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Scientific reviews of ergonomic situation in mechanized forest operations

Siegfried Lewark, ed.

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Abstract		

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Contents

Scientific reviews on ergonomics in mechanised forest operations – Introducing the five reviews of the *ErgoWood* project

S. Lewark

Abstract

The output from the *ErgoWood* project shall be based on a comprehensive review of the science and experience in the field. The scientific reviews done in the project will also serve as a quality control.

Reviews of scientific knowledge and experiences on ergonomics for mechanised forest operations include scientific reviews on (1) social conditions, safety and health, (2) forest machine technical ergonomics, (3) work organisation, (4) costs and benefits and (5) control systems.

This introduction aims at giving one joint starting point for the five different reviews. It outlines the starting point and tries to link the reviews.

The ErgoWood project

ErgoWood – ergoefficient mechanised logging operations – is a three-year project funded by the European Commission to develop guidelines on ergonomic matters for European users, buyers and manufacturers of forest machines. This work will promote the development of safe and efficient forest machines, which are easy to use and maintain, as well as improving the sustainability in human resources. The project also involves developing and sharing good examples of work-crew building, work-shift scheduling, job rotation and work enlargement in logging operation. Different ways of organising forest work will be investigated and assessed.

The measured effects (output) will be presented in terms of economic, social and health output. Reliable measuring methods will be developed. This will make it easier to understand the benefits of ergonomic investments. Finally, the project also will contribute to make forest work attractive to young people.

Working situation of machine operators in mechanised forest operations

The *ErgoWood* project continues work, which earlier has led to the Ergonomic guidelines for forest machines 1999 (Gellerstedt et al., 1999). There the situation has been described:

> “Productivity and health
> After many years in the job, many forest-machine operators are no longer able to maintain a high level of productivity. They may be suffering from chronic fatigue or other illness or have lost their motivation, resulting in an inability to sustain a normal working tempo. This phenomenon is partly attributable to work in a machine cab being unnatural for us. The human body is not naturally disposed for sitting still in a vibrating cab and performing repetitive arm and head movements. Few operators today can cope with this day after day, year after year. Even the best machines are wearing on the operator. Human beings are predisposed for physically active and mentally varied work.”

> “Work organisation
> The harsh conditions prevailing in forestry require both machine and organisation to be adapted to the needs of the operator and the work team. The employer, machine owner and

operator must organize the work together and ensure that the pressure on the operator remains at an acceptable level. …

The tempo and/or quality of the work often tends to decline towards the end of a shift, especially when work is being carried out in the dark. The work must therefore be planned and organised so that the operators can utilize the machine efficiently throughout the shift. Working eight hours a day, day in and day out, is not recommended even on the best forest machines.

The following should be taken into account in attempts to develop profitable organisation of work:

- …
- how the work is organised (schedule, breaks, journey routes, lone working, support and help)
- operator profile (family life, motivation, age, health, etc.)"

The development of mechanised wood harvesting and transport as outlined, seems to be driven by economic and technological developments, ergonomic and organisational design only in second place.

The situation calls – within the given frame conditions, not alterable by the ergonomist, as employment and ownership structure seem to be – for all possible efforts to (further) improve:

- On the *human* side: Qualification, foundation for work (attitudes, emotional stability), make fit, keep fit
- On the *technical* side: (Further improvement of machine ergonomics)
- On the *organisational* side: Propose, test and implement work structuring (job enlargement, job enrichment, job rotation, semi-autonomous working groups) (among other approaches)
- On the *social* side: Co-operation and communication
- On the *economic* side: *Cost and benefit* the perspective of the company/employer/owner and ways of improving their situation, find out impact of interventions?
- On the *ergonomist's* and *work scientist's* side: Monitor situation and its changes
- On an *overall* level: All aspects of good work according to Ulich (1998) like control over working process, participation in decisions, completeness of task, feedback from social environment

The relationships between the ErgoWood reviews

It is seems useful to describe the relationship of the topics of the reviews, especially on ergonomic situation, organisation and technology (machines), as the development of technology and organisation (role of contractors) seems to be the natural starting point for all considerations. Obviously we have to start from the present situation and the recent developments of mechanised forest operations, as we perceive it, when we design our literature searches.

The relationship between the five reviews seems not to be based simply on stimuli and responses or schemes of input/transformation/output, for instance between organisation and physical well being respectively complaints. It is not a question of a given technology and an existing organisation and looking for the impacts on working men, but our aim is to create a basis for intervening and changing the situation, and doing this we will have to base our reviews on interactions to be found.

The MTO-model (Mensch-Technik-Organisation or (hu)Man-Technology-Organisation) from work psychology literature in German may serve as such a model of relationships and interactions. The model itself is presented in Figure 1.1 in a detailed way.

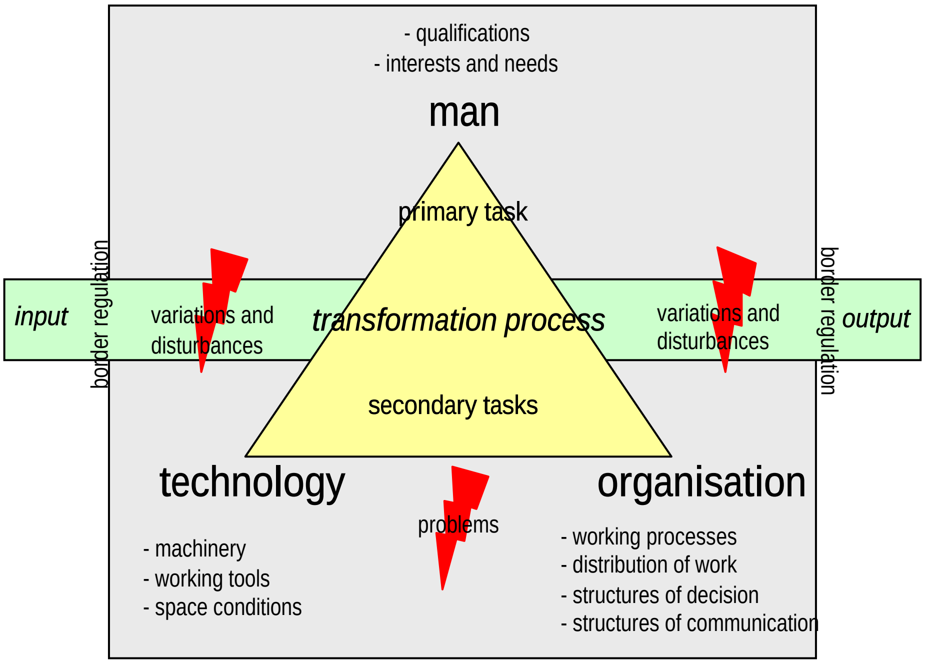

Figure 1.1. Elements of a working system (after Strohm, 1997 (translated from German)).

The triangle of human – technology – organisation as a frame to the task in the centre is pictured in Figure 1.2, where possible differences between the three objects or phenomena considered are indicated in an exemplary way. In this case technology and organisation would dominate the working human, whereas organisation is stronger influenced by technology then vice versa.

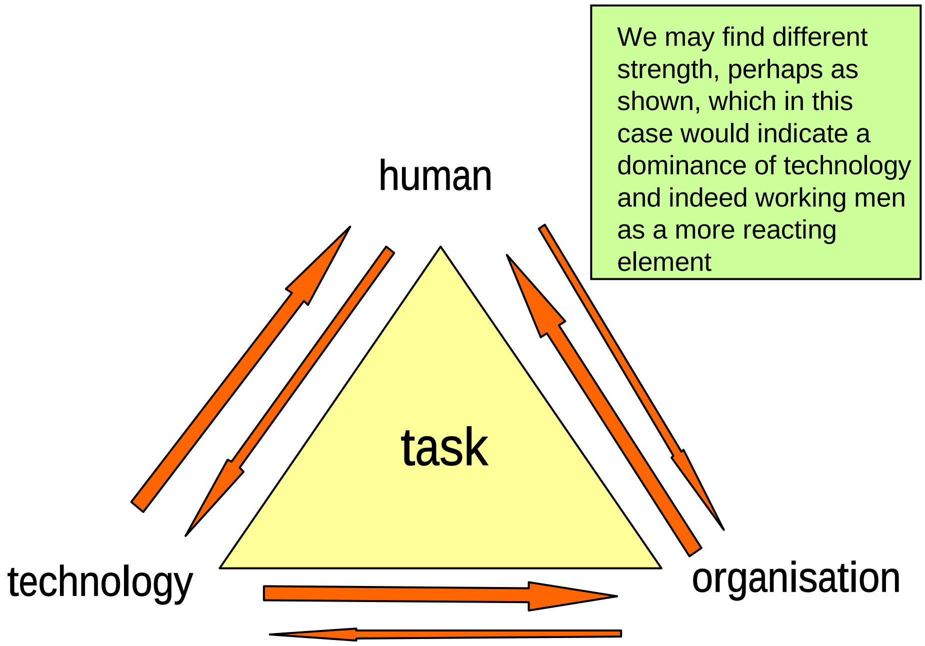

Figure 1.2. The task, human, technology and organisation with their interactions.

Quite obviously the reviews on ergonomics are to be assigned to the human (Figure 1.3), whereas the review on machine ergonomics is attached to technology and the review on organisation to the organisation edge of the triangle.

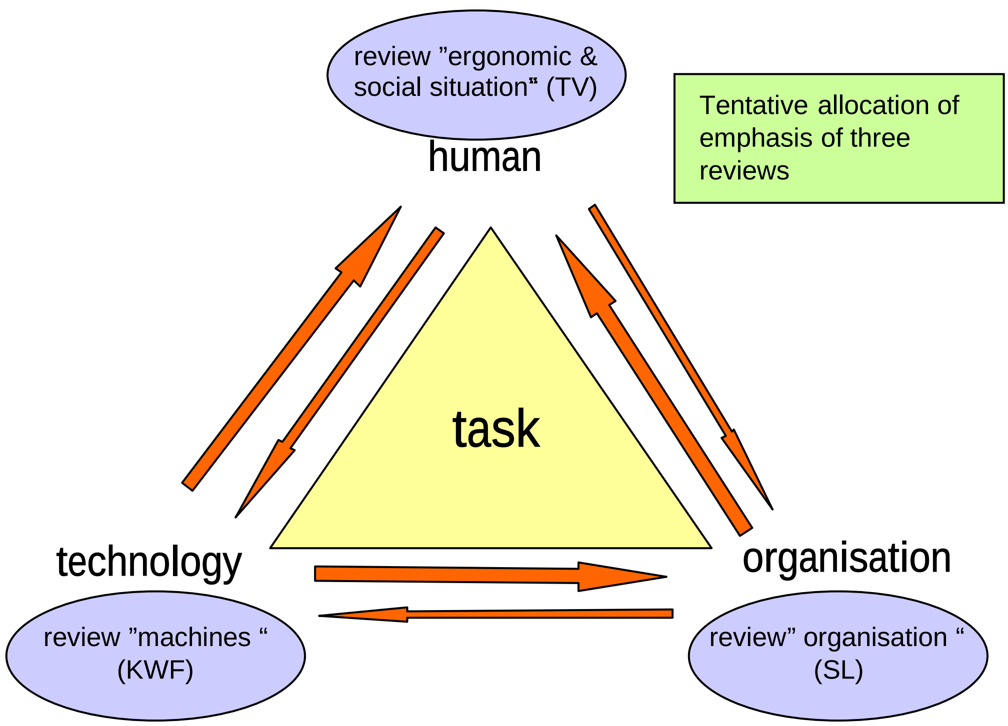

Figure 1.3. The allocation of three reviews around task, human, technology and organisation with their interactions.

The review on monitoring can be seen as focussing on the processes, which are indicated by arrows or at the impacts on working humans or on all of it (Figure 1.4). Interventions aiming at changing the processes could be aimed at all of the processes, the dominating or the less important ones (Figure 1.5).

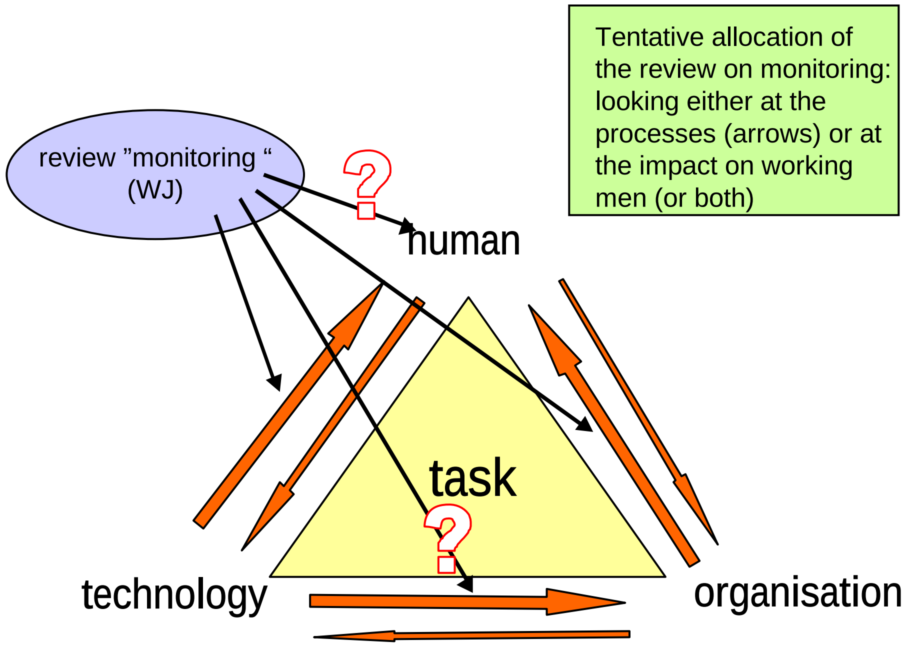

Figure 1.4. The allocation of the review on monitoring in the scheme of task, human, technology and organisation with their interactions.

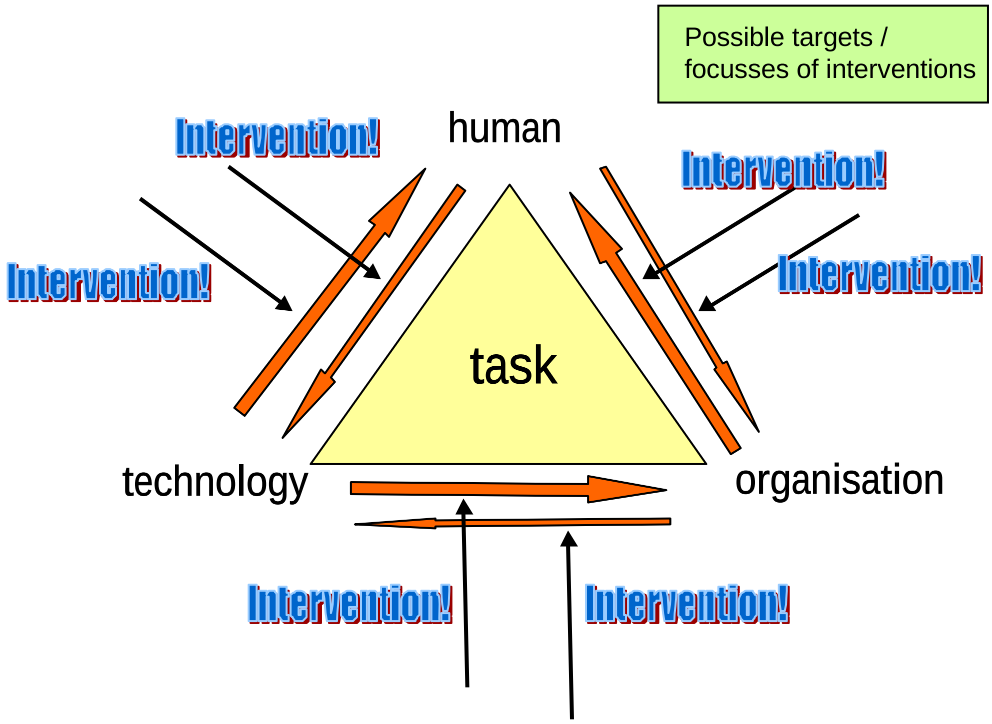

Figure 1.5. The potential directions of interventions in the scheme of task, human, technology and organisation with their interactions.

Finally the review on cost and benefits concerns the economic or perhaps otherwise assessable results of the processes and the interventions (Figure 1.6).

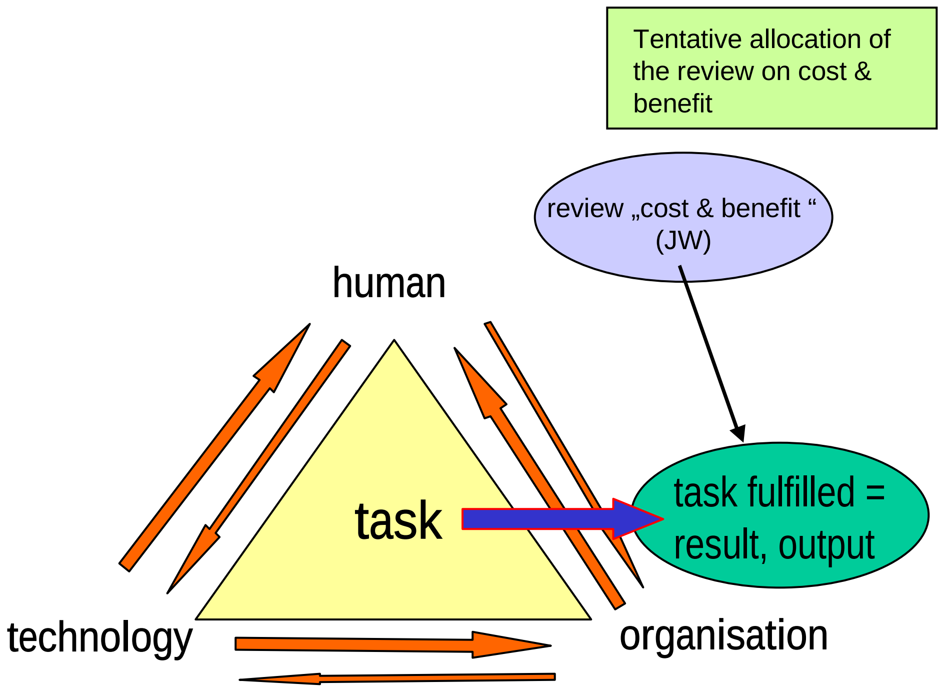

Figure 1.6. The allocation of the review on cost and benefit of ergonomic intervertions in the scheme of task, human, technology and organisation with their interactions.

There are research reports and descriptions in scientific literature describing the situation and experiences with measures taken: Positive examples. Leading questions for the reviews will be:

- What has been described in literature?
- What interventions have been tried or proposed?
- What was the success (economical, work satisfaction; social, health & safety situation)?

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Social conditions, safety and health of forest machine operators

T. Vik & B. Veiersted

Abstract

This survey is based on the knowledge available on forest machine operators' social conditions, safety and health at the start of the ErgoWood project. Through searches in the forestry databases CAB and AGRIS and the medical MEDLINE, OSHLINE, NIOSHTIC, RILOSH, HSELINE, CISDOC and ARBLINE around 2 700 references were found. From these and references from private archives of the authors a total of 280 references have been selected. Both reports and peer-reviewed documentation have been included in this review, but previously published reviews and low quality papers have only been mentioned when there was no equivalent or other source of information.

The studies giving information about social conditions were primarily aimed at working conditions, safety and health. The information on social conditions was given as background information, and was rarely systematically compiled. Information can be found about employment situation, family life, working hours, socialisation at the work site, employment security, fatigue, turnover, attrition, recruitment, training and selection. Most of the information is found in studies from New Zealand, Northern America and the Nordic countries.

In North America and the Nordic countries much awareness is to be observed for the safety aspect. A common experience is that the prevalence of accidents decrease with the rate of mechanisation and the declining proportion of manual and motormanual tasks. However, the prevalence of accidents during mechanised work in the forest is of the same size as accidents in the industry at large. More accidents occur during operation of harvesters than during forwarding. The most common operations when accidents occur are maintenance and alighting the machine. When it comes to safety work, much attention is devoted to strategies that can be implemented through organisational changes.

Several studies on employees in harvesting operations have been performed especially in North America, Oceania and the Nordic countries. Musculo-skeletal disorders, psychosomatic complaints and hearing loss are the most common health complaints. A tendency was found that the occurrence of low back pain has decreased and neck and upper extremity disorders have increased during last decades, probably due to the increasing mechanization in forestry. Vibration injuries were not covered by this review.

Machine operators in forestry

Historical background

The working conditions for workers in the forest have traditionally been characterised by very strenuous tasks and a high risk for severe accidents. The introduction of machines has changed this situation dramatically, but it has also altered the daily work situation for the workers, and this may have other consequences of adverse effects.

The technological development was introduced much later into forestry than into other industries and this has led to a very rapid development during the last few decades.

The present harvesting methods have been developed through a trial and error process, where the traditional manual methods have been modified through the introduction of powered tools and machines (tractors) modified for use in the forest. The first special forestry machines that have led to the present situation were introduced in the 1960'ies. Studies of forest workers at this time operate with the group-designation machine operator (Kylin et al., 1968; Gardell, 1969).

Various types of machine operators

The organisation of work has been altered parallel to the introduction of mechanised harvesting methods. Employments in the forest after the Second World War were in most cases based on some type of fixed employment contract. The main problem was the seasonal character of the work that led to periods of unemployment for the workers.

In the beginning the introduction of mechanised equipment was done mainly by the larger forest companies that had the capital available for investing in this expensive machinery. However, as the new equipment became more reliable and less expensive, partly the forest companies sold out their equipment to the operators, and partly interested persons purchased this machinery to establish themselves as contractors.

This development that has taken place in most countries in some way or other, has led to various types of employment for machine operators. The machine operator employed by a forest company is today rather seldom in most countries, especially in those that started early with mechanisation. The employed machine operators today are most often working for a contractor. However, most of the contractors only have one or two machines and these are often operated by themselves or by family members. In many cases also two or three small contractors are co-operating. In some of the countries with a rather long tradition with contracting, there is a tendency to establishment of larger companies with many machines that are all of them operated by employed operators.

Retrieval of studies

Literature used in this review was retrieved by data base search and from own private archives during the spring of 2003. Tables 2.1-2.3 in Appendix 2.1 show the list of retrieved papers, a few data from the papers and if it is used in the present review. The library at Skogforsk in Norway performed search in the bases CAB and AGRIS. The library of the National Institute of Occupational Health in Norway performed search in the bases of MEDLINE, OSHLINE, NIOSHTIC, RILOSH, HSELINE, CISDOC and ARBLINE. Limits were: Papers concerning humans, published 1968-2003 and in English, German or Scandinavian languages. The following key words were used in the searches:
forest*, logging, processors, harvesters, forwarders
AND
Social, ergonomi*, biomechanic*, rationaliz*, automat*, working hours, shift-work, vacations, climate, nose, vibration, toxic agents, exhaust gases, work content, commuting, training, support, contracts, productivity, stress, lack of control, high demands, work satisfaction, rest, recover,
OR
Health, fatigue, burn out, tension neck syndrome, rotator tendinose, neck pain, shoulder pain, trapezius myalgia, tenosynovitis, forearm pain, tennis elbow, lateral epicondylitis, muscle pain, carpal tunnel syndrome, low back pain, LBP, hypertension, allergy, dyspepsia, cardiovascular disease, anxiety, feeling of stress, hearing loss, hand-arm-vibration syndrome, HAVS, Raynauds syndrome,
OR
Safety, accident, injury, workers protection.

The total number of hits was approximately 2 700 references and approximately 500 of these were selected to be reviewed for possible inclusion in this study. Only studies of forest machine operators including aspects of social aspects, safety and health were considered as relevant, except for a few studies that focused on certain risk factors. Studies on general mechanisms for musculoskeletal disorders were excluded. Several high quality reviews were found, and much information was gained from these as well as from descriptive studies. The quality of original papers that aimed at analysing causal relationship was defined by appropriate design, well-established exposure/effect measurements and suitable statistics. Descriptive studies had to document its representativity. Not peer-reviewed papers were also included.

Mainly high quality papers are cited in this review, papers reviewed but not cited are listed together with the cited papers in Tables 2.1-2.3 in Appendix 2.1. Results from others than high quality papers are, when possible, noticed as indications when cited.

Social conditions

The introduction of machines in forest operations started to a larger extent in the 1960'ies. This event also contributed to changes in the social conditions for the forest workers. Parallel to the introduction of machines, an extensive road network was established in the forest. This made it possible for the forest worker to live in his home during the week and also the possibility emerged for a healthier nutritional regime.

Research on the working conditions of forest machine operators was in the beginning mostly directed against work load, the ergonomics of the machinery and safety. The social conditions were not in special focus, but when we study the pioneering reports on machine operators working conditions during forest operations, we also get some indications of the *development* of social conditions.

The pioneering studies were carried out in Germany, Finland and Sweden. In Sweden a rather extensive study was carried out in 1965 (Kylin et al., 1968; Gardell, 1969). At this time machine operators made up a rather small part of the forestry work force. The selection of persons specially suited for machine work became an interesting question, and Andersson et al. (1968) tried out some special psychological tests for the purpose. In these studies not much information was gathered about social conditions of the studied persons.

More systematic studies of forest machine operators took place in the 1970'ies and 80'ies. Bostrand's (1984) study is a review of the development in Sweden from 1969-1981. She has some thoughts about the background of machine operators at that time. Most of the middle aged and older operators had a background in forestry as cutters or horse drivers. They had no special interest for machines. However, the younger persons being recruited directly to operation of machines were to a larger extent especially interested in machines and machine operations.

Organisation of the harvesting operations has also had consequences for the social conditions of machine operators. In the Nordic countries a change from company employed operators to contractors and contractor employed operators took place during the 1980'ies. In other countries (USA, Canada) where the contractor operations were most common, also changes took place because of the reduction of motor-manual work and introduction of larger and more expensive machines (harvesters and forwarders).

From the 1980'ies and further on, a set of studies have been published where larger groups of machine operators, both individual contractors and employed machine operators have been studied (Lidén, 1987; 1989; 1990; 1995a; b; c; Østensvik, 1997; Greene et al., 1998; Lilley et al., 2000). Even if these studies are aimed at more specific description of working environment, safety, and health conditions for machine operators in the harvesting business, we will try to extract information about social conditions from these and other studies.

Employment conditions

When Lidén (1989) made her study in 1985/86, 35% of the machines involved in forest operations were owned by forest companies. 42% were owned by contractors and also the rest of the machines were owned by machine operators, but these were employed by a forest company. When Lidén (1995c) published a new study for 1992/93, the amount of machines owned by contractors had increased to 70% and only 20% of the machines belonged to forest companies.

The trend seems to be that most of the harvesting operations will be carried out by contractors. This has been the case in USA and Canada for years. In Greene et al.'s (1998) study only contractors and their employees took part.

The contractor will seek commissions with various forest owners. For him a long-term contract can have advantages. It will save him time-consuming search for commissions. This may also apply to the forest owner, especially if he is satisfied with the contractor's work. Lidén (1995b) studied Swedish contractors in 1986/87 and in 1992/93. She found that the amount of contractors working only for one forest owner, most often a company, increased during the period, from 50% to 69%. The contracts were partly seasonal (23%) and partly for more than a year (37%). For the contractor the employment security is tightly connected to the possibility to get contracts. It is therefore a big difference between the contractors having long-term contracts with forest owners or companies and those that have not. Lidén found that in 34% of all cases, the contractors had to find alternative occupation. Also 80% of them did not have a full year's commitment.

The dependence on one or a few forest owners may not always lead to ideal conditions. Problems were often experienced by single contractors when they had contracts with a few forest owners. In many cases it was difficult to satisfy all of them when it came to the time to carry out the work. Other forest owners required the contractor to procure a special machine, and when this was done, the forest owner did not give the contractor any advantage (Lidén, 1995c.).

In Greene et al's (1998) study, it was most common with contracts covering only one operation, but in some cases (39%) contracts were written for a specified time period.

A question of importance for most contractors is the possibility to maintain over a long period a crew of skilled and responsible employees. In his study of safety successful contractors, Reisinger et al. (1994) found that contractors with good personnel management skills, had a good safety record and they also kept their crews for longer periods. A study by Byers (1996) shows high rates of turnover in forest contracting companies. The period the employees worked with the companies was between six weeks and 3.5 years. The yearly turnover amounted to 48%. The experience seems to be that well organised working conditions, well trained operators and a large amount of mechanised work, reduces the turnover rate.

The contractors however, want *some* turnover to inject skill and new ideas (Ashby et al., 2000).

Lidén (1995a) made a study where she studied both machine operators and contractors who had *left forestry*. The group studied had left forestry during a 5-years period ending 2 years before the study started. The reasons for attrition are complex. In Lidén's study the most common reason for leaving work among company employed machine operators were health complaints. Among the younger employees, leaving work was voluntary to a larger extent than among the elder. For the machine operators employed by contractors, financial reasons and work scarcity were the most common causes for quitting. Those leaving because of scarcity of work were those who experienced unemployment to the greatest extent.

In Lidén's (1995c) study health reasons and financial reasons caused most contractors to leave work. These two reasons in combination often caused them to leave the trade.

In another study, Lidén (1989) asked the contractors if they had considered leaving the contracting business, and more than half of them answered the question positively. However, most of those who considered leaving the business were contractors only owning one machine. The reasons for these contractors to leave the business were that they did not have enough time for their families, that the work task was too time consuming and health complaints. These contractors missed the security of the employed machine operator.

When Lidén (1995b) interviewed the contractors about the freedom they felt they had in connection with their work, 85% were of the opinion that they had a reasonable degree of freedom. However, one of the contractors who had quit the work gave this reason: "My family is happy that my time as contractor belongs to the past. Our family life has improved and I do not have to introduce myself to the children when I come home".

