LAPPEENRANNAN TEKNILLINEN KORKEAKOULU
LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

TIETEELLISIÄ JULKAISUJA 9
RESEARCH PAPERS

HEIKKI LAITINEN

DETERMINING RISK POTENTIAL THROUGH ACCIDENTS AND NEAR-ACCIDENTS: AN EMPIRIGAL STUDY IN A STEEL FACTORY

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Thesis for the degree of doctor of Technology to be presented with due permission for public examination and critisism in Auditorium 4 of Lappeenranta University of Technology, Finland, on the 27th of September 1984, at 12 a.m.

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Heikki Laitinen

ABSTRACT

Fatal and permanently disabling accidents form only one per cent of all occupational accidents but in many branches of industry they account for more than half the accident costs. Furthermore the human suffering of the victim and his family is greater in severe accidents than in slight ones. For both human and economic reasons the severe accident risks should be identified befor injuries occur. It is for this purpose that different safety analysis methods have been developed .

This study shows two new possible approaches to the problem. The first is the hypothesis that it is possible to estimate the potential severity of accidents independent of the actual severity. The second is the hypothesis that when workers are also asked to report near-accidents, they are particularly prone to report potentially severe near-accidents on the basis of their own subjective risk assessment.

A field study was carried out in a steel factory. The results supported both the hypotheses. The reliability and the validity of post incident estimates of an accident's potential severity were reasonable. About 10 % of accidents were estimated to be potentially critical; they could have led to death or very severe permanent disability. Reported near-accidents were significantly more severe, about 60 % of them were estimated to be critical. Furthermore the validity of workers subjective risk assessment, manifested in the near-accident reports, proved to be reasonable.

The studied new methods require further development and testing. They could be used both in routine usage in work-places and in research for identifying and setting the priorities of accident risks.

CONTENTS

BASIC TERMS

Accident

An accident in this study is defined as a sequence of unplanned events which cause personal injuries (see Benner 1975 and 1983, Kjellén & Larsson 1980, Leplat 1978, Shannon & Manning 1980b, Tuominen & Saari 1982).

All accidents where the victim visited the nurse or physician were booked as accidents in the empirical part of the study. The accident sequence was devided into two phases, preceding phase and contact phase.

Near-accident

A near-accident is defined in this study as a sequence of unplanned events that could have resulted in personal injury although it did not actually do so. In the empirical part of the study the term near-accident means all cases which are reported by the workers.

Injury

An injury is defined in this study as a personal injury caused by an accident. It is a consequence of an accident.

Hazard

A hazard is defined in this study as having the potential to cause injury (see Goeller 1969, Hammer 1976).

The injury may be caused by energy which can be either external or internal to the individual. So a hazard can also be defined as a source of energy which can cause an injury.

Hazards can, for instance be classified into mechanical, chemical, physical, physiological, biological and psychological types.

Severity of an accident

The severity of an accident means in this study the severity of injuries caused by the accident.

The severity is measured in lost working days. Deaths and permanently disabling injuries are converted into lost working days so that death and totally disabling injury are equal to 6 000 lost days (ANSI 1967).

Potential severity and potentially injured part of the body

The potential severity of an accident and near-accident is defined as the severest injury possible in that situation.

The potential severity is rated by using as a criterion the nature and amount of the burst of energy. Whether the energy could have been directed at people or at a more sensitive part of the body than actually happened is also taken into consideration. This is then called the potentially injured part of the body.

Accident risk

In this study an accident risk is defined as a function of the probability and the severity of injury (Kuhlman 1981).

Objective risk means the empirical estimate of the risk. It is calculated as follows:

$$R = \frac{A \times S}{E}$$

where R = accident risk
A = number of accidents
S = severity of accidents
E = exposure time

As well as the absolute risk figures the relative risks also useful in comparing different groups with each oth The relative risks are calculated by dividing the absol risks with each other (Miettinen 1977, Rowe 1977).

Subjective risk

A subjective risk is defined as the risk estimate made one or a few trials or totally by conjucture (Rowe 1977

Risk potential

The risk potential is defined as a function of the probability and potential severity of accidents or near-accidents.

Risk identification

Risk identification means the discovery and qualitative definition of the risk associated with a particular activity (Rantanen 1981).

Risk estimation

Risk estimation means the calculating the quantitative figures. Risk estimates can be objective or subjective.

Risk determination

Risk determination is a process that covers both risk identification and risk estimation (Rowe 1977).

Risk assessment

Risk assessment is a process comprising identification, estimation and evaluation (Rantanen 1981, Rowe 1977).

Risk evaluation provides individual or social value for an identified and estimated risk. It is a societal process rather than a scientific one (Rantanen 1981, Rowe 1977).

1. INTRODUCTION

1.1. Background and purpose of the study

About 200 000 occupational accidents take place in Finland every year. About 0.1 % of them lead to death and one per cent to permanent disability. In 70 % of the accidents more than 3 working days are lost and in 15 % of the accidents more than one month is lost. In the 1970's more than 2 600 people died in occupational accidents. About 15 000 workers had permanent injuries in 1980 (Vakuutusyhtiöille ja tapaturmavirastolle ilmoitetut tapaturmat 1981).

Fatal and permanently disabling accidents form only one per cent of all occupational accidents but in many branches they account for more than half the lost working days and accident costs (Rönnholm 1983). Most of accident expenses are incurred by accidents which lead to death, permanent injuries or long absence (Skiba & Grabnitzki 1971, Hemminki 1978, Klen 1981, Laitinen 1981; Rantanen 1982). Also the human suffering of the victim and his family is greater in severe accidents than in slight ones. So the severity is an important variable in accident prevention.

Severe and slight accidents have been found to differ in that:

- the severity of accidents varied in different branches (Abt 1982, Cooke & Blomenstock 1979, Laitinen 1983, Mikkola 1981, Rönnholm 1983)
- the accident sequence was longer in lost-time accidents than in non-lost-time accidents (Shannon & Manning 1980a)
- severe accidents reported to safety authorities differed from the average accident in the same branch in relation to the activity of the victim and the source of the injury (Laitinen 1983)

- the victim's activity "work with a machine" was overpresented and "manual work" underpresented in fatal and permanently disabling accidents compared with all accidents (Abt 1982)
- the victim was standing still and the source of injury moving more often in fatal than other accidents (Abt 1982)
- the proportion of "fall to a lower level" was greater in fatal and permanently disabling accidents than in the average of all accidents (Abt 1982, Senneck 1975)
- the proportion of "fall on the same level" was greater in permanently disabling accidents than in the average of all accidents; it was lowest in fatal accidents (Abt 1982)
- fall to a lower level and contact with a moving object caused a long absence more often than other accidents in steel factories (Carlsson 1982)
- injuries to the eye and head caused a short absence more often than other injuries (Työtapaturmat 1981 liite 7) but on the other hand in more than 70 per cent of fatal accidents death was caused by head injuries (Abt 1982)
- the proportion of arm injuries was smaller and leg injuries greater in permanently disabling accidents than in all accidents (Abt 1982)
- lost working days increased with the age of the victim (Skiba & Kröger 1979) but in another study the absence of young victims was longer than that of middle-aged ones (Cooke & Blumenstock 1979).

Behind this study lies the literature review of the economic effects of labour protection made by the author and published in 1975 (Laitinen 1975). In writing that the idea of studying practical solutions to so called "damage control" at factory level was born. The basic concepts being an awareness of accident costs and the extension of prevention from injuries to include property damage and near-accidents.

The empirical study of a damage control system was carried out in 1979-80 in cooperation with Ovako Oy Ab Imatra Steel Factory (Laitinen 1981). The purpose then was to clear up the extent to which accidents and near-accidents are analogous, how great are the costs of accidents and near-accidents to the company, the worker and society and how can a damage control system best be integrated into the normal routines of Finnish companies.

The results showed that the near-accidents reported by the workers differed from the accidents according to the accident sequence. Reported near-accidents seemed to be very serious. This led to the hypothesis that owing to their own subjective risk assessment workers are especially prone to report the kind of near-accidents which could have led to severe injuries. There was no objective measure of the severity of near-accidents however and the hypothesis could not be tested.

The hypothesis of the severity of near-accidents reported by workers forms the grounds for this research. The object of study was extended to the problems of determination of serious accident risks at company level.

In a single factory a severe injury is a statistically rare event and the prevention program can not be directed at them alone. In addition, for ethical and economic reasons, severe injury risks must be identified before injuries.

The purpose of this study is the research and development of methods for determining severe accident risks. For this reason a method of estimating the severest possible injuries in accidents and near-accidents was developed. The use of this method and a near-accident reporting system in determining severe accident risks will be studied. The effect of a near-accident reporting campaign on accident occurrence will also be studied.

1.2. Present risk determination procedures on the basis of accidents.

1.2.1. Present reporting procedure of occupational accidents

Accident prevention has been defined as an integrated program, a series of coordinated activities, directed to control unsafe personnel performance and unsafe mechanical conditions (Heinrich et al. 1980). Every accident is an indication of a failure in the accident prevention program. It is possible to correct the program by analysing failures that have caused a single accident. The other way is the risk assessment on the basis of accident statistics.

Risk is a function of the probability of the unvonted consequence and the value of the consequence to the risk taker (Rowe 1977). An accident risk can be defined as a function of the probability and the severity of the accident (Kuhlman 1981).

Accident risk is normally easy to identify on the basis of the resulting injuries. The injury can be identified immediately and the victim goes for treatment. On this basis the case is registered and investigated. The basic data of occurred accidents is collected in companies in connection with the application of the Accident Insurance and Occupational Disease act. The accident notification form has to be filled in and sent to the insurance company to get compensation (Tapaturmavakuutuslaki 608/48).

In Finland the insurance company has to send the accident notification form to the National Board of Labour Protection which annually prepares the official statistics. All accidents leading to at least three days absence are registered in the official statistics. The frequency rate (accidents per 10^6 man-hours) per sector is presented in the statistics. The accident frequency per occupation (accidents per 10^3 worker in occupation) is also presented. Accident rates are not real risk figures because they do not take the severity of the injury into account.

In Finland accidents leading to death or permanent injuries must be reported to the Finnish safety authorities, who must make an investigation into the accident. A labour protection inspector makes a detailed report of the accident and gives advice on preventing similar accidents. The National Board of Labour Protection has published these reports since 1977 (Työtapaturmaselostusrekisteri 1982).

The insurance companies have their own accident statistics. Accident induced sickness days, lost working days and paid compensation can be studied by through these statistics. The client basis, statistics and classification systems of different insurance companies differ from each other. Due to these differencies it is not possible to combine their information.

Most companies also have their own accident statistics. These statistics most often contain the number of accidents by sections and sometimes also classification by accident type. Furthermore the severity of injuries (days off per accident) is used as a measure in firms' own statistics . A real risk figure can be calculated by dividing the lost working days by the number of man-hours worked (days off per 10^6 man-hours). Accident costs are used as a measure in some firms (Grimaldi & Simonds 1975).

In some plants they make a complete report for every on the job accident, the only criterion being that the victim visited the medical centre. More commonly, reports are required only for accidents producing an injury requiring three or more days off work.

1.2.2. Accident investigation

An accident in this study is defined as a sequence of unplanned events which cause personal injuries. Definitions such as the above are usual in research where accident models are formed (see Benner 1975 and 1983, Kjellén & Larsson 1980, Leplat 1978, Shannon & Manning 1980b, Tuominen & Saari 1982). The events are building blocks for accident investigations.

At least three types of errors may be made by the accident investigator (see Tarrants 1965). The first type arises from the accident investigator's failure to identify and describe all events in the accident sequence. Often the accident report is very short (Työtapaturmat 1981 liite 7) and concentrates only on the injury phase of the accident sequence (Tuominen & Saari 1982).

The second type of error arises from the accident analyst's failure to identify all of the causal factors associated with the accident. Both immediate causes and underlying causes (see Heinrich et al. 1980) should be identified in order to prevent accidents.

With the instructions for modelling the accident an attempt has been made to improve the quality of accident investigation in working places (see Tapaturmatutkimusmalli 1982, Liikennevahinkojen tutkijalautakunnat 1982).

The third type of error arises from the investigator's failure to take remedial action to prevent the same kind of accidents occurring at the same place or in the whole plant. Frequently there is no routine for follow-up at the work-place to make sure that remedial action is taken as a consequence of an accident (Kjellén 1982). The motivation to act is also reduced by the fact that most injuries are slight and there are no other methods in use for determining the importance of the accident (Adams & Hartwell 1977).

There are many factors that cause problems in the quality of accident investigations. One of them is the variation in the sources of reports. Three primary investigators of accidents are the medical centre, the line supervisor and the safety officer. Adams & Hartwell (1977) found that at the medical center level, injury reporting was regarded purely as routine, and attendants only felt obliged to write down in threir reports exactly what the victim chose to tell them. Also many production foremen thought that filling in an accident report was only a time-consuming ancillary activity, having little significance. Only a few plants had made provision for appropriate training in filling in the report.

Also the defective design of report forms and the whole reporting system contributes to the quality of the information yielded. Often there is no feedback information to the investigator (Adams & Hartwell 1977, Kjellén 1982).

1.2.3. Classifications in accident statistics

The aim of accident statistics is to help us prevent accidents, not only record them. It has been found that the quality of the statistics has an effect on the accident rate (Simonds & Shafai-Sahrai 1977). Accident statistics have seldom resulted in recorded decisions to take remedial action (Kjellén 1982), however. One presumed reason for this is that the statistics produced in firms have not been suitable for the identification of important accident problems and for allocating priorities to safety measures (Adams & Hartwell 1977, Kjellén 1982).

Accident prevention on the basis of accident statistics involves at least two kinds of classifications: classifications of the accident sequence and classifications of the exposure groups (occupations, branches).

No two accident sequences are completely alike. We can however make typologies by classifying roughly similar accidents in the same category. With good typologies we can eliminate the separate handling of every single accident and on the other hand a single concept of an accident.

Traditionally accidents have been classified by referring to one variable at a time. In The Classification of Diseases (Tauti- ja kuolinsyyluokitus 1969) accidents are classified by referring to the external cause of the injury. In Finnish statistics of occupational accidents the classifications are made by referring to the injured part of the body, the nature of the injury, the source of the injury and the accident type. In the ANSI-standard there are also hazardous condition and unsafe act classifications (ANSI 1962).

Classifications are not always practical. For example in Finnish statistics one accident type category (striking against objects because of work motions or being struck by moving objects in the work environment) includes about 40 % of all occupational accidents while the remaining 60 % are divided into 34 categories.

The modelling of the accident sequence makes it possible to get more detailed information from accident statistics than the usual classifications allow (Carlsson 1983, Shannon & Manning 1980b, Satistiska meddelanden 1979).

The classifications of occupations and branches of economic activities in the statistics are wide and even large high risk groups can be concealed by the aggregate figures (Laitinen 1983, Rantanen 1981).

1.2.4. Measuring the accident frequency

Not all accidents are reported. The reasons for under-reporting may be both individual and organisational and include self-treatment of injuries, poor data collection systems, and the victim's judgement that the injury does not require treatment.

In some branches of industry slight accidents may cause disability and be recorded more often than in other branches. This may be true for example in the food manufacturing industry because of high standards of food hygiene (Laitinen 1983).

Adams and Hartwell found variations like these to exist even within one company (Adams & Hartwell 1977). The practice may also change in time. For example a safety competition may decrease the frequency rate (Tarrants 1965) and first aid training increase it (McKenna & Hale 1981). The variation is likely to be greatest in the case of slight injuries.

Accident rate and the severity of injuries are not very good measures of safety performance in a single factory (Tarrants 1965 and 1980). Accidents are relatively rare events. The smaller the work force, the less reliable is the frequency and severity rate. Serious accidents in particular, are so rare that identifying serious accident risks cannot be based merely on actual injuries.

1.2.5. Measuring the severity of an accident

The consequences of an accident can be listed as follows:

- Lost working days and costs for the company, for the victim and for society (Ahonen 1983, Laitinen 1975, Sinclair 1972, Skiba & Grabnitzki 1971)
- Premature death, illness and disability, security, self-fulfilment and other human consequences for the victim and the family concerned (Rowe 1977). These consequences are also called "subjective costs" (Sinclair 1972)
- Decreasing general social welfare that is contrary to the aim of public social policy (Ahonen 1983)

A whole range of consequence values can occur for a specific accident, depending on who is doing the evaluation as a risk taker (Rowe 1977). Difficulties arise particularly in measuring intangible consequences such as value of life, health and the quality of life.

Some firms measure the severity by accident costs. It may be a good instrument in motivating the management to instigare accident prevention (Bird & Germain 1966). The insured costs are easy to record. The problem is to identify and record the uninsured cost items, which can be even greater than the insured ones (Laitinen 1981, Markkanen 1973, Skiba & Grabnitski 1971). Usually the accident reporting system does not include these costs.

The severity of accidents is normally measured by lost working days. Lost working days have a good correlation with accident costs (Laitinen 1981) and also with human suffering (Rantanen 1982, Hemminki 1978).

Deaths and permanently disabling injuries have been dealt with separately from other accidents or they have been converted into lost working days so that death and totally disabling permanent injury are equal to 6 000 lost days (ANSI 1967, Grimaldi & Simonds 1975, Rönnholm 1983, Laitinen 1983). The conversion from intangible values to cardinal scales may be useful but there is always uncertainty in such valuation (Rowe 1977).

Also other variables in addition to the medical severity of injuries have an effect on the number of lost working days. One of them is the occupation of the victim. A doctor's decision on the length of the sick leave is always occupationally oriented. For example one hand injury can cause a longer incapasity for work for someone who works with his hands than for a white collar worker. On the other hand hand injuries are not so likely in the white collar occupations.

The progress of medical care tends to shorten sick leaves. Some doctors may give a longer sick leave for the same injury than others. The attitude of the victim and the insurance compensation system may have an effect on the number of lost working days too. These practices may also change in time (Senneck 1975).

Many indexes have been developed that measure the medical health status of the injured person. The interest in indexes for injury has been generated by the need to study their epidemiology and to evaluate alternative programs for prevention, emergency care and long-term health care needs (Krischer 1976, Somers 1983). The severity indexes are intended to correlate with the consequences to the patient, and some kind of estimate of medical care must be included in these assessments (Krischer 1979).

The classified features in the Abreviated Injury Score (AIS) and the Injury Severity Score (ISS) are the injured part of the body and the severity of the injury (Baker et al. 1974). The severity is rated from one (minor) to six (death within 24 hours). Classified features in the Comprehensive Injury Scale (CIS) are threat to life, degree of permanent disability, treatment period and energy dissipation (in burns) (Krischer 1976). Each feature is rated from one to five.

The slightest categories of the medical indexes of severity are so wide that they cover almoust all occupational accidents. For example in the woodworking industry about 90 % of injuries were ranked in the slightest injury category of AIS (Buhl-Nielsen & Jensen 1984). So they are hardly useful in a single factory.

In spite of some weaknesses lost working days seems to be the best measure available for measuring the actual severity of temporary injuries.

1.3. Accident prevention on the basis of near-accidents

1.3.1. Near-accident techniques

The time dimension is important in accident risk identification. We should identify the risk before accidents occur. This is more important the more severe the potential consequences of the accident are. To this purpose different safety analysis methods have been developed especially in the branches of aviation, flights in the stratosphere and nuclear power production. They have also been applied in the other industries. Risk analysis methods have many theoretical and practical problems, however (Saari 1981). The time when the future safety performance of a system can be accurately predicted is still far away.

The near-accident methods fall between accident investigation and safety analysis methods. Risk analysis can be carried out already in the design phase of production but in near-accident techniques the risk is identified on the basis of occurring incidents. On the other hand the accident risks can be identified before injuries occur on a near-accident basis.

