensions, strengths, and skills. Particularly, it should accommodate the human sensory capabilities, support the decision-making processes and adapt to the human performance abilities. Error-prone designs place demands on performance that exceed capabilities of the user, violate the user's expectancies based on his or her past experience, and make the task unnecessarily difficult, unpleasant, and error-likely. One example are back injuries: High physical energy expenditure, no variation in work movements and postures, prolonged standing, sitting or stooping, or repetitive work can contribute to the development of musculoskeletal problems, low-back pain and back disorders.Critical aspects of the success of ergonomic interventions for providing health and psychosocial benefits are a strong management support for the ergonomic program. Further aspects are: the involvement of managers, supervisors and employees, the willingness to participate in defining problems, proposing solutions, and improving work practices; and the application of engineering improvement to reduce biomechanical and physiological loads.

There are various characteristics of working that have generally been shown to have negative physical and/ or psychological consequences, for example, machine-paced work, a lack of task control, high job demands, shift work, time pressure, and poor supervisory relations. A person normally copes with transactional periods of stress by either altering the situation or controlling his or hers reactions. Problems arise when work conditions are in conflict with human capacities and expectations over a long period of time, and when coping fails. The extent of the negative consequences varies from individual to individual depending on the perceived threat, individual constitution, and coping mechanisms. Tension, boredom, worry, anxiety, and irritability are inevitably some of the first indicators of strain. Emotional stress reactions are quite normal responses. Short term stress reactions may include increases in blood pressure, adverse mood states, and job dissatisfaction. Depression and apathy are later symptoms. Long-term stress reactions may even accumulate to cardiovascular diseases and upper extremity disorders (Kalimo, Lindstöm & Smith, 1997).

Job control and social support are beneficial factors for well-being and job satisfaction. The person can have control over various job demands, such as the task itself, pacing of the work, work scheduling, the physical environment, decision making, other people, or mobility. When job control is high, the other job demands tend to have less potential adverse effects on health. Social support is thought to exert a protective function during conditions of stress, i.e. to ‘buffer’ a person against the harmful effects of the social environment. Evidence for the beneficial effect of job control and social support is conclusive enough to promote better job designs and interpersonal interaction at the workplace.

The criteria in job design deal with the physical work environment, compensation systems, institutional rights and decisions, job content, internal and external social relations, and career development. According to quality of working life principles the following characteristics of job content are of main interest: variety of tasks and task identity; feedback from the job; perceived contribution to product or service; challenges and opportunities to use one's own skills; and individual autonomy. Depending on the degree of autonomy, the team design approach allows members to regulate their work activities by themselves. People get a better idea of the significance of their work and create greater identification with the finished product or service. If team members rotate among a variety of subtasks and cross-train on different operations, the team can become more flexible. Teams with heterogeneous background also allow for synergistic combinations of ideas and abilities not possible with individuals working alone, and such teams have generally shown higher satisfaction, better involvement, and superior performance, especially when task requirements are diverse.

In any redesign process there are trade-offs among specific improvements and achieving the best ‘overall’ job design solution. There is no perfect job design that provides complete psychological satisfaction and health for all employees, and maximizes the outcomes of the organization. Making jobs more mentally demanding increases the likelihood of achieving people's goal of satisfaction and motivation, but may decrease the chances of reaching the organization's goals of reduced training, staffing costs, decent wages and error-free products and services. Which trade-offs will be made, depends on the outcomes the organization prefers to maximize.

6 Concluding Remarks

The past two decades have witnessed a significant transformation in how firms are structured. Tall organisations with many management levels have become flatter; competitors that have adopted a modular organisational structure have gained market shares. Organizational delayering and the rise of smaller, often entrepreneur-based firms gives self-management new meaning covering personal self-management, self-leading teams and semi-autonomous units. Companies and public services adopt cooperative forms of work at a very fast pace. Teleworks provides flexibility in both working hours and the location of work and allows employees to cultivate tailored life-styles while working a full-time job. These 'boundary less' organisations e.g. organisations whose membership, departmental identity and job responsibility are flexible create new challenges for safety management, particularly for people management.