Family life, living conditions

The technical development has also led to an improvement of the infrastructure. The modern forest worker can commute to his working place. That means that he can stay with his family the whole week and also have well balanced meals. On the other hand, the distance from home to the working site may be long.

The social conditions of the modern machine operator have been studied in many countries. In the countries where mechanisation started early, there are also studies that took place in an early phase of mechanisation development. They are not always relevant for the present situation. They show, however, steps in the development that may be of interest in countries were introduction of fully mechanised operational methods are recent.

In Østensvik's (1997) study 92 employed machine operators partly working for forest companies (30 operators) and partly employed by contractors (62 operators) took part. Of these a little more than ⅔ were married or co-habitees. 63% had children. Of those working for companies, half the operators always stayed at home during the night, but for those working for contractors this group consisted of only ⅕. The rest lived away from their home in periods. Of the employed machine operators studied by Greene et al. (1998) 64% were married and 26% single.

Østensvik (1997) found in her study that ¾ of the contractors were married or co-habitees and a similar amount had children. A little more than ⅔ had to stay away from their home in periods. Greene et al. (1998) found that 95% of the contractors they studied were married.

In a study from New Zealand, North Island, Byers & Cummins (1997) found that 82% of the contractors were married or co-habitees. 68% were responsible for one or more children or others. Most common was three persons depending on the contractor.

The housing conditions of both machine operators and contractors are very rarely covered in the studies which are relevant. The information of family life and living conditions is very scarce and difficult to find.

Working conditions

For both the contractors and the machine operators, a large part of their occupational life will be in the machine cab. Some time they will be occupied with other activities at the work site and be travelling to and from the working site. This situation may give little opportunity for *contact with other people* during work.

In Sweden it has been developed a shift system called continuous shift. Two machine operators alternate in operating the same machine during a 12 hours period. Each machine operator is present on the harvesting site during 9 hours of which he/she operates the machine for six hours. One operator starts work 3 hours before the other who ends his work three hours after the first has left. During the 6 hours when both operators are on the work site, planning work, preparation of maintenance, meals, etc. take place.

Bostrand (1984) interviewed forest machine operators who worked dayshift, two-shift (morning or afternoon shift) and continuous shift respectively. She asked if they found any advantages with the shift regime they had. 67% of those working dayshift responded positively. For those working two-shift, 57% answered positively but only 46% did so of those working continuous shift. On the other hand, when asked if they had any problems with the shift regime they were operating under, 47% of those working continuous shift, said yes but 54% of those working two-shift had problems. Only 10% of those working only day shift had problems. The type of problems occurring for those working continuous shift were reduced social activities. This applied also for those working two shift, but for these psycho-somatic factors were more common.

Lidén (1989) recorded the working time as hours/week. This was less for employed machine operators than for contractors. Machine operators working for forest companies had a working week with an average of a little more than 40 hours/week compared with those employed by contractors who had in average 43 hours/week. Greatest length of the working week was for the contractors without employees. They worked 55 hours/week as an average.

In a recent study from New Zealand (Lilley et al., 2002) the majority of machine operators had a working day of 8-10 hours. However, 24% had a working day of more than 10 hours.

As mentioned above, the working day for the contractor is most often much too long. In Lidéns's (1989) study from 1987/88, she studied both machine operators employed by companies or contractors as well as contractors, and she found that the employed machine operators worked a little more than 40 hours a week. The contractors worked 35% longer week.

In a study from Norway by Dale et al. (1993) the mean working week for 290 contractors was 46.3 hours and the longest working week was 80 hours. In this material many of the contractors were working part time, and this reduced the mean value.

When it comes to the time used for transport to and from the work site, Lidén (1989) gave data for hours/week. The mean numbers for various categories of machine operators vary from 5.4-7.9. The contractors have longer time for transport than the employed machine operators. In a study by Egan & Taggart (2004) from New England only the travelled distance is given. As a mean for machine operators living in the state where they work, the mean distance travelled was between 45 and 58 km.

Lidén (1989) studied also contractors, but in connection with this study, she found that the employed machine operators had much better contact with other people during the working day. Especially they did have contact with other machine operators. This was not so much the case with the contractors. In Bostrand's (1984) study ¾ of the machine operators were satisfied with the possibilities they had to contact fellow workers. However, the working condition has changed much since this study was carried out.

Recruitment

The studies giving more general information about machine operators do not tell much about the recruitment base. In Greene et al.'s (1998) study, the machine operators were asked if they had any harvesting experience before they got their present employment. 77% had such experience. In her study on attrition Lidén (1995a) found that those leaving forestry voluntarily very often had been recruited without any definite interest for work in the forest. This happened more often among the machine operators working for companies than for those working for contractors or being contractors.

To *select* suitable recruits for machine operation, Swedish forest companies started already in the end of the 50'ies to let recruits go through psychological tests and interviews with psychologists (Andersson et al., 1968). The introduction of tractors with cranes (forwarders) led to an increased need for skill in operating the machines. In 1966 a study was carried out to try to find if the tests had any predictive value when it came to the performance of the selected machine operators. The study focused on operators of forwarders. It turned out that it was a big difference between individual machine operators when it came to the operation of the crane (loading/unloading) and the idle time (repairs and maintenance).

The result shows that it is a relationship between total performance and the results from the test. However, it is difficult to evaluate the total effect as other factors as working environment and the administration and leadership of the operations also influences the result.

With the introduction of one-grip harvesters, a more complicated situation was introduced. In a joint Finnish/German/Swedish project sponsored by the EU's Leonardo programme, a study was made of the relationship between a selection of psychological and suitability tests on one side and performance during operation of a harvester on the other (Jacke et al., 2000). Both validated tests, tests developed for the study (PC-based tests) and practical tests were tried out. The validated tests gave no significant results. Of the PC-based tests, some correlated well with time consumption, selection of logs, and over-all skill. The practical test correlated well with time consumption. This test, however, is much influenced by previous training and experience.

Training

The training of machine operators became a more urgent question when processors were introduced into Swedish forestry in the 1970'ies. A systematically planned training of operators of processors was designed to cover the need for skilled operators in Swedish forest companies. Hall et al. (1972) studied participants in a pilot course. The performance of the trainees was evaluated in comparison to an experienced operator. Already during one week with practical work under supervision half of them achieved 75% of the experienced operator's performance. After one and four months the performance of the group as such had not improved, but after four months the deviation between the trainees had decreased.

The study of Hall et al. (1972) has been of great value for the development of training courses offered by the producers of processors and harvesters. However, a more basic training of potential machine operators is needed, and this would most effectively be offered by the ordinary system of vocational schools.

Even if it seems quite obvious that the best recruits for machine operators would be the graduates from vocational schools giving courses for machine operators in the forest, this is not always the case. Lidén (1989) found that 26% of the company employed and 17% of the contractor employed machine operators had basic education. All in all, the machine operators working for companies were better educated than those working for contractors. Of those working for companies 50% had a 10 weeks machine operators training course, 24% had a welding course, and 14% had a course in electrical installations. The corresponding numbers for those working for contractors were 17%, 19%, and 2%.

Østensvik (1997) asked her subjects about their education beyond compulsory school (9 years in Norway). It was a distinct difference between operators working in forest companies and those working for contractors. The longest training had the operators working for contractors and this was in average 22.5 months. The average for those working for forest companies was 12.4 months. On the other hand the operators working in forest companies had much longer experience in driving machines. This should indicate that they represent a group of people that have got their skill through training on-the-job. That they as a group have a higher mean age (40 versus 32 years) supports this view.

In Georgia, USA, Greene et al. (1998) found that 54% of the machine operators had no training before they were employed. 42% had received on-the-job training and the rest (4%) off-the-job training. The type of training they had received was in 71% of the cases to learn from experience, but 55% had had monitored training. All the interviewed operators were of the opinion that the training they had received was adequate. In their present job, 67% had got on-the-job training and they all found that the training was adequate. The type of training that they found most helpful, was on-the-job training in 77% of the cases, 14% were most satisfied with a local trainer and, 24% with previous experience. 71% got some training periodically.

In a Canadian study (Wallersteiner et al., 1993) two groups of subjects operating log loaders were studied when they used ordinary two-lever controls (joint control) and two-lever controls connected to a computer programme which made the co-ordination between the manipulation of the boom and stick automatically (co-ordinated control). One group studied were novices and the other group had between 18 and 25 years of experience. The study showed that for the novices the co-ordinated control gave the best result during the whole study period. For the experienced operators it took some time to unlearn their ordinary way of operation, but the study concludes that during 6-8 days, an experienced operator should have the same performance with the two systems of operation. The introduction of computer-aided control systems seems to be an improvement as long as training time is concerned.

It seems that a problem has arisen when the ordinary person carrying out the practical work during forest operations has a basic training as a machine operator. The traditional forest worker is not qualified to operate the harvester or forwarder through his vocational training. As seen from the studies quoted above (Lidén, 1989; Østensvik, 1997; Greene et al., 1989) many machine operators are recruited from other branches than forestry. This was also found in Germany where Backhaus (1994a) found that many machine operators were recruited from other trades and their training would consist of an intensive course to master the machine.

The most urgent training need is therefore to upgrade machine operators with experience from other trades. In some countries where the majority of the machine operators do not have any basic vocational training, a system has been developed to train machine operators already with long experience from forest operations. In a study by Byers (1996) on the South Island of New Zealand, it turned out that 82% of the machine operators engaged by contractors were taking courses in a national training programme. However, 51% had no more than two of 11 modules. A similar result was obtained in a study of Byers & Cummins (1997) on the North Island.

In Germany heavy storms in 1990 accelerated the introduction of harvesters and forwarders.

The need for training led to development of special courses for operators of harvesters (Backhaus, 1994b). These required that the participants were familiar with machine techniques, had some experience with the operation of cranes, and were familiar with ordinary forestry work. The course was planned to take place during two weeks and encompass 74 hours.

For the contractors, it is also a question of being trained as managers of harvesting businesses.

Lidén (1989) found that the contractors had less organised training than the machine operators working for forest companies. The contractors with employees in most cases had training that was relevant to repair and maintenance (welding, hydraulics). The single-machine contractors often had some other training, e.g. agricultural school.

The contractors taking part in Greene et al.'s (1998) study were all high school graduates. 32% were college graduates and 58% had started college without completing. 11% had graduated from technical school and 16% had some technical school.

In Dale et al.'s study (1993) it became evident that one out of five contractors was a trained forester. Two out of five had other type of training as mechanics, carpenters, electricians, etc. Nearly half the group only had completed short courses (less than six months).

Byers & Cummins (1997) found that 66% of a group of contractors from North Island, New Zealand had left secondary school without any formal qualifications. Only 4% had undertaken any type of university study, but the most common type of training after secondary school was some type of technical course. They also found that 87% of the contractors were aware of a programme for up-grading, but only 30% had attended any of the modules in the programme.

These studies show that contactors have attended many different types of training. The reason for this is partly that the contractors represent a group which is very little homogenous. For the contractor owning a single machine and working for one or two forest companies, the daily work will be in focus. For the contractor with several employed machine operators, the maintenance of the machines, the financial problems, and organisation will be of much greater interest. The different traditions in USA/Canada and in Scandinavia make it difficult to find any general developments in the education of contractors. What seems to be of greatest importance for the contractors, is to train them as managers of firms.

Conclusion

The introduction of machines into the wood harvesting business has led to rapid changes in the way operations are organised. The machine development itself with fully mechanised systems has been instrumental in the development where contractors take over more and more of the harvesting operations and the forest companies are more and more depending on contracting businesses.

The contractors, however, represent a wide range of organisations from the owner of one machine which he operates himself to the larger companies with many machines and several crews of employed machine operators. The larger contracting businesses will often try to have contracts with larger forest companies. The employment situation will to a large extent be depending on the structure of forest ownership.

The stability of employment may be influenced by several factors. Turnover varies, but seems to a large extent to depend on the quality of management. Machine operators employed by forest companies left work most often because of health complaints. Those employed by contractors often left work from financial reasons and shortage of work. The contractors themselves also often left the business because of financial reasons, but often in combination with health problems.

Information about family life and living conditions is sparse and does not reveal any clear tendencies. Machine operators working for contractors seem to have to stay away from home more often than their colleagues working for forest companies.

The employed machine operator will most often have a normal working day compared especially with the contractor without employees. The machine operators seem to have better contact with other people during their working day than the contractors.

Those recruited as machine operators for harvesting machines, most often have been working in the forest before. This applies most to the elder machine operators. Experiments with methods for selection of recruits have given no definite results.

Training started with courses for forest workers who were transferred from motor-manual work to machines. However, it seems that most training was on-the-job training. In later years when young persons with general training in maintenance and operation of machines had been recruited, the need for forestry skills has become striking.

Safety

Traditionally the forest has been considered a rather dangerous work place. The working place in the forest differs much from the indoor work place of the industrial worker. Climate, terrain conditions, and a great variation in the forest stand cause other challenges to the forest worker than to his colleague in industry. In the factory climate can be regulated, the surface is even and of a non-slippery material and machines and tools can easily be adapted to the workers physical properties. The introduction of machines in the forest has changed the physical working conditions. The working environment in the machine is much easier to manipulate in such a way that the traditional hazards are reduced. However, other hazards may occur as the machinery represents large amounts of unbridled energy.

Accidents

The major problem connected with safety during traditional forest work, is the occurrence of *accidents*. An accident will occur as a consequence of an unforeseen and unwanted event of random character. Accidents may have various consequences from a fatal accident to accidents leading to injury and lost working days or even minor events leading only to material loss and a short interruption in the work. A special event related to accidents is the near-accident where the situation might have led to an accident, but where luck or special alertness led to the avoiding of an accident.

The detailed *recording* of accidents is important to get knowledge as background for developing preventive strategies. Over the years occupational safety and health authorities in various countries have collected accident statistics and in countries where forestry is important, the accident statistics for forestry are also published and commented.

In connection with accident statistics, most often the following variables are recorded:

- Time and place where the accident took place
- Activity which the subject was engaged in when the accident occurred
- Type of injury
- Injured body part
- The event during which the accident occurred
- Object which caused the injury
- Machine, tool etc. which was causative to the accident
- Personnel protective equipment used
- Number of days away from work after the accident

Accident recording may give a great variety of results. The operational situation specified by climate, terrain, and forest conditions plays an important role as well as the technological level, which will be of importance for the type of work, either manual or with machines. The technical level will also be dependent on the economic and cultural situation. Much of the accident statistics from the 1980'ies and 90'ies is already obsolete as the development has been rapid afterwards.

The mechanisation has been rapid in Northern America and Scandinavia. The former methods in these countries were based on motor-manual felling, delimbing, and also bucking. The amount of accidents during these operations were the largest, and in studies of Paulozzi (1987), Myers & Fosbroke (1995), Axelsson (1998), Nieuwenhuis & Lyons (2002), Larsson & Field (2002) and others the highest occurrence of accidents was during motor-manual work, especially motor-manual felling. With the introduction of harvesters, the machine operator is protected from the falling tree by a cab, but most important: The felling aggregate gives much better control of how to direct the falling tree. Laflamme & Cloutier (1988), Axelsson (1998) and Rummer (1995) have demonstrated how the occurrence of accidents has diminished from about 1975 in both Canada, Sweden and USA. Laflamme & Cloutier (1988) analysed data for three years from two forest companies. They found that the average individual risk of an accident on conventional operations were almost three times higher than on mechanised operations. Axelsson (1998) shows how the reduction in accident numbers can be explained by increased use of harvesters, and also Rummer (1995) explains the reduction as a consequence of increased mechanisation.

However, some studies from USA show that the reduction in fatal accidents after introduction of mechanised equipment is not of the same size as for harvesting related illnesses. (Seixas et al., 1999; Bordas et al., 2001).

Hazards in connection with machine work

Even if the safety situation in forest work has been improved with the introduction of heavy machines, still too many accidents occur during harvesting operations. However, Axelsson (1998) found that the accident rate (number of accidents per 1 million working hours) during machine work had been reduced to 17, which represents a 70% reduction during a 20-years period (1970-90). Johansson & Pontén (1990) looked at statistics collected in 20 larger forest companies in Sweden in the 1980'ies. 19% of the accidents took place during work with machines. During the studied period there was a tendency that more accidents took place during harvesting than during terrain transport. The most dangerous sub-operations were repair and maintenance work. Especially during such work in the forest, many accidents took place. Other sub-operations with accidents were mounting and alighting.

Even if the rate of accidents during machine work has decreased, still the rate of accidents is considered to be too high. Also Backström & Åberg (1998) have shown that the number of accidents during machine work in Sweden has been on the same level in recent years, and this level is the same as in all industrial work. They studied a larger number of accidents during operation of heavy forest machines. They selected 5 categories of accidents that made up 68% of the total number. Among these 5 categories were also the accidents that led to the longest period of absence from work. Injuries caused by *mounting and alighting* forest machines made up 21% of the accidents. The number of days off expressed as the median value was 7 days. Most of the accidents happened during alighting, and in most cases because the operator slipped. The other group of accidents with a high amount of cases was fall/slipping/loss of balance when *working/maintaining the machine standing on the vehicle*. This type of accidents made up 20% and the median value for days off was 49 days.

In the whole, the maintenance work seems to create a lot of risks. Two of the remaining categories also occured during adjustment and maintenance of machines, especially harvesters. During 8% of the accidents the operator was injured when *a part of the machine suddenly and unexpectedly starts moving*. This most often happened when the motor was running during adjustment and repair work. These are also serious accidents and the median value for days off was 54.5 days. Most accidents happened during work on the harvester. The best way to avoid these accidents seems to be organisation of the adjustments and repair work in such a way that the motor is not running or that no kinetic energy occur in the system that may cause uncontrolled movements of machine parts. Trouble-shooting may cause a lot of dangerous situations, and to avoid these, perhaps the computer of the harvester can be used when the operator is in the cab. (Backström & Åberg, 1998).

The last category connected with maintenance and adjustments is *injuries caused by loose machine parts and similar objects*. Also in this case the occurrence was 8%, but the days off were a little less, namely 34 days. In many cases, the operator had loosened a machine part, and this fell and hit the operator. Part of the machine constructor's job is to design maintenance routines that do not imply unnecessary risks. The instruction manual following the machine should include detailed instructions how to carry out the various tasks in connection with maintenance and adjustments. Synwoldt (1999) has studied the instruction manuals of forwarders and harvesters both in 1990 and 1998. He found improvement over the time, but still in 1998 much remained to be done before the instruction manuals were satisfactory.

The last category that Backström & Åberg (1998) focused on was accidents occurring during driving such as overturning, collision or being run into. 11% of the accidents belonged to this category and the median for days of absence was 43. This was the type of accident that happened most often during the operation of forwarders. Most often the machine turned over. This happened when driving on uneven ground or with too high speed. It was more seldom that the accidents occurred when the operator tried to climb too steep a slope. The technical development of forestry machines should be focused on improvement of the dynamic stability. A lower point of gravity and a wheel suspension that negotiates terrain obstacles in a good way are desirable.

Studies of accidents in the south-eastern part of the US show that in fully mechanised operations 25% of the accidents happens during repair and maintenance work (Shaffer & Milburn, 1999). However, the same amount of accidents takes place when single trees too big to be handled by the harvester or feller-bunchers are felled manually. The reason for this, Shaffer & Milburn (1999) suspect, is the fact that in most cases this work is done by a person that happens to be available and not necessarily a person who is well trained to perform this kind of work.

Safety work

The prevention of accidents is one of the major challenges for the people involved in forest operations. Both nationally and internationally much work has been carried out to stimulate forest companies to organise effective *safety work*. The International Labour Office has distributed information material that can be used in the safety work in forest companies (ILO, 1981; 1992; 1998).

How to organise the safety work will to a large extent depend on local conditions. The working environment may vary quite a lot, and also the size of the crew or number of employed machine operators will be of great importance. The responsibility for safety work will be up to the company, but also the contractor will have his share of the responsibility.

Strategies

One of the important questions the forest company has to decide is how to approach the problems involved in establishing an efficient safety organisation. Rummer (1995) has analysed various models of how to find out why accidents occur during forest work. He starts with some early models that are based on the employers' possibility to control his employees' behaviour.

The Heinrich model is based on a succession of events where the crucial event is the unsafe act which is prior to the accident. The management's prime task is to instruct the workers and enforce them not to carry out any unsafe acts. Another early model, *the three E's*, is based on engineering, education and enforcement.

Both these models focus on the workers behaviour. A special *behavioural model* has as its starting point the consequences of an act. The worker will have his opinion of which consequences an unsafe act may lead to. It is therefore important to influence the workers opinion of the consequences of his various actions.

More modern models are based on active involvement from the employee. Rummer (1995) point out that the special conditions in forestry often makes the models developed for use in industry not always easy to adapt to conditions in forestry. He therefore gives the advice to combine various models to find a suitable approach to safety work in forest companies. Quite another approach to safety questions than the focusing on the worker is the *sociological model* which looks at the accident as a consequence of poor organisation. This model is the basis for the ILO code of practice for safety and health in forestry work.

The *ergonomics model* is founded on insight in the man-machine system of a working situation. Also this model stresses the management's responsibility to organise the work in a safe way. The ergonomics model emphasises the working conditions and the job should not put excessive strain on the worker through environment conditions, mental and physical load, endurance, influence on comfort, sensory load and strain. The ergonomics model can be of great help in analysing the machine operators' work situation.

Finally Rummer (1995) mentions *the Haddon matrix*. The model was originally developed to evaluate traffic safety and looks at four primary factors (human, equipment, environment and socio-economic) over time. The time scale is divided in pre-event, event, and post-event. All cells in the matrix are described. This model in its original version, does not evaluate the behavioural aspects, and therefore Rummer (1995) includes an extra time period, namely the precursor. He also wants to see the pre-event in connection with the antecedents. In other words, he wants to combine the Haddon matrix with the behavioural model.

Codes of practice

The increasing concern by the public when about forest management has led to the development of recommendations of how the work in the forest should be organised. Such recommendations often have taken the form of codes of practice. Parties responsible for such publications are national forest societies, forest owners associations, national forest services etc. A further development of this has been the introduction of certification systems. Most common is the Forestry Stewardship Council's (FSC) system, but also systems developed by the forest owners associations in European countries. In the certification systems also requirements on the organisation of the work and safety organisation have been included.

The International Labour Office has developed a publication containing an ILO code of practice for safety and health in forestry work (ILO, 1998). The book contains an introduction presenting the general principles, the legal framework, and general duties that apply to forest enterprises as far as safety and health are concerned. Further the publication gives a layout of the safety and health framework at the enterprise level as well as general requirements and technical guidelines for safety and health at the forestry work-site.

Also many countries have worked out regulations for safety and health during forest work. These are based on national labour protection acts where regulations are rather cursory. In a situation where a special industry like forestry turn out to have a high number of accidents, it is usually possible with authority in an act to enforce safety regulations based on the conditions that are specific to the country where the regulations shall be valid. Such regulations have in recent years been enforced in New Zealand (NZ Department of Labour, 1992; 1994) and USA (Occupational Safety and Health Reporter, 1994). The last mentioned is a good example. The Occupational Safety and Health Administration's Safety Requirements for harvesting operations were enforced in February 1995. These safety regulations are valid for all USA and cover most work tasks in connection with forest operations except road construction. The regulations give rather detailed rules for how the employer shall organise the work and behave to avoid accidents.

In recent years the need for certification of forest operations, also has been contributing to the enforcement of safety rules. FAO Forestry Department has been instrumental in the development of FAO model code of forest harvesting practice (Dykstra & Heinrich, 1996) that is intended to be a model code for sustainable forest practice. In a separate chapter, the forest harvesting workforce is covered and principles for safe and healthy organisation of the work are put down.

The ILO code of practice has a chapter on the organisation of safety work on the company level.

Responsibility

In most countries the employer will be the person in principle responsible for the organisation and performance of the work in such a way that the employees are protected from accident and other hazards. The workers themselves are also responsible for their safety and this first of all has to do with their ability to obey the rules and regulations laid down by their employer and official regulations. In larger companies the responsibility for safety is often given to a safety officer. Aminoff & Lindström (1981) looked at how to organise safety work in larger Swedish forest companies. It turned out that in many companies the function of safety work was delegated to special personnel or representatives. The problem with this type of organisation was that the persons responsible for the production did not feel that it was their job to enforce safety measures or see to it that safe procedures were followed. On the other hand, the personnel that had been delegated safety tasks did not have any authority to interfere with the organisation of the work. Aminoff & Lindström (1981) recommend that the responsibility for safety shall be with the person or staff responsible for production. Safety personnel must have instruction authority over the production manager.

Another aspect with the distribution of responsibility for safety is that all personnel must be involved. The workers responsibility to follow safety requirements also means that he must be heard when safety measures are discussed.

In the US, the introduction of the new safety requirements (Occupational Safety and Health Reporter, 1994) has led to a renewed discussion about responsibility. Egan (1996) discusses the concept of danger trees: The forest owner will be responsible if a person is injured by falling objects or trees defined as danger trees. A series of lawsuits has occurred after the introduction of the safety regulations. Both the forest owner, his forest manager and the contractor have been made responsible for injuries to loggers. Egan (1996) gives various pieces of good advice to the forest owner.

Attitudes towards risks

Several studies have been carried out to find out how both employed machine operators and contractors assess risks in their work. In Byers & Cummins' (1997) study from New Zealand, only 19% of the contractors asked were aware of the number of persons killed in accidents the last year. 82% estimated the number to be lower than the actual value.

Machine operators that were interviewed by Bordas et al. (2001) were of the opinion that the largest hazard during their work was caused by the chain saw. This is astonishing, as the use is rather limited. The other main cause of hazards was the general conditions on the landing where workers on the ground could be hit by logs or machines. Few of the persons taking part in this study had any experience with severe accidents, but it seemed that those who had such experience were not more conscious of the hazards in the work than the others. The machine operators felt safe as long as they stayed in the machine cab.

It is difficult to find any justification for the attitudes of machine operators and contractors towards the risks they experience in their daily work. The most objective way of assessing the risk is through the collection of statistics of accidents and near accidents.

Safety organisation

The rules and regulations issued by safety authorities in various countries have instituted routines and organisational efforts that must be followed by forest companies or contractors. This will vary from country to country, and also the rigour with which these rules are enforced vary. In the Scandinavian countries work environment acts have been enforced over the last decades and rather strict organisational measures have been issued. The larger companies shall have safety committees with special tasks. The employees shall elect safety representatives with rather wide authority in safety matters. They are authorised to close down activities that constitute "… a danger for life and health".

The EU has issued directives that influence the production and sale of forest machines and other equipment, and also regulates the organisation and performance of how this equipment shall be used and how the operators shall be trained (Laurier, 1999).

As already mentioned, the USA has issued special rules and regulations for harvesting operations.

The efficiency of these rules and regulations has been the subject of a multitude of studies.

Organisation of safe working methods

To secure safe working methods, it is often important to develop routines where unsafe acts are avoided. In forestry the tradition with manual work under varying conditions has made it difficult in most situations to standardise how the work shall be performed. With the introduction of machines this is made easier and it is easier to develop codes of practice. Nevertheless, the special situation in forestry makes it also difficult to cover all situations with rules and routines.

To assist in the development of safe working methods, a large number of studies have been carried out.

Safe equipment and machines

Ergonomic checklists for forestry machines have been available since the end of the 1960'ies (Hansson & Pettersson, 1969). A new ergonomic checklist was developed in the last part of the 1990'ies (Gellerstedt et al., 1998) where a more dynamic attitude was demonstrated. The quality of the machine should satisfy the most advanced level that can be reached with updated knowledge. This means that most machines will not fulfil the A-level. However, the checklist will indicate which improvements may be obtained. The checklist has been used in some studies, and the points that specially take into account safety aspects are instruction manuals and maintenance. Erikson & Myhrman (1999) found that in three of the most used forwarder types in Sweden, the instruction manuals did not have any description about how to perform tasks in connection with maintenance and adjustments. The instruction books got ratings of C

(1) and D (2). That means that from a safety point of view the manuals are satisfactory but the potential for improvement is great. The maintenance work as such was evaluated by the use of the SAE-standard J817/2. One forwarder got the rating C and the two remaining got rating D.

Protective equipment

When safety work became the object of increased concern in the forest companies in connection with the dramatic increase in number of accidents, the introduction of personal protective equipment (PPE) was one of the most important activities. With the increase of mechanised methods, this is not of the same importance any longer. However, the use of safety belts during driving in the terrain with skidders and forwarders is still of importance. Specially the use of skidders where the operator has to alight and mount the machine with fixed intervals to choker or de-choker stems, the construction of seatbelts is important. Sullman (1998) has performed a study where he has studied the use of safety belts for skidder operators. Four situations were studied: The ordinary seatbelt, an improved version which was much easier to fasten, two types of seat-belt with or without a reminder light on the skidder dashboard. It turned out that the improved version of seatbelt led to an increased use for 36%. When also the reminder light was used, the increase was 58%.

A question that has turned up in various situations is the comfort of using PPE. Especially the use of hard hats during hot conditions has been studied by Davis et al. (2001). In laboratory studies simulating conditions during forest operations in south-eastern USA during the summer, they tested hard hats with and without ventilation and ventilated hard hats with passive and active ventilation. No excessive physiological load was observed with any hard hat, but ventilation contributes to better comfort. The weight and fit are important factors in the design of hard hats.

Control of safety routines

It is obvious from many studies that the new safety regulations in the USA are not well known by the contractors and their machine operators (Egan, 1996; Greene et al., 1998; Bordas et al., 2001). If they are known, they are not much stressed. The reason for this can be that the representatives from the Occupational Safety and Health Authorities are seldom seen at the work sites. Mostly they only turn up after severe, most often fatal, accidents.