A near-accident (non-injury-accident, conflict) is defined in this study as a sequence of unplanned events that could have resulted in personal injury although it did not actually do so. In a near-accident the accident sequence breaks before injury (Kjellén & Larsson 1980). The threatening burst of energy may pass by that part of the body which it could injure or it may be totally avoided. Also personal protective devices may prevent the injury (Figure 1).

The methods of data collection on near-accidents are observation, interviews with workers and self reporting. In the Critical Incident Technique (CIT) an interviewer questions a number of workers and asks them to recall and describe unsafe errors or unsafe conditions that have come to their attention (Butora & Höfle 1979, Gustafsson 1976, Heinrich 1959, Kjellén & Baneryd 1976, Rockwell et al. 1970, Tarrants 1965 and 1980).

In the Traffic Conflict Technique (TCT) traffic safety is studied by observing traffic flow and by registering in advance defined hazardous situations (Kulmala 1980). Video and traffic-radar may be used to help the observation. Video-observation has also been used in studying hazardous situations in working places (Caven & Saari 1982, Cohen 1983).

Voluntary self reporting is used both as a research method (Kjellén & Baneryd 1976, Markkanen 1973, Selin, no printing

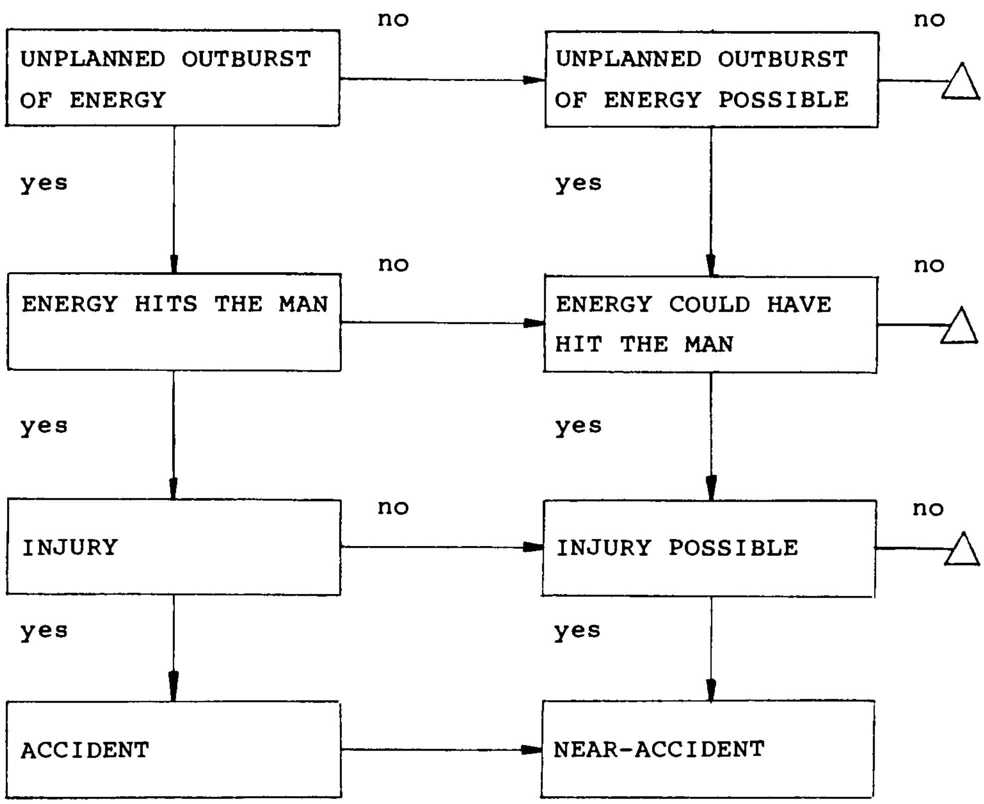

FIGURE 1. The model of accidents and near-accidents

year, Niskanen & Lauttalammi 1983) and as a routine method in working places (Bird & Germain 1966, Gappenberger 1974, Kjellén 1982, Nill 1971).

The relation between reported near-accidents and accidents has varied greatly in different studies. In working places where the voluntary reporting system is in routine use near-accidents have been reported 0.25-2 times as much as the number of accidents (Kjellén 1983). Reporting frequency has been found to decrease during three months period (Saari 1976). More near-accidents have been identified by interviews than by self reporting (Niskanen & Lauttalammi 1983).

Reliable data on near-accidents can be gathered by observation (Cohen 1983, Komaki et al. 1978, Kulmala 1980). The other near-accident methods are not so reliable because of failures in reporting. Reliability may be improved by applying anonymous reporting, a limited reporting period, and directive reporting based on check-lists of near-accidents (Kjellén 1983, Rockwell et al. 1970).

1.3.2. Subjective risk assessment and reporting a near-accident

Subjective risk means the individual's feeling of risk either on the basis of one or a few trials or totally by conjecture (Rowe 1977). Also subjective risk has two elements: the probability and the severity of the consequences. The risk is subjective if either of these elements or both of them are subjective.

Any worker who is directly faced with an accident risk situation makes his own value judgements on risk determination and evaluation. He bases his decisions on subjective risk estimates, not on what is objective (Goeller 1969, Hoyos 1980, Robinson 1975). The decision can be seen in cost/benefit terms: the required cost in effort and the subjective estimate of risk being weighted against the benefit in terms of estimated size and type of reward (Hale & Hale 1970, Häkkinen 1978, Robinson 1975). If the subjective estimate of risk is great (greater than possible benefits) then the worker tries to avoid the risk consequences.

Rowe (1977) has developed a hierarchy of risk consequences based on the conceptual hierarchy of needs developed by Maslow. There the highest priority is the need for survival, which has been broken down into premature death, avoidable illness, and other survival factors. The hierarchy continues through exhaustile resources, physical security, belonging, egocentric needs, and self-actualization. Each major category of needs is dominant over those below it as long as the level of the need remains unfulfilled.

On the basis of this hierarchy it is obvious that accident risks that can cause death or permanent injury are dominant in subjective risk assessment.

Also other variables have an effect on the subjective risk assessment. For example knowledge, voluntariness, familiarity, perceived control and perceived benefit seem to double the standards for acceptable risk and the propensity for risk taking (Fischhof et al. 1978b).

People seem to overestimate the death rates for a few well published causes of death such as botulism, tornadoes, and floods while they underestimate the rates for most chronic causes of death (Fischhoff et al. 1978a, Lichtenstein et al. 1978). There is also greater public concern about hazards that kill people in a catastrophic way rather than singly, or those which are new, or involuntary. One explanation for these findings may be included in Taylor's (1976) definition of subjective risk: subjective risk is perception of loss of control.

The above mentioned studies demonstrate that people cannot accurately judge the probability of death from various causes. The case is different however when we must rate the severity of possible consequences in a particular situation.

Subjects of different forestry personnel groups had a close measure of agreement concerning the relative risk values of nine tree felling situations (Östberg 1980). There were no differencies in the ranking order for various personnel groups. Accident statistics did not disprove the hypothesis on the agreement between subjective and objective ranking of the felling situations. In fact, 12 % of all the accidents, but 80 % of the fatal accidents occurred in the four situations ranked as most serious.

In another study railroad employees were asked to rate the probability and the severity of accidents in different working situations (Zimolong 1979). In most situations there was agreement between subjective risk and accident statistic. In some frequently recurring situations both the probability and severity of accidents were underestimated. Such situations were, for example, bending in order to change the points, coupling the coach and getting into or out of the coach. About 60 per cent of accidents took place in these situations. The probability and severity of accidents were overestimated in some situations in which only a few or no accidents occurred. Such situations were for example travelling on the buffer and walking on the rails, which are clearly potentially fatal situations when an accident does occur.

The foregoing results give support to the Hovdens' (1979) suggestion that the potential severity of injuries dominates the subjective risk assessment more than the probability of the accident. They also comform with the Rowes (1977) hierarchy of risk consequences.

The stages of perception of and response to danger can be classified as follows: hazard seeking, hazard recognition, assessment of the priority and importance of the hazard, allocation of responsibility, knowledge of action, decision to act and action sequence (Hale 1983).

The actions in risk situations can be divided into two phases: first direct actions to avoid the actual danger and second, actions to avoid the repetition of the risk situation. Making a declaration of a near-accident is one action of the second phase.

On the basis of the studies referred to above, it can be supposed that workers are especially prone to report potentially critical situations. This is also supported by Hammarsten´s (no printing year) questionnaire study to workers. This showed that generally one reason for not reporting a near-accident is its assumed slightness and unimportance.

The feeling of control and personal guilt are other factors that may have an effect on reporting a near-accident. This may be one explanation of the findings that most reported near-accidents have been due to technical malfunctions (Kjellén 1982). People may feel that their own human errors are under better control than technical malfunctions.

However, human errors have dominated in studies concerning aviation (Rockwell et al. 1970). The anonymity of the reporters is thought to increase the reporting of near-accidents due to human error (Kjellén 1983). Another explanation may be that the majority of potentially serious near-accidents in flying may be caused by human error whereas the greater part of serious near-accidents in industry may be caused by technical error.

Social factors also have an effect both on subjective risk estimation and on decision making (Wilde 1976). Possibly negative attitudes of other workers and foremen towards reporting decreases reporting activity in near-accidents (Hammarsten, no printing year).

Failure in the reporting of near-accidents does not necessarily make the reporting system invalid for estimating accident risks in a firm. If the loss of information is concentrated mostly on slight near-accidents then the reporting system may give an adequate picture of severe accident risks which are the most important.

1.3.3. Effect of the near-accident reporting on accidents

A decrease in the accident rate has been noted as a result of near-accident reporting in some firms (Bird & Germain 1966, Gustafsson 1976). However, this effect and the possible causes of it have not been analysed.

One possible reason for the decrease in accidents is that workers do not report all accidents during campaigns and thorough investigations of accidents and near-accidents. They do not report slight injuries at all or they may report them as near-accidents. This change occurs quickly and it should cause an increase in the accident severity rate.

Reporting a near-accident is an action of the worker to avoid future accidents. It can be supposed that the reporting campaign also causes other actions. It may lead to a change in the performance of workers and foremen that causes a real decrease in accidents. It has definitely been found that near-accident reporting systems make workers more safety consious in their work (Butora & Höfle 1979, Gustafsson 1976, Perusse 1978, Rockwell et al. 1970). This kind of effect occurs quickly but it may only be temporary if follow-up measures are not introduced.

A third possible reason is the effect of preventive measures based on near-accidents. The routines for the follow-up of near-accidents with preventive measures has been found to be better than the corresponding routines for actual accidents in the same firms (Kjellén 1982). This may lead to more and better preventive measures. The reporting systems may also reinforce communication and participation which have been found to have an effect on accidents (Cronin 1971).The change in the total number of accidents is slow to occur but it should be more permanent than the effect of an information campaign.

1.4. Measuring the potential severity of accidents and near-accidents

Measuring the severity of near-accidents on the basis of actual injuries is not possible. In this respect near-accident techniques are in the same position as the safety analysis methods; The only possible way to measure the severity is the estimation of the potential injury.

We found that the severity of accidents is largely fortuitous. Death can be severest possible consequence of a sequence of unplanned events and no injury the minimum consequence. An accident sequence only hardly ever results maximun possible consequences but the potential severity of accidents can be rated.

In some firms they in fact rate the potential severity of all accidents and direct preventive measures on the basis of accidents that could have lead to either a fatality, a serious injury or property damage (Allison 1967). High potential accidents per million hours worked are used as a measure of safety performance. The same rating system is also used in the hazard analysis of facilities. This method is called the High Potential Accident-Prone Situation Hazard Control Method (HIPO).

Allison says that HIPO provides the safety department and management with a realistic picture of the true hazard problem areas and guidance and direction towards effective hazard control. Jacobs (1980) also considers the method promising but asks for conventional assessment methods and research to validitate them.

The potential severity of an accident and near-accident can be defined in two ways: as the most likely injury in that situation or as the severest injury possible in that situation. The latter definition is more useful for accident prevention and it is used in this study.

There are basically two kinds of factors that have an effect on the severest possible injury in a certain situation. First come the factors of the accident or near-accident sequence that determine the kind and amount of the possible outburst of energy and its possible object. These factors are most interesting in rating the potential severity for accident prevention purposes (figure 2).

The injury is caused by energy which can be either external or internal to the individual. Different parts of the body can tolerate different kinds and amounts of energy (Schmidt 1979, Searle et al. 1979). For instance a leg fracture is possible in a fall of half a meter but a skull fracture in a fall of one meter (Hammer 1976). The threat to life depends on the injured part of the body. For instance arm and leg injuries are seldom fatal (Braunstein 1957). More dangerous are injuries to the neck and cervical spine, head, thorax and thoracic spine and abdomen and pelvis.

The effects of the second kind of factors are dominant after the energy outburst. These factors are, for example, the reaction of the possible victim, personal protective devices, individual characteristics of the victim and the quality of the treatment.

For example, an impact which would be easily tolerated by a young man may well result in serious injury in an elderly woman. Footballers, skiers, ice hockey players and other sportsmen regularly take impacts that would result in broken bones for the weaker members of the population (Searle et al. 1979).

In safety analysis among others the following scales have been used for the severity of identified risks:

- ordinal scale on the basis of injuries and property damage; e.g. no injuries or damage, minor damage, injuries or major damage, death or serious injuries (Hammer 1972)

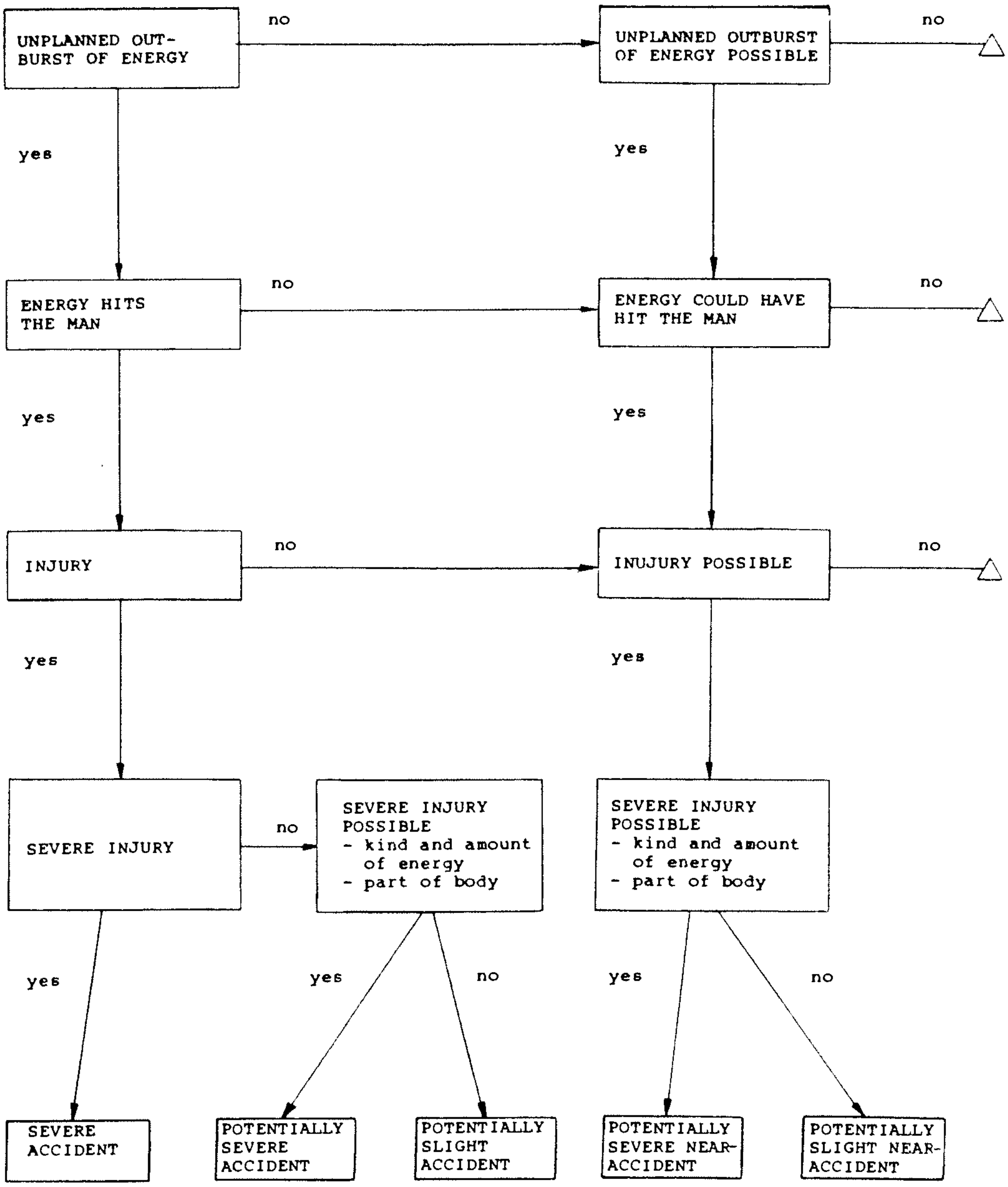

FIGURE 2. The model of the potential severity of accidents and near-accidents

- scales between the ordinal and interval scale on the basis of lost working days; e.g. 0 days, 1-2 days, 3-21 days, 22-300 days, more than 300 days (Suokas et al. 1982)
- scales between the ordinal and interval scale on the basis of both lost working days and permanent injuries; e.g. less than 3 days, 4-40 days, 41-120 days or permanent disability less than 10 per cent, 121-250 days or permanent disability 11-33 per cent, permanent disability 34-66 per cent, permanent disability more than 66 per cent or death (Richter 1972).

Rockwell et al. (1970) have used the estimation method for assessing the relative dangers of pilot errors. He had an ordinal scale with seven danger categories. Pilots were used as graders and there was found to be a good measure of reliability in the scaling procedure. Rockwell also used the paired comparisons method and rank order method and found them to have an exellent degree of agreement with the ordinal scale method.

In addition Östberg (1980) studied several scaling methods for rating danger in different tree felling situations. There was a high correlation between the different methods.

The raters can be workers or other experts, who are familiar with the working area (Rockwell & Bhise 1970). Medical competence is not so important. Östberg (1980) found that the different groups assigned different over-all risk to the situations. The teachers at forestry schools seemed to overestimate the risks involved in the situations, whereas the supervisors underestimated the risk. Safety engineers with forestry companies, pupils at forestry schools, safety officers at administrative level and lumberjacks fell between these groups.

1.5. The theoretical framework and objectives of the research

The substance of the theoretical framework in this research is the separation of the severity of the actual injury from the potential severity of the accident and near-accident (figure 3). An accident that causes a severe injury is always potentially severe assuming that the injury does not get worse during treatment. On the other hand an accident that has caused only a slight injury may be potentially slight or severe.

A near-accident may be potentially severe or slight. It is assumed here that in a voluntary reporting system workers are especially prone to report those near-accidents that they consider potentially severe. Near-accident that workers consider slight on the basis of their own subjective risk assessment are not as likely to be reported as severe ones.

An accident report or near-accident report leads to an investigation of the incident. In doing this the potential severity can also be estimated. This estimation may have an effect on the immediate preventive measures.

Accident and near-accident statistics are kept for instance, in order to fix the priorities of the accident problem at the firm. These priorities should direct the preventive measures even if other factors, like costs and preventability also have an effect on the safety work. Priorities based on the actual severity of accidents may differ from priorities based on the potential severity.

The aim of this study is to prove the hypotheses in the theoretical framework and their practical solution in working places. The hypotheses of the study can be formulated as follows:

Hypothesis 1: The potential severity of accidents and near-accidents can be reliably distinguished from the actual injuries

This is an important premise: thus we can speak of potential severity as a measure of accidents and near-accidents.

Hypothesis 2 : The post incident estimation of the potential severity of accidents and near-accidents is a valid method for separating severe risks from slight ones

This hypothesis means that we are able to separate severe risks from slight risks accurately. We can make two kinds of mistakes: Either a potentially severe case can be rated as slight or a potentially slight case can be rated as severe. In practice the first kind of error is more harmful.