The traditional approach to managing people focuses on selection, training, performance appraisal, and compensation for individuals in specific jobs. It also presumes a hierarchy of control loops rather than horizontal work-flow sequences. When tall organizations become flatter and/ or are restructured around teamwork, different forms of team autonomy and HS responsibilities are emerging. Selection, performance appraisal, and reward policies are the most likely candidates for change. Contingent pay and peer pressure generated by teams are emerging as substitutes for both managerial influence and internalized member commitment. HS criteria, rules, procedures, and achievements have to be reformulated and integrated into the systems. Delayered organizations also need to develop combined systems, particularly, a recruitment system which includes participatory concepts of job analysis and assessment, and a team management system focusing on performance appraisal, compensation, rewards and benefits, and personal career development. Systems are based on peer reviews instead of managerial appraisal and on team based output measures instead of individual performance. This requires an intensive qualification process for the employees and new cognitive and social skills to run the systems.

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8a List of Tables

Note: Table 1 – 4 are identical with tables 31.2; 31.5; 31.6; 31.7; published in chapter 31 of 1997;

8b List of Figures

Note: Figures 2 – 4 are identical with figures 31.2; 31.3; 31.5 of 1997

Table 1 Some forms of possible health hazards

Category	Examples
1. Physical hazard	Noise, temperature and humidity extremes, illumination, vibration, infrared and ultraviolet radiation.
2. Biological agent	Micro organisms, germs, viruses, toxins.
3. Chemical hazard	Include mists, vapors, gases, fumes, dusts, liquids, pastes whose chemical composition can create health problems.
4. Physical workload	Working postures, physiological load, movements and exertion of forces, manual material handling and lifting.
5. Mental workload	Perceptive and cognitive workload.
6. Stress	Resulting from control demands and individual control capabilities, from role conflicts and ambiguity; emotional strain resulting from aggression, loss of feedback, loss of control, helplessness.

Table 2 Hazard analysis and risk assessment techniques.

Instrument	Short description	To be used at
Formal methods: Hazard and operability studies Failure mode and effects analysis Fault tree analysis	HAZOP and FMEA belong to the inductive techniques: What happens if a coolant pump fails? System and its components are analyzed with regard to operability and process to identify hazards, malfunctions, weak points. Mostly complex and time consuming, multi-disciplinary brainstorming sessions. Requires high levels of expertise. FTA belongs to the deductive techniques: How can the failure of the coolant pump happen? Graphical presentation and analysis of logical contributions of errors and failures to one type of malfunction of a system.	Suited for plants and situations with high risk or severe consequences. The objective is to design out risk at early stages of planning or when changes are to be made.
Standards, thresholds, limit values	Simple way of evaluation whether situation is acceptable. Powerful design technique. Some standards or threshold limits are based on epidemiological data. Gives little information about severity or probabilities of hazards.	Evaluation of health hazards, for example noise and vibration levels, exposure to chemical substances; evaluation of several aspects of workplace, especially ergonomic standards for workplace layout, space, environment, tools, equipment, machines.
Risk classification and ranking	Simple classification scheme for various kinds of hazards. A rank ordering of the identified hazards is drawn up, severity and frequency of occurrences are assessed in terms of qualitative effect classes. Outcome gives information of the risk and the priority on precautions to be taken.	Evaluation of safety and health hazards. Simple technique to be used at all levels of organization and at workplaces. Relative ranking of risks. An example is shown in fig. 2.

Table 3 Detection and perception of hazard indicators.
The frequency of demands per hazard is rated in percent (after Hoyos & Ruppert, 1993).