Synwoldt & Gellerstedt (2003) evaluated the effect of a threat from the Swedish Work Environment Authority (SWEA) to enforce special measures on the harvesting business. A special program was initiated to avoid enforcement of regulations and it turned out that the working and health conditions of the machine operators improved, though not to the degree that SWEA would like to see. However, a voluntary system was agreed upon, but there is a pressure upon the industry to show results.

Training in safe working methods

The experience from the US show that in many cases the persons recruited to harvesting activities do not have any formal education. The training is for the most part on-the-job (Greene et al., 1998; Bordas et al., 2001). This means also that they have no specific safety training. In some cases, the employees have passed short courses leading to a first aid certificate, but these certificates are seldom renewed (Bordas et al., 2001).

Promoting positive attitudes

As mentioned above, the awareness of risk is an important factor in the safety work. To make the employees safety conscious is an important task for the employer and his staff. In a classical study Lindström & Sundström-Frisk (1976) demonstrated a very positive effect of sanctioned attitudes towards unsafe practices by the foremen. Heil (1996) discusses the same problem and looks at either an authoritarian attitude by the foreman or those with a laissez-faire attitude. Heil's (1996) solution is to motivate the worker to find his own solution. Heil (1996) also distinguishes between risk, safety and danger. The concept of risk is often connected with the individual's possibility to interfere in contrast to danger that is absolute. The realisation of danger should lead to an act to avoid it, but in the awareness of risk it is often a calculation of the costs. With the use of a dangerous practice in a situation where the safe practice is more strenuous, the worker may choose to take a calculated risk. If the experience is positive in such a way that the danger is not released, it will motivate the worker to repeated risk-taking at least until he experiences the danger (and then it may be too late to modify the behaviour).

Another aspect of the question of risk is the direct cost of reduced production. This is a topic also mentioned by Ashby et al. (2000) in their study of safety successful contractors. This group was contractors with no lost-time injuries in their crew the last 12 months. Among those that did not fulfil this claim, 40% were of the opinion that safety work did not have any effect or did reduce production.

Safety awareness of contractors

The importance of a positive attitude towards safety has been explored in a study by Reisinger et al. (1994). They studied 26 contractors whom they characterised as safety successful.

The enforcement of acts, regulations, and voluntary codes of practice will not have any effect except when they are followed up by the organisations responsible for the enforcement of the regulations. 18 months after the enforcement of the harvesting safety standard in USA, Egan (1998) made a study on its effect. He collected information from the US Department of Labor in all the 50 states where it was supposed to be effective. 289 inspections had taken place, and of these 147 had occurred in South Carolina. Only in 26 states inspections had taken place, and in many of these it was only possible to document one inspection (Connecticut, Florida, Georgia, Maryland, Missouri, New Hampshire, Ohio, Pennsylvania, and Washington). This is the more astonishing as forestry is of great importance in many of these states.

The inspections were in 18% of the cases caused by the occurrence of an accident. Only in 2% of the cases an inspection had taken place as consequence of a complaint. 74% of the inspections were carried out as part of a planned program.

There were 25 inspections in West Virginia, and here 4 inspections were carried out as a consequence of an accident. During these inspections 170 violations of the regulations were found. These violations were stratified as records and paperwork, training, protective equipment, unsafe practices, and treatment of hazardous materials and fires. Most violations were caused by unsatisfactory records and paperwork and by negligent training. In many cases the lack of information on the treatment of hazardous materials (gasoline, bar and chain lubricant, transmission and hydraulic oil) was the case as well as missing data sheets on site for hazardous materials and lack of training on the treatment of hazardous materials. Another violation that happened often was the lack of first-aid courses each third year.

The West Virginia loggers were asked if they found the new harvesting standard to be good for their activity. Only 15% agreed, but 63% agreed with the statement that the new harvesting standard might put them out of business. On the other hand only 36% of the loggers said that they had a good knowledge of the standards.

Another study carried out by Bordas et al. (2001) covered the situation in Alabama. Also in this state the occurrence of inspections was low. However, during a study of more than 60 hours duration of 5 harvesting crews 34 violations of the OSHA regulations were recorded.

In New Zealand, Ashby et al. (2000) made a study to see how contractors viewed safety and health as an important part of their organisational responsibility. A questionnaire was distributed to 118 harvesting contractors in New Zealand, but only 32% responded. From these, 21 contractors were selected that did not have any lost-time injury the last 12 months. The group was defined as safety successful. When asked which factors had contributed to safe operation, three types of answers were given: Measures based on people skills and management (training, skills, selection, etc.), organisational measures (safety systems, hazard identification, meetings, etc.) and mechanical measures (maintenance, mechanisation, separation of people and machines, good safety gear).

Conclusion

The high prevalence of accidents during motor-manual work was not found after the introduction of modern machines like harvesters and forwarders any more. However, still too many accidents occur. An important tool in the activity to reduce the number of accidents is the compilation of statistics of accidents and near-accidents. Based on this information, it may be possible to develop efficient strategies for the improvement of safety during forest operations.

The statistics available seem to show that more accidents take place during harvesting than during forwarding. The most hazardous sub-operation seems to be maintenance work in the forest. Also mounting and alighting represent hazards. During the operation of forwarders the most common accidents occur during driving (overturning, collision).

One of the major challenges for both contractors and machine operators is the prevention of accidents. Various strategies have been developed and a selection of these is described. Of great importance are codes of practice which may be part of certification systems. Also international organisations like ILO and FAO have produced models for code of practice which form basis for national regulations. Many countries have produced such regulations in recent years.

The effect of safety work to a large extent depends on the responsibility of the management. The aim of the safety work must be understood and adopted within the whole organisation and also the machine operators have a great responsibility in this field. Connected to this are realistic understanding and attitudes toward risks.

Various actions can be implemented. Most countries have rules and regulations which enforce the employer to establish a sort of safety organisation. This can be instrumental in introduction of safe working methods, ergonomic favourable machines (use of checklists), introduction of protective equipment, establishment of safety routines, training regimes and not least promotion of positive attitudes towards safety.

Experience from safety work within the harvesting business has been the subject in a number of studies. Especially studies of the effect of rules and regulations are interesting. It turns out that the rules and regulations are seldom followed if not any sort of control is organised. This is the experience in USA and the Nordic countries.

Health

Working conditions and health for forest workers have been studied for many years. McGregor (1960) studied sickness absence in 1958 for 1 115 manual forest workers in Scotland and found that accidents (mainly off duty) and back troubles were the most common causes. A study of 453 Swedish mainly manual forest workers in 1968 focused on general health, low back pain, hand-arm-vibration syndrome and hearing loss, but also on newly introduced use of tractor in field transport of timber (Kylin et al., 1968). Most documentation of forest machine operator’s health was presented after this time and especially after the mid-eighties. Lidén (1995a) got information from 274 Swedish former machine operators (response rate 61%) who quitted

1986-1990 and found that 50% did it because of health reasons. On the other hand, poor subjective health or frequent musculoskeletal symptoms were not predictors of reduced long-term employment for 877 forest workers followed 5 years from 1989 (Liira & Leino-Arjas, 1999). ILO (1981) published a review over working conditions and health of forest workers in 1981. A review of the working conditions of forest machine operators in Sweden was published in 1987 and it also summarised their health situation (Hansson, 1987). A new consensus report on working conditions in forest machines was published by a mainly Swedish group in 1998 (Winkel et al., 1998). The results were concluded in ergonomic guidelines in Swedish 1998 and English 1999 (Gellerstedt et al., 1999), which replaced guidelines from 1969 and 1989.

The following review includes musculoskeletal health, psychosomatic complaints and hearing loss since ergonomic aspects are in focus. Psychological distress, possible health effects of heat stress, skin and lung disorders and reproductive aspects as well as cancer are not considered here. Neither are health effects related to hand-arm vibration and whole-body vibration, except when the latter may be associated to low back pain. Every section is divided into a descriptive part (size of problem) and possible causes. Data not built on high quality papers are mostly described as indications.

Musculoskeletal disorders

To our knowledge, no surveillance system exists that cover the health of machine operators in particular. Data that describe the magnitude of the problem mainly emerge from research projects. Not specified disorders are described to some extent, as repetitive strain injury (RSI), repetitive motion injury, overuse syndrome, body part discomfort (Kirk, 1998), work related upper limb disorders (WRULD) (Jones et al., 1999) and upper limb musculoskeletal disorders among chain-saw exposed (manual) forest workers (Bovenzi et al., 1991). The odds ratios for neck and shoulder symptoms were between 2.3 and 4 among 417 different drivers of all-terrain vehicles, including 215 forest machine operators (Rehn et al., 2000). The risk for elbow and wrist symptoms were also increased. A study of 909 forest workers (not only machine operators) showed that 16% had some kind of diagnoses in the locomotor system (Dolnec, 1995). Musculoskeletal disorders tend to cause longer sick leaves than accidents. Erikson (1995) reported that among 603 forest workers a yearly incident of 25 accidents resulted in 255 sick leave days, whereas 10 overuse disorders resulted in 1 253 sick leave days.

Several reviews of musculoskeletal strain and disorders have been published (Harstela, 1990; Erikson, 1995).

Neck- and shoulder disorders

Size of problem

Löfroth & Pettersson (1982) found indications of an increasing problem with complaints of pain in neck and arm among Swedish forest machine operators. They estimated that approximately 75% in that group had at least some complaints during a 2-years period and 20-30% have had problems that led to consultation of a doctor and/or incapacity related to normal work.

Jonsson et al. (1983) published a survey of 241 machine operators (response rate 88%) showing that 56% had neck complaints and 50% shoulder complaints during the preceding 12 months. 5 years later different complaints were surveyed and compared for 3 415 fellers and 1 112 machine operators (Johansson et al., 1988). The latter complained more of neck/shoulder symptoms (approximately 60 vs. 40%) and less of low back symptoms (approximately 33 vs. 43%). Vik et al. (1984) reported that 65% of 318 forest workers had diagnoses of musculoskeletal disorders compared to 53% of 66 foremen. One half of 65 machine operators in the forest worker group had diagnoses in the neck/shoulder and 30% in the low back. Lidén

& Pontén (1985) found that 50% of 110 machine operators had present neck/shoulder complaints. Pontén (1988) reports in his doctoral dissertation that work with newer machines (built since 1978) did not seem to improve neck and shoulder complaints. Østensvik (1997) found in the late 1990'ies that 46-56% have had neck/shoulder complaints during the preceeding 12 months in questionnaire data from 213 machine operators (response rate 62%). 21% have had neck complaints more than a month the previous year and 18% have had shoulder complaints. An intervention study of seat adjustment by Perkiö-Mäkelä & Riihimäki (1997) indicated that over ⅓ complained of neck/shoulder symptoms more than 30 days during the preceding 12 months.

Hagen et al. (1998) investigated 645 manual forest workers, 66 forest machine operators and 124 administrative workers that all were served by Occupational Health Services and with a response rate of 100%. Approximately 60% of these categories of Norwegian professional workers nation-wide were covered. 35% of machine operators reported neck/shoulder complaints for more than 30 days during the preceding 12 months, somewhat higher than the prevalence of manual forest workers. Neck complaints were more common than for professional car drivers, but less than for truck drivers. No difference was found for shoulder complaints.

Indications exist that 50-60% of machine operators experience symptoms of overload injuries, mainly neck-shoulder complaints (Axelsson & Pontén, 1990). Tender trapezius muscles were found by palpation in 22 of 24 examined machine operators. Tender spinous processes of the vertebrae were found in 40% of the operators compared to only a few percent for taxi-drivers.

In conclusion, considerably over 50% of forest machine operators report neck/shoulder pain during a 12 months period. Approximately, ⅓ reports symptoms exceeding 30 days last year or symptoms resulting in medical consultation.

Possible causes

Already in the mid-eighties, some authors underlined that the major problem however, is the fixed body posture (Nåbo, 1986). In the study by Axelsson & Pontén (1990) cited above, originally performed 1983-1984, the complaint level increased from 43-58% after 2-4 years of work experience in machines manufactured in 1978 or after. The effect of job rotation on complaints was uncertain (Axelsson & Pontén, 1990). Contractors report more complaints than average machine operators, but reported at the same time higher psychological demands, level of control, social support, motivation, and intellectual demands (Østensvik, 1997). This may indicate that psychosocial risk factors are overruled by other factors, e.g. factors as biomechanical load and long working hours. An increasing level of psychological demands and a decreasing prevalence of intellectual discretion were significantly associated with an increasing prevalence of neck/shoulder complaints (Hagen et al., 1998).

Lidén & Pontén (1985) found no reduced complaint level for workers with of 3-hours on and 3 hours off effective machine operating compared to 4 hours per work shift and shorter time off the machine. The authors indicate that the importance of a multifactorial approach to interventions including work place design, work technique and work organisational aspects should be implemented to reduce neck/shoulder complaints. Furthermore the importance of effective use of rest breaks to prevent discomfort has been suggested (Kirk, 1998).

Pontén & Spahr (1991) report an intervention study that implements different assumed improvements of work environment and work organization for 39 machine operators from 1987-1990 and do not find any convincing reduction of neck/shoulder complaints. In a study of why some forest machine operators are healthy Andersson & Hemborg (1985) and Attebrant (1986) found no significant differences in range of motion in the neck, production capacity and EMG measures of the neck and shoulder muscles between healthy and matched pairs of subjects with neck/shoulder disorders. The healthy ones had better working methods, were stronger in the shoulder girdle muscles, were more motivated, experienced less strain and were more general well-being compared to the unhealthy.

In the interventions study cited above Perkiö-Mäkelä & Riihimäki (1997) adjusted the seats (to a angle of the backrest-seat to 105º, seat inclination 5º) and gave the machine operator a lumbar support in different combinations. A significant reduction of neck/shoulder symptoms was found over a two-weeks period for all combinations but especially for the 18 subjects with both interventions.

Gellerstedt (1993b) found in a study of thinning by forest machines that the 6 operators with neck/shoulder symptoms had fewer short interruptions in trapezius muscle activity (EMG gaps) than 8 healthy operators. Similar results were found for 3 forest machine operators who performed mechanised spacing and cleaning of young stands of trees (Gellerstedt, 1997). Rotable and movable driver cabs have shown to improve head postures and viewing angles (Eklund et al., 1994; Gellerstedt, 1998). Mini (or finger) lever compared to hand lever use (see below under arm pain) and moveable compared to fixed arm rest decreased activity in the trapezius muscle (Asikainen & Harstela, 1993, Lindbeck, 1982, Attebrant et al., 1992, 1995, 1997). In conclusion, sustained low-level muscle activity with few interruptions and with long working hours are possibly related to neck/shoulder pain. However, work organisational aspects are also of importance and several authors stress the need for a multifactorial approach for studying these phenomena.

Arm pain

Size of problem
35% of British machine operators had reported complaints in the arm during the preceding 12 months (Jones et al., 1999). Elbow/forearm complaints (27%) were more common for machine operators than for professional car drivers, but no difference was found for wrist/hand complaints (23% for machine operators).

Possible causes
Attebrant showed that a mini-lever with semi-pronated (neutral) hand posture reduced muscle activity in the infraspinatus, extensor and flexor of the forearm muscles (but not in the trapezius muscle) compared to a normal hand lever demanding pronation of the hand (Attebrant, 1995; Attebrant et al., 1997). Some indications exist that pronated hand postures in forest machines predispose to symptoms and sick leave due to muscle pain in the elbow and shoulder (Grevsten & Sjogren, 1996). Seven out of eight subjects working with pronated hands had symptoms and three had a sick leave due to these symptoms for 1-6 months. Six out of eleven with a semi-pronated hand posture had symptoms, but no sick leaves occurred in this group.

Östergren & Hansson (1985) described hand and finger activity of machine operators. Movement of the hand was observed for almost 90% and movements of fingers for almost 20% of the effective working time in harvesters. The work was intensive, monotonous and almost all the time with hands at the hand lever. Corresponding figures for the forwarders were almost 100% and approximately 8%, but the hand levers were only used for 30-50% of effective working time, resulting in a varied work compared to the harvesters.

Forest machine operators used 20 000 joystick movements during a working day with an average force application of 20 N, was reported by Garland (1990). Golsse & Rickards (1990) found that maintenance activities in routine work demanded approximately 33% of maximal oxygen uptake and showed many bad postures. Oliver & Rickards (1995) suggested possible increased risk of carpal tunnel syndrome due to the exertions described by Golsse & Rickards (1990) and possibly also those described by Garland (1990).

In a small New Zealand study 10 out of 23 harvester operators complained of constant pain mainly in the wrist and hands. The complainers generally worked longer hours and received less training than the non-complainers (Byers, 1997).

Low back pain

Size of problem
23% of machine operators reported low back pain for more than 30 days during the preceding 12 months, the same level of prevalence as for manual forest workers (Hagen et al., 1998). In a primary intervention study of seat adjustment (see above) Perkiö-Mäkelä & Riihimäki (1997) found that 31% complained of low-back symptoms more than 30 days during the preceding 12 months.

Possible causes
A systematic critical review and meta-analysis of epidemiological studies dealing with health effects of whole-body vibration (not forest workers specifically) showed an increased risk for low-back pain, sciatic pain, and some degenerative changes in the spinal system (Bovenzi & Hulshof, 1999).

Hagen showed an association between high psychological demands and low back pain for manual workers and machine operators but not for a control group of administrative personnel (Hagen et al., 1998). It is estimated that forest machine operators work at ⅓ of their maximal oxygen uptake during maintenance mechanics, which is supposed to increase risk for accident (Golsse & Rickards, 1990).

Psychosomatic complaints

Description
Lilley et al. (2002) received questionnaire response from 367 forest workers from New Zealand (response rate 97%) on questions on organisation of work, sleep habits and fatigue. Fatigue was registered from the question: “How often do you feel fatigued while at work?” 78% of forest workers reported fatigue sometimes or more at work, but only a approximately of 20% of the machine operators (Lilley et al., 2002). A survey of health complaints in 1988 indicated that machine operators had slightly less psychosomatic complaints than fellers (Johansson et al., 1988). Increase of weight was one of few complaints where machine operators exceeded those of the fellers.

Possible causes
Almost all machine operators work more than 8 hours daily, approximately 25% of them worked more than 10 hours and 5-10% more than 12 hours (Lilley et al., 2002). Almost 20% did not keep regularly scheduled breaks. Only a few other forest workers worked over 10 hours daily and they mainly kept their breaks. Consequently, these variables did not explain the lower level of fatigue for machine operators. Indications exist that increase of feeling of stress and fatigue during a working day increase more among harvester operators than among forwarder operators (Sullman & Gellerstedt, 1997). Indications also exist that work in e.g. single-grip harvester exhibits a very high mental work load (Sullman & Kirk, 1998a). Furthermore, the importance of effective use of rest breaks to prevent fatigue has been suggested (Kirk, 1998).

Hearing loss

Description

Size of problem
Holmgren et al. (1971) found a hearing loss both among manual fellers and among tractor drivers in the late 1960'ies, but found a detoriation during a 3 years period only for the fellers. 22% of forest machine operators in Sweden complained of hearing loss in 1989 (Garland, 1992). In a sample made 1986 of 199 forest workers the mean hearing loss at 4 kHz was 27.3 dB(A) (Pyykko et al., 1989).

Possible causes.
Noise is the main external risk factor for hearing loss, but the effect of aging is of course well known and in addition individual factors as increased serum-cholesterol and use of antihypertensive agents have also been associated to hearing loss (Pyykko et al., 1988). Exposure for noise from chain-saws have been drastically reduced during the last two decades. Work as a forest machine operator does probably not involve harmful noise exposure (ILO, 1981). However, documentation on up-to-date noise exposures diverges. One newer study has shown noise levels below 80 dB(A), except for the skidder for which it was 82 dB(A) (Rummer & Smith, 1990

Conclusions

Pain symptoms from the neck, shoulder and upper limb are rather common among forest machine operators. If the change from manual work to operator functions has caused a decrease in complaints of low back pain is controversial. The fixed working postures, sustained muscle activation, long working hours and negative psychosocial aspects of work may all be of importance as risk factors for neck and upper limb pain symptoms. Fixed sitting working postures and minimal physical activity may be risk factors for low back pain and may have replaced hard physical work as a risk factor.

The magnitude of the work-related musculoskeletal pain symptoms indicates the need for intervention. Long working hours may be difficult to reduce, but reduced amount of fixed working postures, increased variability and use of breaks should be emphasised together with improvement of psychosocial work environment.

Existing literature indicates that psychosomatic complaints (e.g. fatigue, ingestion symptoms) and hearing loss may be minor problems for the forest machine operators in modern forestry.

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Appendix 2.1

Tables of categorised references

Table 2.1. Literature on social conditions.

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in review	Database
Ager & Valinger, 1984	Sweden	Swedish	Research	Unpubl. rep.	No	ARBLINE
Almqvist & Nåbo, 1990	Sweden	Swedish	Research	Report.	No	ARBLINE
Andersson et al., 1968	Sweden	Swedish (e)	Research	Report		
Ashby et al., 2000	New Zealand	English	Scientific	Journal	Yes	RILOSH, HSELINE
Backhaus, 1994a	Germany	German	Practical	Journal	Yes	CAB
Backhaus, 1994b	Germany	German	Practical	Journal	Yes	CAB
Backhaus, 1999	Germany	German	Practical	Journal	No	
Behrndt, 2000	Germany	German	Practical	Journal	No	CAB
Bostrand, 1984	Sweden	Swedish (e)	Scientific	Monograph	Yes	ARBLINE
Brown-Haysom, 2000		English	Practical	Journal	No	HSELINE
Burell, 1991	Sweden	Swedish	Statistics	Report	No	
Byers, 1996	New Zealand	English	Research	Report	Yes	
Byers & Cummins, 1997	New Zealand	English	Research	Report	Yes	
Cristofolini et al., 1990	Italy	English	Research	Journal	No	NIOSHTIC2
Dale et al., 1993	Norway	Norwegian	Research	Report	Yes	
Dolnec, 1995	Sweden	English	Research	Journal	No	MEDLINE
Edenham, 1990	Sweden	Swedish (e)	Research	Report	No	
Ekstrom, 1981	Sweden	English	Practical	Periodical	No	CISDOC
Forbrig, 1996	Germany	German	Practical	Journal	No	CAB

Table 2.1. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in review	
Fosbroke & Myers, 1996	USA	English	Practical	Journal	Yes	NIOSHTIC2
Gardell, 1969	Sweden	Swedish	Research	Book	Yes	
Garland, 1990	USA	English	Research	Journal	No	
Garland, 1992	USA	English	Practical	Proceedings	No	OSH-ROM
Gellerstedt, 1989	Sweden	Swedish	Research	Report	No	ARBLINE
Gellerstedt, 1990	Sweden	Swedish	Research	Report	No	
Gellerstedt, 1993a	Sweden	Swedish (e)	Scientific	Thesis	Yes	ARBLINE
Gellerstedt, 1993b	Sweden	Swedish	Research	Report	No	ARBLINE
Gellerstedt & Dahlin, 1999	Sweden	English	Scientific	Journal	No	CAB
Gellerstedt et al., 1998	Sweden	English	Practical	Publication	Yes	ARBLINE
Goodwin et al., 1982	Great Britain	English	Practical	Journal	Yes	NIOSHTIC2
Golsse & Rickards, 1990	Canada	English	Research	Journal	No	OSH-ROM
Greene, 1996	USA	English	Research	Journal	Yes	
Greene et al., 1998	USA	English	Research	Journal	Yes	
Gullberg, 1995	Sweden	English	Research	Journal	Yes	
Hall et al., 1972	Sweden	Swedish	Research	Report	Yes	
Hanninen & Rytkoenen, 1995	Finland	Finnish	Research	Journal	No	HSELINE
Hansson & Åstrand, 1963	Sweden	Swedish	Research	Report	No	ARBLINE
Heil, 1996	Germany	German	Practical	Journal	No	
Hoss, 1991	Germany	German	Practical	Journal	No	CAB
Hughes, 1982	Great Britain	English	Research	Journal	No	CISDOC
ILO, 1992	Switzerland	English	Practical	Publication	No	CISDOC
Jacke, 1995	Germany	German	Practical	Journal	No	CAB

Table 2.1. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in review	
Jacke et al., 2000	Germany	German	Practical	Journal	Yes	CAB
Johansson, 1995	Sweden	English	Research	Journal	No	CAB
Johansson, 1996	Sweden	English	Research	Journal	No	CAB
Johansson, 1997	Sweden	English	Research	Journal	No	CAB
Kastenholz et al., 1995	Germany	German	Research	Journal	Yes	
Kirk, 1997	New Zealand	English	Research	Report	Yes	
Kirk, 1998	New Zealand	English	Research	Report	Yes	
Laurier, 1999	France	French	Review	Report	No	CAB
Leinert, 1998	Germany	German	Practical	Journal	No	
Lidén, 1987	Sweden	Swedish (e)	Research	Report	Yes	ARBLINE
Lidén, 1989	Sweden	Swedish (e)	Research	Report	Yes	ARBLINE
Lidén, 1995a	Sweden	English	Research	Report	Yes	
Lidén, 1995b	Sweden	English	Scientific	Thesis	Yes	ARBLINE
Lidén, 1995c	Sweden	English	Research	Report	No	
Liira & Leino-Arjas, 1999	Finland	English	Scientific	Journal	Yes	ARBLINE, HSELINE, RILOSH,
Lilley et al., 2002	New Zealand	English	Scientific	Journal	Yes	MEDLINE, RILOSH, HSELINE
Löfroth et al., 2001	Sweden	Swedish (e)	Research	Report	No	CAB
McLean & Rickards, 1998	Canada	English	Research	Journal	Yes	
Myers & Fosbroke, 1995	USA	English	Research	Journal	Yes	NIOSHTIC2
Norin & Lidén, 1998	Sweden	Swedish (e)	Practical	Report	No	
Ohrner, 1998	Germany	German	Practical	Journal	No	
Ohrner, 1999	Germany	German	Practical	Journal	No	
Østensvik, 1997	Norway	Norwegian	Research	Thesis	Yes	

Table 2.1. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in review	
Parenmark et al., 1993	Sweden	English	Research	Journal	Yes	NIOSHTIC2
Parker et al., 2002		English	Methodical	Book	No	RILOSH
Parker et al., 1996	New Zealand	English	Practical	Report	Yes	
Reisinger et al., 1994	USA	English	Research	Journal	Yes	
Rummer, 1994	USA	English	Practical	Proceedings	No	
Rummer & Smith, 1990	USA	English	Research	Journal	Yes	RILOSH
Sirois & Smith ,1985	USA	English	Research	Journal	No	NIOSHTIC2
Smith & Sirois, 1982	USA	English	Practical	Proceedings	No	RILOSH
Stuart et al., 1996	USA	English	Practical	Journal	Yes	CAB
Sullman & Kirk, 1998b	New Zealand	English	Research	Report	No	
Thomas, 1994	USA	English	Scientific	Journal	No	
Yamada & Minato, 1993	Japan	Japanese	Practical	Journal	No	CAB

Table 2.2. Literature on safety.