Hypothesis 3: The workers are prone to report potentially severe near-accidents on the basis of their subjective risk assessment

Hypothesis 4: Firms' accident risk priorities based on the number of accidents and lost working days are not consistent with priorities based on the risk potential

The hypothesis is a logical continuation of the distinction between potential severity and actual injuries. The traditional acccident statistics of firms will be called into question if the hypothesis is true.

Hypothesis 5: A campaign for reporting near-accidents decreases the number of accidents

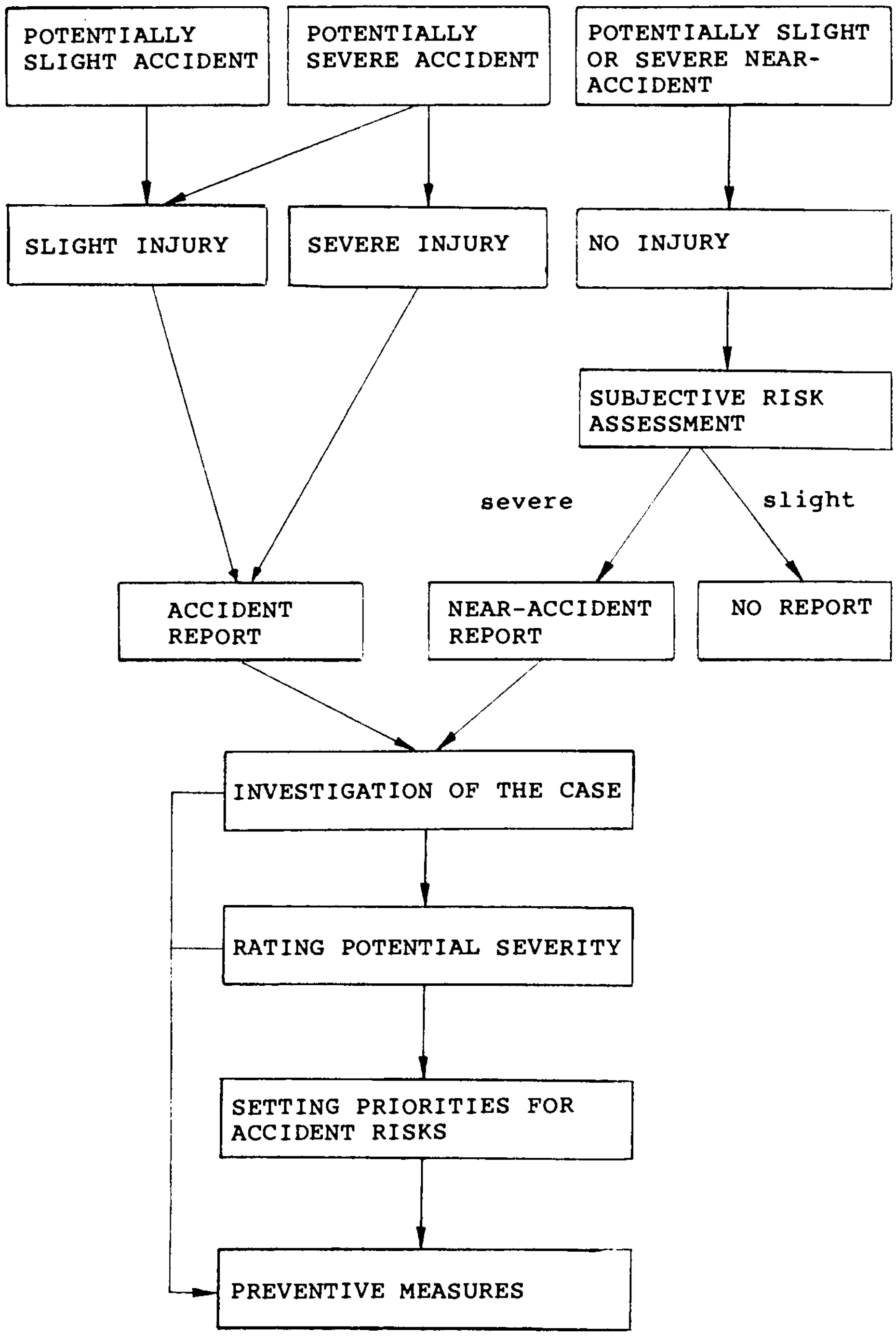

FIGURE 3. The theoretical framework of the research

2. METHODS AND MATERIALS

2.1. The progress of the study

The progress of the empirical study is described in figure 4. The original purpose in developing the reporting system of accidents and near-accidents was to experiment with the damage control system. Ovako Oy Imatra was found suitable for this purpose. It is an electric steel factory that produces mainly rolling-mill products. There were about 1 800 employees at the firm during the field study.

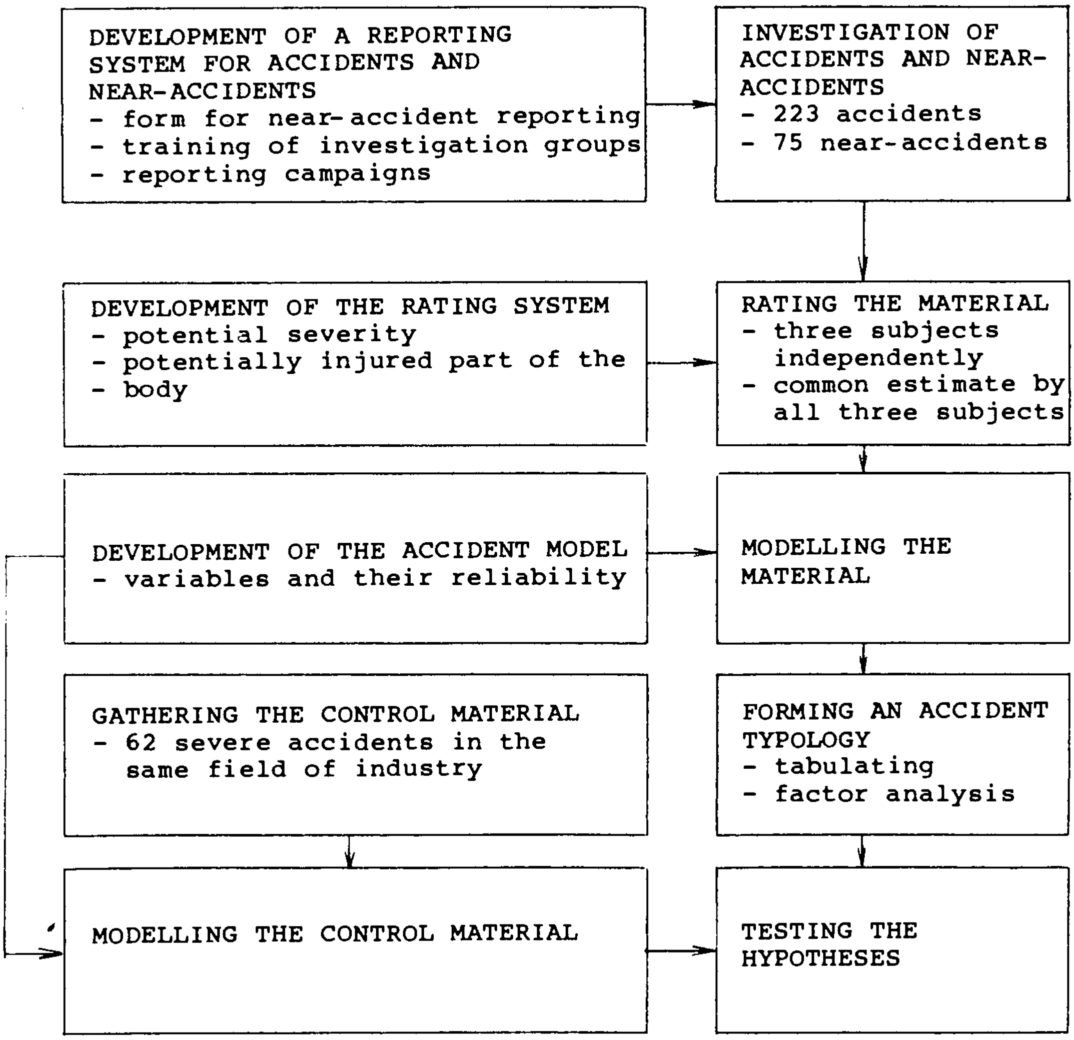

FIGURE 4. The progress of the empirical study

The reporting system was developed in collaboration with the firm in 1979 and most of the subject matter was gathered over six months during the winter of 1979-1980. The results of the experiment were reported in 1981 (Laitinen 1981).

The rating method for potential severity was developed during the spring of 1982 and the ratings were made in June 1982. The accident model was developed after that. Following this, accidents, near-accidents and the control material on severe accidents in the Finnish steel industry were modelled. The author made all the analyses with the WANG 2200 VP computer and SURVO 76 and SURVO EDITOR programmes (Mustonen & Mellin 1980, Mustonen 1981) of Lappeenranta Regional Institute of Occupational Health.

2.2. Material

2.2.1. The reporting system

The existing reporting systems of the factory were used as much as possible. The aim was to develop them at the same time.

All accidents occasioning a visit to the doctor were reported but there was no reporting system for near-accidents. A simple form was drawn up for near-accident reports and two campaigns organised. The first campaign lasted two weeks and the second two months.

A special investigation group investigated all accidents and near-accidents during the six months field study. The group consisted of the supervisor and the workers' safety representative in the section and the research assistant. The supervisors and safety representatives were trained in two hour training courses. About 120 people were trained in three courses.

Information about the reporting campaigns was posted in the firm's paper and on the bulletin boards. Two handbills were distributed at the plant. The campaign was also discussed during management and union meetings.

After the study the firm decided to take the reporting and investigation system into continuous use.

2.2.2. Material

The accident material consists of all the accidents resulting in a visit to the medical center that occurred at the working place during the six months of the study. There were 152 such accidents. This material was supplemented with accidents that had lead to an absence of more than one month in the years 1978-1982. There were 73 of these accidents. Accidents occurring before the field study were investigated by the supervisor. The reports were good enough for modelling.

During the field study 52 near-accidents were reported. This material was supplemented with 23 near-accidents that were reported later. These cases were investigated by the firm's investigation teams.

So the material consisted of 223 accidents and 75 near-accidents at the Imatra Steel Factory.

The severity of accidents was as follows:

days off	number of accidents
0	63
1-2	16
3-5	30
6-20	29
21-40	52
41-60	13
over 60	20

TABLE 1. Injured part of the body and the nature of the injury in the study material (mean number of lost working days per accident in parentheses)

nature of injury	injured part of body: head eye neck	trunk back	upper limbs	hand finger	lower limbs	toes ankle	to-tal
fractures	0	2 (110)	0	6 (74)	1 (226)	5 (33)	14 (68)
dislocations	1 (0)	18 (13)	7 (36)	3 (15)	16 (16)	0	45 (28)
cuts, open wounds	3 (7)	0	3 (2)	11 (7)	1 (5)	1 (3)	19 (6)
abrasions, frag-ments in the eye	18 (1)	0	0	2 (3)	1 (0)	1 (32)	22 (3)
contusions, crushings	6 (0)	7 (14)	9 (24)	39 (17)	19 (18)	13 (16)	93 (16)
burns	5 (8)	3 (7)	1 (0)	4 (1)	8 (34)	6 (32)	27 (20)
other injuries	1 (0)	0	1 (51)	0	1 (27)	0	3 (26)
	34 (2)	30 (19)	21 (25)	65 (17)	47 (34)	26 (23)	223 (20)

There was one permanent injury in the material. That was an amputation of a fingertip. The severest temporal injury caused 226 lost working days. A great deal of injuries were contusions and crushings of the hand, fingers and lower limbs (table 1). The most severe temporal injuries were the fractures. Injuries of lower limbs were the severest and head injuries the slightest.

2.2.3. Control material

The control material was gathered from the register of serious accident reports published by The Finnish National Board of Labour Protection (Työtapaturmaselostusrekisteri 1982). There were 62 accidents which had occurred in the branch of iron and steel production.

The register contains safety inspectors' descriptions of accidents that have caused death or severe injury (permanently disabling injury or absence of more than one year). Such accidents must be reported to the Labour Protection District Authority (Laki työsuojelun valvonnasta 131/73) which has to make an investigation (Asetus työsuojelun valvonnasta 954/73).

There were six fatal accidents in the control material (table 2). Most injuries were fractures, amputations or burns. There were no dislocations and abrasions in the control material. So the injuries of the control material differed clearly from the injuries of the study material.

Not all serious accidents are reported to the safety authorities for which reason some cases are missing from the register. These consist mainly of accidents at small firms where the legislation is not so well known. In the steel industry most firms are large and the safety work at the plants is well organised. So the number of missing cases in the steel industry is assumed to be very small.

Firms also report to the safety authorities accidents that may not be so severe that there is a duty to report them. In these cases the safety inspector can decide whether to investigate the case or not.

In this study the omission of cases has significance if it applies systematically to certain kinds of accidents and injuries. Serious accidental back injuries may be a consistently omitted group as there were no such cases in the register. With this qualification we can say that the control material well represents severe accidents in the Finnish steel industry.

TABLE 2. Injured part of the body and the nature of injury of the control material (in addition, deaths are marked with +)

nature of injury	injured part of body: head eye neck	trunk back	hand finger	lower limbs	toes ankle	multi-injury	to-tal
fractures	4 ++	0	2	9	4	2	21
internal injuries	1	2 +	0	0	0	0	3
amputations	0	0	12	1	3	0	16
cuts, open wounds	3	0	0	0	0	0	3
contusions, crushings	1	3 +	1	1	0	0	6
burns	1	2	1	2	0	3 +	9
other injuries	0	0	1	0	0	3 +	4
	10	7	17	13	7	8	62

2.3. Estimation of potential severity

All accident and near-accident reports were written in a uniform way for the estimation. In reports the accident sequence was described as completely as possible. The reports were randomized.

A scale was prepared for estimating the potential injury severity (table 3) and for the potentially injured part of the body. The estimators were asked to indicate the severest possible injury in each case, as well as the potentially injured part of the body.

TABLE 3. Categories of potential injury severity

category	nomenclature	description, examples
1	small, insignificant	absence less than 3 days
2	minor	absence 3-30 days; e.g. cuts contusions, small particles in eye, fracture of fingers or wrist, strain of wrist, burns
3	significant	absence 1-12 months or permanent degree of disability less than 10 % ; e.g. fracture of leg or arm, loss of forefinger, loss of finger joint
4	severe	absence more than 12 months or permanent degree of disability 10-60 % ; e.g. loss of thumb or two fingers, loss of big toe, loss of whole arm or leg, loss of sight from one eye
5	critical	death or permanent degree of disability more than 60 % ; e.g. loss of both arms or legs, loss of sight from both eyes

In particular the amount and the type of energy involved in the incident and the part of the body on which it would have been concentrated had to be taken into consideration. Medical treatment was presumed to be normal in that the injury would not get worse during treatment.

The estimation was made by the works safety officer, the workers' safety representative and the author. At first we went over 25 cases together for practice and in order to make the interpretations consistent. Thereafter each of us estimated the remaining 273 cases. Finally we together dealt with the cases where the estimations differed from each other and found a common solution acceptable to all three.

2.4. Modelling the accidents and near-accidents

2.4.1. Accident model

Initially the accident sequence was divided into three different events: the contact event and the two preceding events (figure 5). The preceding events were combined with each other during the analysis and the new variable was called the preceding phase.

Other variables in the accident model were source of injury, part of body, nature of injury and lost working days. The variables were classed according to type apart from lost working days which was on a ratio scale.

In addition to the accident sequence the work that the victim was doing at the moment of the accident was also classified. The following variables were used:

- work (taken as a whole of which the victim's activity was a part; e.g. production work, repair work, transport work)
- activity (the activity of the victim at the moment of the accident; e.g. manual work, walking, operating a machine)
- working tools and
- material being handled.

The variables work and activity were combined in some analysis and the new variable was called the working phase.

Information about the victim and the place and time of the accident was also gathered.

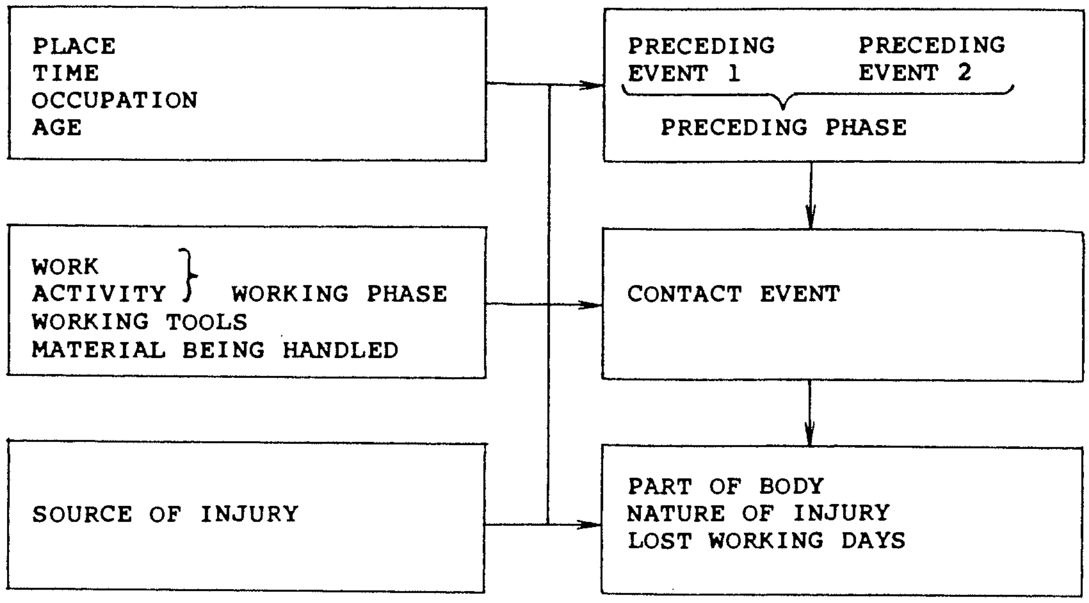

FIGURE 5. The detailed accident model

As far as possible the same information was gathered for near-accidents as for accidents. In the case of near-accidents the source of injury and the contact event had to be estimated on the basis of the report. Information about the victim and his work and activity was not always available and could not be estimated.

2.4.2. Reliability

With the help of an assistant the author classified part of the material before deciding on the final accident model and classes. On the basis of this the definitions of many classes were corrected and some classes were rejected and new classes were formed.

A new parallel classification of 75 cases was made. The reliability was then 72-92 % (table 4). The reliability of only two variables was less than 80 %. These were the two preceding events. In almost 10 % of cases one subject classified an event as the first preceding event and the other subject classified it as the second preceding event. For this reason these variables were combined. The reliability of the combined variable preceding phase, was 89 %.

TABLE 4. The reliability and number of classes of variables in the accident model

variable	number of classes	reliability %
work	7	84
activity	7	92
working tool	23	92
object of activity	23	81
contact event	13	88
source of injury	23	84
1st preceding event	16	72
2nd preceding event	16	72
preceding phase	10	89

2.5. Developing the accident typology

It was desirable to group the cases on the basis of the accident sequence before testing the hypothesis. The purpose was to divide the material for the analysis into groups that would be as internally homogenous, while the separate groups were as different from each other, as possible.

Developing the typology while tabulating several variables proved to be difficult. So it was tried with a factor analysis. The typologies made in this way seemed to be sensible and more accurate than classification made by tabulation. For example the accident type "cinder in the eye" was only separated from the type "contact with a flying object" in factor analysis.

The quality scaled variables were changed to new dichotomic variables for the factor analysis. Making this kind of false dichotomic variable is permitted when checking the internal connections of the material (Valkonen 1981).