	Requirements	Rated total %
1.	Visual recognition	77.3
2.	Selective attention	63.0
3.	Division of attention	57.5
4.	Rapid identification and responsiveness	56.3
5.	Perception of incessant hazards	51.5
6.	Observation and maintenance of distance	44.2
7.	Detection of potentially dangerous objects	28.0
8.	Vigilance	25.0
9.	Auditory detection	21.2
10.	Recognition of changing danger zones	19.9
11.	Directed attention (distance)	17.9
12.	Auditory recognition e.g. of warnings	15.9
13.	Visual recognition e.g. of warnings, labels	7.3

Table 4 Prediction and evaluation of hazard indicators.
The frequency of demands per hazard is rated in percent (after Hoyos & Ruppert, 1993).

	Requirements	Rated total %
1.	Estimates of physical units (e.g. weight, force and energy)	32.7
2.	Identification (screening) of defects and inadequacies	29.6
3.	Prediction of structural weaknesses	25.1
4.	Expectancy of warning stimuli (e.g. railway signal lights)	19.8
5.	Perception of visual cues (e.g. flags, traffic or warning signs)	19.6
6.	Subjectively perceived somatic symptoms (e.g. dizziness, breathlessness, nausea)	19.5
7.	Predictions of non-obvious dangers (e.g. radioactive contamination, bacterial infection)	17.7
8.	Recognition of instable storage (e.g., open paint containers, excessively high piles of bricks)	16.3
9.	Comprehension of warning-signals (e.g. symbols, colors)	16.1
10.	Evaluation of material stress (e.g. material pressures, efficacy of heat resisting clothing)	16.0
11.	Interpretation of displays and data (e.g. gauges, switches, monitors)	5.4