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Alberta Forest Products Association, 1991	USA	English	Practical	Booklet	No	CISDOC
Alberta Logging Association, 1992	Canada	English	Practical	Book	No	CISDOC
Aminoff & Lindström, 1981	Sweden	Swedish (e)	Research	Report	Yes	
Ashby et al., 2000	New Zealand	English	Scientific	Journal	Yes	RILOSH, HSELINE
Attebrant et al., 1996	Sweden	English	Practical	Proceedings	No	
Axelsson, 1998	Sweden	English	Research	Journal	Yes	
Backhaus, 1994	Germany	German	Practical	Journal	Yes	CAB
Backström & Åberg, 1998	Sweden	Swedish	Research	Report	Yes	
Bentley & Parker, 2001	New Zealand	English	Scientific	Journal	Yes	RILOSH, HSELINE
Bordas et al., 2001	USA	English	Research	Journal	Yes	MEDLINE
Byers, 1996	New Zealand	English	Research	Report	Yes	
Byers & Skerten, 1996	New Zealand	English	Research	Report	Yes	
Cummins et al., 1999	New Zealand	English	Research	Report	No	
De Hoop et al., 1997	USA	English	Practical	Journal	No	
Driscoll et al., 1995	Australia	English	Research	Journal	Yes	CISDOC, NIOSHTIC2
Egan, 1996	USA	English	Practical	Journal	Yes	
Egan, 1998	USA	English	Research	Journal	Yes	
Ekstrom, 1981	Sweden	English	Practical	Periodical	No	CISDOC
Erikson & Myhrman, 1999	Sweden	Swedish	Practical	Report	No	
Forest Products Accident Prevention Association, 1990	Canada	English	Practical	Booklet	No	
Fosbroke & Myers, 1996	USA	English	Practical	Journal	Yes	NIOSHTIC2
Greene, 1996	USA	English	Scientific	Journal	Yes	
Hansson, 1987	Sweden	English	Research	Report	Yes	

Table 2.2. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Hansson, 1990	Sweden	English	Research	Journal	No	
Hansson et al., 1989	Sweden	Swedish	Practical	Booklet	Yes	
Hansson et al., 1990	Sweden	English	Practical	Booklet	Yes	
Health and Safety Executive, 1999	Great Britain	English	Regulations	Booklet	No	
Hefferman, 1996	USA	English	Practical	Journal	Yes	
Heil, 1996	Germany	German	Practical	Journal	No	
ILO, 1981	Switzerland	English	Practical	Report	No	
ILO, 1998	Switzerland	English	Practical	Book	Yes	
ILO, 2000	Switzerland	English	Practical	Book	No	
Johansson & Pontén, 1990	Sweden	Swedish (e)	Statistics	Report	No	
Jones et al., 1999	Great Britain	English	Practical	Journal	No	
Kastenholz et al., 1995	Germany	German	Research	Journal	Yes	
Kirk, 1996	New Zealand	English	Research	Report	No	
Kirk et al., 1996a	New Zealand	English	Practical	Report	Yes	
Kirk et al., 1996b	New Zealand	English	Practical	Report	Yes	
Laflamme & Cloutier, 1988	Canada	English	Research	Journal	Yes	
Landström & Myhrman, 1995	Sweden	Swedish	Research	Report	No	
Larsson, 1990	Sweden	English	Research	Journal	No	HSELINE
Larsson & Field, 2002	Australia	English	Research	Journal	Yes	
Lilley et al., 2002	New Zealand	English	Scientific	Journal	Yes	MEDLINE, RILOSH, HSELINE
Lindström & Sundström-Frisk, 1976	Sweden	Swedish	Research	Report	Yes	
Löfgren, 1999	Sweden	English	Research	Report	No	
Löfgren et al., 1999	Sweden	Swedish	Research	Report	No	
Löfroth & Hallonborg, 1998	Sweden	Swedish	Research	Report	No	

Table 2.2. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Marshall, 1994	New Zealand	English	Research	Journal	Yes	CAB-FPA
Myers & Fosbroke, 1995	USA	English	Research	Journal	Yes	NIOSHTIC2
Myhrman, 2000	Sweden	Swedish	Research	Report	No	
Nienuwhuis & Lyons, 2002	Ireland	English	Research	Journal	Yes	
Nord, 1991	Sweden	Swedish	Research	Thesis	No	
Nordén & Thor, 2000	Sweden	Swedish	Research	Report	No	
NZ Department of Labour, 1992	New Zealand	English	Practical	Book	Yes	HSELINE, CISDOC
NZ Department of Labour, 1994	New Zealand	English	Practical	Book	Yes	ARBLINE, HSELINE, CISDOC
Occupational Safety and Health Reporter, 1994	USA	English	Regulations	Journal	Yes	HSELINE
Ohrner, 1994	Germany	German	Practical	Journal	No	
Parker et al., 2002	New Zealand	English	Practical	Book	No	
Paulozzi, 1987	USA	English	Research	Journal	No	MEDLINE
Ratliff, 1992	Canada	English	Practical	Proceedings	No	
Reisinger et al., 1994		English	Research	Journal	No	CAB-FPA
Rummer, 1995	USA	English	Methodical	Journal	Yes	
Safety Express, 1999	Great Britain	English	Practical	Journal	No	OSH-ROM
Salminen et al., 2001	Finland	English	Research	Journal	No	
Shaffer & Milburn, 1999	USA	English	Research	Journal	Yes	
Slama, 1981	Check Rep.	English	Scientific	Journal	No	ARBLINE, NIOSHTIC2
Slappendel et al., 1993		English	Research	Journal	No	NIOSHTIC2
Sullman, 1998	New Zealand	English	Research	Journal	No	
Sullman et al., 1996	New Zealand	English	Methodical	Report	Yes	
Synwoldt, 2001	Sweden	English	Research	Thesis	Yes	

Table 2.2. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Synwoldt & Gellerstedt, 2003	Sweden	English	Research	Journal	Yes	
Tapp et al., 1990	New Zealand	English	Research	Report	Yes	CAB-FPA
Varynen, 1983	Finland	English	Research	Journal	No	MEDLINE, OSH-ROM
Varynen, 1984	Finland	English	Research	Journal	No	HSELINE, NIOSHTIC2
Varynen, 1988	Finland	English	Research	Journal	No	NIOSHTIC2
Värynen & Könönen, 1991	Finland	English	Research	Journal	No	OSH-ROM
Victoria Department of Labour and Industry, 1984	Australia	English	Practical	Book	No	CISDOC
Webb, 2001	Canada	English	Research	Report	No	
Wettmann, 1997	Germany	German	Practical	Journal	No	HSELINE
Williams et al., 1996		English	Research	Journal	No	MEDLINE

Table 2.3. Literature on health conditions.

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Ahlgren et al., 1982	Sweden	Swedish	Research	Report	No	
Alaranta & Seppalainen. 1977	Finland	English	Scientific	Journal	No	MEDLINE
Almqvist, 1992	Sweden	Swedish	Practical	Report	No	ARBLINE
Altunel & De Hoop, 1998		English	Research	Journal		
Andersson & Hemborg, 1985	Sweden	Swedish	Research	Report	Yes	ARBLINE
Asikainen & Harstela, 1993	Finland	English	Research	Journal	Yes	
Askling, 1990	Sweden	Swedish	Research	Report		ARBLINE
Asp et al., 1994	Finland	English	Research	Journal		NIOSHTIC2
Attebrant, 1995	Sweden	English	Research	Report	Yes	ARBLINE
Attebrant et al., 1996	Sweden	English	Practical	Proceedings	No	ARBLINE
Attebrant et al., 1992	Sweden	English	Research	Report	Yes	ARBLINE
Attebrant et al., 1997	Sweden	English	Research	Journal	Yes	RILOSH, HSELINE, NIOSHTIC2, MEDLINE
Attebrant et al., 1993	Sweden	English	Research	Book		ARBLINE
Augusta et al., 2002	Germany	German	Research	Journal		CABI
Axelson, 1974	Italy	English	Review	Report		CISDOC, ARBLINE
Axelsson, 1998	Sweden	English	Review	Journal		
Axelsson & Pontén, 1990	Sweden	English	Research	Journal	Yes	HSELINE, NIOSHTIC2
Bates et al., 2001		English	Research	Journal		
Boileau & Raqkheja, 1990	Canada	English	Research	Journal		NIOSHTIC2
Boileau & Scory, 1988	Canada	French	Research	Journal	Yes	HSELINE
Bovenzi et al., 1999	Italy	English	Review	Journal		
Bovenzi et al., 1991	Italy	English	Research	Journal		
Branczyk, 1995	Germany	German	Practical	Journal		CABI

Table 2.3. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Breathnach, 1988	Ireland	English	Practical	Journal		HSELINE
Brown-Haysom, 2000		English	Practical	Journal		HSELINE
Buchberger & Muhlertahler, 1984	Switzerland	English	Research	Journal		MEDLINE, NIOSHTIC2
Bunger et al., 1997		English	Research	Journal	No	MEDLINE, NIOSHTIC2
Byers, 1997	New Zealand	English	Research	Report	Yes	
Carlsöö, 1982	Sweden	Swedish	Research	Report	No	
Carlsöö et al., 1978	Sweden	Swedish	Research	Report	No	
Carlsson, 1993	Sweden	Swedish	Research	Report		ARBLINE
Corrao et al., 1989	Italy	English	Research	Report		CISDOC, NIOSHTIC2, HSELINE
Crocker et al., 1974		English	Scientific	Journal		NIOSHTIC2
Cummins et al., 1999	New Zealand	English	Research	Report		
Dave et al., 1988	Great Britain	English	Research	Journal		NIOSHTIC2
Davis et al., 2001	New Zealand	English	Research	Journal		
Dolnec, 1995		English	Research	Journal	Yes	MEDLINE
Dupuis, 1994	Germany	English	Research	Journal		NIOSHTIC2
Edenhamn, 1990	Sweden	Swedish (e)	Research	Report		
Eklund et al., 1994	Sweden	English	Research	Journal	Yes	HSELINE, NIOSHTIC2, MEDLINE
Erikson, 1995	Sweden	Swedish	Research	Report	Yes	
Gellerstedt, 1993a	Sweden	Swedish	Research	Thesis	Yes	ARBLINE
Gellerstedt, 1997	Sweden	English	Research	Journal	Yes	RILOSH, HSELINE, CISDOC, NIOSHTIC2
Gellerstedt, 1998	Sweden	English	Research	Journal	Yes	CABI
Gellerstedt, 2002	Sweden	English	Research	Journal		
Gellerstedt & Berg, 1995	Sweden	English	Research	Report		CABI

Table 2.3. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Gellerstedt et al., 1998	Sweden	English	Practical	Booklet	Yes	ARBLINE
Ghassemi et al., 1982		English	Research	Journal		
Glass, 1989		English	Research	Journal		HSELINE
Granlund et al., 2002	Sweden	Swedish	Practical	Report		CABI
Grevsten & Sjogren, 1996	Sweden	Swedish	Research	Journal	Yes	RILOSH, HSELINE, CISDOC, NIOSHTIC2
Hagen & Harms-Ringdahl, 1994	Norway	English	Research	Journal		MEDLINE
Hagen et al., 1997	Norway	English	Research	Journal		NIOSHTIC2
Hagen et al., 1998	Norway	English	Research	Journal	Yes	RILOSH, HSELINE, CISDOC
Hagen et al., 1993	Norway	English	Research	Journal		RILOSH, MEDLINE
Hägg & Sjöberg, 1995	Sweden	English	Research	Proceedings		ARBLINE
Hansson, 1987	Sweden	English	Research	Report	Yes	RILOSH, HSELINE
Hansson & Suggs, 1973	Sweden	English	Research	Report		NIOSHTIC2
Hansson & Wikström, 1974	Sweden	Swedish (e)	Research	Report		
Harstela, 1990	Finland	English	Research	Journal	Yes	HSELINE, NIOSHTIC2
Health and Safety Executive, 1999		English	Practical	Journal		HSELINE
Hirvonen & Leskinen, 1996	Finland	English	Research	Journal		HSELINE
Holmgren et al., 1971	Sweden	English	Research	Book		NIOSHTIC2
ILO, 1981	Switzerland	English	Practical	Report	Yes	CISDOC
ILO, 1998	Switzerland	English	Practical	Book		
Imatomi, 1997	Japan	English	Research	Journal		CABI
Isfort, 1993	Germany	German	Research	Journal		CISDOC
Johansson et al., 1988	Sweden	Swedish	Research	Report	Yes	ARBLINE
Johansson & Pontén, 1990	Sweden	Swedish	Research	Report		

Table 2.3. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Jones et al., 1999	Great Britain	English	Practical	Journal	Yes	
Jonson et al., 1983	Sweden	Swedish	Research	Report	Yes	ARBLINE, CISDOC
Jørgensen & Andersen, 1985	Denmark	English	Research	Journal		HSELINE
Kirk, 1998	New Zealand	English	Research	Report	Yes	
Kirk et al., 1998	New Zealand	English	Research	Report		
Kylin et al., 1968	Sweden	Swedish	Research	Report	Yes	ARBLINE
Lasser, 1969	Germany	German	Research	Report		NIOSHTIC2
Lidén, 1990	Sweden	Swedish	Research	Report	Yes	ARBLINE
Lidén & Pontén, 1985	Sweden	Swedish	Research	Report	Yes	
Liira & Leino-Arjas, 1999	Finland	English	Research	Journal	Yes	ARBLINE, RILOSH, HSELINE
Lilley et al., 2002	New Zealand	English	Research	Journal	Yes	MEDLINE, RILOSH, HSELINE
Lima et al., 1998	Spain	Spanish	Research	Journal	Yes	CABI
Lindbeck, 1982	Sweden	Swedish	Research	Report	Yes	
Lindbeck, 1986	Sweden	Swedish	Research	Report	Yes	ARBLINE
Löfgren et al., 1994	Sweden	Swedish	Research	Report		
Löfroth & Pettersson, 1982	Sweden	English	Research	Int. report	Yes	
Mäkelä & Riihimäki, 1997	Finland	English	Research	Journal		HSELINE
McFarland, 1989	New Zealand	English	Practical	Report		
McGregor, 1960	Great Britain	English	Research	Journal	Yes	HSELINE
Miranda et al., 2001	Finland	English	Research	Journal		MEDLINE
Mitchell, 1986		English	Research	Journal		NIOSHTIC2
Musson, 1999	New Zealand	English	Research	Journal		CABI
Myers & Fosbroke, 1995	USA	English	Practical	Journal		NIOSHTIC2
Nåbo, 1990a	Sweden	Swedish	Research	Report	Yes	ARBLINE

Table 2.3. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Nåbo, 1990b	Sweden	Swedish	Practical	Report		
Nakata et al., 1992	Sweden	English	Research	Report		ARBLINE
Nieuwenhuis & Lyons, 2002	Ireland	English	Research	Journal		
Norlander, 1997	Sweden	Swedish	Research	Thesis		ARBLINE
NZ Department of Labour, 1992	New Zealand	English	Practical	Book		CISDOC, HSELINE
NZ Department of Labour, 1994	New Zealand	English	Practical	Book		ARBLINE, HSELINE, CISDOC
Oestergen & Hansson, 1985	Sweden	Swedish	Research	Report	Yes	HSELINE
Oliver & Rickards, 1955	Canada	English	Research	Journal	Yes	
Opsahl, 1994	Norway	Norwegian	Research	Thesis		
Østensvik, 1997	Norway	Norwegian	Research	Thesis	Yes	
Parenmark et al., 1993	Sweden	English	Research	Journal		NIOSHTIC2
Perkiö-Mäkelä & Riihimäki, 1997	Finland	English	Research	Journal	Yes	RILOSH, NIOSHTIC2
Pfaffli et al., 2002	Finland	English	Research	Journal		MEDLINE
Pontén, 1988	Sweden	English	Research	Report	Yes	ARBLINE
Pontén & Spahr, 1991	Sweden	Swedish	Research	Report	Yes	ARBLINE
Pyykko et al., 1989	Finland	English	Research	Journal		MEDLINE, CISDOC
Pyykko et al., 1988	Finland	English	Research	Journal		NIOSHTIC2
Rehn et al., 2000	Sweden	English	Research	Proceedings	Yes	ARBLINE
Rodvall et al., 1996	Sweden	English	Research	Journal		
Rummer & Smith, 1990	USA	English	Research	Journal		NIOSHTIC2
Safety Express, 1999	Great Britain	English	Practical	Booklet		
Seixas et al., 1999	USA	English	Research	Journal		CABI
Seppalainen, 1972	Finland	English	Research	Journal		NIOSHTIC2
Smith, 1984	USA	English	Research	Proceedings		RILOSH

Table 2.3. (cont.)

Author(s)	Country of origin	Language	Type of publ.	Availability	Referred to in the review	Database
Smith et al., 1985	USA	English	Research	Journal		RILOSH, HSELINE, NIOSHTIC2
Stoner, 1986		English	Research	Journal		NIOSHTIC2
Storrs, 1982	USA	English	Research	Book		
Sullman & Gellerstedt, 1997	New Zealand	English	Research	Journal	Yes	CABI
Sullman & Kirk, 1998	New Zealand	English	Research	Report		CABI
Sweeny, 1994		English	Research	Book		NIOSHTIC2
Tharr, 1994		English	Research	Journal		NIOSHTIC2, HSELINE
Tingvall & Sundback, 1982		English	Research	Proceedings		NIOSHTIC2
Toppila & Pyykkoo, 2001	Finland	English	Research	Journal		HSELINE
Värynen & Könönen, 1991	Finland	English	Research	Journal		
Vayrynen & Rieppo, 1982	Finland	English	Research	Report		CISDOC
Vik et al., 1984	Norway	Norwegian	Research	Journal	Yes	
Waesterlund, 1998	Sweden	English	Review	Journal		RILOSH, HSELINE, CISDOC, MEDLINE
Wegsheid, 1994		English	Research	Journal		
Wikström & Eskilsson, 1984	Sweden	English	Research	Newsletter		HSELINE
Wikström et al., 1991	Sweden	English	Research	Journal		NIOSHTIC2
Wickstrom, 1978	Sweden	English	Research	Journal		CISDOC
Winkel et al., 1998	Sweden	Swedish	Review	Report	Yes	RILOSH, HSELINE, ARBLINE
Young & Shepard, 1983	USA	English	Research	Journal		NIOSHTIC

Scientific review of forest machine technical ergonomics

R. Tobisch, M. Walker & G. Weise

Abstract

The aim of this review is to give the interested reader an overview of the ergonomics of the forest machine-man interface. Although machines are improved continuously, the need for further optimisation of this arduous workplace can be recognised in the number of publications about the health risks to forest machine operators and the plethora of standards covering the various safety requirements for forest machines. Many of these risks can be directly linked to the ergonomic design of the machine (awkward work postures and visibility, whole-body vibration and seat design, fatigue, and concentration). The International Labour Organisation has produced a Code of Practice (ILO, 1998) for improving the safety of forest work, which lists the most important basic requirements for mobile forest machines. It is a good illustration of how health and safety requirements and ergonomic design are closely related. This review attempts to give the reader an overview of the most recent research publications concerning health hazards to machine operators and forest machine ergonomics.

Since many of the ergonomic problems associated with forest machines are also applicable to agricultural machines and heavy construction vehicles, the relevant publications are also included here. Some consideration is also given to the available ergonomic guidelines and testing procedures and the relevant standards and directives are included at the end of the review.

Some of the topics covered in this review have not been subject to recent scientific research. However, all features are, to a degree, covered by German (DIN) and international (ISO) standards. Where applicable, the authors also cites basic guidelines and handbooks on the ergonomic design of mobile machinery.

The review is divided into three main sections; the first deals briefly with the historical development of ergonomic evaluations of forest machines and test procedures; the second section reviews the recent publications related to this subject and relevant standards and directives; the third section provides the reader with a list of references and relevant standards.

The development of ergonomic evaluation guidelines for forest machines

Initial test procedures at the KWF in Germany

Official guidelines for evaluating the ergonomics of forest machines were first introduced in Germany in 1977 by Rehschuh & Tzschöckel (1977) and formed the basis for the test procedures carried out in the KWF (Kuratorium für Waldarbeit und Forsttechnik). Many of the problems outlined in this early guideline still make ergonomic assessments difficult today. For example, the close relationship between ergonomic considerations and the requirements of safety technology. Many of the demands could only be formulated in very loose terms. It is very difficult to define objective evaluation standards in this field.

At this time only tractors were subject to official testing. Harvesters and forwarders were unknown then. However, tractors could be equipped with winches, hydraulic bundlers, butt plates, stabilisers, skid tongs and cranes.

The test began with a description of the machine and technical data, a procedure that is still followed today. The first ergonomic criterion to be assessed was the mode of accessing the cab and the cab door. Similar elements of this test are still in use today. The same applies to the internal dimensions of the cab. Apart from a general question whether "the cab appears to be stable" cab stability played only a minor role in the test. ROPS, FOPS and OPS test ISO-standards were not known in those days.

Seat tests were limited to the measurement of the SRP (seat reference point). The tests were rather primitive in view of today's more stringent requirements. There was also an exception for narrow gauge tractors. The biggest ergonomic advance from a wood seat or metal pan mounted on leaf springs to a comfortable seat had already taken place.

The tests also included an evaluation of the warning signals and display instruments and of the moving distances and operational forces required to move controls. Thus, the maximum force for turning the steering wheel was limited to 250 N.

Visibility was another topic. The test required a sketch of the horizontal of view around the machine and the vertical field of view in front of the machine. The machines were required to be equipped with windscreen wipers and a defrosting or windscreen drying unit. The illumination value for working lights had to exceed 30 Lux for the work area. However, the guidelines did not include a method for measuring luminous intensity.

The standards required that the working temperature in the cab should attain 16°C. Exceptions were made for machines without a closed cab. The permitted values for toxic gases were:

Carbon monoxide (CO)	50 ppm or 55 mg/m³
Formaldehyde (HCHO)	1 ppm or 2 mg/m³
Nitrogen dioxide (NO_2)	5 ppm or 9 mg/m³

The upper noise limit was 90 dB(A) for an equivalent constant noise level for an average 8-hour shift. 75% of the machines registered before the 1.1.1978 achieved this value during nominal speed. This means that the upper noise limit could attain values significantly above 90 dB(A). Some form of additional sound protection (ear muffs, plugs) were recommended. Exposure to whole-body vibration was tested according to ISO 2631, which was the standard at the time.

The checklist for the ergonomic evaluation was an attempt to record the physical and psychological strain placed on the operator. However, the answers given to these questions could not really form the basis for an objective evaluation.

Under the general safety heading, questions were asked about the adequacy of protection from falling and penetrating objects and the presence of a walkie-talkie with an emergency call system. The complete list of safety requirements is still valid today. The list also includes remarks about the operation of the machine and requirements for the operator's manual. The test questions regarding maintenance and machine repairs still fulfil current requirements.

In summary the complete machine was tested. The evaluation was based on verbal descriptions for each test section. A comparison between machines was not possible.

Initial FERIC test procedures in Canada

In 1979 the Forest Engineering Research Institute of Canada (FERIC) published a preliminary work on evaluating the ergonomics of Canadian forestry equipment. This report was updated by Gollse (1994) to account for the ongoing evolution in machinery and safety standards. The new report guides the evaluations of a machine's ergonomic characteristics in 10 areas: Entry and egress, operating station, instrumentation, controls, visibility, lighting, cab environment, noise, vibration and service and maintenance. A final summary table is provided to permit an overall ergonomic ranking of a machine and to permit comparison with other machines.

First official Swedish test

An ergonomic checklist for Swedish forest machines (Ergonomisk Checklista för Skogsmaskiner (ECS)) was published by Hansson et al. (1989) where an ergonomic evaluation is carried out at the end of each chapter. This is a test of how the machines meet the requirements set in the checklist.

After evaluating the work posture of the operator, the test continues with the internal cab dimensions and the driver seat. The requirements for these aspects of machine design have also been superseded by current demands. The maximum force required to move controls have been reduced to a value far below those defined by Rehschuh & Tzschöckel (1977). However, the permitted maximum force for turning the steering wheel is still 230 N. The checklist includes an optimum working area for control positioning and a number of requirements for the instruments.

The cab climate is also subject to evaluation. The checklist includes temperature and air speed requirements. There is no provision for machines with open cabs.

Visibility is also assessed. No sketch is required. The lights should illuminate the work area with a value of at least 30 Lux. The checklist also includes some statements about peripheral lighting.

The maximum noise levels should not exceed 85 dB(A) or 75 dB(A). The exposure to exhaust fumes is divided into long-term (over the whole day) and short-term (in 15 min period) exposures:

	Short-term	Long-term
Carbon monoxide	100 ppm	35 ppm
Formaldehyde	1 ppm	0.5 ppm
Nitrogen dioxide	5 ppm	2 ppm
Oil mist	5 mg/m^3	2 mg/m^3
Nitrogen monoxide	-	25 ppm

Vibration is measured according to ISO 2631 and ISO 5349, which were in effect at this time. A distinction is made between whole-body and hand-arm vibration. Maintenance and repair work play a major role in this checklist.

Current testing procedures at the KWF

The KWF test procedure, based on the checklist published by Rehschuh & Tzschöckel (1977), soon proved to be impractical. For example, the guideline specified an assessment of the physical and psychological strain placed on the operator by the test machine. For this, the procedure provided eight questions, which were categorised into good, middle and bad. Typical questions were “Are strains to eyes and ears avoided?” or “Is the probability of operational errors leading to serious consequences reduced to a minimum?” The test engineer was required to answer these questions. Clearly, no two engineers would provide the same answer to these questions. There is no objective standard. For this reason the results of the procedure precludes any possibility for comparing machines. Consequently this part of the test was useless and was rejected.

As new standards were issued, these had to be taken into account in the testing procedure. In Germany, this resulted in the KWF and the Agricultural Occupational Co-operative producing a continuously updated loose leaf collection. The last version was issued in 1998. This latest collection includes ergonomic and safety requirements. In addition to this, the KWF maintains specific test procedures for each machine type for assessing machine performance including several key ergonomic characteristics such as noise and vibration. There has been no attempt to create a new general procedure for testing forest machine ergonomics in Germany.

Since 1999 a visual sketch is no longer required in Germany. Up to then, this diagram was created for each machine tested. However, the persons responsible for the test declared that the time required for this procedure was in opposition to the actual benefits of the diagram.

At the same time, the regular presentation of an illumination diagram or lighting curve was also repealed. These measurements were only then carried out in cases of concrete complaints about the lighting or if weak illumination was suspected.

The heating performance was never tested at the KWF. In order to obtain a reliable assessment of this capacity, the test machine must be placed in a climatic chamber. The costs of such a procedure and the transport costs bear no relation to the actual benefits of the test. The same also applies to air conditioning tests. In this case, the presence of an air conditioning system is only noted.

The brakes of the machine are also a special case. These are not tested at the KWF. This is not required since the machines are generally licensed for road traffic. This licence is issued by a different test authority, where brakes are sufficiently tested. The opinion of the KWF is that any brakes that are good enough for the road will certainly be sufficient in the forest.

This KWF test is carried out in one and a half days in a testing area and one day in the forest, where noise and vibration tests are carried out. (to save time this test excludes lighting and visibility). The test results are black and white only: Either the ergonomics are acceptable or not.

Nordic Guidelines for forest machines

The most comprehensive guidelines for testing ergonomics to date was published in 1999 by Gellerstedt et al. (1999) in Sweden in a collaboration between the Swedish National Institute for Working Life, Skogforsk (the Forestry Research Institute of Sweden) and the Swedish University of Agricultural Sciences. Titled Ergonomic Guidelines for Forest Machines (EGFM), it begins with a general description of the importance of ergonomics.

The ergonomic characteristics of a machine are divided into 16 sections, which are also assessed separately. The machine is assigned to one of 5 classes, A to D or a class 0 for unacceptable ergonomics. Each section contains specific requirements, which are also assigned to classes. The final classification for a section is based on the worst evaluation for a requirement within that section. The end result of the test is an ergonomic profile of the machine, which can be compared to other machines.

The test does not introduce new areas to be assessed. The test methods have been extended, tuned, and adapted to the new standards. The tests include many questions that cannot be answered unambiguously. Two test engineers will probably obtain different answers.

This test requires three days of two persons; one dark night at a test site and one day in the forest.

Current SMP test

The Ergonomic Guidelines for Forest Machines were adapted by Löfroth et al. (2003) in 2003 for the Swedish Machinery Testing Institute (SMP). Many questions and methods were either left unchanged or only slightly modified. The resulting test procedures are currently in use at the SMP.

The test renounces the visibility diagram to save testing time. The section operating the machine is also not included in this test. This decision was taken because of the necessity for surveying several operators of the same machine in order to be sure of a reasonably objective answer. The same reasoning also applies to the excluded section on instructions and training. The section on climate control in the cab was also excluded for the same reasons as it was abandoned in the KWF test.

One large modification to the Ergonomic Guidelines for Forest Machines is the introduction of points for evaluating the requirements within each section. The final classification of the machine into one of five classes (A to E) is based on the total sum of these points. Class E indicates that the machine is ergonomically unacceptable. This usually results in a higher classification of the machine than in the Ergonomic Guidelines for Forest Machines. This is a direct result of the point system, which prevents that an unfavourable evaluation of single requirement, which is difficult to fulfil, can lead to a down classification of the whole section. The end result of this test is also an ergonomic profile, which can be compared to other machines.

The test requires two days and one night at a testing area and one day in the forest. The test is currently only accepted for harvesters and forwarders but not for skidders.

Comparison of the known tests

The following table (Table 3.1) summarises the tests required for the various guidelines. However, it must be noted that the quality of the required tests can be vary different.

Table 3.1. Comparison of known ergonomic tests.

	KWF 1977	ECS 1989	KWF 1998	EGFM 1999	SMP 2003
Machine data	X	X	X	X	X
Cab access	X	X	X	X	X
Working posture		X		X	X
Cab	X	X	X	X	X
Visibility	X	X	X	X	X

Table 3.1. (cont.)

	KWF 1977	ECS 1989	KWF 1998	EGFM 1999	SMP 2003
Visibility diagram	X		B	X	
Operators seat	X	X	X	X	X
Controls	X	X	X	X	X
Machine operations	X			X	
Instruments	X	X	X	X	X
Noise	X	X	F	X	X F
Vibrations	X	X	F	X	F
Climate control	X			X	
Gases and particulates	X	X		X	X
Lighting	X	X	X	X	X
Lighting diagram			B	X	X
Warnings	X	X	X	X	X
Manual	X	X	X	X	X
Instruction and training	X			X	
Maintenance	X	X	X	X	X
Brakes				X	X
Operator safety	X	X	X	X	X
Physic and psychic strain	X				
Electromagnetic compatibility				X	
Software					
Remote control					

X is required in the guideline
F special test in the forest
B only when necessary

Literature review

Methods

The initial method used to obtain an overview of the most recent publications on forest machine ergonomics was by means of a keyword search in the internet. Most information was found using a combination of words from this list:
Forest machine(s), ergonomic(s), research, harvester, forwarder, health, safety, operator(s), and any of the ergonomic items such as cab, access, brakes, lighting, maintenance etc.

In many cases this led to relevant websites, where literature was available for downloading (for example the Journal of Forest Engineering), or which provided links to other relevant sites. Keyword searches for particular ergonomic items such as the seat etc., often led to publications about agricultural or earth moving machinery. Much of the research on vibration, for example, does not specifically involve forest machines.

Another approach for obtaining an overview of all current research was by means of a full text search in the electronic periodicals library available at the Technical University of Darmstadt aus well as in the German periodicals subscribed by the library of the KWF.

General

Mobile machine ergonomics

Sachs et al. (1994) describes that the ergonomic design of the man-machine-environment is aimed at increasing the *reliability*, *flexibility* and *effectiveness* of this system. Thus, ergonomic design also aims to achieve the targeted performance of the machine by optimally utilising the available manpower. Failure to integrate ergonomic principles in the design of machines can result in subjecting the operator to an unacceptably high level of physical and psychological stress. This not only affects the performance of the man-machine system but can also have a detrimental health effect on the operator.

Surveys of accidents involving mobile construction vehicles indicate that 18.5% of the incidents can be directly attributed to ergonomic deficits. In most cases this involved *inadequate steps and ladders* and unfavourable *visibility*. The scenario is similar for agricultural machines and earth moving machines.