2.6. Testing the hypotheses

The reliability of the potential severity rating was tested by studying the reliability of estimates made by three subjects of the same cases (table 5). Correlations were used as a measure of severity estimates even if the scale was ordinal. This can be justified by the simplicity of the analysis and the insignificance of the error (Valkonen 1981). In order to check the error the author calculated some correlations using the figures converted into lost workingdays. Differences were negligible.

The reliability was tested with the categories of the potentially injured part of the body and potential severity in order to find out if reliability can be improved by developing these classifications.

Both the concurrent and structural validity (Pietilä 1976) of hypotheses two and three were studied. Concurrent validity means the agreement of measurements on two different methods regarding the same observation units. The validity of estimating an accident's potential severity as agreed upon by the three subjects was tested by using the actual severity as a parallel measure.

TABLE 5. Testing procedure, main variables and used statistical methods of different hypotheses

Hypothesis	testing procedure, main variables	statistical methods
1	reliability of three subjects' estimates - severity, part of body - influence of actual injury - influence of part of body categories - influence of severity categories	tabulating, correlation, % of agreement, partial correlation analysis, regression analysis, variance analysis, Cohen's coefficient
2	concurrent validity of potential severity with actual severity of accidents	tabulating
	structural validity of potentially severe accidents with control material - work, activity, working tool, material being handled, source of injury, preceding phase, contact event accident type, part of body	tabulating, chi-square test, log-linear models, rank correlation analysis
3	potential severity of reported near-accidents compared with that of accidents	tabulating, chi-square test
	structural validity of near-accidents with control material and potentially severe accidents in material - same variables as in hypothesis 2	tabulating, chi-square test, log-linear models, rank correlation analysis
4	comparing risk priorities measured on different standards - accident type, occupation, working phase, production phase	rank correlation analysis, absolute and relative risk figures
5	reporting activity and trend of accident situation - short-term changes - long-term changes	tabulating, chi-square test, Brilon's confidence limits
	preventive measures on the basis of accidents and near-accidents	tabulating, chi-square test

The fact that the worker has reported a near-accident is here presumed to show that he considers it potentially severe. The concurrent validity of this subjective risk assessment was examined by using the estimates of a near-accident's potential severity approved in common by the three subjects.

Structural validity means that certain variables and their categories separate certain groups of observations from each other and can be predicted on the basis of some theory (Pietilä 1976). Here the structural validity of the post incident estimation of potential severity of the accidents is tested by comparing potentially severe accidents with potentially slight accidents and the control material of actual severe accidents in Finnish steel industry.

The structural validity of subjective risk assessments is tested by comparing the reported near-accidents with the control material. Near-accidents are compared also with potentially severe accidents and potentially slight accidents of the material.

So there were four groups in the comparison: potentially severe accidents, potentially slight accidents, near-accidents and control material of actual severe accidents. The structural validity is good if potentially slight accidents are different from the other groups and the other groups are equal.

Tabulating and chi-square test were used as analysis methods in testing the hypotheses two and three. Log-linear models for contingency tables (Everit 1977) were used in order to find out the interactions between the variables. Rank order correlations were used by examining the agreement between priority orders of different accident and near-accident groups.

3. ACCIDENT TYPOLOGY

3.1. Typology on the basis of accidents

The variables potential severity, potentially injured part of the body, injury source, contact event and preceding phase were used in the factor analysis. The potential severity was ordinally scaled. The categories of the other variables were converted into new dichotomic variables. So there were 34 variables in the factor analysis. The factor matrix was rotated according to the varimax criterion.

Ten factors were selected. The eigenvalues of the last factors approached one and the solution was no clearer with nine factors.

The sum of the communalities was 20.8 and the degree of the accountability 61 %. The contact event accounts for the result best (17 %). The interpretation of the preceding phase, source of injury and potentially injured part of the body is 14-15 %.

The factor matrix on the basis of the accident material is presented in table 6. The factor solution is clear even though many variables are weighted in two factors. It was divided into the following factors (accident types):

1) Cinder in the eye (1st factor)

The variables contact with a flying object, eyes and dust and cinders were weighted under the first factor. The variable spatters was also weighted under this factor but not as heavily as in factor six.

This factor was called cinder in the eye. This type describes cases where the energy of the flying particle is so small that it cannot injure any other part of the body than the eye and eye-injuries may also be only slight.

VARIABLES FAKTORS	1	2	3	4	5	6	7	8	9	10
POTENTIAL SEVERITY	-0.1298	0.2370	0.1043	0.0477	-0.0741	0.6146	-0.0638	0.2075	-0.3489	-0.1066
PART OF BODY										
head	-0.0509	0.4426	0.0564	0.0035	-0.0609	0.2399	-0.0141	0.0381	-0.5806	0.1501
eyes	0.8423	-0.1297	-0.0531	-0.0424	-0.0002	-0.0163	0.0285	0.0824	-0.0213	0.0613
fingers	-0.2314	-0.3885	0.1306	-0.3404	-0.4406	-0.1846	-0.1236	-0.2195	-0.2468	-0.1596
upper limbs	-0.1082	0.3523	-0.2038	0.0166	0.0162	-0.0922	0.3105	0.0019	0.3013	-0.4413
toes	-0.0746	-0.1128	0.1184	0.7273	-0.0500	-0.0652	-0.0719	-0.0617	-0.0645	0.0513
lower limbs	-0.1223	0.0895	0.1845	-0.0269	-0.1610	0.0629	-0.1356	0.2086	0.6266	0.3186
trunk	-0.2098	-0.2229	-0.2272	-0.0629	0.7571	0.0741	0.0081	-0.0541	-0.1131	0.0484
SOURCE OF INJURY										
hand tool etc.	-0.2485	-0.2828	-0.5303	-0.0540	-0.1861	-0.1194	0.2467	0.0409	-0.0595	0.2168
transportation equipment	-0.1045	-0.0269	0.0374	0.1945	-0.1662	-0.1337	-0.5992	-0.0266	-0.2783	-0.0785
machine	-0.0940	0.0479	0.0082	0.0469	-0.0473	0.0766	0.0964	-0.0738	-0.0406	-0.7127
products etc.	-0.2236	-0.0398	0.5567	0.1538	-0.0101	-0.1000	0.2516	-0.1429	0.1978	0.2546
floor,construction,ground	-0.0770	0.6759	-0.0611	-0.1283	0.0818	0.0285	0.0274	-0.0287	0.0257	0.0384
spatters, sparks,chips	0.4550	-0.1850	-0.0607	-0.0942	0.1897	0.6824	-0.0006	-0.1207	-0.0118	0.1024
dust,cinders	0.7527	0.0019	-0.0138	-0.0313	-0.0131	-0.4202	-0.0152	-0.0540	0.0236	0.0241
no	-0.1067	-0.0937	0.0178	-0.2024	0.2974	-0.0575	-0.2173	0.5746	0.1451	0.0916
CONTACT EVENT										
cont. on stationary object	-0.0994	0.8417	-0.0345	-0.1223	-0.0178	0.0198	-0.0234	-0.0880	-0.1732	0.0699
cont. with flying object	0.8722	-0.1375	-0.0482	-0.0849	0.1291	0.2692	0.0557	-0.1197	-0.0232	0.1229
cont. with falling object	-0.0049	-0.0494	-0.1310	0.0155	0.1575	0.1643	-0.5483	-0.0159	0.1561	-0.0029
cont. with falling handled object	-0.1159	-0.0548	0.0428	0.7570	-0.0861	0.0456	-0.1453	-0.0714	0.1885	0.1382
cont. with other moving object	-0.1647	-0.2286	0.6401	-0.1209	-0.1767	0.0564	-0.0330	-0.0859	-0.0067	-0.4333
hurting oneself with handled object	-0.2226	-0.2698	-0.4167	-0.1994	-0.4980	-0.1026	0.1236	-0.2594	-0.0486	0.0645
strenuous movement	-0.2904	-0.1343	-0.1486	-0.1066	0.7518	-0.2594	0.1397	-0.0233	0.0476	0.0823
other, unknown	-0.0091	-0.0116	-0.0260	0.0492	-0.1228	-0.1249	0.0768	0.8081	0.0077	0.0227
PRECEDING PHASE										
slipping of tool etc.	-0.2565	-0.0261	-0.3965	-0.0818	-0.3760	0.1348	0.0872	-0.0800	0.1861	-0.0259
fall on same level	-0.0230	0.6633	-0.0761	0.0596	-0.0640	0.0160	0.1357	0.0970	-0.0024	-0.1748
jump	-0.1279	0.3533	0.1649	-0.2508	0.1348	0.0020	-0.1795	-0.0336	0.0954	0.2203
fall to lower level	-0.0894	0.0734	-0.0394	0.0032	-0.0313	0.0678	0.0624	0.3812	-0.3477	0.1153
breakage, technical error	0.0573	-0.0401	0.0139	0.4584	0.0694	0.0407	-0.0239	0.0659	-0.2412	-0.1097
fire, explosion	0.0574	-0.0752	-0.1228	-0.0559	0.0807	0.2504	0.0721	0.4759	0.0162	-0.0222
other falling object	-0.0009	-0.0478	-0.1514	0.4434	0.0374	0.1432	-0.6461	-0.0816	0.2390	0.1012
other sudden moving object	0.0329	-0.2612	0.5925	0.0417	-0.1225	0.4183	0.2386	-0.2026	0.0649	0.1484
accidental starting	-0.0698	-0.1268	0.1133	-0.1552	-0.0511	-0.0152	-0.2120	-0.0206	-0.0458	-0.6619

TABLE 6. The Factor matrix of the accident material

2) Fall on the same level (2nd factor)

The weighted variables were contact on a stationary object, floor etc., fall on the same level and the head. The factor was called fall on the same level.

3) Other moving object (3rd factor)

In the third factor some variables were heavily weighted positively and some negatively. Positive weighting can be construed as one accident type and negative as another.

The variables contact with another sudden moving object, other moving object and product etc. were positively weighted. This type was called contact with other moving object.

4) Hurting oneself with a hand tool (3rd factor)

The variables hand tool etc., hurting oneself with a handled object and slipping of tool etc. were negatively weighted in the third factor. This type was called hurting oneself with a hand tool.

5) Falling of a handled object (4th factor)

The variables contact with a falling object from the hand, toes, breakage etc. and other moving object were weighted in factor four. This factor was called falling of a handled object.

6) Strenous movement (5th factor)

The variables trunk and strenous movement were positively weighted in factor five. This type was called strenous movement.

7) Hurting oneself with other handled object (5th factor)

The variables hurting oneself with a handled object and fingers were negatively weighted in factor five. This type was called hurting oneself with other handled object.

8) Flying object (6th factor)

The variables spatters etc., potential severity, head, contact with flying object and explosion etc. were positively weighted in factor six. This type was called flying object.

The variables dust etc. and no preceding event were negatively weighted in factor six. This could not be interpreted as a new accident type.

9) Falling object (7th factor)

The variables contact with a falling object, other falling object and transportation equipment were weighted in factor seven. This type was called falling object.

10) Other accident type (8th factor)

The variables other or unknown contact event, no source of injury and fire etc. were weighted in factor eight. It was difficult to interpret this factor exactly and it was called other accident type.

11) Fall to a lower level (9th factor)

The variables head, fall to lower level and potential severity were negatively weighted in factor nine. This type was called fall to lower level.

The variable lower limbs was positively weighted in factor nine but this could not be interpreted.

12) Accidental starting (10th factor)

The variables machines, accidental starting, contact with moving object and fingers were negatively weighted in factor ten. This type was called accidental starting.

3.2. Typology on the basis of near-accidents

The factor analysis was made with the same variables as with the analysis of the accident material. Only the variables contact with a falling object from the hand and strenuous movement were excluded since there were no near-accident cases in these categories. The number of variables was thus 32.

The clearest result was obtained with seven factors. The sum of the communalities was 17.5 and the degree of the accountability 55 %. The preceding event accounted for the result best (17 %). The interpretation of the contact event, source of injury and potentially injured part of the body was between 15 and 10 %.

The factor matrix on the basis of near-accidents is presented in table 7. The factor solution is clear and most variables are weighted strongly in only one factor. It was divided into the following factors:

1) Hurting oneself with a handled object (1st factor)

The variables hurting oneself with a handled object, slipping of tool etc., hand tool and fingers were positively weighted in factor one. This type was called hurting oneself with a handled object.

2) Fall on the same level or to a lower level (2nd factor)

The variables contact on a stationary object, fall to a lower level, fall on the same level and floor etc. were positively weighted in the second factor. This type was

TABLE 7. The Factor matrix of the near-accident material

VARIABLES FAKTORS	1	2	3	4	5	6	7
POTENTIAL SEVERITY	-0.4904	-0.0675	-0.0083	0.0186	-0.0345	-0.0792	-0.5793
PART OF BODY							
head	-0.1206	0.2784	-0.2958	-0.2210	-0.4149	0.4350	-0.2226
eyes	-0.0790	-0.1094	0.1364	-0.0396	-0.1414	0.1119	0.7205
fingers	0.6914	-0.0088	-0.0216	-0.0618	0.0808	-0.1257	-0.0171
upper limbs	0.0635	-0.0206	-0.0877	0.7130	-0.0553	0.0980	-0.0421
toes	0.3505	-0.1487	-0.0778	-0.0093	-0.1371	0.1579	-0.0871
lower limbs	0.0056	0.0883	-0.1344	-0.0810	0.5685	0.1268	0.2802
trunk	-0.1775	-0.1650	0.2297	-0.0129	-0.0337	-0.6779	-0.1004
SOURCE OF INJURY							
hand tool etc.	0.4498	-0.1009	0.0552	-0.1071	0.1185	0.1060	0.2105
transportation equipment	-0.0544	-0.2670	-0.4587	0.0399	0.1327	0.5034	-0.1529
machine	-0.1133	-0.1999	0.0701	0.2775	-0.1184	0.1122	-0.1254
products etc.	-0.0126	0.0141	-0.2030	-0.1883	-0.0185	-0.7576	0.0366
floor, construction, ground	-0.0932	0.6832	0.1183	0.1207	0.0004	0.0423	-0.0899
spatters, sparks, chips	-0.0692	-0.1143	0.6768	-0.0677	-0.0583	0.0148	0.0744
dust, cinders	-0.0751	-0.0790	0.0590	-0.0995	-0.1639	0.1069	0.6223
no	-0.0171	-0.0462	0.1048	-0.0998	-0.0717	0.1680	-0.2447
CONTACT EVENT							
contact on stationary object	-0.0810	0.9188	-0.1423	-0.1274	-0.1081	0.0412	-0.0300
contact with flying object	-0.1153	-0.1347	0.8292	-0.1247	-0.1368	0.0032	0.1974
contact with falling object	-0.2245	-0.4528	-0.4881	-0.3799	-0.3122	-0.0434	-0.2754
cont. with other moving object	-0.0592	-0.0606	-0.1254	0.8566	0.0339	-0.0114	0.2031
hurting oneself with handled obj.	0.8995	-0.0244	-0.0695	-0.0638	0.0352	-0.0404	0.0254
other, unknown	-0.0776	-0.0521	-0.0198	-0.0866	0.8108	0.0715	-0.0862
PRECEDING PHASE							
slipping of tool etc.	0.8038	-0.0684	-0.0596	0.1365	-0.1139	0.1386	-0.0707
fall on same level	-0.0494	0.4017	-0.1281	-0.0966	0.0152	0.0954	0.0250
jump	-0.0562	0.2994	-0.0289	-0.0316	0.1510	0.0429	0.0767
fall to lower level	-0.0421	0.7344	-0.0736	-0.0765	-0.2102	-0.0355	-0.0881
breakage, technical error	-0.2534	-0.4583	-0.3116	-0.3022	-0.3338	0.2406	0.1744
fire, explosion	-0.0461	-0.0640	0.8166	-0.1037	0.0026	0.1135	-0.2831
other falling object	-0.0956	-0.1900	-0.2278	-0.1014	-0.1277	-0.6214	-0.1721
other sudden moving object	0.0635	0.0541	-0.0017	0.0742	0.2149	-0.0941	0.5345
accidental starting	-0.0980	-0.0443	-0.0702	0.8251	-0.0637	0.0531	-0.0647
no	0.0553	-0.0399	-0.0715	-0.0246	0.7586	-0.0152	-0.1343

called fall on the same level or fall to a lower level.

3) Other falling object (2nd factor)

The variables contact with a falling object and breakage etc. were negatively weighted in the second factor. This type was called other falling object.

4) Flying object (3rd factor)

The variables contact with a flying object, explosion etc. and spatters etc. were positively weighted in the third factor. This type was called flying object.

5) Falling transportation equipment (3rd factor)

The variables contact with a falling object and transportation equipment were negatively weighted in the third factor. This type was called falling transportation equipment.

6) Accidental starting (4th factor)

The variables contact with a moving object, accidental starting and upper limbs were positively weighted in factor four. This type was called accidental starting.

7) Other accident type (5th factor)

The variables other or unknown contact event, no preceding event and lower limbs were positively weighted and the variable head negatively weighted in factor five. It was difficult to interpret this factor accurately and it was called other accident type.

8) Falling product (6th factor)

The variables product etc., other falling object and trunk were negatively weighted in factor six. This type was called falling product.

The variables transportation equipment and head were positively weighted in factor six but this could not be interpreted.

9) Cinder in the eye (7th factor)

The variables eye, dust etc. and other moving object were positively weighted in factor seven. This type was called cinder in the eye.

3.3. Comparison of the typologies

The accident types in both typologies can be divided into three categories as follows:

- accident types where the injury is caused mainly by contact on some stationary object as a result of the kinetic energy of the human body
- accident types where the injury is caused mainly by contact with a moving object as a result of the kinetic energy of the object and
- other accident types where there is no clear contact or collision with any object or the amount of energy is small.

3.3.1. Injuries caused by the kinetic energy of the human body

There were two accident types representing injuries caused by the kinetic energy of the human body in the typology of the accident material: fall on the same level and fall to a lower level. In the analysis of the near-accident material these types were combined.

3.3.2. Injuries caused by the kinetic energy of an object

The following accident types represented injuries caused by the kinetic energy of an object in the analysis of the accident material:

- falling of a handled object
- flying object
- falling object
- accidental starting and
- other moving object.

In the analysis of the near-accident material the types falling of a handled object and other moving object did not appear. In addition there were three types representing falling objects: falling transportation equipment, falling product and other falling object.

3.3.3. Other accidents

The following accident types represented injuries in other mishaps in the accident material analysis:

- cinder in the eye
- hurting oneself with a hand tool
- hurting oneself with other handled object and
- strenuous movement

The types hurting oneself with a handled object and cinder in the eye also appeared in the analysis of the near-accident material.

In the analysis of both the accident and near-accident material there was the category other accident type. About ten per cent of all the material belonged to this type. Under closer examination these cases revealed the following groups:

- contact with a moving vehicle (two accidents and four near-accidents)
- explosion of an oxygen hose (four accidents and one near-accident)
- hurting oneself on a stationary object (18 accidents) and
- other or unclear casualties (four accidents).

Of these cases contact with a moving vehicle was combined with the type other moving object. The explosions of an oxygen hose were combined with the type flying object.

3.4. Combined accident typology

On the basis of the factor analyses a combined typology of twelve categories was formed (table 8).

TABLE 8. The combined accident typology

accident type	accidents	near-accidents
KINETIC ENERGY OF HUMAN BODY		
fall on same level	27	4
fall to lower level	4	6
KINETIC ENERGY OF MOVING OBJECT		
flying object	27	17
falling of a handled object	20	0
other falling object	4	25
accidental starting	8	5
other moving object	35	11
OTHER ACCIDENT		
hurting oneself with a handled object	36	5
hurting oneself on a stationary object	18	0
strenuous movement	29	0
cinder in the eye	12	1
other, unclear	3	1
total	223	75

The combined typology is different from the typology of the official Finnish statistics and from the ANSI-standards. The types low or high temperature, contact with electric current and toxic substances are missing from this typology. There were no cases involving electric current and toxic substances in the material. There were many cases of contact with hot spatters etc. but they were combined with the type flying object.