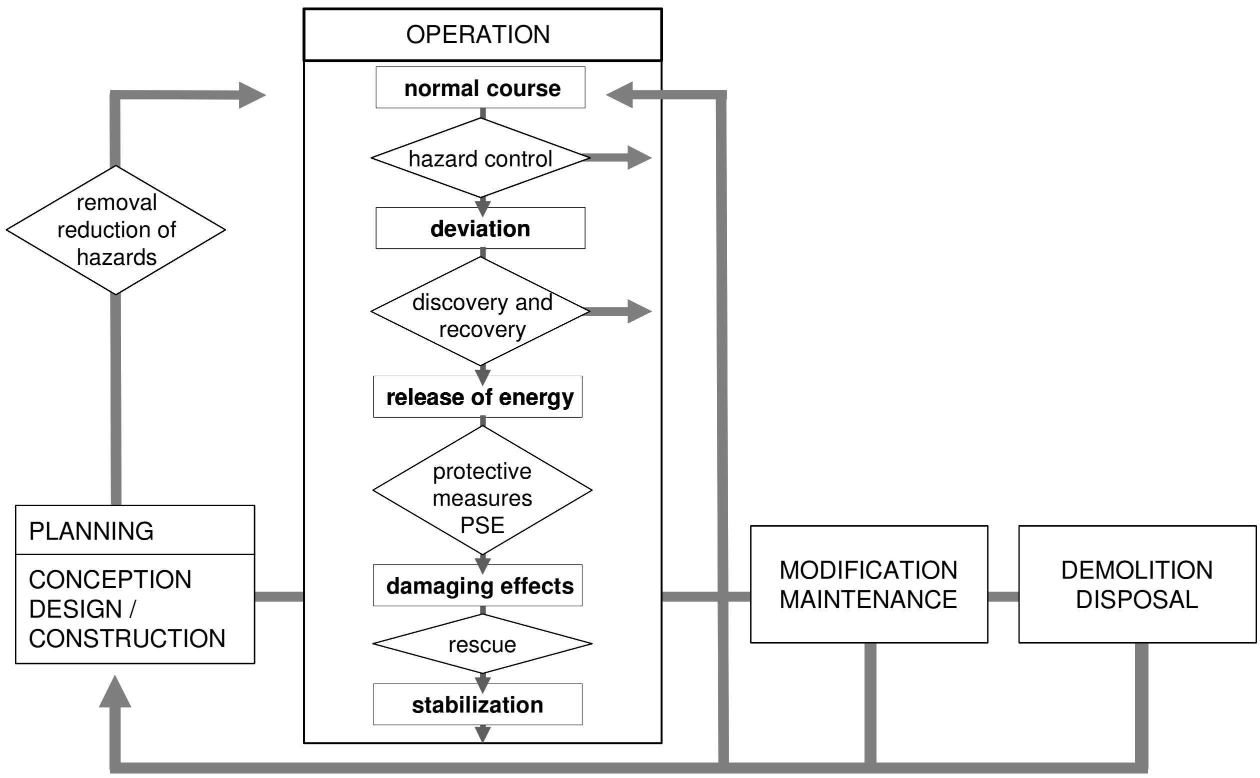

Fig. 1 Risk assessment and effect management through life cycle of business activities. Process consists of four steps: identify, assess, control, and recover. Hazards are interpreted as deviations from standards. Four generic life cycle phases – design/planning, operation, modification/maintenance and demolition - are shown from left to right. For the operation phase, the normal, deviation and rescue phase is exemplarily depicted.

Risk Index

What could have happened ?

How often can the consequences occur ?

P (injuries of persons)	**S (damage of property)**	extremly seldom (once in 5 years)	seldom (once a year)	sometimes (once a month)	often (once a week)	very often (more than once a week)	
First-Aid Accident	< DM 5,000	0	0.01	0,1	0,5	1	1
Accident without absence from work	< DM 50,000	0,02	0,1	1	5	10	2
Accident with absence from work	< DM 100,000	0,2	1	10	50	100	3
death	< DM 1,000,000	2	10	100	500	1.000	4
several cases of death	> DM 1,000,000	20	100	1.000	5.000	10.000	5
		A	B	C	D	E	