Mobile machine operators are exposed to *noise* and *whole-body vibrations* over long periods of time (their working life). This is known to have deleterious health effects on the auditory system, the spinal column and the digestive system.

Much research has been carried out to optimise the ergonomic design of mobile machines. These have resulted in a multitude of state directives and legislation. There are also a number of general manuals and textbooks available covering ergonomic machine design (e.g. Clark & Corlett, 1984; Sachs et al., 1994).

Forest machine ergonomics

A considerable part of the mobile equipment used in forestry is based on *modified agricultural tractors*. The manufacturers took these and adapted them to fulfil specialised tasks such as harvesting or forwarding in unfavourable terrain conditions, while still keeping within the legislation covering agricultural equipment. Hughes (1982) illustrates the basic modifications required for adapting agricultural machines to forest working conditions:

- *Complete underguarding*
- *Larger diameter wheels*
- *Protection of windscreen*
- *Retractable steps*
- *New control system based on 6 or 2 levers*

Ergonomic limitations of forest machines

In a new survey of 711 Swedish forest machine operators Synwoldt & Gellerstedt (2003) showed that the most prevalent shortcomings of harvesting machines were related to *cab access, noise* and the *comfort of the operator’s seat*.

Evaluating the ergonomic design of vehicles

The results of a field study by Vedder (1999) of an ergonomic design and evaluation system proved successful for the evaluation of vehicles under ergonomic criteria. The paper also contains a historical review of ergonomic design.

Occupational health of forest machine operators

The introduction of highly mechanised harvesting systems has brought about a shift in the type and degree of stress the workers are exposed to in comparison to conventional methods. Gröger & Lewark (2002) describe that machine operators are mainly exposed to *static rather than dynamic stress*. The seated work posture in the machine can lead to *increased strain on the neck, shoulder and back muscles*. Typical symptoms for machine operators are *shoulder-arm problems*, which are a consequence of the awkward work posture and the exertion required for accessing the cab. *Hand, arm, neck and shoulder strains* can also result from *Repetitive Strain Injury (RSI)***.** Studies have shown that 50% of forest machine operators suffer from this syndrome.

While forest machine operators are less exposed to noise and hand-arm vibrations when compared to chain saw operators, they are more exposed to *whole-body vibrations* which are a potential cause for degenerative changes in the vertebral column.

Psychological stress plays a more important role than physical stress in machine operators. The numerous complex movements required to operate a forest machine requires utmost concentration, a high degree of attention and an continuous readiness to adapt to the working speed of the machine. *Stress, hectic, monotony and isolation* are the common phrases associated with this type of work.

Gellerstedt (1997) reports on the limits posed on forest cleaning productivity by operator strain. This highly intensive task results in an *increase in stress, fatigue and exertion* during the shift. *Neck and shoulder problems* prevail among the operators. *Bad visibility, jarring motion, uncomfortable work posture and twisting and turning the head* all contribute to this situation. The author suggests various solutions for alleviating the observed problems including the use of autonomous robots.

Schmid-Vielgut (1986) were among the first to describe how forest machine operators were exposed to an *increased psychological stress* in combination with *fatigue* in comparison to chain saw operators. In the long term, these detrimental health effects result in a *weakening of the immune system* with concomitant increased *vulnerability to physical and psychological illness* leading to *depressions*.

In a sample of Norwegian forest workers Hagen et al. (1998) found that an increase *in low-back disorders* in machine operators was closely linked to an *increase in psychological demands. Neck and shoulder disorders* are more common among forest machine operators than forest administrative workers. The frequency of the musculoskeletal disorders increased with age.

In a study of forest tractor drivers in Finland, Perkiö-Mäkelä & Riihimäki (1997) found that 88% had suffered from *neck-shoulder* and 74% from *lower-back symptoms* within the 12 months preceding the study.

Rehn et al. (2002) assessed the risk of experiencing *neck-shoulder and upper and lower back symptoms* for professional drivers of various categories of all-terrain vehicles and the association between symptoms and duration of exposure to *whole-body vibration* (WBV) and shock from driving all-terrain vehicles. In agreement to the results cited in the present review, they found that the risk of neck and shoulder syndromes are significantly higher for forest machine operators when compared to a control group. The study also indicated that the risk of upper back symptoms is also higher than in the control group. In contrast to other findings, lower back symptoms were not significantly higher in all terrain vehicle drivers than in the control group.

Synwoldt &Gellerstedt (2003) found that *Neck and shoulder* symptoms and *chronic fatigue* prevail among forest machine operators even when working with machines of the highest ergonomic rating. Long-term exposure to vibration, the repetitive movements of the arm and head and the continuously high concentration levels required by the operator are the risk factors that contribute to these disorders. These can be minimised by *improving working conditions* of the operators. The introduction of job rotation schemes in Sweden has led to a reduction in the occupational health risk.

Harvesting safety research

Rummer (1995) reviews models for analysing how accidents are produced by the design of harvesting systems. He suggests a combination of the available models to improve the understanding of how accidents are caused by harvesting systems. An *integrated, multi-factor approach* is required, which includes management and personal decisions, the social interactions, task structure, equipment and human factors such as training and capabilities.

Axelsson (1998) describes how *improved ergonomics, safety organisation* and *worker training* produced a 73% reduction in accident frequencies in Swedish harvesting machine operators between 1970 and 1990.

Operator opinions about forest machine ergonomics

To date there has been no published survey of forest machine operators concerning their views on forest machine ergonomics and safety.

Cab access

Mounting and descending; potential hazards

In a study of cab *descending techniques* and *landing impact forces*, Patenaude et al. (2001) indicated that descending with the *back to the truck* produced the highest ground impact forces, with an *increased compressive force* exerted on the back. The importance of *handrails* as well as the *visibility* of the steps from the cab during the descent is stressed in the report. The design of the cab and handrails should prevent the use of the steering wheel as an aid for mounting the cab.

Beutnagel (1990) carried out a statistical analysis of a survey conducted among agricultural vehicle operators and revealed the following potential dangers involved in mounting and descending from the cab:

- 60% of the drivers *descend the steps facing forward*, the most hazardous method
- *Unfavourable positioning of platforms, handrails* and *steps*
- *Dirty platforms, handrails and steps* leads to a high risk of slipping, especially when descending forward

Human behaviour is an important cause of accidents. *Fatigue, stress* and *sudden changes in the work process* increase the risk of accidents.

In view of the high risk to injury when descending from tractors, Fathallah & Cotnam (2000) stress the benefits of using *steps* and *handrails* and the need for designers to take into account *anthropometric data*. The inability to reach exit aids increases the risk of operators *jumping* from the cab (producing a force up to *12 times body weight*). *Training* must also emphasise the potential hazards of improper descent.

Ergonomic design of cab entrance

From the ergonomic point of view *cab access remains unsatisfactory* for many vehicles. To date there has been no useful ergonomic method for assessing the design of cab entrances. Using up to date methods for analyzing movements while entering and exiting cabs, Paul (2002) was able to prove that there is a close correlation between *entry parameters, biomechanical and subjective strain*. The results indicate that the *width* of the entrance has the greatest effect on the biomechanical and subjective strain. The author also recommends a step height of *310 mm + foothold* thickness which is much lower than the height recommended for tractors in DIN ISO 3411 and 2867 (400-550 mm).

Working posture

Working posture and stress

Berger (2001) indicates that *stress* in harvester operators is linked to both *psychosocial factors* such as work hours, shift work and social isolation as well as to the *physical work conditions*. Stress can result in a *sloppy or strained seating posture* both of which are widespread among harvester drivers. Both seating postures have a detrimental effect on the *inter-vertebral discs* resulting in a massive health problem.

Awkward working postures

Operators of *heavy construction vehicles* were required to assume *awkward postures* in the course of performing their jobs. In general, these postures were notable for the *neck*, *shoulder*, and *back* (descending order). Kittusamy (2002) describes that deviation of the back can be explained by the inherent nature of the job. Workers must bend over to see the ground that they are digging or moving. Deviation of the shoulder can be explained by the requirements of operating various controls (i.e. levers and gears) located inside the cab. Deviation of the neck was mainly due to the operator maintaining eye contact with the work, which was located at or below ground level.

The results of a study by Torén (2001) showed that *twisted trunk postures* might be a risk factor for low-back pain.

A study performed by Torén et al. (2002) links *twisted working postures* to an increased risk of *hip symptoms* in tractor drivers. When exposure to extreme twisted postures is low, this risk is reduced despite the prolonged exposure to sitting and whole-body vibration.

Hamberger (2000) describes how creating access corridors by using mulchers by the stake method requires the driver to continuously turn his head for orientation purposes. A *twisted working posture* in conjunction with considerable *vibration* poses a particular strain on the vertebral column.

The number of turns of the head can be reduced by 90% using a specially created GPS navigation system. The driver orientates himself using a computer screen which shows the current position of the mulcher and the direction of the proposed corridor.

Donati (2002) describes the correlation between the positional stress and vibration stress in producing back pain. The optimisation of the operators working posture falls into two categories:

- Reduce the need for awkward postures (improve visibility and control position)
- Provision of a seat with the correct profile, taking into account driver anthropometrical dimensions, cab dimensions and driver tasks.

Fitting cab design to operator size

Thomas et al. (1994) describe *difficulties encountered* in the USA when basing cab design on *anthropometric SAE* or *ILO data standards*. Workers in the USA tend to be taller and heavier than the SAE reference. The ILO was deemed unsuitable because of the limited dimensions considered. The observed differences would lead to *poor visibility, increased seat damage* and *awkward work postures*. The authors suggest that critical design values should reflect the 99^{th} percentile global operator.

Farm tractors equipped for forestry work

Castren (1992) carried out a comparative study of the load experienced by farm tractor operators during forestry work. The results indicate that *heart rates* were related to make of tractor and that the left *trapezius* was consistently more active during felling and preparation operations than the right.

Cab

Comfort

Since machine operators spend long hours in the cab, comfort is an important design aspect. The results of a survey of earth moving vehicle operators by Kujit-Evers et al. (2003) showed that nearly 80% of the operators of machines less than 4 years old rated cab comfort as good and very good. This dropped to 40% for older machines. Very few aspects were rated poor by more than 20% of the participants. These included: *seat comfort*, *vibration* and *damping* and *dashboard* and *displays*. However, among the participants cab comfort is not rated as one of the most important aspects for working well with the machine.

Seat belts

Sullman (1998) shows in a study that improving seat belt design and adding a *reminder light* can improve seat belt usage in forest machines by 58%. Seat belts are a useful method for reducing the number of injuries from machine *rollovers*.

Visibility

General aspects

Donati (2002) describes how visibility is linked to operator work posture and therefore to the ill-effects of vibration exposure. Lack of visibility will always be compensated by changing the *posture*. Machines should be designed to prevent operators adopting an unusual or awkward posture. External visual information should be available by *direct vision*. This can be ensured by the provision of *moveable seats* and *cabs*.

Since most information required for operating a forest machine is obtained via the eyes, Schulz (1997) describes how good visibility has a positive effect on:

- *work efficiency*
- *work quality*
- *operator comfort*
- *safety*

Basic equipment for ensuring good visibility are windscreen wipers, defrosting systems and vibration free mounting of mirrors.

Visibility is often limited by obstructions such as the hood, posts, exhaust pipe, screen curvature, wiped field of view and control visibility.
Visibility of forest vehicles must comply with SAE 941 or EC directive 77/649.

Self-levelling and swivelling cab

Self-levelling and swivelling cabs provide good general visibility. However, Gellerstedt (1998) describes that some difficulties occur in different forest types as well as in adverse climatic conditions

Visibility and automation in single-grip harvester

Current log feeding speed (4m/s) limits operator ability to see defects. Operators have difficulty in perceiving trees in the outer operational zone when positioning the machine and when selecting and felling trees. Gellerstedt (2002) suggests that *automatic scanning functions* (laser) may overcome some of the problems associated with restricted view. A qualitative study shows that operators require better visibility as well as visual and orientation aids.

Rear view video camera

Collisions between people and machines are a perennial problem in forestry. Rear view mirrors are often damaged or covered in dirt. Backing up machinery often requires the operator to twist in his seat to obtain a rear view. The experimental installation of a rear view video camera to a logger (Cloutier, 2002) shows that operators *reduced their number of glances* to the left and right, thus avoiding twisting movements.

Operator seat

Evaluation of seat comfort

In view of the lack of a widely accepted definition of sitting comfort de Looze et al. (2003) describe the various factors that underlie sitting discomfort and comfort at the human, seat, and context level:

- Human level: Exposure, physical capacity of the human, emotions
- Seat level: Physical features, design
- Context level: Physical environment, task, psycho-social factors

In a comparison of subjective ratings and objective measurements, the authors present evidence that *pressure distribution* is statistically correlated to local discomfort. However the general conclusion is that there is not enough evidence to link other variables such as spinal profile or muscle activity to subjective ratings.

In a review of the research information regarding the biomechanical criteria for understanding seat dynamics and seating discomfort, Mehta & Tewari (2000) discuss the most appropriate procedures for assessing seating comfort during tractor driving. Seat discomfort assessments should include both *objective* and *subjective assessments*. The suggested objective assessments include *seat pressure distribution, body support, ride vibration, body posture*, and *cushion materials* used. They also suggest a subjective assessment based on rating the various seat features, a body area chart discomfort checklist, and a rating of the frequency and duration of each work posture.

Seat adjustment and comfort

In a study of the effect of adjusting tractor seats on comfort and health of forest tractor drivers, Perkiö-Mäkelä & Riihimäki (1997) noted that most operators (67%) felt that seating comfort was good. Minor shifts of the back rest inclination had little effect on healthy operators but had a positive effect on those suffering from *neck-shoulder syndromes*. Better effects were seen when these adjustments were combined with an *additional lumbar support*. Low back symptoms seemed to be relieved by the additional lumbar support only.

Grapple skidders

Wegscheid (1994) indicates that skidder seat suspensions must be capable of reducing *vertical vibrations* that peak at about 2.2 Hz. The study indicates that the suspensions of the test vehicles are too stiff to achieve the necessary attenuation. Skidder rides can be improved if the seats are required to pass tests similar to those developed for seats in earthmoving equipment and agricultural tractors (ISO 7096 and ISO 5007).

Controls

Joint and co-ordinated control systems

Wallersteiner et al. (1993) evaluated the human factors of joint and co-ordinated control systems for log loaders. Joint controls, where implements are controlled by two and three-axis hand levers, are widely in use in forest, agricultural and earth-moving machines. In log loaders the two joint controls move the grapple, stick, boom and cab. Since there is no correspondence between the movement of the hand controls and the actual movement of the implement, these controls place a *high perceptual* and *psychomotor demand* on the operator.

Some reduction of operational complexity can be achieved by *computer assisted controls*. There are two controls, one for fine grapple movements and one for gross machine functions. A program interprets the controller movements by the operator.

The results show that novices performed better with the co-ordinated controls, indicating that these controls simplify the task of operating such a complex machine. Experienced operators were able to equal their performance on joint controllers after 5 days of training on the co-ordinated system.

Small control levers

Using mini-levers in a simulation reduces *trapezius* muscle constriction. Asikainen & Harstela (1993) report how forest machine operators have indicated that pains in the *neck, shoulders* and *arms* have *decreased* since using mini-levers. Precision is increased by the use of mini-levers, as indicated by the decrease in tree damage in comparison to conventional levers.

Controls and operator fatigue

Gellerstedt (2002) found that operators manipulate the controls of one-grip harvesters 4 000 times per hour, 88% of the time, mainly for moving the boom. Intense work with harvesters causes few pauses in the trapeze muscle. Boom work involves many small tip corrections, which could be reduced by an automatic boom tip control.

Machine operation

Control locations in the cab

General guidelines for the position of the controls can be found in various publications (Clarke & Corlett, 1984; Sachs et al., 1994; Gellerstedt et al., 1999).

Sachs et al. (1994) also provide details on the ergonomic principles behind various control types, their form, and the forces required for activation.

Casey & Kiso (1990) studied the operator acceptability of control locations in 69 different tractors. They noted a high variability of the control locations. When compared to the acceptability ratings the authors found that operators have a unique most preferred location for each of the controls.

Visualisation of machine working process

Ergonomic guidelines about the arrangement and design of indicators, dials and acoustic signals can be found in Sachs et al. (1994) and in Clark & Corlett (1984).

Noise in the machine

Self-levelling and swivelling cab

Gellerstedt (1998) reports that the construction of the self-levelling and swivelling cab is such that motor noise is not transmitted to the cab, thus *reducing* the *noise levels* inside the cab. The highest measured noise level was 70 dB(A).

Noise levels of forest machines

Above *60 dB(A)* noise has a *negative effect on operator concentration, mood, blood pressure* and *heart rate*. *Damage to the ears sets in above 90 dB(A).* The levels measured at the ear of working machines currently ranges between 70 and 80 dB(A). The motor is the main source for noise, where the exhaust and the motor block make the greatest contribution to the total noise levels.

Primary protective measures are (Sachs et al., 1994):

- Suction noise reduction, soft combustion, double walled exhaust pipes
- High quality bearings and gearing in the transmission
- Low noise hydraulic pumps and valves
- Curved windscreens (lower vibration)

Secondary measures include:

- Noise insulation of motor
- Noise insulation cab
- Elastic mounting of cab and motor
- Insulated control openings

Tests of new machines by Seixas et al. (1999) indicate that maximum tolerable noise levels (for Brasil, 85dB) are not attained. Further studies after a period of wear are announced.

Vibration

Standard vibration measurements

Seat Effective Amplitude Transmissibility (SEAT) values obtained by Gunston & Griffin (1999) using a *dummy* were found to be highly repeatable. There was no significant difference between the seat performance with the dummy and with human subjects at vibration magnitudes up to the occurrence of severe seat suspension top stop impacts. However, SEAT values for human subjects were higher than those measured for dummies during severe seat suspension top stop impacts.

Vibration levels

For heavy construction vehicle operators the study by Kittusamy (2002) evaluated the:

- *Vibration at the seat/operator interface* in three directions (x-, y- and z-axis)
- *Transmissibility of vibration in the Z-axis* (vertical vibration)
- *Psychophysical ratings of vibration level and vibration discomfort* (operator rating of perceived discomfort)
- *Postural requirements of the job*

Transmissibility data showed that the *seat amplified vibration*, particularly in the lower frequencies. The seats appeared to be *insufficient* in protecting operators from long-term effects of vibration exposure. High positive correlation was found among subjective ratings (vibration discomfort and vibration level), but moderate positive correlation was found between subjective ratings and quantitative vibration levels. Postural evaluations revealed that the operators were required to assume awkward postures of the neck, shoulder and trunk while performing their jobs.

Results reveal that operators performing dynamic tasks are exposed to whole-body vibration higher than the allowable limit established by the European Commission. Seats can be improved to attenuate the levels of vibration at the lower frequencies (1-8 Hz). Other measures suggested to minimise the effect of whole-body vibrations include ensuring proper maintenance of the seat and avoiding jumping from the vehicle after prolonged exposure to vibration.

Vibration levels and driver fatigue

A report by the a Australian Transport Safety Bureau (2001) summarises the scientific evidence available linking *vibration levels* and heavy vehicle driver *fatigue*. The following items outline the results of literature review:

There is some evidence supporting a relationship between *low frequency vibration* (3 Hz) and *increased fatigue* or *drowsiness*. Heavy vehicle truck drivers usually experience vibration levels around this frequency while driving.

Intermittent and *random vibration* can have a *stimulating* or wakening effect.

Vibration exposure has been found to cause *changes to body metabolism* and chemistry that could lead to fatigue effects.

Truck drivers have shown many of the symptoms of *adverse health effects* associated with *whole-body vibration* exposure.

Typical whole-body vibration exposure levels of heavy vehicle drivers are in the range 0.4 – 2.0 m/s^2 with a mean value of 0.7 m/s^2 in the vertical (z-axis). Vertical vibration is highest in the frequency range 2-4 Hz.

The average whole-body vibration level experienced by drivers of heavy transport vehicles exceed health, fatigue, and comfort limits of the Australian standard and most exposures are within the Caution zone (for health) according to the current international standard. Many typical exposures will reach the likely health risk zone of the international standard. According to these standards, many truck drivers are at risk of incurring adverse health effects from prolonged exposure to vibration.

There is evidence that truck drivers have back complaints that could be partly attributable to whole-body vibration exposure.

There are at present *no vibration exposure limits* in relation to *fatigue inducing effects* that are accepted by experts in the field. However, specific research on vibration and fatigue is limited and many authors have assumed a relationship without reference to supporting research. Some research shows a *possible link between constant low frequency vibration and fatigue* but more extensive research is required to establish meaningful exposure limits.

There is sufficient evidence to associate *vibration exposure* to *back problems*. The relatively high vibration exposure levels combined with long-term exposure and prolonged sitting are likely to contribute to back pain and other health effects.

The current International Standard ISO 2631:1997 on whole-body vibration provides useable guidelines for *vibration exposures* and *predicted health effects*.

Epidemiological studies (Kittusamy, 2002) show that drivers and operators seated in or on mobile machinery (construction vehicles and machinery, farm and forestry tractors) have increased probability of suffering *lower back pain* and *sciatica* when compared with other employees. Frequent exposure to *vibration* and *repeated shocks* at sufficient levels over several months or years can cause injuries to the spinal vertebrae or disks.

Vibration control

According to Donati (2002) the engineering solutions for minimising the exposure of machine operators to vibrations can be grouped into three categories:

- *Vibration reduction at the source* (improvements to the terrain, proper maintenance of the machine, careful selection of the vehicle)
- *Incorporation of suspension systems* (tyres, vehicle suspensions, suspension cab and seat)
- *Improvement of cab ergonomics* to optimise the work posture

In a detailed review of these techniques Donati also describes how only the consideration of *all factors* can lead to a useful solution for reducing the risks of lower back injury. The author explains that while the Machinery Directive 89/392/EEC requires manufacturers to integrate newest technical developments for reducing the exposure to physical agents (noise and vibration), there is no standard in effect for taking into account the *ergonomic aspects* for improving the operator posture. This factor may be the *prime contributor* to *spinal disorders*.

Altunel & de Hoop (1998) showed that *lower tire pressure* reduces the vibration recorded at the driver seat of forest transporters. However, the differences in vibration attenuation with high and low pressure inflation were less than expected.

Similarly, Rummer et al. (1990) found that *increasing tire deflation* may not significantly reduce the vibration exposure of the driver. However, it clearly reduces the vibration levels to which the truck is subjected.

Wegscheid (1994) noted that the *aggressiveness of the operator* can have a pronounced effect on the whole-body vibration level he experiences.

The vibration isolation efficiency of seats can be determined by the SEAT value (seat effective amplitude transmissibility). Values less than 100% indicate an overall improvement of the ride. In a study of SEAT values of seats mounted in a wide range of work vehicle types, including tractors and excavators, Paddan & Griffin (2002) showed that most (75%) values were below 100%. However, there was a wide variation of transmissibility between seats and the study also showed that the selection of seats may be a prime factor in controlling occupational whole-body vibration exposure. The results indicate that 94 of the 100 vehicles tested could benefit from changing the seat.

In a study of the effect of tractor *seat cushion materials* in attenuating vibration Mehta & Tewari (2002) found that the thickness of cushion is correlated with degree of vibration transmission at low frequencies (1-4 Hz). Thinner cushions transmit higher frequencies more readily. The paper includes recommendations for suitable seat pan and backrest cushioning materials.

The *vibration exposure time* for the operator of an agricultural tractor can be increased substantially by activating an electronically controlled *front axle suspension system*. Marsili et al. (2002) also noted a significant vibration attenuation for most of the track conditions tested.

The INRS (2000) suggests that the best anti-vibration strategy is often a *low-frequency suspension* for the cab or chassis fitted, if possible, with *suspension seats*.

The cab floor of *mobile agricultural and work machines* is subject to pronounced vibration despite the widespread implementation of suspended front axles and cabs (Hauck & Tattermusch, 1999). Further isolation of the operator from these vibrations is achieved by using *passive suspension seats*. However, the isolation effect of the passive spring and dampening elements has natural limits. The main excitation frequencies of the vehicle, which lie between 2 and 4 Hz, are equivalent to the natural frequency of the dampening elements. This has led to the development and introduction of *adaptive dampening systems***,** which can be adjusted by the operator to suit his needs. On the downside, these seats present the operator with yet another adjustment in the cab.

In a study of suspension seats with *automatically controlled dampening* Hauck & Tattermusch (1999) showed that these seats provided better isolation between 1.3 and 3 Hz than passive seats. Negative acceleration values were reduced by 38% in comparison to passive seats. The authors describe best *control algorithm* for the suspension and conclude that certain modifications of the dampening system could improve the isolation effect of controlled dampening seats even more.

Whole-body vibration exposure

The highest *WBV exposure levels* of all forest work was found by Neitzel & Yost (2002) in *mechanized log processor* and *front end loader operators*. The summary weighted WBV AEQs exceeded the Commission of the European Communities' 8 hour action limit (0.5 m/s^2) by about 80% for these workers.

Wegscheid (1994) found that the vibration levels in grapple skidders are lowest in fore-aft direction and *highest in the vertical direction*. Fore-aft vibrations are higher on the cushion than at seat base because of roll and pitch of the vehicle. Since this is a multi-input system, lateral and fore-aft vibrations *cross-couple* to contribute to the high level of vertical vibrations.

Rehn et al. (2002) indicate that WBV is not the only factor determining the risk of neck-shoulder and thoracic symptoms in forest machine operators. Other factors include *prolonged static seating* and *repetitious arm work*.

Climate control in the cab

Heat stress

A comparison of three metabolic rate assessment methods of ISO 8996 by Wästerlund (2001) indicated large variations between the assessments depending on the method chosen. *Full hydration* resulted in a significant *lower percentage of heart rate reserve* used, as well as a *reduction of time consumption* when compared to mild dehydration. During harvesting, the physical condition and work manner of the forest workers was correlated to the fluid consumption levels.

Microclimatic requirements

Sachs et al. (1994) describes the microclimatic requirements for tractor and agricultural machine cabs. Basic reference values are that the cab should have an internal temperature of at least 14°C when outside temperature is -10°C. Furthermore, the inside temperature of the cab should not exceed values over 5°C above the outside temperature in summer.

The optimum workspace requirements are more stringent and should be aimed for when designing machine cabs. All climatic parameters should be achieved in a closed cab. Some individual regulation, especially of temperature, should be possible. The authors continues with details about heating systems and air conditioners available for machine cabs.

Cab climate

According to Schulz (1998) the regulation of the cab climate in winter conditions is usually good. However, difficulties arise in summer conditions since the large glass area as well as the good insulation of the cab create a, where working conditions can quickly attain the discomfort levels:

- Temperature at head level >37°C
- Relative humidity >85%

Efficient shading and air conditioning are necessary to prevent excessive climatic stress under these circumstances.

Exposure to gases and particles

Sachs et al. (1994) and Gellerstedt et al. (1999) both describe the importance of protecting the operator from exhaust fumes and dusts in the cab. Modern machines are equipped with air filters. Gellerstedt provides guidelines for improving the cab air whereas Sachs et al. provides details on the available measures for cleaning the cab air.

Lung capacity of machine operators

Jansson (2002) reports on findings from Sweden that indicate that 70% of a group of forest machine operators showed a *decrease in lung volume* by at least 0.5 litres within a 2 year period. While there may be several factors that contribute to these findings, the author concludes that an increased exposure to particles and exhaust in the work area is the most likely cause.

Lighting

General guidelines

Gellerstedt et al. (1999) provide guidelines for the optimal lighting of the boom operation envelope and the periphery. Sachs et al. (1994) provide the scientific background to lighting and workplace visibility around mobile machines. Little in the way of original scientific research could be found on this topic.

Comparison of xenon and halogen lights

Following a comparison of xenon and halogen light performance, Cloutier (2002) states that xenon lights provide a more intense and uniform lighting which promotes better visibility during forest operations at night.

Instruction and training

Education, training, and safety

Gellerstedt & Dahlin (1999) compared *three forest worker education systems* with respect to the effects these have on worker motivation and work efficiency. The evidence suggests that short courses or on-the-job training for a task such as mechanised cut-to-length does not contribute to improving motivation and efficiency.

Gellerstedt (2002) found that operating a single-grip harvester efficiently requires approximately *5 years of experience*.

Greene et al. (1996) reported that the introduction of educational efforts in Georgia, USA produced a *reduction of accidents* involving harvesting-tractor trailers.

Simulators

Forest machine simulators are available from all leading manufacturers. They have proven extremely useful for *training purposes* enabling students to learn to safely deal with dangerous situations. The European collaboration between forest worker schools and The Institute for Robotics in Dortmund resulted in the production of a simulator program which runs on cost-effective PCs. Using head mounted displays as well as passive stereo projection, students obtain an optimal 3-D impression of the working environment.

Using these methods, students were able to *increase their work efficiency* (no. of felled trees) by 30% while *reducing the number of collisions* by 40%. Positioning of the harvester boom and head was quicker and more precise.

Simulators are described as ideal for efficient and market orientated training of forest machine operators (Rossmann & Wagner, 1999).

The results of the *EU Project Forest worker training organisation* indicate that there is no statistical difference between 2-D simulator trained students and those trained on real machines in the early training stages. According to Jacke et al. (2000) forest machine simulators are an efficient, less hazardous, and environmentally friendly method for training machine operators. The introduction of 3-D simulators is expected to bring more advantages both for training purposes as well as in refresher courses.

Maintenance and machine design

Requirements

Gellerstedt et al. (1999) provides the basic requirements for operator manuals. Appendix 3.1 of this review also contains the various standards governing the contents of the operator manual.

Gellerstedt et al. (1999) also covers the ergonomic assessment of maintenance work on the machine.

This topic has produced little research interest.