Otherwise this typology is like the ANSI-typology (ANSI 1962) which is however more detailed. The official Finnish typology (Työtapaturmatilaston luokitusperiaatteet 1977) differs greatly from this typology. The only equivalent types in both typologies are fall on the same level, fall to a lower level, falling of a handled object, other falling object and strenuous movement. The type "striking against objects because of work motions or being struck by moving objects" in the official typology covers almost all other categories in this typology. The official Finnish typology makes no distinction between the energy sources.

4. RELIABILITY OF POTENTIAL INJURY ESTIMATES

4.1. The reliability of potential severity estimates

4.1.1. The reliability between estimates of the three subjects

There were no big differences in the overall estimation of the potential severity between the safety officer and workers' safety representative (table 9). However, the safety officer rated more cases into category three and the safety representative into category four. The author rated less cases into categories one and four but more into category five than the other estimators.

TABLE 9. Severity estimates of the works safety officer, the workers' safety representative and the author and the common estimate acceptable to all three according to the category of potential severity

potential severity	safety officer	safety representative	author	common estimate
1 small	26	26	19	23
2 minor	84	92	91	84
3 significant	80	47	80	68
4 severe	35	62	19	39
5 critical	48	46	64	59
	273	273	273	273

TABLE 10. The agreement between the severity estimates of the works safety officer and the workers' safety representative

		estimates of the safety officer				
		1	2	3	4	5
estimates of	1	15	9	2	0	0
the safety	2	4	55	29	1	3
representative	3	1	11	23	6	6
	4	5	8	18	23	8
	5	1	1	8	5	31

The safety officer and the safety representative rated 147 (54 %) cases into the same category of potential severity (table 10). The correlation stating the reliability between the estimates was 0.64.

The reliability figures between the severity estimates of the safety officer and the author was 0.55 and between the estimates of the safety representative and the author 0.64. So the reliability of the estimates of potential severity was 0.61 on average.

In the original categories the degree of reliability between the author and the representatives of the factory was not significantly worse than the degree of mutual reliability between the representatives of the factory.

The classifications of each estimator were also compared with the common estimates. The correlation of the common estimates was 0.76 with the estimates of the safety officer, 0.80 with the estimates of the safety representative and 0.71 with the estimates of the author.

Potential severity was more reliably estimated in near-accidents (r=0.68) than in accidents (r=0.57).

4.1.2. The influence of the severity categories

In order to eliminate any error caused by coincidental agreement the alternative categories were compared using Cohen's coefficient of agreement for nominal scales as a measure (Komulainen 1974). In the original categories Cohen's coefficient was 0.39 on average. Coefficient varied from category to category and it was highest in the slightest and in the severest injury categories (table 11).

Categories three and four were the most difficult to estimate. One of the reasons for this might have been the fact that their descriptions included both the duration of the absence and the degree of permanent disability. In some cases these may be contradictory. For example the loss of a finger joint does not necessarily lead to an absence of more than a month.

TABLE 11. Average reliability between three subject's severity estimates by category on the severity scale, N=3x91[1]

category	Cohen's coefficient
1 small, insignificant	0.57
2 minor	0.39
3 significant	0.22
4 severe	0.33
5 critical	0.54
total	0.39

1) Includes only such cases where all 3 subjects had estimated the same part of the body

The possibility of increasing the reliability by combining the categories was examined by calculating the Cohen's coefficient with different combinations (table 12).

TABLE 12. Average reliability between the three subject's severity estimates in various category combinations measured with Cohen's coefficient (r_c)

4 classes	r_c	3 classes	r_c	2 classes	r_c
1-2, 3, 4, 5	0.42	1-3, 4, 5	0.47	1, 2-5	0.57
1, 2-3, 4, 5	0.46	1, 2-4, 5	0.53	1-2, 3-5	0.53
1, 2, 3-4, 5	0.43	1, 2, 3-5	0.48	1-3, 4-5	0.50
1, 2, 3, 4-5	0.40	1-2, 3-4, 5	0.46	1-4, 5	0.55
		1, 2-3, 4-5	0.48		
		1-2, 3, 4-5	0.43		
total	0.43		0.48		0.54

Decreasing the number of categories increased the reliability significantly (variance analysis, table 13). This analysis showed that the reliability of different pairs of estimators differed. The mutual reliability of the representatives of the factory was higher than that between the author and the representatives of the factory. The result is different from that of the above analysis using the original categories.

TABLE 13. The effect of the number of categories and the pair of estimators on the reliability of severity estimates

source	SS	DF	MS	F
between category combinations	0.095	3	0.032	16.97
between pairs of subjects	0.041	2	0.021	11.03
interaction	0.007	6	0.001	0.65
residual	0.062	33	0.002	
total	0.205	44	0.005	

$F_{0.001}(3,30)=7.05 < 16.97$; $p < 0.001$
$F_{0.001}(2,30)=8.77 < 11.03$; $p < 0.001$
SS = sum of squares DF = degrees of freedom
MS = mean of squares F = test parameter

The highest reliability was achieved with a two-category variable by leaving either the slightest or the severest category alone and by combining the rest. One category is thus very heterogenous which means that the advantage of high reliability is dissipated. The most recommendable variable with two categories seems to be where categories 1-2 are classed as slight and categories 3-5 as severe accidents.

The highest reliability when using combinations of three categories was achieved by keeping the slightest and the severest category separate and by combining categories 2-4. The second category is thus fairly heterogenous. On the whole it seems better to keep only the slightest category independent and to class categories 2-3 as severe and categories 4-5 as critical accidents.

The highest reliability in combinations of four categories was achieved by combining categories two and three and by keeping the other categories separate.

4.2. The reliability of the part of the body estimates

4.2.1. The reliability between estimates of the three subjects

There were only a few differences between the overall estimation of the three subjects (table 14). The safety representative rated more injuries of lower limbs than the safety officer. The author rated more head injuries and lower limb injuries than the other subjects but less multi-injuries.

There was a systematic difference between the author and the other subjects concerning the multi-injuries. The author tried to find the potentially most severely injured part of the body while the others were more prone to rate the multi-injury. This difference is also reflected in the other categories, especially the head and lower limb injuries.

TABLE 14. Estimates of the potentially injured part of the body made by the three subjects and the common estimate agreed by all three

part of the body	safety officer	safety re-presentative	author	common estimate
1 head	34	43	57	46
2 eye	26	28	29	31
3 fingers	45	39	35	45
4 upper limbs	33	23	36	32
5 toes, foot	19	10	7	14
6 lower limbs	27	40	60	42
7 trunk	28	30	31	43
8 multi-injury	61	60	18	20
	273	273	273	273

The safety officer and the safety representative rated 185 cases into the same part of the body category (table 15). The reliability was 68 %. When category 8 (multi-injury) is omitted the reliability is 74 %. Correspondingly the reliability between the estimates of the author and safety officer was 69 % and between the estimates of the author and the safety representative 76 %. The reliability was 73 % on average between the three estimators.

There was no significant difference in the part of the body estimates between accidents (72 %) and near-accidents (78 %).

4.2.2. The influence of the part of the body categories

The reliability of the part of the body estimate was best in potential eye injuries, 91 %. The reliability was less than 70 % only in the case of upper limbs, toes and foot (table 16).

TABLE 15. The agreement between estimates of the potentially injured part of the body made by the safety officer and the workers' safety representative

		estimates of the safety officer							
		1	2	3	4	5	6	7	8
estimates of	1	24	1	0	10	0	0	2	6
the safety	2	2	23	0	0	0	0	0	3
representative	3	0	1	33	1	0	0	0	4
	4	0	0	8	13	1	1	0	0
	5	0	0	0	0	7	1	0	2
	6	4	0	0	5	5	23	2	1
	7	3	0	0	1	1	2	20	3
	8	1	1	4	3	5	0	4	42

By combining the categories of finger and upper limbs, the reliability of the category whole arm by using the same estimates turned out to be 84 %. Correspondingly, the estimation reliability of the combined category of the whole leg was 79 %. Thus the reliability of the group with five variables (head, eye, arm, leg, body) turned out to be 82 % on average, which can be considered good.

The severity of the potential injuries of the limbs was estimated best. The estimates concerning the severity of potential body injuries were the most uncertain. By combining the part of the body categories they can be made more heterogenous, but its weakening influence on the reliability of the severity estimates remained, however, minor. The reliability of the combined categories was 0.69 while otherwise it was 0.70.

TABLE 16. Reliability of the three subjects' estimates according to the part of the body

potentially injured of the body	reliability: severity[1] N=3x142 r	reliability: part of the body N=3x273 %	
head	0.62	72	
eye	0.68	91	
fingers	0.72	83	84[2] (fingers + upper limbs)
upper limbs	0.78	52	
toes, foot	-	45	79[2] (toes, foot + lower limbs)
lower limbs	0.71	70	
trunk	0.52	78	
total	0.70	73	82[2]

1) Includes only such cases where all three subjects were unanimous about the the part of the body
2) With combined categories

4.3. Influence of actual injury on reliability

It was assumed that the reliability would be increased if the estimates were similar to the actual injuries. This was studied using the estimates of the safety officer and the safety representative.

The reliability in both severity estimates and in part of the body estimates was better when the estimated part of the body was the same as the injured part of the body (table 17). The agreement between the severity estimate and the actual severity did not have much effect on the reliability.

The interrelations between these factors were examined by creating four new, dichotomic variables and studying them with partial correlation analysis (table 18) and linear regression analysis.

TABLE 17. The effect of the agreement between the part of the body estimate and the actually injured part of the body on the reliability, %

		Body estimate of the safety officer same as injured part of body	
		yes	no
body estimates of the safety officer and the safety representative unanimous	yes	75	30
	no	25	70
severity estimates of the safety officer and the safety representative unanimous	yes	61	17
	no	39	83

Correlations do not reveal anything about the direction of the influence. This must be estimated on the basis of the temporal order or some other logical association. The presumed directions of the influences between variables are presented in figure 6.

TABLE 18. Influence of actual injuries on the unanimity of the estimates, partial correlation matrix, N=207

	1	2	3
1 body estimate same as injured part of the body (yes/no)	1		
2 severity estimate same as actual severity (yes/no)	0.205	1	
3 agreement on body estimate (yes/no)	0.449	0.067	1
4 agreement on severity estimate (yes/no)	0.140	-0.007	0.243

There was more agreement in the part of the body estimates when the estimate was similar to the actual injury. Regression analysis showed the relationship to be significant. The whole model explained 24 % of the variation in agreement in the part of the body estimates.

The regression analysis showed that the agreement of the severity estimates was increased significantly if the estimate of the part of the body was unanimous. The other variables had no significant effect. The whole model explained only 6 % of the agreement of the severity estimations.

The eye and head were more often estimated as the potentially injured part of the body than actually occurred in practice.

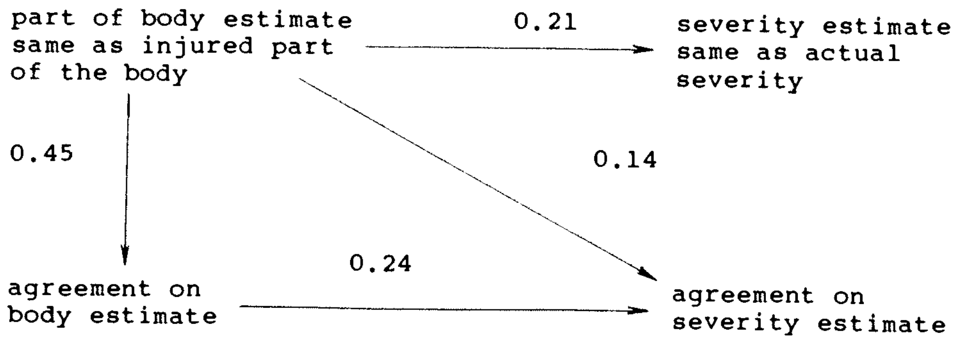

FIGURE 6. The presumed directions of the influence between the variables of estimated and actual injuries

4.4. Influence of accident type on reliability

The reliability of the severity estimates was highest in the accident types; accidental starting, hurting oneself on a stationary object and fall to a lower level. It was lowest in the types; fall on the same level, falling of a handled object and strenuous movement (table 19).

TABLE 19. The reliability of the potential injury estimates of three subjects according to accident type

accident type	N	reliability	
		severity r	part of body %
accidental starting	13	0.71	63
hurting oneself on a stationary object	18	0.69	64
fall to a lower level	10	0.53	89
other falling object	26	0.51	91
other moving object	38	0.50	68
flying object	41	0.46	81
cinder in the eye	13	0.39	90
hurting oneself with a handled object	39	0.36	84
strenuous movement	29	0.34	81
falling of a handled object	15	0.22	67
fall on the same level	28	0.18	61
other	3	-	-
total	273	0.61	73

The reliability of the part of the body estimates was highest in the accident types; other falling object, cinder in the eye and fall to a lower level. It was lowest in the types; fall on the same level, accidental starting and hurting oneself on a stationary object.

The variance analysis showed that differencies of the reliability of both severity and part of the body estimates were significant between the different accident types.

5. VALIDITY OF THE POST INCIDENT ESTIMATES AND WORKERS' SUBJECTIVE RISK ASSESSMENTS

5.1. Concurrent validity

5.1.1. Potential and actual severity of the accidents

Lost working days caused by the accidents were used as a criterion when examining the concurrent validity of the common severity estimate. The incorrectness of the severity estimate is indicated only if the actual injury is more severe than the one estimated as potentially the most severe. In the other cases we can not know if the estimate is right or wrong.

The potential severity of an accident was estimated to be the same as the actual severity in 35 % of the cases (table 20). In 57 % of the cases the estimated potential severity was higher than the actual severity.

In only 8 % of the cases was the potential severity lower than the actual severity. In these 17 incorrectly estimated cases the estimate was one category lower than the actual severity. In six cases the estimate was a maximum of two lost working days whereas the actual absence was six days on average. In eleven cases the estimate was a maximum of 30 lost working days whereas the actual absence was 41 days on average. Thus the degree of error in these estimates was not large.

There was no actual severe or critical injury in the material but 22-32 % of the actual small, minor and significant accidents were estimated potentially severe or critical. In this respect, the actual severity had no significant efect on the potential severity (chi-square test)

TABLE 20. The potential and actual severity of the accidents

potential severity	actual severity 1	2	3	total
1 small, insignificant	16	6	0	22
2 minor	32	36	11	79
3 significant	11	29	25	65
4 severe	14	10	8	32
5 critical	6	10	9	25
total	79	91	53	223

The absence of victims younger than 32 years was 14 days on average. The absence of the 32-47 year old victims was 20 days and for those older than 47 years it was 31 days on average. The difference between the absence of the youngest and oldest group was statistically significant (t-test). The result is in agreement with the results of Skiba & Kröger (1979) and differs from the results of Cooke and Blumenstock (1979). Here the relationship between age and days off seemed to be linear whereas Cooke and Blumenstock found a curvilinear relationship.

The potential severity of accidents in different age groups did not differ significantly. Thus it seems that the long absence of the old victims is not due to the accident sequences so much as characteristics of the individual.

5.1.2. Potential severity of near-accidents

The potential severity of near-accidents was significantly larger than that of the accidents (table 21). The near-accidents were concentrated in the severest categories and the accidents in the middle severe categories. More than half of the near-accidents were critical, which means that there was a possibility of death or a very serious

TABLE 21. Accidents and near-accidents by potential severity

potential severity	near-accidents	accidents
1 small, insignificant	2	22
2 minor	9	79
3 significant	10	65
4 severe	12	32
5 critical	42	25
	75	223

$X^2=69.80$
$p< 0.001$

permanent disability. Only about 10 % of the accidents were potentially so severe.

One explanation for the severity of the near-accidents could be that they were concentrated in the severe accident types. This was tested using log-linear models for contingency tables.

The log-linear analysis was done with the variables potential severity and accident type. The only model providing an adequate fit for the data when near-accidents were compared with accidents was the model 12,13,23, which means that there are interactions between all variables (table 22). Near-accidents are concentrated in the severe accident types. This alone however, can not explain the high severity as near-accidents were still more severe than accidents when the accident type was made constant. This is particularly noticeable in the types; fall to a lower level, other falling object and other moving object.

TABLE 22. Accidents and near-accidents according to accident type and potential severity, N=398

3 accident type	1 group	near-accidents			accidents		
	2 pot.severity[1]	1	2	3	1	2	3
fall on same level		1	0	3	5	12	10
fall to lower level		0	1	5	0	1	3
flying object		4	0	13	9	1	17
falling of a handled object		0	0	0	4	13	3
other falling object		1	4	20	1	2	1
accidental starting		0	0	5	2	3	3
other moving object		1	3	7	7	16	12
hurting oneself with handled object		3	2	0	24	8	4
other accident		1	0	1	49	9	4

1) 1=classes 1-2, 2=class 3, 3=classes 4-5

model	X^2	df	p
12,13,23	12.89	11	0.300
13,23	25.20	13	0.022
other models			0.000

5.2. Structural validity

5.2.1. Single-variable analyses

The accidents were divided into two groups. The cases where the potential severity was small or minor formed one group which was called slight. The remaining accidents formed the other group which was called severe.

The two groups of accidents were compared with near-accidents and the control material of actual severe accidents in Finnish steel factories.

The victim's work did not differ significantly in the different groups (chi-square test). In the near-accidents the work could not be defined as often as in the other groups, however. Most accidents and near-accidents occurred in repair work, cleaning and disturbance removal (about 40 %). About 25 % of the accidents and near-accidents occurred in transportation and only 20 % in production work. The distribution is similar to that of fatal accidents in the German steel industry (Henter & Hermans 1982).

In slight accidents the activity of the victim differed from all the other groups (table 23). There were more slight accidents than others in manual work and less in machine work and driving a vehicle.

Among the near-accidents the activity could not be defined any more often than in the other groups. There were no other significant differences between potentially severe accidents, near-accidents and the control material.

TABLE 23. Potentially slight and severe accidents, near-accidents and actual severe accidents in the branch according to the activity of the victim (%)

activity	pot. slight N=101	pot. severe N=122	near-accidents N=75	actual severe N=62
manual work	68	45	21	37
hand work with tools	7	11	11	10
machine operation, driving a vehicle	6	19	23	34
walking etc.	15	22	12	15
other, unclear	4	3	33	5
	100	100	100	101

The working tool that the victim used did not differ significantly among the different groups. There was no tool in over half the cases. A hand tool was used most often. In near-accidents and in the control material however, the most frequently used working tool was tranportation equipment.

The material being handled only differed significantly between the groups, potentially slight accidents and severe accidents in the branch. There was no material in one third of the cases. In a quarter of the cases the material was scrap steel or a steel product and in another quarter it was a machine or transportation equipment.

In potentially slight accidents the source of the injury differed very significantly from all the other groups. Potentially severe accidents also differed in this respect from the control material. There were no other significant differences between the groups concerning the source of the injury (table 24).

TABLE 24. Potentially slight and severe accidents, near-accidents and actual severe accidents in the branch according to the source of the injury (%)

source of the injury	pot. slight N=101	pot. severe N=122	near-accidents N=75	actual severe N=62
hand tool	28	14	9	5
transportation equipment	8	15	24	37
machine	8	17	13	21
product, raw material	24	23	27	11
floor, construction etc.	6	13	16	8
spatters, sparks, chips	7	13	8	13
dust, cinder, other	20	5	3	5
	101	100	100	100

A hand tool or dust and cinder were more often the sources of the injuries in slight accidents and transportation equipment or a machine more seldom than in other groups.

The preceding phase did not differ between near-accidents and the control material (table 25). The other groups differed from each other. The differences were greatest between potentially slight and the other groups. The preceding phase could not be identified in the slight accidents any more often than in the other groups. In other words the accident sequence was shorter in the slight accidents than in the other groups.