Fig. 2 Determination of a risk index

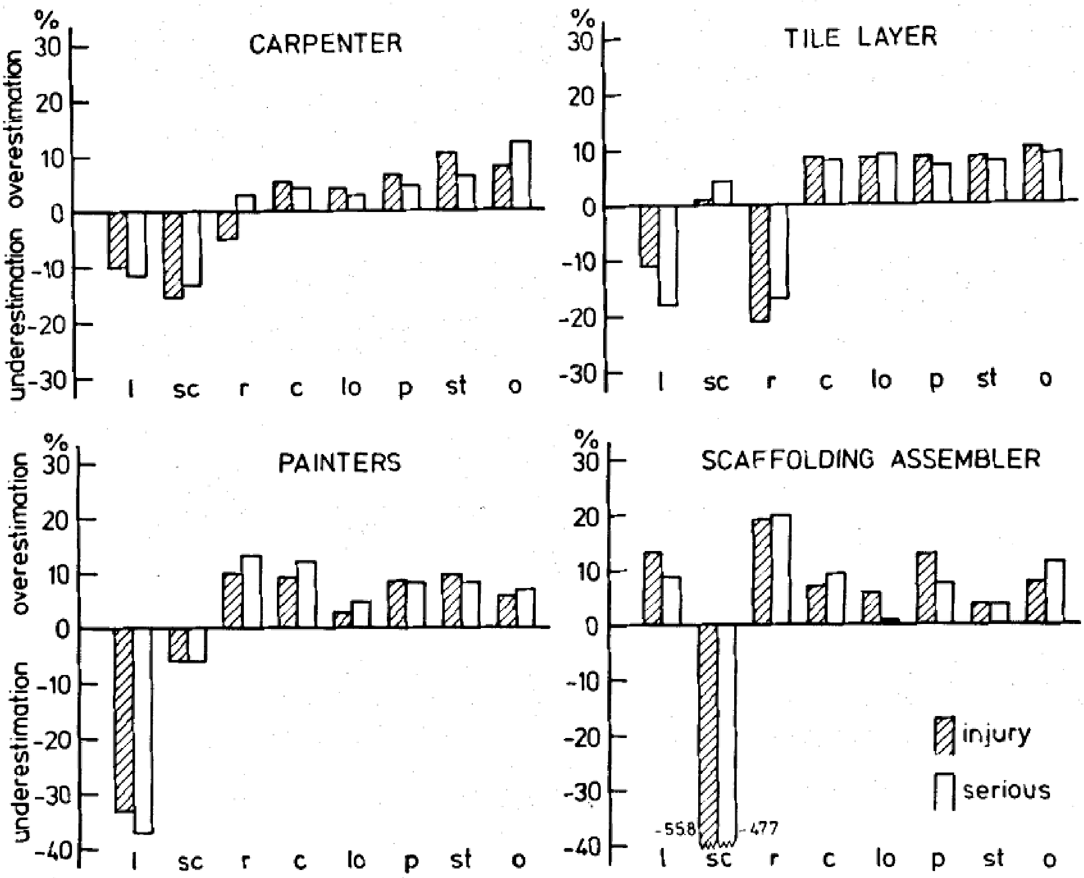

Fig. 3 Subjective risk estimation of accidental falls from various work sites. Columns depict positive percent figures (overestimation) and negative figures (underestimation) of specific work place risks. Assessments were made separately for eight different work sites including ladder (l), scaffolding (sc), roof (r) and stairs (st). (From Hoyos and Zimolong, 1988, p.175)

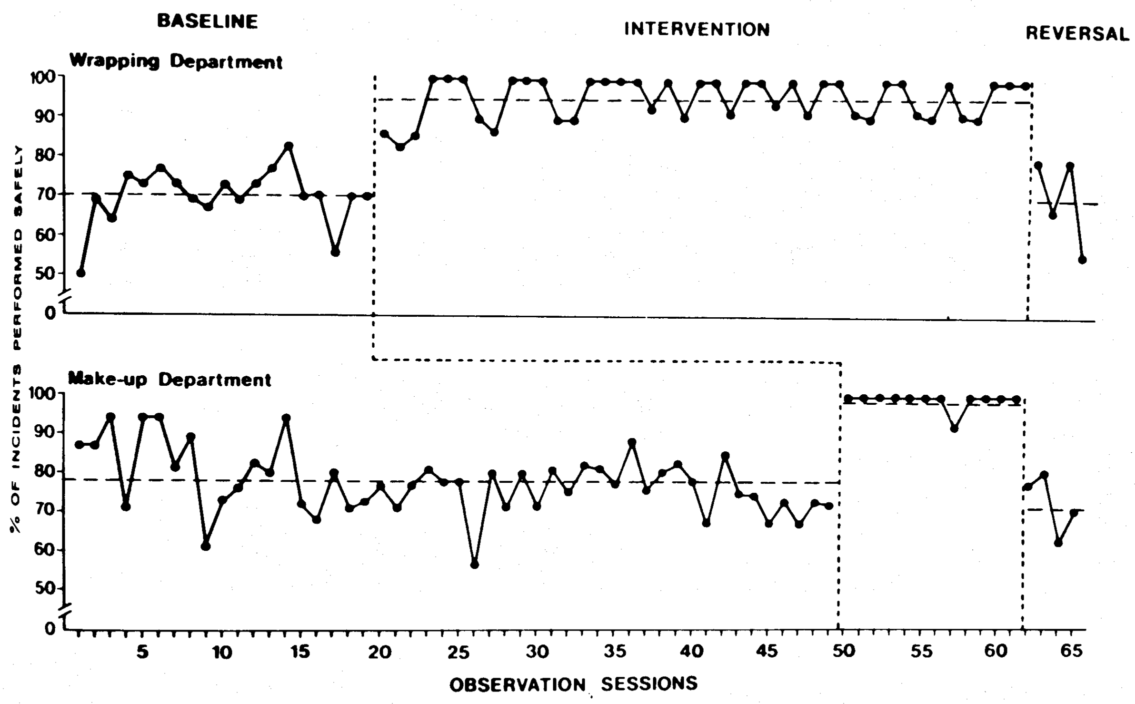

Fig. 4 Effects of goal-setting and feedback on safe performance in two departments of a food manufacturing plant. (From Komaki et al., 1978).