Brakes and operator safety

ROPS, FOPS, and OPS

ROPS, FOPS and OPS are some of the most basic safety structures that are integrated, by law, in the design of the forest machine. International standards are listed in Appendix 3.1 of this review.

A general review of safety measures are available from nearly all governmental bodies and associations involved in harvesting. A comprehensive guide is published for example by the NZ Department of Labour (1999).

Gellerstedt et al. (1999) provides guidelines for assessing operator safety features.

In a detailed survey of the development of ROPS standards Stockton et al. (2002) identified 40 vehicles not covered by ROPS standards including excavator harvesters, feller-bunchers, all-terrain vehicles and tractor harvesters. At present, each sector such as forestry, agriculture, mining or construction has its own set of ROPS standards. In total, the authors identified 51 valid ROPS standards. The authors suggest a potential opportunity for combining ROPS standards across the market, especially in the case of tractors, since these form the base machine for a number of sector specific tasks.

They also suggest that the use of safe cell technology can be an alternative to the more traditional structures.

Electromagnetic compatibility and radiation

EMF fields and health effects

The International EMF Project (co-ordinated by the WHO) has issued a number of reports about possible adverse health effects of exposure to EMF fields. A report about extremely low frequency fields (WHO, 1998) indicates that there is little evidence suggesting a risk to the public health. A more recent report (WHO, 2001) classifies ELF fields as *possibly carcinogenic to humans* based on epidemiological studies of *childhood leukemia*. There is no concrete evidence suggesting that other forms of cancer can be caused by exposure to ELF fields.

Gellerstedt et al. (1999) states that there is little evidence to suggest that the levels of extremely low frequency electric and magnetic fields found in the cab may have a detrimental effect on the health of the operator.

High frequency electromagnetic fields are associated with mobile phones. There have been some reports linking health problems to overuse of mobile phones. This does not seem to be a major threat in the everyday working life of a forest machine operator.

Legal standards covering this topic can be found at the end of this review.

Summary

This literature review shows a clear trend in forest machine ergonomic research. This is a direct result of the documented health problems of forest machine operators. Various surveys show that forest machine operators risk suffering from neck-shoulder and upper and lower back syndromes (Gellerstedt, 1997; Gröger & Lewark, 2002; Rehn et al., 2002; Synwoldt & Gellerstedt, 2003). There is widespread agreement that this is caused by a combination of long-term whole-body vibration exposure and a seated (static) work posture (Gröger & Lewark, 2002; Kittusamy, 2002; Rehn et al., 2002). A number of reports also point out that operators are exposed to a high level of psychological stress leading to chronic fatigue, neck and shoulder disorders, and even to depressions (Schmid-Vielgut, 1986; Hagen et al., 1998). There is also some evidence that there is a link between low frequency vibration and driver fatigue (Australian Transport Safety Bureau, 2001).

As a consequence of these findings, much recent research has focused on vibration and vibration control as the key to alleviating symptoms shown by forest machine operators. The seat is the main contact point between the operator and the machine and plays a prominent role as a means of controlling the vibration exposure levels. Some reports suggest that the isolation efficiency of the seats may need some improvement (Kittusamy, 2002; Paddan & Griffin, 2002). This can be achieved either by improving the cushioning materials (Mehta & Tewari, 2002) or by introducing an adaptive dampening system (Hauck & Tattermusch, 1999). The vibration attenuating effect of reducing tire pressure is not yet fully confirmed (Rummer et al., 1990; Altunel & de Hoop, 1998). On a completely different level, the personality of the operator can have a distinct effect on his vibration level exposure (Wegscheid, 1994).

However, vibration exposure is not the only factor that can lead to the observed symptoms. The mode of descending from the machine (Beutnagel, 1990; Fathallah & Cotnam, 2000; Patenaude et al., 2001) can lead to back problems. The use of mini-levers has apparently reduced pain in the neck shoulder and arms (Asikainen & Harstela, 1993). However this may still play a role where old machines are still in use.

The awkward work posture associated with operating forest machines is also closely linked to the typical syndromes (Hamberger, 2000; Berger, 2001; Kittusamy, 2001; Torén, 2001; Donati, 2002; Torén et al., 2002), particularly in combination with vibration. Research results show that working posture can be improved by various means. Improving the visibility reduces the number of twisted seating positions (Donati, 2002). Rear view cameras (Cloutier, 2002) and the introduction of a GPS navigation system can have the same effect (Hamberger, 2000). The working posture may also be improved simply by making appropriate adjustments to the seat and using an additional lumbar support (Perkiö-Mäkelä & Riihimäki, 1997). Psycho-social factors also have an effect on the seating posture (Berger, 2001; de Looze et al., 2003).

Machine operators suffer more from psychological stress than physical stress. Bad visibility and the complexity of the task, not to mention hectic, monotony, and isolation, are important stress factors (Schmid-Vielgut, 1986; Gellerstedt, 1997; Berger, 2001; Gröger & Lewark, 2002). The ergonomic design of the machine can help to alleviate some of these problems. For example, the complexity of the job can be reduced by introducing computer assisted controls (Torén et al., 2002), increasing the level of automation (Gellerstedt & Dahlin, 1999; Gellerstedt, 2002) and generally improving visibility.

While this review was limited to the technical solutions to some of the syndromes observed in forest machine operators, it should be noted that there is sound evidence suggesting that changing the work conditions can have a positive effect on operator health (Axelsson, 1998; Berger, 2001; Synwoldt & Gellerstedt, 2003).

Since so many technological aspects of forest machines are covered by directives and standards, the prevalence of psychological and physical syndromes among forest machine operators suggests that there is still some need for ergonomic improvement of this workplace. Harvesting safety research has highlighted the requirement for an integrated, multi-factor approach (Rummer, 1995; Axelsson, 1998). This review shows that this should also form the basis for ergonomic research. Psychological stress is not caused by any one factor but can be linked to vibration, visibility, job complexity and isolation among others. On the technological side, more research is required on effective methods for attenuating vibration at the seat and of the cab, since vibration seems to amplify the effect of the awkward work position. More research is also required to substantiate the link between vibration and fatigue. In the evidence of shrinking lung capacities among Swedish machine operators, there is also some need to establish the causes behind these observations.

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Appendix 3.1

International standards

This is a review of the international standards covering the ergonomic aspects of moving machinery. For easy reference, the standards are ordered according to the general headings found in the literature review.

The title of each directive and standard can be located in the section on list of standards in numerical order, where these are ordered in ascending sequence.

The more recent standards are divided into three groups:

- Type A standards (fundamental safety standards). Standards giving basic concepts, principles for design, and general aspects that can be applied to all machinery.
- Type B standards (group safety standards). Standards dealing with one safety aspect or one type of safety related device that can be used across a wide range of machinery:
  - Type B1 standards on particular safety aspects (e. g. safety distances, surface temperature, noise),
  - Type B2 standards on safety-related devices (e. g. two hand controls, interlocking devices, pressure sensitive devices, guards).
- Type C standards (machine safety standards). Standards giving detailed safety requirements for a particular machine or group of machines.

General standards

This section includes those standards covering basic ergonomic aspects.

<u>EN 414</u>

Safety of machinery – Rules for the drafting and presentation of safety standards.

EN 1070

Safety of machinery – Terminology; Trilingual version.

This European Standard collects together concepts (terms and their definitions) relating to machinery safety, expressed in the three official languages English, French and German.

prEN 292-1 = ISO/DIS 12100-1

Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology.

This standard defines basic terminology and methodology used in achieving safety of machinery. It may also be used for other technical products having similar hazards. This standard does not deal with damage to domestic animals, property or the environment.

prEN 292-2

Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles.

This standard defines technical principles to help designers in achieving safety in the design of machinery. It may also be used for other technical products having similar hazards. This standard does not deal with damage to domestic animals, property or the environment.

EN 614-1

Safety of machinery – Ergonomic design principles – Part 1: Terminology and general principles.

Establishes the ergonomics principles to be followed during the process of design of work equipment, especially machinery. Although the principles in this standard are orientated towards equipment for occupational use, they are applicable also to equipment for private use. This standard applies to the interactions between the operator and the work equipment when installing, operating, adjusting, maintaining, cleaning, repairing or transporting equipment and outlines the principles to be followed in taking the health and safety of the operator fully into account. The ergonomics given in this standard fully apply to all ranges of individual ability. Information on dimensions will need to be interpreted to suit the intended population.

EN 614-2

Safety of machinery – Ergonomic design principles – Part 2: Interaction between the design of machinery and work tasks.

Establishes the ergonomics principles and procedures to be followed during the design process of machinery and operator work tasks. Deals specifically with task design in the context of machinery design, but the principles and methods may also be applied to job design. It is directed to designers and manufacturers of machinery and other work equipment. It will also be helpful to those who are concerned with the use of machinery and work equipment, e.g. to managers, organisers, operators and supervisors. The designer refers to the person or group of persons responsible for the design.

EN 1050

Safety of machinery – Principles for risk assessment.

This is a Type A standard and describes a systematic procedure for assessing the risk potential of machines according to section 6 of EN 292-1.

EN 1005-1

Safety of machinery – Human physical performance – Part 1: Terms and definitions.

Provides terms and definitions on concepts and parameters used for EN 1005, parts 2 to 4. Basic concepts and general ergonomic principles for the design of machinery are dealt with in EN 292-1, EN 292-2 and EN 614-1.

prEN 1005-2

Safety of machinery – Human physical performance – Part 2: Manual handling of machinery and component parts of machinery.

Specifies ergonomic requirements for the design of machinery concerned with manual handling in industrial and professional applications. This standard applies to the manual handling of objects of 3 kg or more. The standard provides data for ergonomic design and risk assessment concerning lifting, lowering and carrying in relation to the construction, transport and commissioning (assembly, installation, adjustment), use (operation, cleaning, fault finding, maintenance, setting, teaching or process changeover) and decommissioning, disposal and dismantling of machinery.

EN 1005-3

Safety of machinery – Human physical performance – Part 3: Recommended force limits for machinery operation.

Presents guidance to the designer of machinery or its component parts and the writer of C-standards in controlling health risks due to machine-related muscular force exertion. Specifies recommended force limits for actions during machinery operation including construction, transport and commissioning (assembly, installation, adjustment), use (operation, cleaning, fault finding, maintenance, setting, teaching or process changeover), decommissioning, disposal and dismantling. Applies primarily to machines which are manufactured after the date of issue of the standard. Applies on one hand to machinery for professional use operated by the adult working population, who are healthy workers with ordinary physical capacity, and on the other hand to machinery for domestic use operated by the whole population including youth and old people. The recommendations are derived from research on European population.

prEN 1005-4

Safety of machinery – Human physical performance – Part 4: Evaluation of working postures and movements in relation to machinery.

Presents guidance to the designer of machinery or its components parts in assessing and controlling health risks due to machine-related postures and movements, i.e. during assembly, installation, operation, adjustment, maintenance, cleaning, repair, transport and dismantling. The standard specifies recommendations for postures and movements with minimal external force exertion. The recommendations are intended to reduce the risks for nearly all healthy adults.

EN ISO 10075-1

Ergonomic principles related to mental workload – Part 1: General terms and definitions.

Represents an extension of ISO 6385, subclasses 3.7-3.9, describing terms and definitions in more detail.

Annex A forms an integral part of this standard.

EN ISO 10075-2

Ergonomic principles related to mental workload – Part 2: Design principles.

Gives guidance on the design of work systems, including task and equipment design, design of work places as well as working conditions. Relates to the adequate design of work and use of human capacities.

prEN 14386

Safety of machinery – Ergonomic design principles for the operability of mobile machinery.

Establishes the ergonomic principles to be followed during the process of design of mobile machinery with special emphasis on the points where mobile machinery differs from other machinery. The ergonomic principles given in this standard apply to either or both working seated and standing up positions. It applies for the operator's workplace.

EN 13861

Safety of machinery – Guidance for the application of ergonomics standards in the design of machinery.

This European standard provides a methodology to achieve a coherent application of various ergonomics standards for the design of machinery. This standard presents a step model calling upon specific standards. This standard can only be used in combination with other relevant ergonomics standards.

This European standard elaborates EN 1050:1996, Annex A, especially Clause 8 Neglecting ergonomic principles. This standard refers to European and international ergonomics standards in the various relevant fields. The standards for ergonomic design of machinery, as referred to in this document, can help to avoid or reduce numerous hazards and risks, as assessed at the design stage, whilst considering the intended use, the expected use and the foreseeable misuse of the machinery.

The designer of machinery is under an obligation to assess the risks during all phases of the life cycle of the machinery (see EN 292-1:1991, Clause 5). This includes knowledge and experience of the design, use, incidents, accidents and harm.

EN 1553

Agricultural machinery – Agricultural self-propelled, mounted, semi-mounted and trailed machines – Common safety requirements.

ISO 11850

Machinery for forestry – Self-propelled machinery – Safety requirements.

ISO 6814

Machinery for forestry – Mobile and self-propelled machinery – Terms, definitions and classification.

Cab access – mounting and alighting

EN 547-1

Safety of machinery – Human body measurements – Part 1: Principles for determining the dimensions required for openings for whole body access into machinery.

Specifies the dimensions of openings for whole body access as applied to machinery as defined in EN 292-1. It provides the dimensions to which the values given in EN 547-3 are applicable. Values for additional space requirements are given in annex A. Has been prepared primarily for non-mobile machinery; there may be additional specific requirements for mobile machinery.

EN 547-2

Safety of machinery – Human body measurements – Part 2: Principles for determining the dimensions required for access openings.

Specifies the dimensions of openings for access as applied to machinery as defined in EN 292-1.

It provides the dimensions to which the values given in EN 547-3 are applicable. Values for additional space requirements are given in annex A. Has been prepared primarily for non-mobile machinery; there may be additional specific requirements for mobile machinery.

EN 547-3

Safety of machinery – Human body measurements – Part 3: Anthropometric data.

Specifies current requirements for human body measurements (anthropometric data) that are required by EN 547-1 and EN 547-2 for the calculation of access opening dimensions as applied to machinery. The anthropometric data originate from static measurements of nude persons and do not take into account body movements, clothing, equipment, machinery operating conditions or environmental conditions.

EN ISO 2867

Earth-moving machinery – Access systems.

EN ISO 2860

Earth-moving machinery – Minimum access dimensions.

Working posture

prEN ISO 15537

Principles for selecting and using test persons for testing anthropometric aspects of industrial products and design.

EN ISO 6682

Earth moving machinery – Zones of comfort and reach for controls.

Cab

EN ISO 3411

Earth-moving machinery – Human physical dimensions of operators and minimum operator space envelope.

prEN ISO 15537

Principles for selecting and using test persons for testing anthropometric aspects of industrial products and design (ISO/DIS 15537:2002).

Determines the procedures to be applied to the composition of groups and persons whose anthropometric characteristics are to be representative of all prospective users of any specific object under test. These procedures will be applicable to the anthropometric aspects of testing of industrial products and designs having direct or indirect contact with the human body and its functions.

Visibility

ISO 5006-1

Earth-moving machinery – Operator's field of view – Part 1: Test method.

ISO 5006-2

Earth-moving machinery – Operator's field of view – Part 2: Evaluation method.

ISO 5006-3

Earth-moving machinery – Operator's field of view – Part 3: Criteria.

Operator seat

prEN ISO 6683

Earth-moving machinery – Seat belts and seat belt anchorage.

ISO 11112 AMD

Earth-moving machinery – Operator's seat – Dimensions and requirements; Amendment 1.

Controls

EN 842

Safety of machinery – Visual danger signals – General requirements, design and testing.

Specifies the safety and ergonomic requirements and the corresponding test methods for visual danger signals. It also provides guidance for the design of the signals to be clearly identified and distinguished as required in 5.3 of EN 292-2:1991. It does not apply to danger indicators, presented either in written or pictorial form, transmitted by data display units. Special regulations, such as those for public disaster and public transport, are not affected by this standard.

EN 894-1

Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators.

Applies to design of displays and control actuators on machinery. It specifies general principles for human interaction with displays and control actuators to minimise operator errors and to ensure an efficient interaction between the operator and the equipment. It is particularly important to observe these principles when an operator error may lead to injury or damage to health.

EN 894-2

Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 2: Displays.

Gives guidance on the selection, design and location of displays to avoid potential ergonomic hazards associated with their use. It specifies ergonomics requirements and covers visual, audible, and tactile displays.

EN 894-3

Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 3: Control actuators.

This Standard gives recommendations on the selection, design and location of control actuators so that they are adapted to the requirements of the operators and take account of the circumstances of their use. It applies to manual control actuators used in equipment for occupational and private use. It is particularly important to observe the recommendations in this standard where operating a control actuator may lead to injury or damage to health either directly or as a result of a human error.

EN 61310-1

Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, auditory and tactile signals.

Specifies safety-related information requirements, at the man-machine interface and for exposed persons. It gives general rules for a system of colours, safety signs, markings and other warnings, giving information for use for the indication of hazardous conditions, for warning of health hazards and for meeting certain emergencies. It also specifies ways of coding visual, audible and tactile signals for indicating and actuating devices in order to facilitate the safe use and monitoring of the machinery.

EN 61310-2

Safety of machinery – Indication, marking and actuation – Part 2: Requirements for marking.

Specifies requirements for the marking of machinery. It gives general rules on marking for identification of machinery for safe use related to mechanical and electrical hazards and for the avoidance of hazards arising from incorrect connections.

EN 61310-3

Safety of machinery – Indication, marking and actuation – Part 3: Requirements for the location and operation of actuators.

Specifies safety-related requirements for actuators, operated by the hand or by other parts of the human body, at the man-machine interface. It gives general requirements for the standard direction of movement for actuators, the arrangement of an actuator in relation to other actuators

and the correlation between an action and its final effects.

<u>EN ISO 7250</u>

Basic human body measurements for technological design.

Provides a basic list of anthropometric measurements for use in the establishment of common comparative definitions of population groups. The basic list specified in this standard is intended to serve as a guide for ergonomists who are required to define population groups and apply their knowledge to the geometric design of the places where people work and live. This list is not intended to serve as a guide for how to take anthropometric measurements but it shall give information to the ergonomist and designer on the anatomical and anthropometrical basis and principles of measurements which are applied in the solution of design tasks. This standard may be used in conjunction with national or international regulations or agreements to assure harmony in defining population groups. In its various applications, it is anticipated that the basic list will be supplemented by specific additional measurements.

Machine operation

<u>EN 894-1</u>

Safety of machinery – Ergonomic requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators.

<u>EN 894-2</u>

Safety of machinery – Ergonomic requirements for the design of displays and control actuators – Part 2: Displays.

<u>EN 894-3</u>

Safety of machinery – Ergonomic requirements for the design of displays and control actuators – Part 3: Control actuators.

Visualisation of machine working process

<u>EN 457 = ISO 7731, modified</u>

Safety of machinery – Auditory danger signals – General requirements, design and testing.

Specifies the safety and ergonomic requirements and the corresponding test methods for auditory danger signals and gives guidelines for the design of the signal to be clearly perceived and differentiated as required in 5.3 of EN 292-2:1991. This standard does not apply to verbal danger warnings (e.g. shouts, loudspeaker announcements). Special regulations such as those for a public disaster and public transport are not effected by this standard.

<u>EN 981</u>

Safety of machinery – System of auditory and visual danger and information signals.

Is applicable to all danger and information signals which have to be clearly perceived and differentiated as specified in 5.3 of EN 292-2:1991, by other requirements or by the work situation and to all degrees of urgency; from extreme urgency to an all clear situation. Where visual signals are to be complementary to sound signals, the signal character is specified for both.

ISO 3767-1

Tractors, machinery for agriculture and forestry, powered lawn and garden equipment – Symbols for operator controls and other displays – Part 1: Common symbols.

ISO 3767-4

Tractors, machinery for agriculture and forestry, powered lawn and garden equipment – Symbols for operator controls and other displays – P art 4: Symbols for forestry machinery.

ISO 3767-4 AMD 1

Tractors, machinery for agriculture and forestry, powered lawn and garden equipment – Symbols for operator controls and other displays – Part 4: Symbols for forestry machinery; Amendment 1: Additional symbols.

ISO/DIS 6405-1

Earth-moving machinery – Symbols for operator controls and other displays – Part 1: Common symbols (Revision of ISO 6405-1:1991, Amendment 1:1997 and Amendment 2:1999).

ISO 9244

Earth-moving machinery – Safety signs and hazard pictorials – General principles.

ISO 11684

Tractors, machinery for agriculture and forestry, powered lawn and garden equipment – Safety signs and hazard pictorials – General principles.

Noise in the machine

EN ISO 4871

Acoustics – Declaration and verification of noise emission values of machinery and equipment.

This standard gives information on the declaration of noise emission values, describes acoustical and product information to be presented in technical documents for the purposes of noise emission declaration and specifies a method for verifying the noise emission declaration. It applies to machinery and equipment.

EN ISO 11200

Acoustics – Noise emitted by machinery and equipment – Guidelines for the use of basic standards for the determination of emission sound pressure levels at a work station and at other specified positions.

Provides brief summaries of the basic international standards for determining emission sound pressure levels from all types of machinery at work station and at other specified locations and gives guidance on the process of selection. The guidance given does apply only to airborne sound.

EN ISO 11201

Acoustics – Noise emitted by machinery and equipment – Measurements of emission sound pressure levels at a work station and at other specified positions – Engineering method in an essentially free field over a reflecting plane.

Specifies a method for measuring the emission sound pressure levels of machinery and equipment at a work station and at other specified positions nearby in an essentially free field over a reflecting plane.

EN ISO 11202

Acoustics – Noise emitted by machinery and equipment – Measurement of emission sound pressure levels at a work station and at other specified positions – Survey method in situ.

Specifies a method for measuring the emission sound pressure levels of machinery and equipment at a work station and at other specified positions nearby in a semi-reverberant field. Emission sound pressure levels are measured as A-weighted or C-weighted peaks.

EN ISO 11203

Acoustics – Noise emitted by machinery and equipment – Determination of emission sound pressure levels at a work station and at other specified positions from the sound power level.

Specifies two methods for determining the emission sound pressure levels of machinery and equipment at a work station and at other specified positions nearby by calculation from the sound power level. Permits the comparison of the sound power of different units of a given family of machinery.

EN ISO 11204

Acoustics – Noise emitted by machinery and equipment – Measurement of emission sound pressure levels at a work station and at other specified positions – Method requiring environmental corrections.

Specifies a method for measuring the emission sound pressure levels of machinery and equipment at a work station and at other specified positions nearby in any environment which meets certain requirements. Gives instructions for the installation and operation of the machine under test and for the choice of microphone positions for the work station.

EN ISO 11688-1

Acoustics – Recommended practice for the design of low-noise machinery and equipment – Part 1: Planning.

Serves as an aid to understanding the basic concepts of noise control in machinery and equipment. The recommended practice presented is intended to assist the designer at any design stage to control the noise of the final product. Makes references to numerous technical publications dealing with acoustical problems.

EN ISO 11688-2

Acoustics – Recommended practice for the design of low-noise machinery and equipment – Part 2: Introduction to the physics of low-noise design.

Provides the physical background for the low-noise design rules and examples given in part 1 and supports the use of extensive special literature. It is intended for use by designers of machinery and equipment as well as users and buyers of machines and authorities in the field of legislation, supervision and inspection. Equations given in this standard shall improve the general understanding of noise control. In many cases they allow a comparison of different versions of design, but they are not useful for the prediction of absolute noise emission values.

EN ISO 11689

Acoustics – Procedure for the comparison of noise emission-data for machinery and equipment.

EN ISO 11690-1

Acoustics – Recommended practice for the design of low-noise workplaces containing machinery – Part 1: Noise control strategies.

Outlines strategies to be used in dealing with noise problems in existing and planned workplaces by describing basic concepts in noise control (noise reduction, noise emission, noise emission and noise exposure). It is applicable to all types of workplaces and all types of sources of sound which are met in workplaces including human activities. It includes those important strategies to adopt when buying a new machine or equipment.

EN ISO 11690-2

Acoustics – Recommended practice for the design of low-noise workplaces containing machinery – Part 2: Noise control measures.

Deals with the technical aspects of noise control in workplaces. The various technical measures are stated, the related acoustical quantities described, the magnitude of noise reduction discussed and the verification methods outlined.

EN 1746

Safety of machinery – Guidance for the drafting of the noise clauses of safety standards.

Gives guidance on how to deal with noise in type C-standards where noise is identified as a significant hazard. As such, this standard supplements the rules given in EN 414. The exact way that noise is dealt with for a particular type of machinery will depend on the structure of the type C-standards and is the responsibility of the type C standard technical committees.

EN ISO 3744

Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering methods in an essentially free-field condition over a reflecting plane.

Specifies a method of measurement. Gives requirements for the test environment and instrumentation as well as techniques for obtaining the surface sound pressure level from which the sound power level of the source is calculated leading to results which have a grade of accuracy.

ISO 1999

Acoustics – Determination of occupational noise exposure and estimation of noise-induced hearing impairment.

Specifies a method for calculating the expected noise-induced permanent threshold shift in the hearing threshold levels of adult populations due to various levels and duration of noise exposure. It provides the basis for calculating hearing handicap according to various formulae when the hearing threshold levels at commonly measured audiometric frequencies or combinations of such frequencies exceed a certain value.

ISO 9921-1

Ergonomic assessment of speech communication – Part 1: Speech interference level and communication distances for persons with normal hearing capacity in direct communication (SIL method).

Provides a method for the prediction of the effectiveness of speech communication in the presence of noise generated by machinery as well as in noisy environments. Parameters are the ambient noise at the speaker's position, ambient noise at the listener's position, distance between the communication partners and a great number of physical and personal conditions.

ISO/DIS 9921

Ergonomics – Assessment of speech communication.

Specifies the requirements for the performance of speech communication for verbal alert and danger signals, information messages and speech communication in general. Methods to predict and to assess the performance in practical applications are described and examples are given. Acoustical danger and warning signals are in general omni-directional and therefore may be universal in many situations. Auditory warnings are of great benefit in situations where smoke, darkness or other obstructions interfere with visual warnings. It is essential that, in the case of verbal messages, a sufficient level of intelligibility is achieved in the coverage area. If this cannot be achieved non-voice warning signals (see ISO 7731, IEC 60849) or visual warning signals (ISO 11429) may be preferable.

EN ISO 11546-1

Acoustics – Determination of sound insulation performances of enclosures – Part 1: Measurements under laboratory conditions (for declaration purposes).

EN ISO 11546-2

Acoustics – Determination of sound insulation performances of enclosures – Part 2: Measurements in situ (for acceptance and verification purposes).

EN ISO 11957

Acoustics – Determination of sound insulation performance of sound protecting cabins – Laboratory and in situ measurements.

EN ISO 12001

Acoustics – Noise emitted by machinery and equipment – Rules for the drafting and presentation of a noise test code.

EN ISO 3747

Acoustics – Determination of sound power levels of noise sources using sound pressure – Comparison method for use in situ.

EN ISO 9614-1

Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points.

EN ISO 9614-2

Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement by scanning.

EN ISO 15667

Acoustics – Guidelines for noise control by enclosures and cabins.

EN 1746

Safety of machinery – Guidance for the drafting of the noise clauses of safety standards.

EN ISO 3744

Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering method in an essentially free field over a reflecting plane.

ISO 6394

Measurement of airborne noise emitted by machines – Measurement at the operator's position – Earth-moving machinery (stationary test condition).

Vibration

CR 12349

Mechanical vibration – Guide to the health effects of vibration on the human body.

Aim of this report is to provide information on the possible adverse health effects caused by exposure to vibration at work. The report addresses manufacturers as well as employers and employees using vibrating machinery in order to improve their understanding of the possible health problems arising from occupational exposure to vibration.

EN ISO 5349-1

Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements.

EN ISO 5349-2

Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 2: Practical guidance for measurement at the workplace.

Provides guidelines for the measurement and evaluation of hand-transmitted vibration at the workplace in accordance with ISO 5349-1 (ENV ISO 25349). Describes precautions to be taken to make representative vibration measurements and to determine the daily exposure time for each operation in order to calculate the 8 hour energy-equivalent vibration total value.

ENV 25349 = ISO 5349

Mechanical vibrations – Measurement and the assessment of human exposure to hand-transmitted vibration.

Specifies general methods for measuring and reporting hand-transmitted vibration exposure in three orthogonal axes for the one-third octave bands having centre frequencies from 6.3-1 250 Hz, the octave bands having centre frequencies from 8-1000 Hz, and a frequency-weighted measure which covers the frequency range from 5.6-1400 Hz.

EN 1032

Mechanical vibration – Testing of mobile machinery in order to determine the whole-body vibration emission value – General.

Specifies the evaluation of vibration emission at operators place during testing and operation of mobile machinery. It is intended to be used for defining magnitudes of whole-body vibration transmitted from supporting surfaces to the human body in the frequency range 1 Hz to 80 Hz. According to this standard, the magnitudes are stated as r.m.s. values of representative vibration. This standard provides requirements for the vibration test codes to be incorporated in the machinery related standards, including the conditions under which the measurements shall be made (e.g. operating conditions). This standard applies to sitting and standing positions. It is applicable to all mobile machinery producing periodic or random vibration with or without transients. Only rectilinear vibrations are dealt with in this standard. The purpose of this standard is to ensure consistency and compatibility of test and evaluation methods. It does not present limits or recommended vibration values.

EN 1033

Hand-arm vibrations – Laboratory measurement of vibration at the grip surface of hand-guided machinery – General; Geraman version.

Describes the basic requirements for evaluating vibration at the machine-hand contact surface of hand-guided machines, e.g. lawn mowers, single axis tractors, vibratory rollers and other types of machines which are provided with handles, guiding beams or similar means of control. Test codes are designed to give information on the vibration characteristics of a specific type of machinery enabling comparisons to be made between similar machinery but of different manufacturers. The standard does not apply to hand-held power tools and to fixed machinery in which the vibration is transmitted to the hands of the user through the work piece nor does it apply to the measurement of vibration to the handle of the user via steering wheels or similar controls of vehicles. This standard is not intended for assessment of human exposure to vibration. The measurement and assessment of human exposure to hand-transmitted vibration in the workplace is given in ENV 25439.