The preceding phase involved some kind of technical fault in the near-accidents and in the control material more often than in the other groups.

The contact event in the potentially slight accidents differed from that of all other groups very significantly (table 26). Also the other groups differed from each other in this respect but not as much as they did from slight accidents.

TABLE 25. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to the preceding phase (%)

preceding phase	pot. slight N=101	pot. severe N=122	near-accidents N=75	actual severe N=62
slipping of tool etc.	11	15	5	11
fall on same level or to lower level	6	23	13	15
technical fault, explosion	5	7	48	24
accidental starting	2	7	7	10
other moving object	16	35	19	35
not identified	60	13	8	5
	100	100	100	100

TABLE 26. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to the contact event (%)

contact event	pot. slight N=101	pot. severe N=122	near-accidents N=75	actual severe N=62
contact with stationary object	9	22	13	13
contact with flying object	19	12	23	21
contact with falling object	5	16	33	21
contact with other moving object	8	27	16	39
hurting oneself with handled object	24	11	7	0
strenuous movement	25	3	0	0
other, unclear	10	9	8	6
	100	100	100	100

Hurting oneself with a handled object and strenuous motion were more often the contact events in the slight accidents while contact with a falling object or other moving object were less common than in the other groups. Contact with a flying object was as common in slight accidents as in the other groups but the object in most slight accidents was dust or cinders.

The different groups according to accident type are presented in table 27. Because of the low frequency of occurrence in many categories the differences between the distributions of the groups could not be tested. However, the differences were tested with the chi-square test within separate categories according to accident type.

The accident types hurting oneself with a handled object, strenuous movement and cinder in the eye occurred more

TABLE 27. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type (%)

accident type	pot. slight N=101	pot. severe N=122	near-accidents N=75	actual severe N=62
fall on same level	5	18	5	2
fall to lower level	0	3	8	10
flying object	9	15	23	21
falling of a handled object	4	13	0	11
other falling object	1	2	33	10
accidental starting	2	5	7	10
other moving object	7	23	15	34
hurting oneself with a handled object	24	10	7	0
hurting oneself on a stationary object	9	7	0	2
strenuous movement	25	3	0	0
cinder in the eye	12	0	1	0
other	3	0	1	2
	101	99	100	102

often in the potentially slight accidents than in the other groups. Other moving object occurred less often in slight accidents than in the other groups. In addition the type flying object occurred less often in the slight accidents than in either near-accidents or in the control material.

There were more cases of falls to a lower level in near-accidents and in the control material than in the other groups. Falls on the same level occurred more frequently in potentially severe accidents than in all the other groups.

TABLE 28. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to combined accident type (%)

accident type	pot. slight N=101	pot. severe N=122	near-accidents N=75	actual severe N=62
kinetic energy of human body	5	21	13	11
kinetic energy of moving object	23	58	77	85
other accidents	72	20	10	3
	100	99	100	99

Fallings of a handled object occurred more often and other falling objects less often in near-accidents than in all the other groups.

The accident types were divided into three categories according to the source of the energy. When this was done the potentially slight accidents differed very significantly from all the other groups (table 28). The accident type, other accident occurred more often in slight accidents while kinetic energy of a moving object was less common.

Furthermore, potentially severe accidents differed from near-accidents and from the control material. There were less occurrences of moving objects and more occurrences of other accidents in potentially severe accidents than in these groups.

Near-accidents did not differ from the control material in this respect.

5.2.2. The accident type and the activity

The interaction between the accident type and the activity of the victim in different groups was examined using

TABLE 29. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and activity of the victim, N=325

	1 group pot. slight			pot. severe			near-accidents			actual severe		
3 activity	2 accident type T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
manual work, work with hand tools	2	17	57	5	50	14	3	16	5	4	24	1
machine operation driving vehicle	0	4	2	4	16	3	1	15	1	1	20	0
walking etc.	3	2	10	3	7	2	6	3	0	2	6	1

T1= kinetic energy of human body
T2= kinetic energy of moving object
T3= other accident

log-linear models. Scales with three categories were used both in the accident type and in the activity (table 29).

When examining all groups at the same time the simplest model that provided an adequate fit to the data was the model 12,23 (table 30). This means that the group and the activity are independent from each other when the accident type is made constant. The accident type is dependent on the group and the activity.

When comparing the potentially slight accidents by pairs with the other groups the result was the same as stated above. Thus the accident type differed from the other groups in slight accidents but the activity did not differ when the accident type was constant.

The simplest model that provided an adequate fit to the data when separately comparing near-accidents with potentially severe accidents and actual severe accidents in the branch was 23,1. This means that the accident type was

TABLE 30. The fit of different log-linear models to the data by the variables; group (1), accident type (2) and activity (3)

groups in analysis	model[1]	X^2	df	p
all	12,13,23	16.54	12	0.167
"	12,23	28.78	18	0.051
pot.slight/pot.severe	12,13,23	4.56	4	0.336
" "	12,23	8.88	6	0.179
pot.slight/near-accidents	12,13,23	2.24	4	0.695
" "	12,23	9.02	6	0.171
" "	12,13	27.31	8	0.001
pot.slight/actual severe	12,13,23	3.29	4	0.512
" "	12,23	8.06	6	0.233
" "	12,13	16.08	8	0.041
pot.severe/near-accidents	12,13,23	7.20	4	0.124
" "	12,23	10.46	6	0.106
" "	13,23	8.49	6	0.204
" "	23,1	12.51	8	0.129
pot.severe/actual severe	12,13,23	8.93	4	0.062
" "	12,23	12.43	6	0.053
" "	13,23	22.73	6	0.001
near-accidents/actual severe	12,13,23	5.42	4	0.245
" "	12,23	5.58	6	0.473
" "	12,13	21.12	8	0.007
" "	13,23	10.37	6	0.109
" "	12,3	21,27	10	0.019
" "	13,2	26.07	10	0.004
" "	23,1	10.52	8	0.229
" "	1,2,3	26.22	12	0.010

1) Includes only such models where $p > 0.000$

dependent on the activity but the group was independent of both of these. Thus near-accidents were similar to potentially severe accidents and to the control material on these variables.

This analysis showed for example, that the potential severity is dependent on the accident type but not on the activity. About 80 % of the falls either to a lower or on the same level and 75 % of the contacts with a moving

TABLE 31. The accident material by the accident type and activity (%)

accident type	manual work N=145	machine operation N=29	walking N=42
kinetic energy of human body	7	11	43
kinetic energy of moving object	41	76	17
other accident	52	13	39
	100	100	99

object are potentially severe. The figure for the other accidents is only 25 %. The accident type other accident is most common in manual work while the type contact with a moving object is most common in machine operation. Accident types fall to a lower or on the same level and other accident are most common in walking (table 31).

5.2.3. The accident type and the source of the injury

Different groups were also compared according to accident type and the source of the injury (table 32). The only model that provided an adequate fit to the data was the model 12,13,23. This means that all variables are mutually dependent but there is no need to postulate any second order interaction. The analysis by pairs of groups did not give any clear proof of the hypotheses.

The analysis was continued with Spearman's rank correlation analysis. Rank order numbers were given to the cells of table 32. In order to eliminate zero-cells the cells selected for the analysis were so arranged that five cells of most cases in all groups were included. This can be further justified by the fact that the first orders are the most important in setting priorities. So, there were altogether eight cells from every group in the analysis (table 33).

TABLE 32. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and source of injury, N=360

3 source of injury	1 group pot. slight 2 accident type T1	T2	T3	pot. severe T1	T2	T3	near- accidents T1	T2	T3	actual severe T1	T2	T3
hand tool	1	0	27	3	7	7	0	5	2	0	2	2
transportation equip.	0	3	5	2	13	3	1	16	1	1	22	0
machine	2	3	3	4	12	5	0	10	0	0	13	0
product, etc.	1	7	16	5	20	3	3	15	2	0	7	0
floor, etc.	1	1	4	11	0	5	6	5	1	5	0	0
spatters etc.	0	7	0	0	16	0	0	6	0	0	8	0
dust, cinder, other	0	2	18	1	3	2	0	1	1	1	1	1

T1= kinetic energy of human body
T2= kinetic energy of moving object
T3= other accident

Potentially slight accidents were weighted in other accidents with hand tools, products or dust and cinders. The other groups were weighted in contacts with a moving object.

Potentially slight accidents had a negative correlation with all the other groups (table 34). The mutual correlations of the potentially severe accidents, near-accidents and the control material were positive. All correlations were statistically significant exept the correlation between the potentially slight and severe accidents.

TABLE 33. Rank orders of potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and source of the injury, N=360

	1 group pot. slight			pot. severe			near-accidents			actual severe		
3 source of injury	2 accident type T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
hand tool			1			6			6			6
transportation equip.		6			3			1			1	
machine		7			4			3			2	
product, etc.		4	2		1	7		2	7		4	8
floor, etc.	8			5			4			5		
spatters etc.		5			2			5			3	
dust, cinder, other			3			8			8			7

T1= kinetic energy of human body
T2= kinetic energy of moving object
T3= other accident

TABLE 34. Spearman's rank correlation coefficients between the rank orders of the potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and source of injury (N=8)

	pot. slight	pot. severe	near-accidents	actual severe
pot. slight	1.00			
pot. severe	-0.43	1.00		
near-accidents	-0.62*	0.81**	1.00	
actual severe	-0.67*	0.76*	0.86**	1.00

* $p < 0.05$
** $p < 0.01$

5.2.4. The accident type and the part of the body

Different groups were also compared according to accident type and the part of the body (table 35) with Spearman's rank correlations. The cells were selected for analysis so that five cells of most cases in every group were included. Thus there were eleven cells in the analysis from every group (table 36).

The potentially slight accidents were concentrated in other accidents to the arm, trunk and leg. The potentially severe accidents were concentrated in contacts of a moving object with the leg, arm or eye. Near-accidents and the control material were concentrated in contacts of a moving object with the arm, trunk, head and leg; and in the falls on the same or to a lower level, with leg injuries.

Potential head and arm injuries also produced many cases of falls on the same level or to a lower level in the group of potentially severe accidents. There was only one such case among the control material.

TABLE 35. Potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and the potentially injured part of the body, N=360

	1 group pot. slight			pot. severe			near-accidents			actual severe[1]		
3 potentially injured part of the body	2 accident type T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
head	1	4	3	11	4	4	1	18	1	1	9	0
eyes	0	3	12	0	13	2	1	2	1	0	2	1
arm	0	6	28	11	21	13	0	11	2	0	17	1
leg	4	8	11	3	26	3	2	8	2	5	13	0
trunk	0	2	19	1	7	3	1	19	1	1	12	0

T1= kinetic energy of human body
T2= kinetic energy of moving object
T3= other accident
1) actually injured part of the body

TABLE 36. Rank orders of potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and the potentially injured part of the body

	1 group pot. slight			pot. severe			near-accidents			actual severe[1]		
3 potentially injured part of the body	2 accident type T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
head	11	8		5	7		9	2		7	4	
eyes		9	3		3	11		6	10		6	8
arm		6	1		2	4		3	7		1	9
leg	7	5	4	8	1	9	5	4	8	5	2	10
trunk		10	2		6	10		1	11		3	11

T1= kinetic energy of human body, T2= kinetic energy of moving object, T3= other accident
1) actually injured part of the body

Potentially slight accidents had a negative correlation with all the other groups (table 37). The mutual correlations of the potentially severe accidents, near-accidents and the control material were positive. However, only the correlations of the control material with the potentially severe accidents and near-accidents were statistically significant.

TABLE 37. Spearman´s rank correlation coefficients between the rank orders of the potentially slight and severe accidents, near-accidents and severe accidents in the branch according to accident type and the potentially injured part of the body (N=11)

	pot. slight	pot. severe	near-accidents	actual severe
pot. slight	1.00			
pot. severe	-0.29	1.00		
near-accidents	-0.48	0.52	1.00	
actual severe	-0.52	0.65*	0.85**	1.00

* $p < 0.05$
** $p < 0.01$

6. ACCIDENT RISK PRIORITIES

6.1. Priorities according to accident type

The priorities of accident types were calculated using five different measures: 1) number of accidents, 2) lost working days in accidents, 3) risk potential of accidents, 4) risk potential of near-accidents and 5) lost working days in the control material of actual severe accidents in the branch.

The risk potential was calculated using estimates approved by the three subjects together. The estimates were first converted into lost working days using the following coefficients (Schulz 1973). The same coefficients were used in calculating the lost working days from injuries of the control material.

potential severity		coefficient
1	small, insignificant	1
2	minor	10
3	significant	100
4	severe	1000
5	critical	6000

The accident type flying object was the most important on the basis of the risk potential of accidents (table 38). It was also prominent in relation to near-accidents and to the control material.

The second most important accident type in relation to the accidents' risk potential was fall on the same level. It was also prominent in relation to the number of accidents and resulting lost working days but not in relation to near-accidents or to the control material.

The third most important accident type in terms of the accidents' risk potential was contact with other moving object. It was prominent on the bases of all the other measures too.

TABLE 38. Rank order of the accident types measured on different scales

accident type	measure 1	2	3	4	5
fall on same level	4	2	2	6	8
fall to lower level	10	9	5	4	3
flying object	5	6	1	2	2
falling of a handled object	6	3	6	10	3
other falling object	11	10	10	1	5
accidental starting	9	5	9	5	6
other moving object	2	1	3	3	1
hurting oneself with a handled object	1	8	8	8	10
hurting oneself on a stationary object	7	7	4	11	7
strenuous movement	3	4	7	12	11
cinder in the eye	8	11	11	9	12
other, unclear	12	12	12	7	9

1=number of accidents, 2=lost working days in accidents, 3=risk potential of accidents, 4=risk potential of near-accidents, 5=calculated lost working days in the control material

In relation to the number of accidents the types hurting oneself with a handled object and strenuous movement were also prominent. The type hurting oneself with a handled object is not prominent on the other scales. Strenuous movement is prominent in relation to lost working days.

Falling of a handled object is prominent in relation to lost working days due to accidents while other falling object is prominent in terms of the risk potential of near-accidents. These two accident types are also prominent in relation to the control material.

Accident risks measured on five different scales were compared by using Spearman´s rank correlation coefficient (table 39). The rank order on the basis of the number of accidents correlated significantly with those formed on the bases of lost working days and on the risk potential of the accidents. Its correlation with the rank orders formed on the bases of the risk potential of near-accidents and on lost working days resulting from the control material was zero or negative.

The rank order based on accident-induced lost working days correlated significantly only with that based on the accidents´ risk potential. The rank order based on the risk potential of the accidents had a significant positive correlation with those based on all other scales exept the risk potential of near-accidents. Thus it seemed to be a better measure of risk than the number of accidents or lost working days.

TABLE 39. Spearman´s rank correlation coefficients for rank orders of different accident types measured on different scales (N=12)

		1	2	3	4	5
1	number of accidents	1.0				
2	lost working days in accidents	0.68**	1.0			
3	risk potential of accidents	0.55*	0.69**	1.0		
4	risk potential of near-accidents	-0.24	-0.05	0.18	1.0	
5	calculated lost working days in control material	0.00	0.42	0.57*	0.62*	1.0

* $p < 0.05$
** $p < 0.01$

The rank order based on the risk potential of near-accidents correlated significantly only with the rank order based on the control material.

6.2. Relative risk of different occupations

The occupations were divided into three groups: production workers, maintenance workers and transport workers. The accident risk was examined using three measures:

- accidents per one thousand workers
- lost working days per one thousand workers and
- risk potential of accidents per one thousand workers.

The relative risk between two occupations was calculated on each measure by dividing the absolute risks with each other. This was presented in the following format (see Rowe 1977):

$$RR = \left[\begin{array}{l} \text{group 1} \\ (RR_{min},\ RR_{mean},\ RR_{max} \\ \text{group 2} \end{array}\right.$$

where RR = the relative risk of group 1 with group 2
RR_{min} = smallest relative risk
RR_{mean} = mean of relative riks
RR_{max} = greatest relative risk

The relative risks between occupations differed when calculated on different scales (table 40). The risk of maintenance workers was the highest and the risk of transport workers lowest in terms of the number of accidents. The opposite was true on the basis of lost working days. On the basis of the risk potential of accidents the risk of production workers was the highest and the risk of transport workers the lowest.

TABLE 40. The accident risk of different occupations measured on different scales

measure	production worker N=781	maintenance worker N=252	transport worker N=285
number of accidents per 10^3 workers	180	190	110
lost working days per 10^3 workers	3 300	2 800	3 600
risk potential of accidents per 10^3 workers	170 000	113 000	99 000

The risk of production workers was on average 1.2 times higher than the risk of maintenance workers when measured on different scales. The greatest difference in risk was in terms of risk potential:

$$RR = \left[\begin{array}{l} \text{production workers} \\ 1.0, \quad 1.2, \quad 1.5 \\ \text{maintenance workers} \end{array} \right.$$

The risk of the production workers was on average 1.3 times higher than that of the transport workers on the different scales. The greatest difference in risk was in terms of risk potential:

$$RR = \left[\begin{array}{l} \text{production workers} \\ 0.9, \quad 1.4, \quad 1.7 \\ \text{transport workers} \end{array} \right.$$

The risk of maintenance workers was 1.2 times higher than that of transport workers. The greatest difference was presented under risk potential:

$$RR = \left[\begin{array}{l} \text{maintenance workers} \\ 0.8, \quad 1.2, \quad 1,7 \\ \text{transport workers} \end{array} \right.$$

6.3. The risk of a production worker in different working phases

The variables work and activity of the victim were combined and the new variable was called the working phase. The relative accident risk in different working phases was investigated by calculating the percentage of risk and the percentage of working time in each working phase and dividing these with each other. The risk was calculated using the same three measures as for the risks in different occupations.

The percentage of working time in different working phases was calculated on the basis of the MTM time-studies of the factory. In these studies the work was divided into task-components and the working time for each task-component in minutes or percentages was given (Rationalisoinnin käsikirja 1979). These task-components were smaller work units than working phases. So first we worked out which working phase each task-component belonged to and after that the time percentage in each working phase could be calculated.

This part of the study was limited to production work. There were 144 accidents among production workers in the material and 90 of them occurred in work where an MTM-study was available.

It proved difficult for an outsider to decide which working phase each task-component belonged to. So this was done by a time-study operative at the factory. The reliability was not examined but because of the simplicity of classifications it can be presumed adequate.

Walking from one place to another was not always separated in MTM-studies. So this time could not be calculated in the working phase . This causes some error in working phase times but the error is hardly significant.

Other factors that have an effect on the reliability are the scope of the accident material and the MTM-studies and the accuracy of the MTM-studies. The accuracy of the MTM-studies is adequate for our purpose. At least half the accidents in every production phase occurred in work that had been studied with MTM. If the time distribution of the remaining accidents differs from that in the studied work this will cause some error in the results.

Possible errors caused by the foregoing factors were taken into consideration in the analysis by giving quite a wide range of variation for the calculated time in each working phase. The range was 4 %-units or at least 20 % of the calculated time. The risk was calculated both within the calculated time and wihtin the upper and lower limits of the range.

TABLE 41. The distribution of the accidents and working time into different working phases (%)

working phase	accidents[1]	time[2]
machine operations in production	8	35
manual production work	26	29
machine operations in transport	4	7
fastening or loosening of load	10	4
manual transfer	2	1
adjustment, cleaning, disturbance removal	21	2
repair work	5	-
walking etc.	18	-
other, unclear	7	22
	101	100

1) Calculated of the percentages of the three measures; number of accidents, lost working days and risk potential of accidents
2) The time could not be calculated in the working phases repair work and walking

The number of accidents, lost working days and risk potential presented a similar picture of the focuses of accident risk by different working phases (r_s=0.83-0.88, N=9).