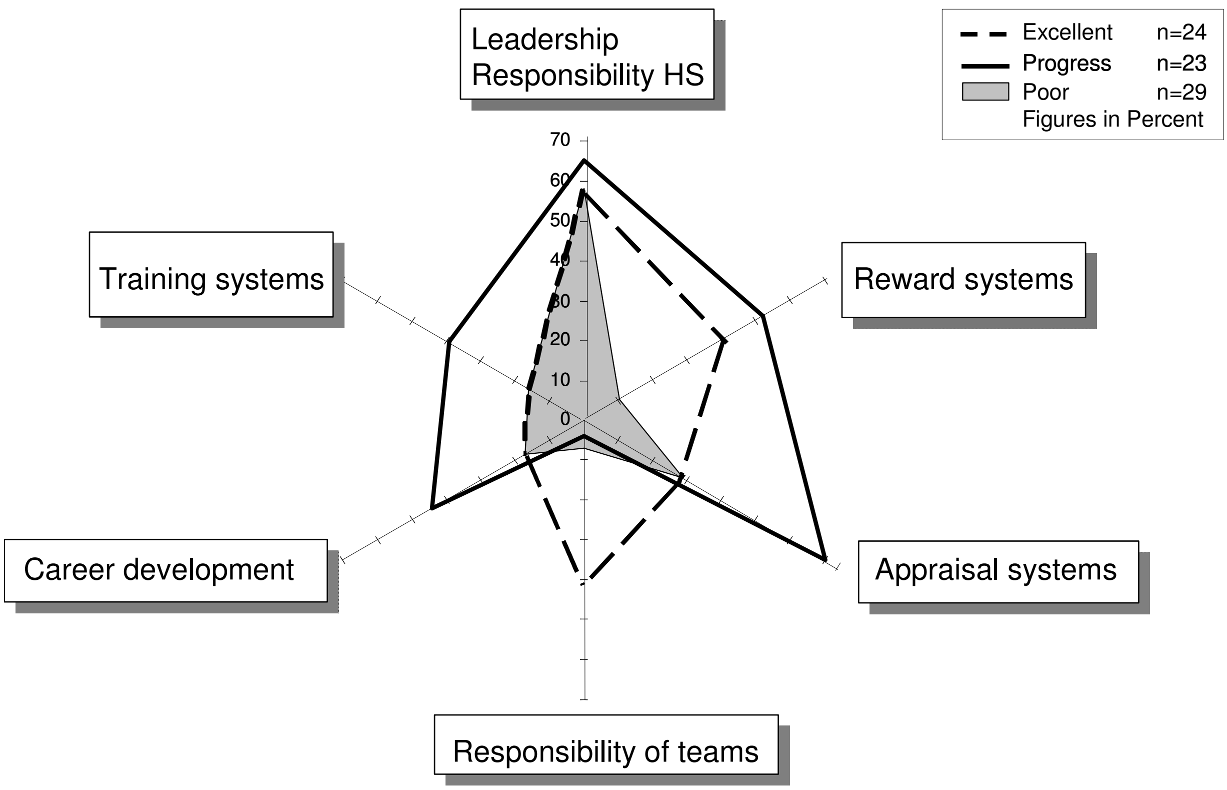

Fig. 5 Application rate of human resource systems for the management of health and safety in excellent, progress and poor companies. Excellent management uses a combination of systems: strong leadership accountability, appraisal, and reward systems.