EN 1299

Mechanical vibration and shock – Vibration isolation of machines – Information for the application of source isolation.

Gives guidelines to ensure that manufactures of machines provide adequate information on application of vibration isolation of their machines. Guidelines are also provided to ensure that users furnish sufficient information regarding their applications to suppliers to enable the Optimum selection and design of vibration isolation. This standard is restricted to source isolation.

EN 30326-1 = ISO 10326-1

Mechanical vibration – Laboratory method for evaluating vehicle seat vibration – Part 1: Basic requirements.

This part of the standard specifies basic requirements for the laboratory testing of vibration transmission through a vehicle seat to the occupant. These methods for measurement and analysis make it possible to compare test results from different laboratories. It specifies the test method, the instrumentation requirements, the measuring assessment method and the way to report the test result. This part of the standard applies to specific laboratory seat tests which evaluate vibration transmission to the occupants of any type of seat used in vehicles and mobile off-road machinery. Application standards for specific vehicles should refer to this part of ISO 10326 when defining the test input vibration that is typical for the vibration characteristics of the type of vehicle or machinery in which the seat is to be fitted.

EN ISO 7096

Earth-moving machinery – Laboratory evaluation of operator seat vibration.

EN ISO 13753

Mechanical vibration and shock – Hand-arm vibration – Method for measuring the vibration transmissibility of resilient materials when loaded by the hand-arm system.

DIN V 45695 = CR 1030-1 + CR 1030-2

Hand-arm vibration – Guidelines for vibration hazards reduction – Engineering and management measures.

CR 1030-1

Hand-arm vibration – Guidelines for vibration hazards reduction – Part 1: Engineering methods by design of machinery.

These guidelines outline feasible ways in which possible hand-arm vibration hazard associated with hand-held, hand-guided and other machinery may be reduced by machinery design in order to provide practical professional aid to designers and manufactures of machinery. The document covers four principal aspects of the reduction of the effects arising from exposure to hazardous machinery vibration: Reduction of vibration magnitude at source, reduction of vibration transmission from the source to handless and other surfaces in contact with the hands, reduction of vibration transmission from the grips or handles of the machine to the hand-arm system of the operator by ergonomic design measures and thermal design to optimise hand temperature.

EN 12786

Safety of machinery – Guidance for the drafting of the vibration clauses of safety standards.

Gives guidance on how to deal with vibration in type C standards where vibration is identified as a significant hazard. As such, this European Standard supplements the rules given in EN 414. The exact way that vibration is dealt with for particular machinery will depend on the structure of the type C standards and is the responsibility of the type C standards technical committees.

ENV 28041 = ISO 8041

Human response to vibration – Measuring instrumentation.

This standard specifies instrumentation for a method of measurement of vibration in a given frequency range given in ISO 2631-1 for assessing the vibration as perceived by human beings. It applies to instrumentation for the measurement of hand-arm vibration and whole-body vibration. This standard specifies electrical, vibration and environmental tests to verify compliance with the characteristics specified. It also determines the method for sensitivity calibration. The purpose of this standard is to ensure consistency and compatibility of results and reproducibility of measurements realised with different measuring instrumentation using this method of measurement. An instrument or an instrument collection may be realised which fulfils only the necessary requirements for measurement of hand-arm or whole-body vibrations under certain conditions, for example in the z-direction, provided that the purpose is clearly stated and pertinent requirements of this standard are fulfilled. In conjunction with spectral analysis proper filter characteristics shall be applied.

ISO 2041

Vibration and shock – Vocabulary.

Defines terms in English and French. An alphabetical index is provided for each of the two languages.

ISO 2631-1

Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements.

Defines methods for the measurement of periodic, random and transient whole-body vibration. It indicates the principal factors that combine to determine the degree to which a vibration exposure will be acceptable.

ISO 2631-2

Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 2: Vibration in buildings (1 Hz to 80 Hz).

ISO 2631-4

Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed guide way transport systems.

ISO/DIS 2631-5

Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 5: Method for evaluation of vibration containing multiple shocks.

ISO 5805

Mechanical vibration and shock – Human exposure – Vocabulary.

Defines terms relating to human biodynamics or which are used in specific contexts in other standards pertaining to the evaluation of human exposure to mechanical vibration and shock. It provides standard definitions of terms and supplements ISO 2041 but does not contain general terms readily found in dictionaries.

ISO 8727

Mechanical vibration and shock – Human exposure – Biodynamic coordinate systems.

Specifies anatomical and basicentric co-ordinate systems for biodynamical measurements, for reference purposes in cognate standards development and for precisely describing human exposure to mechanical vibration and shock. The segmental anatomical co-ordinate systems defined in this standard are for the head, root of the neck (driving-point for the head and neck system), pelvis and hand. General principles are stated for the establishment of corresponding anatomical co-ordinate systems for other skeletal body segments. The biodynamic co-ordinate systems defined in this standard can serve as frames of reference for the description and measurement of both translational and rotational vibration and shock motion affecting humans.

EN 28662-1 = ISO 8662-1

Hand-held portable power tools – Measurement of vibrations at the handle – Part 1: General.

This part of ISO 8662 describes the basic requirements for evaluating vibrations in the handles of hand-held power-driven tools. It is not intended for assessment of human exposure to vibrations. The measurement and assessment of human exposure to hand-transmitted vibration in the workplace is given in ISO 5349.

EN ISO 7096

Earth-moving machinery – Laboratory evaluation of operator seat vibration.

EN 12786

Safety of machinery – Guidance for the drafting of the vibration clauses of safety standards.

Climate control in the cab

EN 27726 = ISO 7726

Thermal environments – Instruments and methods for measuring physical quantities.

Specifies the minimum characteristics of appliances for measuring physical quantities characterising an environment as well as the methods for measuring the physical quantities of this environment. This standard shall be used as a reference when establishing a) specifications for manufacturers and users of instruments for measuring the physical quantities of the environment and b) a written contract between two parties for the measurement of these quantities. It applies to the study of hot, comfortable or cold environments in any place occupied by man.

EN ISO 7730

Moderate thermal environments – Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.

The purpose of this international standard is a) to present a method for predicting the thermal sensation and the degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments and b) to specify acceptable thermal environmental conditions for comfort. The international standard applies to healthy men and women and was originally based on studies of North American and European subjects but agrees also with recent studies of Japanese subjects and is expected to apply with good approximation in most parts of the world. Applies to people exposed to indoor environments where the aim is to attain thermal comfort or indoor environments where moderate deviations from comfort occur.

ENV ISO 11079

Evaluation of cold environments – Determination of required clothing insulation (IREQ).

Proposes methods and strategies to assess the thermal stress associated with exposure to cold environments. They apply to continuous, intermittent, and occasional exposure and in both indoor and outdoor work. Specific effects associated with certain meteorological phenomena (e.g. precipitation) are not covered and should be assessed by other methods.

EN 12515 = ISO 7933

Hot environments – Analytical determination and interpretation of thermal stress using calculation of required sweat rate.

Specifies a method of analytical evaluation and interpretation of the thermal stress experienced by a subject in a hot environment. It describes a method of calculating the heat balance as well as the sweat rate that the human body should produce to maintain this balance in equilibrium. This sweat rate is called the required sweat rate. The various terms used in the determination of the required sweat rate show the influence of the different physical parameters of the environment on the thermal stress experienced by the subject. In this way, this international standard makes it possible to determine which parameter or group of parameters should be modified, and to what extent, in order to reduce the risk of physiological strains. The main objectives of this international standard are a) the evaluation of the thermal stress in conditions likely to lead to excessive core temperature increase or water loss for the standard subject, b) the determination of the modifications to be brought to the work situation in order to reduce or exclude these effects and c) the determination of the maximum allowable exposure times required to limit physiological strain to an acceptable value.

EN ISO 13731

Ergonomics of the thermal environment – Vocabulary and symbols.

The aim of this standard is to give vocabulary and symbols for the quantities used in standards on ergonomics of the thermal environment and to provide a reference of vocabulary and symbols to be used in writing future standards or other publications on the ergonomics of the thermal environment.

EN 27243 = ISO 7243

Hot environments – Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature).

This international standard gives a method, which can easily be used in an industrial environment, for evaluating the heat stress to which an individual is subjected in a hot environment and which allows a fast diagnosis. It applies to the evaluation of the mean effect of heat on man during a period representative of his activity but it does not apply to the evaluation of heat stress suffered during very short periods or to the evaluation of heat stresses close to the zones of comfort.

EN 28996 = ISO 8996

Ergonomics – Determination of metabolic heat production.

The metabolic rate, as a conversion of chemical into mechanical and thermal energy, measures the energetic cost of muscular load and gives a numerical index of activity. Knowledge of metabolic rate is necessary to measure metabolic heat production for the evaluation of human heat regulation. Specifying methods for determination metabolic rate, this standard can also be used for other applications; for example the assessment of working practices, the cost of specific jobs or sport activities, the total cost of activity etc.

ISO 10263-1

Earth-moving machinery – Operator enclosure environment – Part 1: General and definitions.

ISO 10263-2

Earth-moving machinery – Operator enclosure environment – Part 2: Air filter test.

ISO 10263-3

Earth-moving machinery – Operator enclosure environment – Part 3: Operator enclosure pressurisation test method.

ISO 10263-4

Earth-moving machinery – Operator enclosure environment – Part 4: Operator enclosure ventilation, heating and/or air-conditioning test method.

ISO 10263-5

Earth-moving machinery – Operator enclosure environment – Part 5: Windscreen defrosting system test method.

ISO 10263-6

Earth-moving machinery – Operator enclosure environment – Part 6: Determination of effect of solar heating on operator enclosure.

ISO 14269-1

Tractors and self-propelled machines for agriculture and forestry – Operator enclosure environment – Part 1: Vocabulary.

ISO 14269-2

Tractors and self-propelled machines for agriculture and forestry – Operator enclosure environment – Part 2: Heating, ventilation and air-conditioning test method and performance.

ISO 14269-3

Tractors and self-propelled machines for agriculture and forestry – Operator enclosure environment – Part 3: Determination of effect of solar heating.

ISO 14269-4

Tractors and self-propelled machines for agriculture and forestry – Operator enclosure environment – Part 4: Air filter element test method.

ISO 14269-5

Tractors and self-propelled machines for agriculture and forestry – Operator enclosure environment – Part 5: Pressurization system test method.

Exposure to gases and particles

EN 626-1

Safety of machinery – Reduction of risk to health from hazardous substances emitted by machinery – Part 1: Principles and specifications for machinery manufactures.

EN 626-2

Safety of machinery – Reduction of risk to health from hazardous substances emitted by machinery – Part 2: Methodology leading to verification procedures.

Lighting

EN 1837

Safety of machinery – Integral lighting of machines.

Specifies the parameters of integral lighting systems designed to provide illumination in or at both stationary and mobile machines to enable the safe use of the machine and the efficient performance of the visual task within or at the machine to be carried out.

EN 12464-1

Light and lighting – Lighting of workplaces – Part 1: Indoor work places

Specifies lighting requirements for work places, which meet the needs of visual performance, comfort and safety.

Work places include both indoor and outdoor task areas. All usual visual tasks are considered including DSE (Display Screen Equipment).

prEN 12464-2

Light and lighting – Lighting of work places – Part 2: Outdoor work places.

EN 12665

Lighting and lighting – Basic terms and criteria for specifying lighting requirements.

Defines basic terms for use in all lighting applications; specialist terms with limited applications are given in individual standards. This standard also sets out a framework for the specification of lighting requirements, giving details of aspects which shall be considered when setting those requirements.

ISO 8995

Lighting of indoor work systems.

Identifies the parameters that influence visual performance. It also presents the criteria that have to be satisfied in order to achieve an acceptable visual environment. It is applicable to working areas in industrial buildings, offices and hospitals, but not to those working areas of low luminance used for such activities as projection, viewing of transparencies and handling of photosensitive materials.

Instructions and training

EN 1677-1

Components for slings – Safety – Part 1: Forged steel components, grade 8.

EN 1677-2

Components for slings – Safety – Part 2: Forged steel lifting hooks with latch, grade 8.

EN 1677-3

Components for slings – Safety – Part 3: Forged steel self-locking hooks, grade 8.

EN 1677-4

Components for slings – Safety – Part 4: Links, grade 8.

EN 1677-5

Components for slings – Safety – Part 5: Forged steel lifting hooks with latch, grade 4.

EN 1677-6

Components for slings – Safety – Part 6: Links, grade 4.

ISO 3600

Tractors, machinery for agriculture and forestry, powered lawn and garden equipment – Operator's manuals – Content and presentation.

Maintenance and machine design

EN 13202

Ergonomics of the thermal environment – Temperatures of touchable hot surfaces – Guidance for establishing surface temperature limit values in production standards with the aid of EN 563.

This guidance document describes methods for the assessment of the risk of burning when a hot surface is touched by unprotected skin. It also describes how surface temperature limit values can be established in product standards with the aid of EN 563. The guidance is for establishing temperature limit values in all fields where surface temperature limit values are required. Its field of application is not restricted to the safety of machinery. It is applicable for all kinds of products where hot surfaces cause a risk of burning. It applies as well for electrically powered products as for all other products. This document does not set surface temperature limit values. It provides guidance to technical committees to carry out assessments of the risk of burning and to establish appropriate surface temperature limit values if necessary. Provides the possibility of harmonising surface temperature limit values in standards for all kind of products. Provides additional information not contained in EN 563, including burn thresholds for contact periods below 1 second, burn thresholds for different textures of material and the assessment of burning risks for people other than healthy adults.

EN 563

Safety of machinery – Temperatures of touchable surfaces – Ergonomics data to establish temperature limit values for hot surfaces.

This is a type B safety standard concerned with the risk of burns caused by contact between human skin and hot surfaces. This standard applies to hot surfaces of all products and equipment that must or can be touched during their normal use. That includes the area of safety of machinery as well as any other applications. This standard provides data concerning circumstances under which contact with a hot surface may lead to skin burns. These data allow the assessment of risks of burning. This standard also provides data to be used to establish temperature limit values for hot surfaces to protect against skin burns. These data can be used in the development of standards for specific equipment where temperature limits are required. This standard does not apply if a large area of the skin (approximately 10% or more of the skin of the whole body) can be in contact with the hot surface. This standard also does not apply to skin contact with more than 10% of the head or contact which could result in burns of vital areas of the face (e.g. burns resulting in the restriction of airways). In these cases severe injuries may occur, even if the surface temperature does not exceed the values specified in this standard. The data of this standard apply to surfaces of objects with relatively high thermal capacity when compared with that of the skin of the human body. This standard applies to the skin of adults. As far as there are no special data for the skin of children, this standard may also be used to assess the risk of burning of children's skin in contact with hot surfaces. This standard does not provide data for the protection against pain. If the burn thresholds specified in this standard are not exceeded, there is normally no risk of burning when the skin comes in contact with the hot surface but pain may occur nevertheless. lf there is also a need for protection against pain, surface temperature values should be taken from other suitable sources.

prEN ISO 13732-3 = ISO/DIS 13732-3

Ergonomic of the thermal environment – Touching of cold surfaces – Part 3: Ergonomics data and guidance for application.

Applies to cold surfaces of all products and equipment that must or can be touched in accordance with their normal use. This standard provides data to assess the risk of injuries caused by contact of the skin with a cold surface. This standard also provides data to be used to establish temperature limit values for cold surfaces to protect against skin or body injuries. These data shall be used in the development of standards for specific equipment where temperature limits are required. This standard applies to solid surfaces.

EN 294

Safety of machinery – Safety distances to prevent danger zones from being reached by the upper limbs.

EN 349

Safety of machinery – Minimum gaps to avoid crushing of parts of the human body.

EN 809

Pumps and pump units for liquids – Common safety requirements.

EN 811

Safety of machinery – Safety distances to prevent danger zones being reached by the lower limbs.

EN 953

Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards.

EN 981

Safety of machinery – System of auditory and visual danger and information signals.

EN 983

Safety of machinery – Safety requirements for fluid power systems and their components – Pneumatics.

EN 1012-1
Compressors and vacuum pumps – Safety requirements – Part 1: Compressors.

EN 1012-2
Compressors and vacuum pumps – Safety requirements – Part 2: Vacuum pumps.

EN 13478
Safety of machinery – Fire prevention and protection.

EN ISO 3457
Earth moving machinery – Guards and shields – Definitions and specifications.

ISO 3795
Road vehicles, and tractors and machinery for agriculture and forestry – Determination of burning behaviour of interior materials.

ISO 10532 = SAE J/ISO 10532
Earth-moving machinery – Machine-mounted retrieval device – Performance requirements.

ISO 10533
Earth-moving machinery – Lift-arm support devices.

ISO/DIS 10570
Earth-moving machinery – Articulated frame lock – Performance requirements (Revision of ISO 10570:1992).

ISO 13852
Safety of machinery – Safety distances to prevent danger zones being reached by the upper limbs.

Brakes and operator safety

EN 418
Safety of machinery – Emergency stop equipment, functional aspects – Principles for design.

EN 818-1
Short link chain for lifting purposes – Safety – Part 1: General conditions of acceptance.

EN 818-2
Short link chain for lifting purposes – Safety – Part 2: Medium tolerance chain for chain slings, grade 8.

EN 818-3
Short link chain for lifting purposes – Safety – Part 3: Medium tolerance chain for chain slings, grade 4.

EN 818-4
Short link chain for lifting purposes – Safety – Part 4: Chain slings, grade 8.

EN 818-5

Short link chain for lifting purposes – Safety – Part 5: Chain slings, grade 4.

EN 818-6

Short link chain for lifting purposes – Safety – Part 6: Chain slings; specification for information for use and maintenance to be provided by the manufacturer.

EN 818-7

Short link chain for lifting purposes – Safety – Part 7: Fine tolerance hoist chain, grade T (Types T, DAT and DT).

EN 1037

Safety of machinery – Preventation of unexpected start-up.

EN 1050

Safety of machinery – Principles for risk assessment.

EN 1070

Safety of machinery – Terminology; Trilingual version.

ISO 8082

Self-propelled machinery for forestry – Roll-over protective structures – Laboratory tests and performance requirements (ROPS).

ISO 8083

Machinery for forestry – Falling-object protective structures – Laboratory tests and performance requirements (FOPS).

ISO/FDIS 8084

Machinery for forestry – Operator protective structures – Laboratory tests and performance requirements (OPS).

EN 13510 = ISO 3471 + A1 modified

Earth moving machinery – Roll-over protective structures – Laboratory tests and performance requirements (ROPS).

EN 13531= ISO 12117 modified

Earth-moving machinery – Tip-over protection structure (TOPS) for compact excavators – Laboratory tests and performance requirements.

EN 13627 = ISO 3449 modified

Earth-moving machinery – Falling-object protective structures – Laboratory tests and performance requirements (FOPS).

EN ISO 3450

Earth-moving machinery – Braking systems of rubber-tyred machines – Systems and performance requirements and test procedures.

EN 13411-1
Terminations for steel wire ropes – Safety – Part 1: Thimbles for steel wire rope slings.

EN 13411-2
Terminations for steel wire ropes – Safety – Part 2: Splicing of eyes for wire rope slings.

prEN 13411-3
Terminations for steel wire ropes – Safety – Part 3: Ferrule secured eyes.

EN 13411-4
Terminations for steel wire ropes – Safety – Part 4: Metal and resin socketing.

prEN 13411-5
Terminations for steel wire ropes – Safety – Part 5: Wire rope grips for eyes.

prEN 13411-6
Terminations for steel wire ropes – Safety – Part 6: Asymmetric wedge socket clebis.

ISO 11169
Machinery for forestry – Wheeled special machines – Vocabulary, performance test methods and criteria for brake systems.

ISO 11512
Machinery for forestry – Tracked special machines – Performance criteria for brake systems.

prEN ISO 4254-1
Agricultural machinery – Technical means ensuring safety – Part 1: General.

ISO 4254-2
Tractors and machinery for agriculture and forestry – Technical means for providing safety – Part 2: Anhydrous ammonia applicators.

ISO 4254-3
Tractors and machinery for agriculture and forestry – Technical means for ensuring safety – Part 3: Tractors.

ISO 4254-4
Tractors and machinery for agriculture and forestry – Technical means for ensuring safety – Part 4: Forestry winches.

ISO 4254-5
Tractors and machinery for agricultural and forestry – Technical means for ensuring safety – Part 5: Power-driven soil-working equipment.

ISO/DIS 4254-6
Tractors and machinery for agriculture and forestry – Technical means for ensuring safety – Part 6: Sprayers and liquid fertilizer distributors.

ISO/DIS 4254-7

Tractors and machinery for agriculture and forestry – Technical means for ensuring safety – Part 7: Combine harvesters, forage and cotton harvesters.

ISO 4254-9

Tractors and machinery for agriculture and forestry – Technical means for ensuring safety – Part 9: Equipment for sowing, planting and distributing fertilizers.

EN 12643 = ISO 5010 modified

Earth-moving machinery – Rubber-tyred machines – Steering requirements.

ISO 15078

Machinery for forestry – Log loaders – Location and method of operation of two-lever operator controls.

Electromagnetic compatibility and radiation

EN ISO 14982

Agricultural and forestry machines – Electromagnetic compatibility – Test methods and acceptance criteria.

ISO 13766

Earth-moving machinery – Electromagnetic compatibility.

EN 12198-1

Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery – Part 1: General principles.

Deals with the emission of radiation from machinery. This radiation emission may be intended for processing or may occur unintentionally. This standard is intended to give advice to C-type standardisation groups how to identify radiation emissions, how to decide on their significant and intensity, how to assess the possible risks and what means could be used to avoid or reduce radiation emissions. This advice should be elaborated in C-type standard for specific classes of machines into assessable requirements. This standard may also be used to give advice to manufactures for the construction of safe machinery if no relevant C-type standard exists.

EN 12198-2

Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery – Part 2: Radiation emission measurement procedure.

EN 12198-3

Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery – Part 3: Reduction of radiation by attenuation or screening.

ENV 50166-1

Human exposure to electromagnetic fields – Part 1: Low frequency (0 kHz to 10 kHz).

Deals with the prevention of adverse short-term effects of human exposure to static and low-frequency electric and magnetic fields in the frequency range from 0-10 kHz. In this region of the electromagnetic spectrum the electric and magnetic fields must be considered separately. The rationale is set out in annex A. This pre-standard does not apply to the deliberate exposure of persons to electric or magnetic fields during medical research, diagnosis or treatment. Safety hazards which may be associated with the ignition of flammable materials or the triggering of explosive devices in strong fields are not covered. Compliance with this pre-standard may not exclude interference with or effects on some examples of implants such as cardiac pacemakers. It is recognised that it will not always be possible to comply with the provisions of this standard under exceptional operating conditions, such as momentary short-circuit or fault currents, inherent in the technology of electrical equipment.

ENV 50166-2

Human exposure to electromagnetic fields – Part 2: High frequency (10 kHz to 300 GHz).

Deals with the prevention of adverse short-term effects of human exposure to electromagnetic fields in the frequency range of 10 kHz to 300 GHz. The rationale is set out in annex A. It does not apply to the deliberate exposure of persons to electric or magnetic fields during medical research, diagnosis, or treatment. Safety hazards, which may be associated with the ignition of flammable materials or the triggering of explosive devices in strong fields, are not covered. Compliance with this pre-standard may not exclude interference with or effects on some examples of implants such as cardiac pacemakers.

List of standards in numerical order

prEN 292-1:1991 = ISO/DIS 12100-1:2004. Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology.

prEN 292-2:1991 = ISO/DIS 12100-2:2004. Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles.

EN 294:1992. Safety of machinery – Safety distances to prevent danger zones from being reached by the upper limbs.

EN 349:1993. Safety of machinery – Minimum gaps to avoid crushing of parts of the human body.

EN 414:2000. Safety of machinery – Rules for the drafting and presentation of safety standards.

EN 418:1992. Safety of machinery – Emergency stop equipment, functional aspects – Principles for design.

EN 457:1992 = ISO 7731:1986, modified. Safety of machinery – Auditory danger signals – General requirements, design and testing.

EN 547-1:1996. Safety of machinery – Human body measurements – Part 1: Principles for determining the dimensions required for openings for whole body access into machinery.

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Work organisation in mechanised forest operations

S. Lewark

Abstract

How are mechanised forest operations organised, what are the trends of development of work organisation and what does this mean for working conditions of machine operators? These were the leading questions for this review on work organisation in mechanised forestry with a focus on mechanised harvesting.

It seemed to be sensible to define concepts of organisation before then first reporting on frameworks for work organisation. Then state of organisation in the narrow sense was reported under the headings decision making, work division and work structuring. All structures of work organisation reported are to be found for employed labour, only partly transferable to self-employed wood harvesting.

Work structuring comprises concepts like job enrichment, job enlargement, job rotation and part-autonomous group work. They have consequences for work division and their introduction is based on decisions of the managerial level of enterprises – lower levels of hierarchy may participate. The concepts will determine autonomy, variation and cooperation, all of them as well as shift work schemes and numbers of working hours will influence job satisfaction, fatigue and strain, but these impacts are not treated in this review. The most mentioned and practiced concept of job rotation rather enlarges variety of work and is not intended to enlarge autonomy. Giving power of decision and planning and controlling tasks to the executive level is raising autonomy. Most promising in this respect is part-autonomous group work.

But ergonomics for mechanised working places today is not a problem any more, which would require basic research and risk analyses and subsequent development of measures of health protection. It is rather a problem of implementation – and this is the big challenge of today for work science and practical forest work.

Introduction

The working situation of the machine operator in mechanised forest operations today, in particular in wood harvesting with harvesters and forwarders, has been characterised by working systems of high technological standard with high working speed leading to high concentration demand and stress (Lewark, 2005 (this vol.)). This working situation has been described in more detail by Vik & Veiersted (2005, (this vol.)), who also give a historical sketch of the introduction of mechanised forest operations, which is most advanced in the Nordic countries. Working situation became closer to the working situations of industrial working places. Work organisation has been considered to have the highest potential for improving the situation, the most important elements of organisation in this respect being length of working shift, division of work tasks and responsibilities, job rotation, team work and payment systems (Jones et al., 2005 (this vol.)).

All this is common knowledge, at least for insiders. But a review of the scientific publications on work organisation in mechanised forest operations is lacking and therefore has been undertaken in the course of the *ErgoWood* project in order to provide a description of the starting points for organisational interventions in the project.

The leading questions for this review were: How is mechanised harvesting organised, what are the trends of development of work organisation and what does this mean for working conditions? These overall questions for this review are also partly covered in the introductory text (Lewark, 2005 (this vol.)) and in the other reviews mentioned, to which I will refer.

For the review of findings concerning these questions in publications first the concepts of work organisation shall be clarified, starting from the MTO-model (triangle) of working systems (cf. Lewark, 2005 (this vol.)). Quite obviously in the working systems the ergonomic situation of machine operators as the human aspect, is mainly being influenced by technical working means and by organisation, which again influence each other. Organisation has to be regarded on different levels, on the levels of enterprise, working group and individual.

Important goals of work organisation according to Gellerstedt et al. (1999) are:

- Physically, mentally and socially varying work assignments
- Acceptable working intensity that allows the operator to vary his working tempo
- A machine that is suitable for the prevailing conditions
- To tailor spells in the cab, the working tempo, etc., to the ergonomic profile of the machine
- Adequate short, micro and long breaks to obviate cumulative fatigue over time
- A positive social climate, with opportunities for information, help and support from others
- Influence in drawing-up shiftwork schedules and over choice of machine and the organisation and planning of work
- Periodic training and opportunities to advance in career

Retrieval of literature has been done in several phases: Starting with the author's private archives and in different data banks in a systematic using search words was similar to the way described by Vik & Veiersted (2005 (this vol.)), and in a third attempt in an internet search.

The general experience was that, even if hundreds of references were found under the search words in the beginning, insights was converging very soon, so that the main findings could be based on a rather limited number of references, some of them could have been exchanged for others without very much changing the findings and conclusions.

Searching you will immediately see, that there is an abundance of publications including organisational aspects for mechanised forest operations, but the great majority is based on practical observations rather than on scientific research and furthermore in most cases there are descriptions rather than analyses of the underlying causalities. Therefore number of selected and included papers here will be limited.

Searching you will immediately see, that there is an abundance of publications including organisational aspects for mechanised forest operations, but the great majority is based on practical observations rather than on scientific research and furthermore in most cases there are descriptions rather than analyses of the underlying causalities. Besides as also stated other places quite a few details of aspects also of relevance in this review are covered in other reviews, especially that by Vik & Veiersted (2005 (this vol.)). Therefore, in order to avoid too much redundance number of selected and included papers here will be limited and also a detailed description of the search strategy and and checked references and articles did not seem to be sensible here.

Terminology: Concepts of organisation, focus of review

Work organisation in general, which also applies to mechanised forest operations, refers (according to Strohm, 1997) to:

- Hierarchical structure
- Division of work and roles
- Structures of decision
- Work related planning
- Co-ordination and control

The underlying MTO-model (Mensch-Technik-Organisation or (hu)man-technology-organisation) from German work psychology literature as a model of relationships and interactions has been presented in Figure 1.1 of Lewark (2005 (this vol.)). The triangle of human – technology – organisation as a frame to the task in the centre is pictured in Figure 1.2 (Lewark, 2005 (this vol.)).