The focuses of accidents were manual production work, adjustment, cleaning, disturbance removal and walking (table 41). Most of the active working time was spent in machine operation and manual production work.

The relative risk in different working phases was calculated by dividing the percentage of accidents by the percentage of working time in each working phase (table 42). The relative risk is clearly highest in the working phase adjustment, cleaning and disturbance removal. Also the risk in fastening or loosening the load is above average. The working time was short and a wide range of variation was allowed for in these working phases. That is why the relative risk also has a wide variation.

TABLE 42. The relative accident risk of the production worker in different working phases

working phase	relative risk[1]		
	min.	mean	max.
machine operations in production	0.2	0.2	0.3
manual production work	0.8	0.9	1.0
machine operations in transport	0.4	0.6	0.8
fastening or loosening of load	1.7	2.5	5.0
manual transfer	0.5	1.0	1.0
adjustment, cleaning, distubance removal	4.2	10.5	21.0
other, unknown	1.3	1.4	1.5

1) The mean is calculated on the basis of the calculated time, while the minimun and maximum on the basis of the upper and lower limits of the time variation

The other and unknown working phase is also more dangerous than working phases on average. Most accidents in this phase occurred when the victim was walking.

The machine operations in production is the safest working phase. The accident risk in this phase is only 20 % of the average in all working phases and only 5 % of the accident risk in adjustment, cleaning and disturbance removal.

6.4. Focuses of the accident types in different working phases

The study was limited to the six working phases in which most accidents occurred.

On the basis of the number of accidents the type other accident was emphasized in all working phases more than it was on the bases of the other measures (figure 7). A moving object (most often, flying object) was the greatest risk in manual production work in relation to all measures.

The focus of the accident risk differed on each measure in fastening or loosening a load. It was fall on the same or to a lower level in relation to risk potential, moving (most often falling) object in relation to lost working days and other accident in relation to the number of accidents.

The focus of the accident risk in repair work was moving (most often flying) object in relation to risk potential. Moving object was also a focus in relation to lost working days but most lost working days were due to falling objects. Type other accident was the focus in repair work in relation to the number of accidents.

The type moving object was the focus of accident risk in adjustment, cleaning and disturbance removal in relation to all measures. In walking the focus was fall on the same or to a lower level.

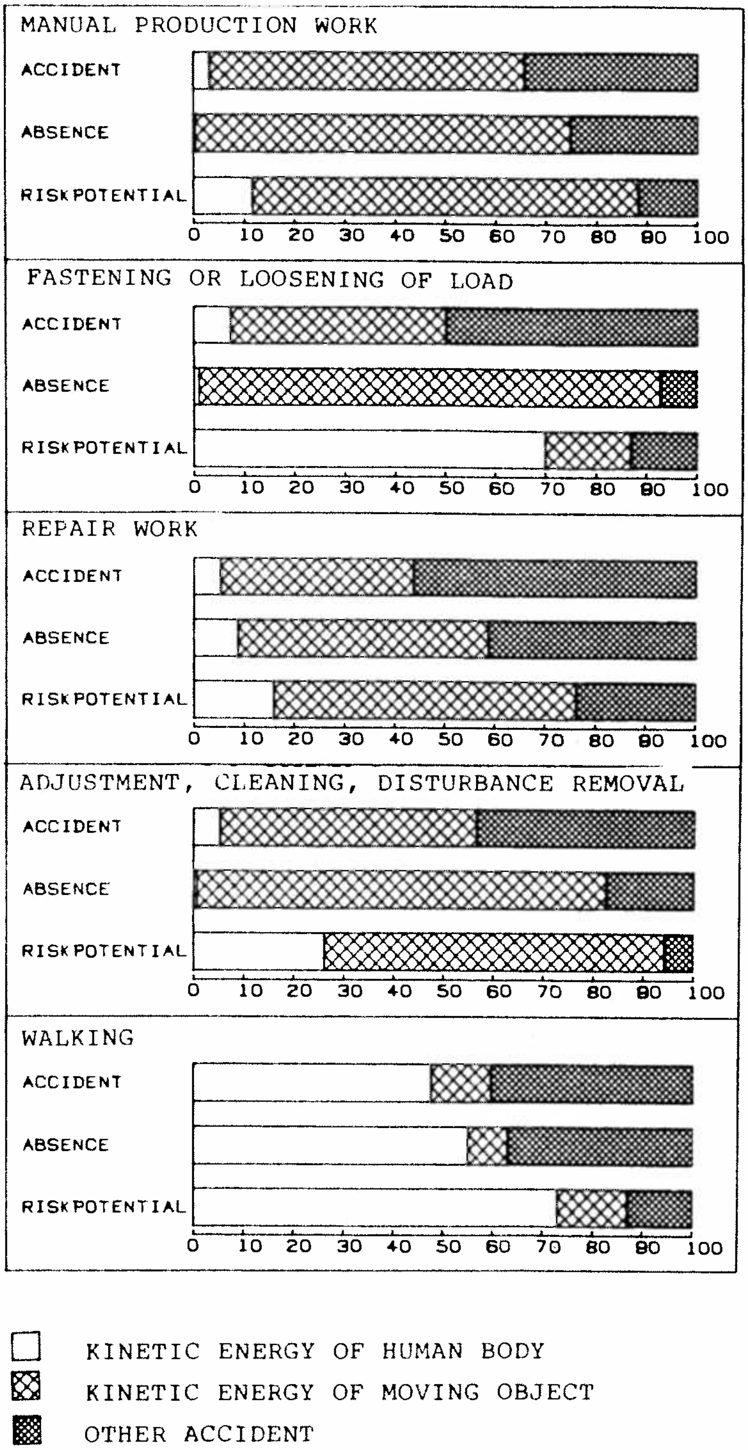

FIGURE 7. Focuses of the accident types in different working phases (%)

6.5. Relative risk of different production phases

The production process of the factory was divided into three phases: smelting works, rolling and steel treatment. The relative accident risk in the different production phases was calculated in the same way as the relative risk in different occupations.

The smelting works was the most dangerous production phase and steel treatment the second most dangerous production phase in relation to all measures (table 43).

TABLE 43. Accident risk in different production phases by different measures

measure	smelting works	rolling	steel treatment
accidents per 10^3 workers	283	153	185
lost working days per 10^3 workers	5 480	2 740	3 640
risk potential of accidents per 10^3 workers	328 000	64 100	145 000

The risk in the smelting works was on average three times higher than the risk in rolling mills. The difference was smallest in relation to the number of accidents and greatest in relation to risk potential:

$$RR = \left[\frac{\text{smelting works}}{\text{rolling}}\right] \quad 1.8, \quad 3.0, \quad 5.1$$

The risk in the smelting works was on average about two times greater than the risk in treatment. The difference was greatest on the basis of risk potential:

$$RR = \left[\begin{array}{lll} \text{smelting works} & & \\ 1.5, & 1.8, & 2.3 \\ \text{steel treatment} & & \end{array}\right.$$

The risk in treatment was about 1.5 times higher than the risk in rolling. The difference was smallest in terms of the number of accidents and greatest in terms of risk potential:

$$RR = \left[\begin{array}{lll} \text{steel treatment} & & \\ 1.2, & 1.5, & 2.3, \\ \text{rolling} & & \end{array}\right.$$

6.6. Focuses of the accident types in different production phases

The focuses of the accident types differed in different production phases. The focuses differed also on different scales. (figure 8).

The most important accident type in smelting works on all scales was a moving object. The objects were most often flying molten steel.

The most important accident type in the rolling mills in terms of risk potential was a moving object. The type other accident was also a focus on the bases of the other measures.

The most important accident type in the steel treatment in relation to risk potential was a fall on the same level or to a lower level. However, the focus on the basis of lost working days was a moving (most often falling) object. The focuses on the basis of the number of accidents were the types other accident and a moving object.

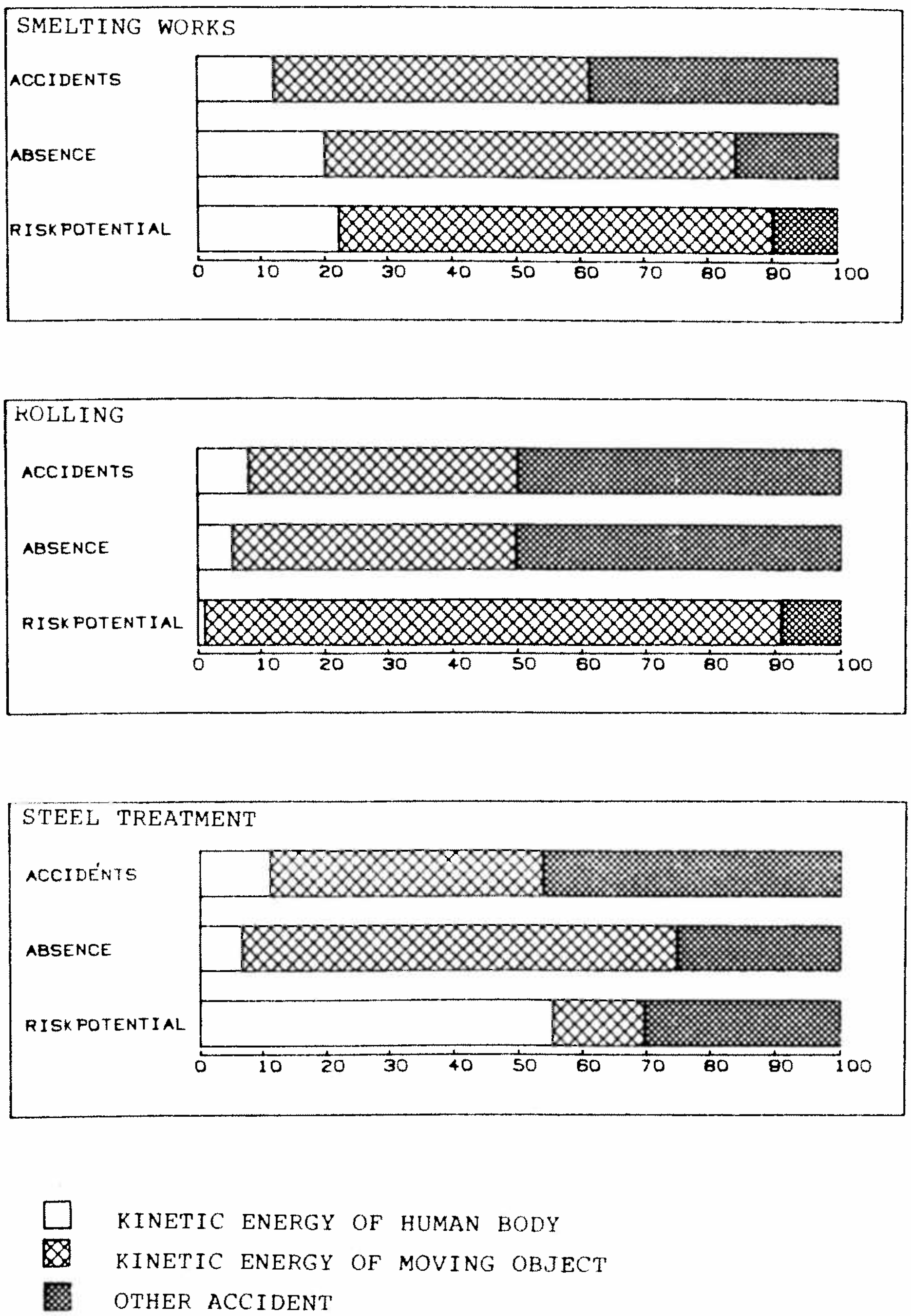

FIGURE 8. Focuses of the accident types in different production phases (%)

7. EFFECT OF THE NEAR-ACCIDENT REPORTING CAMPAIGN ON ACCIDENTS

7.1. General

There are many difficulties and weaknesses in this kind of before-after study. Besides the studied effect of the near-accident campaign there are many other possible variables that may have an effect on the accidents at the same time; the natural variation, other parts of the study, other changes in safety work of the factory, changes in production and regression.

There were no other documented changes in the safety work at the factory during the study. Also production was pretty steady. The work-force was reduced in 1981. This may have had some effect on the accident situation after the study but it is difficult to say in which direction.

41 near-accidents were reported during the two campaigns. 43 accidents occurred during the same period. Thus the ratio was 0.95 reported near-accidents per one actual accident. Before the campaign but during the study the ratio was 0.15 reported near-accidents per one accident.

The reporting activity varied greatly in different sections of the factory (table 44). There were 2.4 reported near-accidents per one accident in the three most active reporting sections but in the other sections the workers reported more accidents than near-accidents.

Among the high-activity near-accident reporting sections there were both high and low risk sections in relation to accident rate. The same was true for the less active sections. The differences in accident risk did not account for the differences in reporting activity.

It is supposed that there were also more near-accidents in passive sections but for some reason the campaigns were not

TABLE 44. Near-accidents Reporting activity and accident rate in the nine production sections before, during and after the field study

	sections 1	2	3	4	5	6	7	8	9
average number of workers in 1978-79	61	72	55	108	96	168	244	48	32
average number of accidents per year in 1978-79[1]	7	10	7	26	25	14	38	12	2
average accident rate 1978-79[2]	72	75	37	137	127	48	90	147	33
accident rate 1.10.-31.12.1979	143	29	0	184	146	56	100	143	67
accident rate 1.1.-31.3.1980	0	39	0	136	114	71	84	100	143
accident rate in 1980	95	34	23	135	108	43	78	113	78
near-accident reporting activity during campaigns[3]	250	117	63	54	45	32	28	24	0

1) All accidents that cause at least one lost working day
2) Accidents per million working hours
3) Near-accident reports per million working hours

successful in these sections. This gives us the opportunity to compare the accident trends in active and passive sections.

7.2. Short-term effects

The accident trends from August 1979 to the following March in the five most active sections and the other sections are presented in figure 9. The number of accidents increased in the five most active sections and decreased in the other sections from August to November.

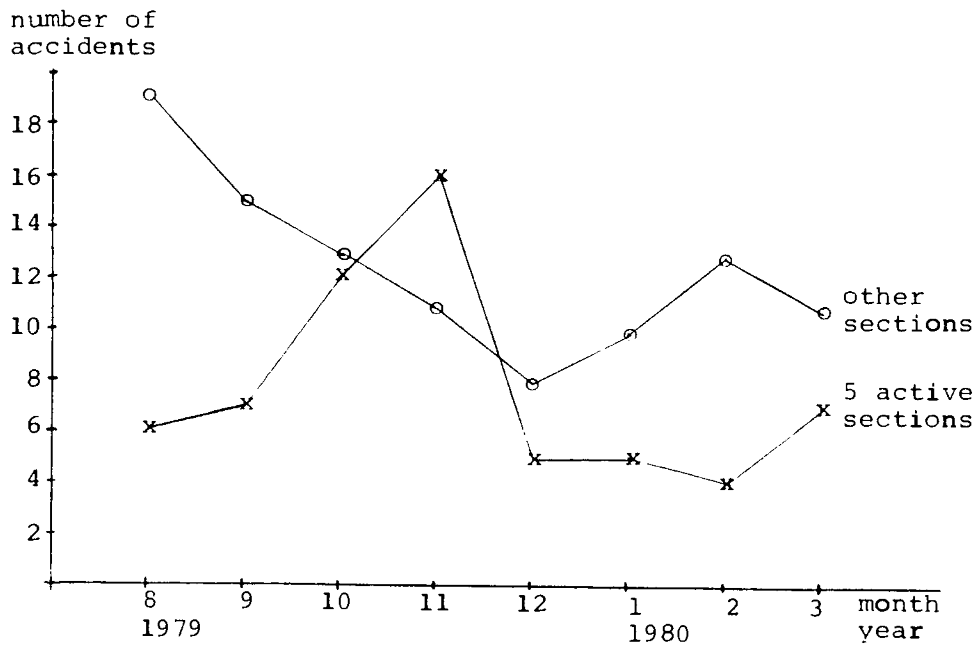

FIGURE 9. The monthly number of accidents in the five most active sections and in the other sections 1.8.1979-31.3.1980

The accident investigations by the investigation groups began on 1.10.1979. It had no significant effects on the accident situation during two months.

After the first reporting campaign began in December the number of accidents dropped immediately and stayed at the lower level during the following four months in the five most active sections. The decrease in the number of accidents from November to December in the active sections was significant when tested with Brilon's (1973) confidence limits ($p < 0.01$). There was no other significant changes in the accident situation during the study.

Seven slight accidents in the active sections and three slight accidents in the other sections were reported as near-accidents during the campaigns. Even when this is taken into consideration, the number of accidents decreased significantly in the five most active sections during the campaigns (table 45). The decrease in the other sections was not significant (Brilon 1973).

TABLE 45. The number of accidents before and during the near-accident reporting campaign in the five most active and other sections

	5 most active sections[1]	other sections[1]
accidents 4 months before	41[2]	58[3]
accidents 4 months during	19 (+7)	42 (+3)

1) Accidents reported as near-accidents are in parentheses
2) Lower confidence limit 27 when $p < 0.01$ (Brilon 1973)
3) Lower confidence limit 42 when $p < 0.05$ (Brilon 1973)

The severity rate of accidents increased during the campaign in the active sections and decreased in the other sections (table 46). The changes were not great, however, when the accidents reported as near-accidents were taken into consideration.

TABLE 46. Lost working days per accident before and during the campaign in the five most active and other sections

	5 most active sections[1]	other sections[1]
4 months before	8.4	7.0
4 months during	12.4 (9.1)	6.0 (5.6)

1) Accidents reported as near-accidents are included in the calculations in the figures in parentheses

There were changes in the accident types in the active reporting sections during the campaigns. Before the campaigns 68 % of accidents were the severe types kinetic energy of the human body or moving object. During the campaign only 47 % of the accidents were of this type while the majority were other accidents. The change was not really significant however (chi-square test). There was a converse change in the other sections. 56 % of the accidents were of a severe accident type before the campaign and 62 % during it.

About one third of the decrease in accidents in the five active departments was due to reporting slight accidents as near-accidents. In addition some slight accidents may have occurred and not been reported at all. Against this is the fact that the number of accidents in slight accident types increased during the campaign.

7.3. Long-term effects

Long term changes in the accident situation were examined by studying the accident frequency in the years 1978-1981. The accident rate in both active and passive sections decreased from 1979 to 1980 but the decrease was not significant. In fact, annually no significant changes occurred between 1978 and 1981.

The statistics of the factory were kept on a different basis than the official Finnish statistics and the accident rates could not be compared exactly. The figures showed however that the accident rate of the Imatra Steel Factory was clearly lower than that of the Finnish steel industry in general. The trends of the accident rates were similar in the years 1978-1980. In the year 1981 the accident rate increased in the steel industry on average but the decrease continued in Imatra.

The variation in the accident rate was on average wider in the Imatra Steel Factory than in the branch. This is natural and is caused by the greater random variation in a smaller unit.

7.4. Preventive measures

About 73 % of reported near-accidents but only 37 % of accidents led to immediate preventive measures. The difference is highly significant (table 47).

TABLE 47. Accidents and near-accidents according to the number of preventive measures (%)

measures per case	accidents N=152	near-accidents N=52
no measure	64	27
one measure	32	58
two measures	5	15
total	101	100

$X^2=22.72$
$p < 0.001$

There was no significant difference in the quality of the measures. Almost half of them were soft measures like new oral or written instructions or increased supervision. One quarter of the measures were technical such as installing a handle or a protective device or some kind of structural change. One fifth of the measures were connected with the motivation of workers' safety behaviour such as information about the danger. In some cases the maintenance program or the working method was changed. The lightning was improved in some cases.

8. DISCUSSION

8.1. Methods

8.1.1. Methods used in gathering the information

The method used in gathering the near-accident and accident material was laborious and costly. The reporting system for near-accidents had to be developed as there was no appropriate reporting system for them in any suitable firms. Interviews by telephone might have been a more effective way of getting near-accidents reported than the self reporting method used (Niskanen & Lauttalammi 1983).

Investigation of near-accidents and accidents at the place where they occurred was also a laborious method. It guaranteed the most reliable data however. The data gathered from the normal accident reports would not have been as dependable and accurate with regard to the accident sequence, at least not with slight accidents.

The firm's aim in developing its own routines for near-accident reporting and accident investigation also influenced the choice of methods. In this respect the project was successful considering the statements of the firm's representative. The work involved in gathering the information was not wasted in this regard either.

The factory's time studies were used in finding out the exposure time when calculating the accident risk according to working phase. By and large this proved to be a useful method. One deficiency was that time studies weren't available for all the work. Another deficiency was that the working phase walking was not generally distinguished from the other working phases in the time studies.

The use of the time studies can be justified by the fact that the work in them is divided into phases and safety can be dealt with in detail in the separate working phases. In fact it would be best to integrate safety into time studies and other work studies so that these would include some kind of safety analysis. This involves one possible source of error in this study however; the sample will differ from the other work if the time study has led to some kind of safety measures and a resulting decrease in the risk in some working phases. However, this error is hardly significant.

It proved difficult to get an accurate picture of the effect of the campaign on the safety situation in the factory through accident statistics alone. The reason is the small number of accidents and the high proportion of random variation among them (Tarrants 1980). The effects of various minor inaccuracies will increase in the long run and these are difficult to control. This was known at the beginning of the study but more laborious measurement methods were not worth-while as the focus in this study was on other hypotheses. The results are not accurate in this respect.

A more accurate picture of trends in the safety situation may be achieved using different observation methods (Cohen 1983, Komaki 1978, Grimaldi 1970). Immediate changes may be caused mainly by changes in the safety behaviour of the workers and foremen. That is why questionnaires may also be effective (Hammarsten, no printing year).

8.1.2. The estimation method of the potential severity

The weakness of the method used in the estimation of the potential severity of near-accidents and accidents was the small number of subjects. It is possible that the subjects of the study were exeptionally unanimous. However, the results are in agreement with the results of Rockwell (1970) and Östberg (1980) who used several subjects but a smaller number of cases in the estimation.

For practical purposes it is important that the method can be used by medically unqualified safety personnel and supervisors of factories.

The demands for the reliability of the method are not so great in practice as they are in research. It seems that reliability is no problem in applying this method of estimating the potential severity of accidents in working places.

The method may have many advantages: Real severe accident risk can be identified better than on the basis of all-purpose accident investigations and statistics (Allison 1967) The motivation to take preventive measures is probably increased in the case of potentially severe accidents.

The method enables researchers to classify even a small sample according to severity and thus saves research costs. This is not always possible on the basis of lost working days.

The possibility of congruously measuring risks identified by different methods such as accidents, near-accidents and safety analysis is also interesting. This could also have practical applications if it is thus possible to combine separate occupational safety information systems.

Severe injuries may occur even in the slight accident types if the accident sequence leads towards a more severe type. For example a slight mishap may, in some situations, lead to a fall to a lower level or contact with a moving object. In the study this kind of potential accident was not recorded in the case of an actual accident, even if it was taken into account when estimating the potential severity. There were not many cases where it differed from the actual accident type however.

The estimating method is worth developing further. Developing and testing it, particularly for practical use in different working places is important. Then the object of the study would be both the method with its classifications and instructions and its usage and effects in working places.

8.1.3. The accident model and statistical methods

Testing the reliability of the variables in the accident model beforehand proved to be useful. This made it possible to correct several classes. Even after correction the reliability of two variables was lower than 80 % which was regarded as a criterion of acceptability. These variables were then combined with each other. The reliability of all variables in the final accident model was good and the results are accurate in this respect.

Factor analysis was used in the preliminary analysis of the material when forming the accident typology. It is a linear method and may lead to great errors with non-linear material and dichotomic variables. The method proved to be adequate for the preliminary classification of the material.

The typology formed by the factor analysis was clear and proved to be useful in separating severe and slight accident risks. The typology was quite similar to the ANSI-standard (1962) which is however more detailed. The lack of the type, contact with a hot object, may be seen as a minor flaw in the typology. The typology may not be suitable for other branches of industry.

The reliability of the severity estimates was studied using correlations and variance analysis even on ordinal scales. This can be justified by the simplicity of the analysis and the insignificance of the error (Valkonen 1981).

The chi-square test, log-linear models for contingency tables and Spearmann's rank order correlations were used in testing the differences between separate accident and near-accident groups. Log-linear models have not been used earlier in accident research. In this method the logic of the linear model has been generalized for cases where variables are nominal or ordinally scaled. The method is suitable for analysing the interactions of three or more variables and it gives a statistical criterion for the conclusions (Everitt 1977). The method proved to be good in comparing different groups.

In some analyses the interactions were so complicated that even a log-linear model including all the first-order interactions was inadequate. In this case the analysis was continued using Spearmann's rank order correlations. In order to eliminate zero-cells the cells selected for the analysis were so arranged that the five first cells in priority order in every group of material were included. This is reasonable as the first orders are the most important in setting priorities. The rank order analysis proved to be very good for comparing the priority orders of separate groups in relation to two variables at the same time.

8.2. Results

8.2.1. Hypothesis 1: The potential severity of accidents and near-accidents can be reliably distinguished from the actual injuries

The results supported the hypothesis. The reliability of the part of the body estimates was good. The reliability of the severity estimates was reasonable when the part of the body estimates were unanimous.

Agreement on the part of the body estimate was lower when the estimate differed from the actually injured part of the body. This emphasizes the importance and difficulty of identifying the alternative potential injuries.

On the basis of the results we can state that the reliability of both the severity and part of the body estimates can be improved by developing the categories and their instructions. In the part of the body categories it seems best to include the whole arm from fingers to the shoulder in one category and correspondingly the whole leg in another category.

Decreasing the number of categories increased the reliability of the potential severity estimations. At the same time the degree of accuracy decreases however. So the number of categories must be decided on the basis of these conflicting requirements.

Reliability was highest in the slightest and severest categories. This result is logical. The definitions of the middle severe categories included both the duration of the absence and the degree of permanent disability which may also make estimation more difficult. The estimation of these categories may be helped by increasing the number of examples in the instructions.

The occupation of the victim may have an effect on the number of lost working days. This may cause a variation in estimates of the potential severity in the slightest categories. The effect is hardly significant and it can be eliminated by standardizing the occupation in the instructions.

The reliability of the estimates varied among the different accident types. The reliability of the severity estimates seemed to be higher in cases of moving objects than in other accidents. The estimation of both the part of the body and severity in the accident type fall on the same level was the most difficult. Furthermore the part of the body estimate often differed from the actually injured part of the body in this type.

The mutual reliability of the representatives of the factory was higher than that between the author and the representatives of the factory. This result emphasizes the need for local knowledge. The differences were not great however, so good local knowledge is not essential for a reasonable estimate.

8.2.2. Hypothesis 2: The post-incident estimation of the potential severity of accidents and near-accidents is a valid method for separating severe risks from slight ones

The results supported the hypothesis that post-incident estimation of the potential severity of accidents is a valid method for separating severe risks from slight ones.

The estimated potential severity of accidents was not in contradiction with their actual severity.

Accidents estimated as potentially severe were similar to near-accidents reported by workers and to the control material of actual severe accidents in the Finnish steel industry in regard to accident sequence. At the same time they differed from accidents estimated as potentially slight.

Potentially slight accidents differed from the other groups according to almost all the variables:

- there were more slight accidents than others in manual work and less in machine operation which conforms with the results of Abt (1982)
- a hand tool or dust and cinder was more often the source of the injury in slight accidents while transportation equipment or machines were less common than in other groups, which also conforms with earlier results (Mikkola 1981)
- the preceding phase was missing in slight accidents more often than in other groups which conforms with the results of Shannon & Manning (1980a)
- the accident types, hurting oneself with a handled object, strenuous movement and cinder in the eye occurred more often and other moving object less often in potentially slight accidents than in other groups which conforms with the results of Abt (1982).

Potentially severe accidents, near-accidents and actual severe accidents in the steel industry were similar to each other and differed in comparison to potentially slight accidents with regard to the following paired variables:

- accident type and activity of the victim
- accident type and source of injury and
- accident type and part of the body.

Accident type proved to be a decisive factor in distinguishing severe and slight risks when analysing several variables simultaneously. Most accidents of the types; fall to a lower or the same level and moving object were potentially severe and most accidents of the other accident types were slight. The amount of energy is greater in the former accident types than it is in other accidents and it can cause more severe injuries. This result is logical and it conforms with the results of earlier studies (Abt 1982, Calsson 1982, Laitinen 1983, Mikkola 1981, Senneck 1975, Shannon & Manning 1980a).

There was no sign of the potential severity being underestimated in any accident type. Falls on the same level occurred more in estimated severe accidents than in the control material which may indicate overestimation of the potential severity of this accident type. On the other hand Abt (1982) found an even greater proportion of falls on the same level among permanently disabling accidents than there were among potentially severe accidents in this study.

Falls on the same level were only estimated as potentially more severe than actual injuries in production phase steel treatment. In those sections there was a lot of steel stock and workers had to walk between stocks of steel and climb on them. A fall on the same level in these circumstances may result in contact with a sharp steel bar and a severe injury.

Strenuous movement and overexertion of the back was generally estimated as slight. No such cases were recorded among near-accidents or actual severe accidents in the steel industry. Abt's results supported these results. The results do not necessarily show that no serious back injuries occur in the steel industry however. They may show that these injuries are neither accidental nor registered as occupational accidents. Ergonomical OWAS-analyses made in the Imatra Steel Factory may have decreased injuries caused by overexertion.

8.2.3. Hypothesis 3: The workers are prone to report potentially severe near-accidents on the basis of their subjective risk assessment

The results supported the hypothesis regarding the validity of subjective risk assessment in separating severe risks from slight ones.

The reported near-accidents were potentially much more severe than the actual accidents. Risks that could have caused death or more than 60 % permanent disability were particularly overrepresented among the near-accidents. Near-accidents were concentrated in the severe accident types but they were still more serious than accidents when the accident type was made constant.

The severity of near-accidents and actual accidents has not been compared in earlier studies. However, near-accidents in the studies of Markkanen (1973) and Niskanen & Lauttalammi (1983) seem to be very severe on the basis of the published descriptions. Thus it is probable that a comparison would have shown the same results as in this study.

The reported near-accidents were similar to the potentially severe accidents in the factory and to the control material of actual severe accidents in the Finnish steel industry. They were different from the potentially slight accidents in the factory.

In about half of the near-accidents, the preceding phase was some technical fault or explosion which agrees with the results of Kjellén (1982). However, technical faults were also more general among the control material than among all the accidents of the factory. The results seem to show that cases which include technical faults are more severe than average and also that people report them for that reason. Results of Rockwell et al. (1970) which emphasized human errors in flying are propably caused by the peculiarities of the work in this respect. Technical equipment also has to be much more dependable and technical faults much rarer in airplanes than in most industrial machines and equipment.

Near-accidents differed from both potentially severe accidents and the control material with regard to two characteristics: Fallings of a handled object occurred more often and other falling objects less often in near-accidents than they did in the other groups. Falling objects were also more common in near-accidents than in fatal accidents in the German steel industry (Abt 1982).

It is possible for example that the falling of a load from a crane has such a high priority in the individual´s risk assessment that this kind of hazard is better avoided than average. Fall of a handled object may not have such a high priority in risk assessment. Feelings of personal guilt and doubts about the necessity of preventive measures may also decrease the reporting activity.

The lack of information about near-accidents regarded as slight by workers has been thought to be a problem and attempts have been made to stimulate reporting activity in this regard (Hammarsten, no printing year). However, the risk of workers and supervisors becoming frustrated through dealing with potentially slight near-accidents makes this of questionable value.

Loss of near-accident reports is a problem only if it is also concentrated on potentially severe near-accidents. It is of course possible that workers do not recognise all severe situations or they underestimate some of them. If this happens reporting should be activated using concrete information and training (Hale 1983). It´s better to try to activate the reporting of those near-accidents which are known to be severe than all near-accidents no matter how slight.

In summary, the results support the hypothesis that workers particularly tend to report potentially severe near-accidents and that their subjective risk assessment is realistic. The results demonstrate that any omission in the reporting of near-accidents is concentrated on potentially slight cases. The results agree with the statement that in particular the potential threat to life has an effect on peoples' risk performance.

Despite being much smaller the reported near-accidents material revealed more potentially fatal or severely disabling accident risks than all the accident material. In fact the reported near-accidents revealed more of these risks than the number of actual severe accidents occurring in the Finnish steel industry over a period of four years. Near-accidents are thus a very good source of information for safety work in a factory. They also seem to lead to preventive measures more often than accidents.

8.2.4. Hypothesis 4: Firms' accident risk priorities based on the number of accidents and lost working days are not consistent with priorities based on the risk potential of accidents

The results partially supported the hypothesis when studying the priorities according to accident type. The rank order on the basis of the number of accidents correlated significantly with those formed on the bases of lost working days and of the accidents' risk potential. This contradicted the hypothesis. However the rank order based on actual severe accidents in the steel industry only correlated with that based on the risk potential of both accidents and near-accidents. Some clear differences were found in rank orders based on the factory material: Hurting oneself with a handled object was only a significant risk on the basis of the number of accidents and a flying object was only a significant risk on the basis of accidents' and near-accidents' risk potential.

The results supported the hypothesis when studying the relative risks of different occupations. The number of accidents, lost working days and risk potential produced different results in this respect. The differences were not great however.

The risk of production workers was on average somewhat higher than the risk of maintenance workers or transport workers when measured on different scales. It is possible and even probable that there are smaller groups having a wider variation of risk within these occupations. More detailed categories of occupation and a greater range of accident material would be needed in identifying these groups.

The accident risk of a production worker varied widely in different working phases. Different risk scales agreed in this respect. This was inconsistent with the hypothesis.

Adjustment, cleaning and disturbance removal was the most hazardous working phase which conforms with the results of Saari (1977). The risk in this phase was ten times higher than average. The risk was also above average in the working phase fastening or loosening a load. All the working phases mentioned above accounted for only a small part of the working time but for a great deal of the accidents. In these working phases the worker has to be more than usually careful as he is near the danger zones of machines and equipment which is potentially hazardous (Hoyos et al. 1981).

The safest working phase was machine operation in production. The risk was only 20 % of the average.

The priorities of accident types in each working phase differed in relation to different risk scales which was in accord with the hypothesis. The slight accident types were emphasized more heavily on the basis of the number of accidents than on the bases of other scales.

The results did not support the hypothesis when comparing the relative risk between different production phases. The smelting works was the most dangerous production phase and steel treatment the second most dangerous production phase on the bases of all scales. The risk in the smelting works was on average three times higher than the risk in the rolling mills and about two times higher than the risk in steel treatment.

The Priorities of the accident types were different in each production phase in relation to the different scales however.

To sum up; the results supported the hypothesis when studying the priorities of accident types in relation to some group, working phase or production phase. Then the results based on the number of accidents, lost working days and risk potential differed from each other. In contrast, the results did not support the hypothesis when studying the relative risk of different working or production phases. In this case the results based on different scales were similar.

The explanation may be that both severe and slight accidents occur in all working or production phases and thus the differences between the different scales are compensated for. This will not happen if the average potential severity of accidents differs greatly between the compared groups. This may be why the accident risk of transport workers was relatively lower on the basis of the number of accidents than on the basis of the accidents' risk potential.

Scales based on the number of accidents seemed to emphasize the slight accident types. Lost working days is a better measure in this respect. Accident statistics of firms have traditionally been used to compare the accident risk from section to section within the firm and the different scales did not differ when thus employed. Thus developing the measurement scales alone is not enough. More thorough changes should be made in order to take advantage of the new scales. The statistics should also be able to point to the priorities of accident types for preventive measures. Unless this is done, the main significance of estimating potential severity seems to be the possible effect it will have on the preventive measures taken immediately after an accident or near-accident, not it´s application to statistics.

8.2.5. Hypothesis 5: A campaign for reporting near-accidents decreases the number of accidents

The results gave some support to the hypothesis over a short period. The hypothesis could not be tested over a longer period using these methods.

Near-accident reporting activity differed in different sections. The accident rate in the section did not account for the variation in reporting activity. The personal opinion of the author and the representatives of the factory is that the positive attitudes of the foremen contributed to the success in the active reporting sections. This was not studied however.

Near-accidents led to immediate preventive measures more often than accidents and one incident often resulted in several measures being taken, even if the same investigation groups investigated both kind of cases. The possible explanation may be that they also considered near-accidents more severe than accidents. Another explanation may be that near-accidents, being technical faults, were more easy to prevent than accidents. The result also conforms with the results of Kjellén (1982) who found that the routines for the follow-up of near-accidents with preventive measures were better than the corresponding routines for actual accidents.

There were no significant differences in the quality of the preventive measures between near-accidents and accidents. Only one quarter of them were technical measures and the rest were soft measures like increased supervision, instructions and information about the danger.

The number of accidents decreased in the most active reporting sections during the reporting campaign while there was no significant change in the less active reporting sections in the short term. About one third of the decrease in the number of accidents in the active sections was due to slight accidents being reported as near-accidents. The severity rate of accidents increased a little in the active reporting sections also when these "near-accidents" were taken into consideration. At the same time there was a shift towards more slight accident types. Thus the results do not indicate any omission in reporting slight injuries although some loss is possible however.

The results seem to show that there was a real decrease in the number of accidents in the most active reporting sections during the near-accident reporting campaign. Over a longer period the difference between the sections evens out.

A decrease in the number of accidents as a result of near-accident reporting has also been noted by Gustafsson (1976) but he did not show the statistical significance of the change. The number of accidents has also decreased in many companies which have routines for near-accident reporting (Bird & Germain 1966, Gappenberger 1974).

No case of an increase in the number of accidents as a result of near-accident reporting has been reported and it is difficult to imagine any logical argument for such a change. We can state that if near-accident reporting has any effect on accidents it is to decrease them in number.

Over a short period the decrease may be due to workers' and foremens' higher awareness of safety and subsequent changes in their safety performance. This kind of effect has been noted by Rockwell et al. (1970), Perusse (1978) and Butora & Höfle (1979). All kinds of safety campaigns should have the same effect. The effect is likely to be temporary if it is not followed up with new campaigns or other actions.

Preventive measures made on the basis of reported near-accidents should cause a decrease of the number of accidents over a longer period.

9. CONCLUSIONS

The following conclusions about identifying accident risks and accident statistics in companies may be drawn from the results:

1) A near-accident reporting system is a good method for identifying and reducing potentially severe accident risks when it works. Workers subjective risk assessment seems to be realistic. However, final conclusions cannot be drawn on the basis of this study. The hypothesis should also be tested with other materials.

Simple reporting methods for near-accidents and ways of further improving the subjective risk assessment of workers should be developed for working places.

Paying too much attention to near-accidents which are considered slight by the workers and foremen may result in needless frustration. Special effort should be made to utilize the subjective risk assessment of workers when activating the reporting.

2) It is possible to focus attention more intensive investigation and preventive measures in severe-risk cases through estimating the potential severity of accidents.

A risk index for routine use in working places could be developed from the estimation method. The instructions, rating scale and examples should be developed and tested according to the demands of different branches of industry. Their adaptability for use by supervisors and workers' representatives at departmental level within a company should be tested. The use and effects of the method on working places should also be studied.

3) The study highlighted the problems companies face in using accident-risk indicators based on the number of accidents as these emphasize slight accident types. In addition it is difficult to draw reliable conclusions about trends in the safety situation on this basis.

Lost working days due to accidents are a better measure than the number of accidents. Furthermore the potential risk index mentioned above could be used in statistics. However, it is useful only if there is also a classification of accident type in the statistics.

More sensitive yardsticks than those based on the actual accidents should be developed for controlling the safety situation in companies.

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