Summarized these named aspects become visible in structures and processes in organisations (you may say: An *organisation* (i.e. structure) has an *organisation* (i.e. processes)). This is a common subdivision in organisational textbooks, but (Schreyögg, 1999) states, that this concept has not been used much in practice. This subdivion in younger literature is rather neglected, work flow is seen structured from the start and structures and processes are seen together.

- Following this aspects which characterise systems of mechanised forest operations comprise:
- Ownership of forest and wood harvesting enterprise: type, size
- Working areas: concentration, sizes, distances
- Contract partners, type of contracts
- Wage system, level of wages
- Certification
- Staff: qualification, responsibilities, competences
- Turnover, recruitment, competition
- Machinery, equipment
- Quality management, environmental management, safety and health management
- Organisation of operations
- Working hours, shift system
- Further training

All this is influencing directly or indirectly, strongly or less organisation within enterprises, i.e. organisation in narrow sense. Within this framework we come to the "organisation of the organisation" and finally to the organisational embedding of the single working places.

Historical development and present situation of some of the framework on top of the list have been included in another review (Vik & Veiersted, 2005 (this vol.)) and will only be summarized in the following section as framework for work organisation.

Finally, the *impacts* of the organisational patterns for working conditions have to be examined (safety and health, job satisfaction, job attitudes, efficiency). With these points we best approach the ergonomic situation. But they have also been covered elsewhere (Vik & Veiersted, 2005 (this vol.); Jones et al., 2005 (this vol.)) and must not be repeated here in detail.

So the focus of this review will be clearly and decidedly on the organisation in the narrow sense. But the aspects listed above do not all seem to be covered by the MTO model and the five headings by Strohm (1997). So how to structure the search and the findings?

Strohm's definition is very much concentrating of division of work, roles as well as planning and control – thus not really including the important factors named by Jones et al. (2005 (this vol.)), as cited above.

Johansson Hanse & Winkel (2005) came through factor analysis of single items used in the enquiries of the *ErgoWood* project to factors and gave them the following five headings:

- Job control
- Variation
- Job rotation
- Breaks
- Rate of work

Johansson Hanse & Winkel (2005) looked at the impact on the "depending variable" job satisfaction in a first attempt (the impacts will not be cited here following the procedure not to include *ErgoWood* results into the reviews). For the purpose of the statistical analysis undertaken it has been useful to treat all factors respective the underlying single items as independent, but in the context of this review job control and job rotation (perhaps even as part of job control) are considered independent. But variation was considered as resulting, where rate of work here is on a different level of consideration and certainly dependent of the framework.

Connecting these five headings from Johansson Hanse & Winkel (2005) to the MTO model we find:

- *Job control:* Immediate result of Organisation or rather constituent element, partly influenced by Man, but predominantly influence on Man: Main question: Who decides about what?
- *Variation*: Between Organisation and task in the center of the model: If the task is uniform and limited, there is little room for organisational enlargement of variety – if there is room, this has consequences for the single working place, in this case that of an machine operator; besides: The term variation refers to task and impact on the operator; seen from organisational side it would be connected to job division.
- *Job rotation*: Pure organisational decision, under Organisation (and under job control, if this is including the basic decisions of the organisation and not only decisions on operational level).
- *Breaks*: Same as job rotation; besides: Number of working hours are not part of job rotation, rather of work structuring.
- *Rate of work*: Could be same as job rotation, but also partly determined by Techniques (though that is not automatism, but a question of decision – and connected to the nature of the task) and determined by framework (economical pressure).

Consequently the structure to be used here, after the framework in the section below, will be modified to *decision making, work division* and *work structuring*.

Framework for work organisation in mechanised forest operations

"The introduction of machines into the wood harvesting business has led to rapid changes in the way operations are organised." (Vik & Veiersted, 2005 (this vol.)). The authors state, that connected to the introduction of mechanised working systems there was a general shift to contractors work. This general development of outsourcing is most advanced in the Nordic countries, but also to be found for instance in Germany. Now we have employed machine operators, employed by forest owners or by contracting enterprises of different size, and self-employed, the level of owner-operator – and special cases according to Lidén (cf. Vik & Veiersted, 2005 (this vol.)).

"The employed machine operator will most often have a normal working day compared especially with the contractor without employees. The machine operators seem to have better contact with other people during their working day than the contractors." (Vik & Veiersted, 2005 (this vol.)). This is illustrating, that in mechanised forest operations all aspects of organisation and their impacts for working conditions depend on the dichotomy of employed and self-employed machine operators, which in turn is very much connected to size of enterprises.

Typically all structures of work organisation reported here are to be found for employed labour, only partly transferable to self-employed wood harvesting, also only partly to small scale enterprises – most of the findings are valid for enterprises of certain minimum size, independent of employment by forest owners or contracting enterprises. So this is applicable to the traditional focus group of forest work science, employed labour – even if forest work science today is regarding contractors' work as well.

Looking at employed labour we find structural factors (and resulting impacts): This includes types of contracts (long term – short term) and conditions of employment (full time – part time – seasonal) as well as safety of working place. In all these respects there is a growing speed of changes (Vik & Veiersted, 2005 (this vol.)).

Also partly outside of single enterprises (wood owners or contracting enterprises) employing harvesting operators there are factors forming the framework for organisation like qualification system, labour market situation, demographic development, legal environment and collective agreements, economic situation of the forestry sector, situation of commissions, extent of utilisation of capacity of the enterprise and competence between enterprises. At the same time outside organisations come into the game as trade unions or forest entrepreneurs organisations. Again: The pressure from a difficult economic situation is directly on self employed, indirectly on employees.

Connected with this framework are areas of work (stable or varying, of different size), distances between working sites, frequency of change of working places, travelling hours, familiarity with working area and stands etc. – partly covered by Vik & Veiersted (2005 (this vol.)).

Other factors of framework for the organisations or parts of the working environment include image of the business and also the current certifications of processes and products from forestry and finally the general political developments and framework. Looking for instance at EU policy on Mainstreaming equal opportunities policies: Women and men (European Commission, 1997): "Employment is declining in typical traditional male jobs with traditional work organization, such as heavy manufacturing industries, and growing in the service sector, where women have a stronger position and where new ways of working are more developed. The question is whether the new organization of work, emphasizing social skills, broader skills and multi-tasks, can contribute to the promotion of equal opportunities." Even if we consider contracting business in forestry as service oriented we do not find any developments like that here – but a high number of women doing office work in family owned contracting enterprises.

Work organisation in the narrow sense is organisation within an enterprise and down to the level of single operations and working places. After having described in short or just mentioning some factors of organisation of enterprise and framework for it, the focus of the following chapter will be on work organisation in the narrow sense.

Patterns of organisation of mechanised forest operations

Decision making

Structures of decision making refer to the questions, who decides what on company level and on the levels of the work day and the single operation – and who may participate in decision making and responsibility. Whereas self-employed forest machine operators naturally decide for themselves employed ones principally are subjects to decisions from the management level of their enterprises. Regulations on decisions are different for different forest owner and contractor enterprise structures of different countries, partly according to collective agreements.

But even if principally decisions were managers' sake traditionally there was always a certain degree of freedom for decisions in forest work, for instance about the organisation of the working day or about number, time and length of breaks, as there was no permanent control of the working groups moving from one working place to another. This informal freedom applies more to organisation of the working day than to decisions on higher level, e.g. about purchasing and using of machinery or the way or sequence of tasks to do. Extent of control through superiors has generally decreased in the course of forestry as a whole becoming less intensive and introducing principles of lean management.

In general, transfer of decision to lower levels of the hierarchy in a company is part of the processes of lean management and thus part of rationalisation. But this way of rationalisation cannot just be introduced by the management – motivation of those who will participate in decision making and sharing responsibility must be prepared to seize it (Bullinger, 2000).

Extending power of decision on the executive level is often called autonomy of working persons at that level. Early, at least for German forestry the necessity of introduction of more autonomy into mechanized forest work has been articulated (Closen, 1984). A special and far reaching model of giving power of decision to the executive level is constituent of the part-autonomous group work, which has been introduced to Swedish forestry on a large scale, whereas in Germany is has been introduced later and only in a limited number of forest enterprises. Obviously the concept of part-autonomous group work is only working in enterprises which at least have one working group, thus not in very small contractors' firms.

Other work structuring concepts, especially the most mentioned and practiced concept of job rotation (see below under work structuring) rather enlarge variety of work and is not intended to enlarge autonomy (cf. Figure 4.1).

Introduction of part-autonomous group work in Sweden was mostly done in the 1990ies, and even later in Germany. Mühlsiegl (2003) studied the realized degree of autonomy among other characteristics of part-autonomous group work using the job diagnostic survey and proved the significant raise of autonomy in working groups after moderated introduction of part-autonomous group work (according to the Swedish concept "the strong team") in several forest enterprises in Rhineland-Palatinate. This was mainly in groups working motor-manually. Findeisen (2002) reports about similar experiences from mechanized working groups after introduction of part-autonomous group work according to the same model and by the same moderators.

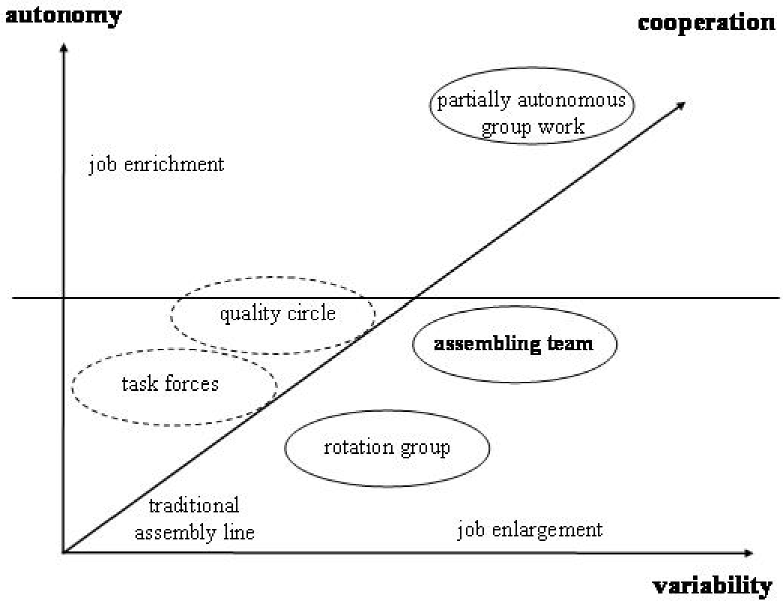

Figure 4.1 Degrees of autonomy, cooperation and variability of work in different concepts of work structuring (after Antoni, 1994).

Work division

Work division, i.e. allocation of different tasks in an enterprise to different levels of a hierarchy and to the single working persons on each level, is an essential part of the organisational constitution of a company. This is originally and principally one of the main decisions of the management, principles going back to Taylor (1911). Participation in work division may be using the experience of working persons on all levels. This would be a new approach, again giving autonomy to executive levels.

Reducing the degree of work division, which was most extreme in traditional assembly lines, and going back, at least partly, to carrying out complete tasks according to old structures of craftsmanship in approaching is one of the principles of good work of modern work psychology – the holistic approach. At the same time it would be enlarging variety of work during a work day, which is one of the main ways of lightening the stress of machine operators in mechanised forest operations (Gellerstedt et al., 1999). Work structuring concepts achieving this are job rotation, job enlargement and part-autonomous group work (see below under work structuring).

Arguments in favour of work division in mechanised forest operations and against job rotation sometimes heard: Highly sophisticated machinery may be sensitive to nonproper handling – proportions of productive hours versus maintenance hours are believed to depend on qualification of operators and numbers of operators per machine.

Work structuring

Work structuring comprises concepts like job enrichment, job enlargement, job rotation and part-autonomous group work. They have consequences for work division and their introduction is based on decisions of the managerial level of enterprises – lower levels of hierarchy may participate (see above). The concepts named will determine autonomy, variation and cooperation (Figure 4.1), all of them will influence job satisfaction, fatigue and strain. The same is true for shift work and working hours, but impacts will not be further described here.

Information on shift work and working hours, mainly in the Nordic countries, is given by Vik & Veiersted (2005 (this vol.)), for Germany there is more, but similar information by Hecker & Schmid-Vielgut (1998) and Hecker & Wurm (2000). Gellerstedt (1997) proposed and tested shift rosters in New Zealand.

The technologically highly developed machinery and equipment is demanding for big investments of the enterprises, which must pay, so this calls for maximisation of machine working hours. Together with the time restraints this may result in long working hours for the operators. But it must be stressed again: This is not a question of regulations and concepts for independent contractors: In contrast in employment regulated by collective agreements as in German state forest services numbers of working hours are clearly restricted by collective agreements to around 40 hours per week on five working days.

Effective work structuring concepts as well as shift systems and numbers of working hours have consequences not only for variation versus monotony of work and their impacts, but also for loneliness or contact.

The logistic demand from the wood processing industry (fresh wood, delivered just in time) leads to time restraints, which may be problematic with changing weather and resulting road conditions. High productivity also means high speed of work, which again means short times in single stands, moving often.

Jones et al. (2005 (this vol.)) list work patterns particularly significance worthy of consideration for control and monitoring:

- Regular breaks and a relaxed working technique
- Physical exercises
- Job rotation

Conclusions

A great number of statements and articles from practical forestry as well as from forest operations research and work science are indicating, that development of work organisation in mechanised forest operations is highly dynamic.

The driving force seems to be in the first place the difficult economic situation leading to a permanent need of rationalisation, in all ways. The fast technical development has reached a extremely high standard, for forest machinery as well as for information and communication equipment. Organisational means of rationalisation are working towards lean management structures accompanied by reduction of number of staff – and outsourcing.

This leads on the personal side for the machine operators, employed or self-employed to a demand for improved qualification and competences, and in many places it seems to be difficult to find and hire sufficiently competent personnel. For the self-employed it sometimes seems to be working without limits and work at any price.

This we knew at the start of the *ErgoWood* project, but the reviews collected a lot of proof of mechanisms of cause and effect, including functioning of organisational concepts and measures.

For the employed staff and much more for self-employed machine operators all this is leading to a densification of work within the working hours (need for breaks), for more working hours (especially in contracting business) and to shift work and work in the dark.

There is a need to lower this burden as stated in many places in this volume, and work organisation seems to be particularly promising. But the most simple approach of limiting the numbers of working hours and thus limiting the time of exposition to stress seems to be most difficult to realise. So within a given number of working hours all ways of variation of tasks must be tried. This includes job rotation and giving power of decision and planning and controlling tasks to the executive level, in other words raising autonomy. Most promising in this respect is the concept of part-autonomous group work.

So ergonomics for mechanised working places today is not a problem any more, which would require basic research and risk analyses and subsequent development of measures of health protection. It is rather a problem of implementation – and this is the big challenge of today for work science and practical forest work.

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Literature survey on costs to and benefits from a better work environment

F. Bohlin

Abstract

The literature review was undertaken to identify results from and methodology for cost-benefit analyses of ergonomic interventions in forest harvesting. Many case studies of illness costs and ergonomic interventions have been identified. Main benefits of ergonomic investments on company level include evaded illness costs and improved productivity. In reported cases, pay-back times range between four months and two years, largely due to productivity gains. Three methods for costing illness and ergonomic investment have been identified. Costing of single investments, costing of systematic work environment monitoring and costing of illness in forestry work. Whereas the methodology of cost-benefit estimation is well established, its application to ergonomics is very difficult for three main reasons. The incidence of illness and accidents may be uncertain within a small company, the exact impact of illness on productive performance is unclear and the effectiveness of measures to counteract illness is frequently difficult to estimate.

Introduction

Occupational safety and health problems are dominant to working life. According to the 1996 Survey on Working Conditions in Europe 54% of workers work at a very high speed and 25% do so on a permanent basis. 37% of workers perform monotonous work consisting of short repetitive tasks and 57% make repetitive movements of hands and arms. High level of noise is experienced by 28% and painful postures by 45% (Costa and Verborgh, 1997).

How do these stress situations, these unhealthy situations, translate into direct illness costs? Solid statistics are unavailable, Swedish and Norwegian studies indicate that work-related diseases make up 20-30% of total number of occurrences of diseases. More generally it has been estimated that work related illness translates to a cost of 1-4% of GNP (Mossink, 1997).

General cost-benefit analysis is widely used within economics to analyze investment decisions and production management. The main difficulty of performing cost-benefit analysis remains with acquiring input data, which data to incorporate in the analysis, how to access data and, since the analysis is generally concerned with future developments, selecting the appropriate discount rate. Cost-benefit analysis of occupational health and safety measures is not so well documented a field, particularly for enterprises (Oxenburgh, 2004). The occurrence and consequences of work related illness are difficult to foresee exactly, especially for the small enterprise. Cost-benefit analysis of ergonomic investments is rendered more difficult since there is no clear cut framework for costing illness. National standards vary substantially regarding the classification of illness, e.g. whether a medical certificate is needed, the extent of cost coverage for illness, and what costs are allocated to the individual, the company and the state (see below) (Grundemann and Vuuren, 1997).

Method of scientific review

The scientific review was undertaken with the purpose to establish the state of the art of cost-benefit analysis of ergonomic interventions in forest work and forest machines. The survey has been carried out using the search terms cost benefit, cost effectiveness and cost efficiency combined with forestry, machine operator and ergonomics. Data bases used in a first attempt were:

Data base/Journal	Number of articles
CAB, Econlit	8
AGRIS	8
LIBRIS (All Swedish university data base)	20
Wiley Publishers, e.g. Human factors and ergonomics in manufacturing, American journal of industrial medicine	35
Elsevier Science Ltd, e.g. International Journal of Industrial Ergonomics	8

No articles pertaining to forestry or machine operation and cost effectiveness of ergonomics were found. In subsequent searches more titles were identified by searches of other data bases (Web of science, Web of knowledge, Social sciences citation Index, Kluger publishers) and other key words, e.g. on “occupational” or “work place” instead of “ergonomics” or “benefits” instead of “costs and benefits”. Some focus has also been on work related musculo-skeletal diseases (MSD) since this is a major factor also in connection with machine operator health. Still nothing was found on cost-benefit analysis to ergonomic investments in forestry or machine operation. Since the topic is relatively new, appeals were also made to knowledge centres through networking in Sweden, Germany, France and the UK to identify studies which might have been carried out in the “grey zone” of non-refereed publication. One such study was identified in Sweden, “Det handlar om oss” (Arbetarskyddsnämnden, 2002).

Reference selection

The collected material was sorted and double references deleted. Articles have been retained primarily for their interest from a result or methodological point of view.

Costs at the individual and societal levels

A number of costs which fall outside the narrow sense cost-benefit considerations on company level must still be paid, either by the individual or by society.

The research on the individual level focuses on the costs which work related accidents and illness give rise to for the individual. Benefits are largely made up of evading some portion of these costs. The enumeration of individual costs may start with the fact that not all work related illnesses are reported. Punnett found in a study of auto manufacturing plants that only about 20% of workers with MSD symptoms had reported to the company’s medical department (Punnett, 1999). Similar findings, a reporting rate of 9-45% is reported by Biddle (1998). There may be a number of reasons for not filing for compensation, including fear of reprisal, a belief that pain is a normal reaction from work and a lack of management response on earlier reports. Effects of the illness will also in many cases remain long after the patient has been declared healthy, and there is danger of a repeated illness (Pransky et al, 2000).

Calculating the earnings lost by MSD is surrounded by a number of methodical difficulties. The "injury" is often treated as a short period prior to the first visit to the doctor (Biddle and Roberts, 2004). Next comes how to diagnose the severity of the pain and the extent of disability. And, in a last instance, how to calculate the compensation for the disability and compare it to a normal income. Going through this scheme, Biddle and Roberts estimate that the least severe injury group lose 16.5% of their previous earnings, while the most severe group loses 47.1% of their pre-injury earnings.

There is a strong link between the individually born costs and societal cost, and in fact Biddle's article is entitled "More evidence of the need for an ergonomic standard". A similar approach is entered by Weil (2001) who compares different methods of economic valuation of injuries and fatalities in a literature survey covering the last 25 years of experience of how to measure different aspects of economic consequences. He finds that estimates of the costs and injuries tend to underestimate the true economic costs from a social welfare perspective. Departing from a reasoning on disability pathways, which start with an illness or injury which then proceeds either to a fatality or an impairment, which may in the end turn out to be either temporal or functional, Weil deals with the question how these different stages are accounted for in different articles. A fatality may then be valued according to two principles. According to net present value of incomes foregone the value of a median life would be $890 000, according to WTP (willingness to pay) a medium value would be $3.7 million. Earnings losses due to work related illnesses may also show a very great variation depending on the severity of the illness and the method used. Lastly there are the costs of non-work disabilities including negative effects on household income, household activity and quality of life.

The social consequences of occupational injuries and illnesses (workers' psychological and behavioural responses, vocational functioning and family and community relationships) are rarely monetized. A literature review and development of a conceptual framework for how to develop the research on these issues was proposed by Dembe (2001). Even though Dembe does not pay particular attention to cost-benefit issues, the material gives a good background for identifying issues within this realm.

National legislation or regulation impose restrictions on different stake holders, a cost-benefit analysis is therefore frequently called for in order to prove the effectiveness of the intervention (Oxenburgh, 2004). Such an analysis was carried out for introducing an ergonomic rule for the prevention of MSD by the Washington State Department (2000). The rule is to provide ergonomics awareness education for workers in jobs exposed to work-related musculoskeletal disorders (WMSD), analyze the "caution zone jobs" for WMSD hazards and reduce exposure to identified hazards. Main costs were associated with time spent on investigating work environments and training personnel. Estimated cost-benefit ratio at a 50% effectiveness of the intervention programme was 4.24:1.

Costs at the company level

Company interest in safety and health is not only a matter of pure economics. National legislation or regulatory frame works will exert a strong influence (Oxenburgh, 1991). Within countries company strategies may vary according to company culture, company size, profitability and other factors (Oxenburgh, 1993). A self enforced ergonomic code of practice may be one way of adjusting for these differences, giving companies an indication of a common standard to refer to without needing regulation or legislation. (McLean and Richards, 1998).

The company costs due to illness which are to be mitigated by ergonomic interventions may be either direct or indirect. In a review on financial costs of occupational injuries it was found that the relationship between direct and indirect costs ranged from 1:1.58 to 1:20 with a median of 1:4.10 (Andreoni, 1986). The large variation is partly due to the variation of magnitude of indirect costs across industries, but also due to different classification of costs between researchers. The nominal salary cost is at the core of the direct cost, setting the level both for sick pay and temporary fill-in costs. Indirect charges, administration and productivity losses are then added to arrive at the indirect costs.

Hendrick (2003) outlines the likely company costs and benefits resulting from an ergonomic intervention. Under the cost side of the balance sheet there are: Supplementary personnel costs (e.g. sick pay, temporary extra personnel), equipment and materials, disruption of normal working and overheads. Under the savings side he identifies: Increased productivity, reduced errors and accidents, reduced training time, reduced absenteeism and personnel turn over, reduced maintenance, materials and equipment and an improved image of the company. To stress the importance of early ergonomic interventions Hendrick presents a scale of increasing costs over time to illustrate how they increase the later the intervention is made. He estimates that the costs range from 1% of total costs if initiated in the design and development programme to over 12% of the total budget by the time ordinary operations have been established. Hendrick also points to other factors which influence the success of ergonomic interventions such as management commitment, participatory ergonomics and integration with other improvement programmes.

Oxenburgh (1991) describes 60 cases of ergonomic improvements, primarily from the manufacturing industry. Typical pay-back times on investments ranged between 1 and 2 years, largely due to improved productivity in the new system solutions. (Method described in the following section, “Three models for economic evaluation of ergonomic interventions”.) Helander and Burri (1995) relate how the ergonomics and productivity programme at IBM was set up and its cost effectiveness. Management objectives were investigated in unstructured interviews, factory plants were investigated according to check lists, operators and first line supervisors were interviewed and field measurements were taken of light, sound and work station design. The shortest pay back time reported from the study was approximately one week, due to improved productivity. Oxenburgh (1997) describes two cases, one from a small manufacturing plant where the pay-back time was one month, the other from a large manufacturing plant where the pay-back time was 4 months. The short pay-back times were in both cases primarily due to increased productivity. Seeley and Marklin (2003) investigate a case which concerns the occurrence of two work-related instances of MSD within a large American electricity utility. The recommended solution, battery-operated presses and cutters, shows a pay-back time of four months (out of a projected operation time of five years). This pay-back time is solely based on reduced illness costs, no productivity increase is entered into the calculations.

A model for cost-benefit analysis of systematic safety work based has been presented by Harms-Ringdahl (1990). Four cases were investigated, two of which showed drastically reduced accident occurrence. Given the large uncertainty which surrounded many of the estimates, economic evaluation of outcomes were set for a “low benefit” and a “high benefit” case. Where accidents became less frequent this gave a good economical situation, in the other cases benefits arose mainly from an improved production. Capitalized benefits (10 years of operation time, 10% interest) ranged from 2.5 to 28 times the invested capital. (Method described in the following section.)

The only encountered costing tool for ergonomic interventions in forest harvesting is “Det handlar om oss” (Arbetarskyddsnämnden, 2002). Five historical cases of illness in Swedish forest harvesting were investigated concerning primarily MSD, musculoskeletal disorders (neck and shoulder pains) but also one accident. Total company costs for long-term illnesses including e.g. lost production, rehabilitation, switching to new tasks, recruitment of supporting personnel varied 3 000 to 180 000 Euro. Illness costs are then used as “critical values” showing possible investment volumes for specific ergonomic investments. (Method described in the following section).

Three models for economic evaluation of ergonomic interventions

The three models presented here have the common assumption that investment costs for interventions aimed at decreasing work related illness and injuries should be recuperated by the company through decreased illness costs and/or increased productivity.

The productivity model

A well established method for cost-benefit analysis of ergonomic investment measures at the company level is the productivity model developed by Oxenburgh (1991; 1997; 2004). The productivity model is a cost-benefit model designed specifically for work place health problems, it addresses the benefits that come from implementing ergonomic measures as well as costs evaded.

This presentation of the model is abbreviated, for a full account see Oxenburgh (1991). The model comprises calculation in eight steps. Steps one to five concern the true company cost of illness, steps six and seven concern the cost and effectiveness of ergonomic improvements, in step 8 the pay-back period is calculated.

Step 1
Calculation of the productive hours worked. First, the nominal hours paid for are noted as “available time”. Then, all legitimate absences from work are deducted (vacation, statutory holidays) since they do not make up for the productive time which is the basis for the costs of absence due to ill health. A quota for productive time is then calculated according to

$$Productive\ time = \frac{Available\ time}{Paid\ \ time}.$$

Step 2
Calculating the true salary cost. Apart from direct wages, all obligatory charges such as worker’s compensation, pay roll and other taxes and fees must be added. Apart from direct management/supervision costs there are also indirect costs for administration and overhead.

	Currency/year
Nominal salary	....
+ Obligatory charges (e.g. retirement, vacation, taxes)	....
+ Other charges(e.g. bonus)	....
+ Administration	....
= Average salary cost/year	....

This salary cost is then divided by the nominal hours worked and multiplied by the quota from step 1 to arrive at the average wage cost per employee and productive hour.

Step 3
Employee turnover costs. Calculating the recruitment, temporary personnel and training costs.

Currency/year

Recruitment cost (administration, advertisement, interviews, selection)...........................

Training cost (introduction, training, reduced production and quality) ....

If true turnover rates and the proportion that is related to illness are known the total costs can be divided by total man hours worked and added to the salary cost. This cost is then divided by number of employees and multiplied with the productive time coefficient to arrive at turnover costs/employee/productive hour.

Step 4
Productivity and quality losses due to illness. Calculating overtime, over-employment, substitution costs. Additional costs due to lowered production, reduced quality and potential loss of customers. Applicable cost categories, if information is available

Currency/year

Overtime...

Over-employment...

Substitution (products or services purchased)..

Lowered production ....

Reduced quality...

Loss of customers, slow delivery etc. ....

The items above are added to arrive at total company loss costs.......................................

If true loss costs are known the total costs can be divided by total man hours worked and multiplied with the productivity coefficient to arrive at productivity loss/employee/productive hour.

Step 5
Total costs for employment and production losses are added up from steps 2, 3 and 4.

Step 6
Estimated health and safety benefits. Benefits are made up of a reduction of the costs calculated in step 5 and, sometimes, productivity increases or other benfits. Benefits may include:

- Reduction of absence through illness

- Productivity increases through improved production design
- Other benefits.

Reduction of absence is never 100%. Measures are targeted for specific health problems (e.g. noise, MSD) and rarely 100% effective within that area. The benefits from reduced absenteeism will be a part of the costs derived in step 5 proportional to the effectiveness of measures taken. Productivity increases are added and a total benefit derived.

Step 7
Costs for improvement intervention. Costs may include e.g. personnel time, consultancies, protective equipment, engineering, new investment in machinery.

Step 8
Pay back period. The cost for the improvement is divided by the estimated benefit. If the benefit is a yearly amount, the pay-back time will be in years. (This is a model which works for small investments at specific points in time. For larger investments discounting will be needed.)

NB!
To small companies some costs, cf. employee turnover, quality and production losses due to illness may be very difficult to calculate. The effectiveness of introduced measures may also be very difficult to estimate. If no more specific figures are derived during the study, Oxenburgh suggests the following assumed effectiveness of ergonomic measures:

- Engineering solutions: 70-90%
- Protection (e.g. noise): 40-70%
- Work method, organisation: 20-50%
- Education alone: 10-20%

Accounting for systematic safety work

Many cost-benefit calculations target just one investment. However, to properly account not only for single investments but for the totality of work environment improvement we need a larger model to account for all activities which may be appropriate. Harms-Ringdahl (1990) analyses a model for systematic safety work built on three steps or stages, 1) system investigation (e.g., accident investigation, resulting in suggestions for improvements), 2) implementation of measures and 3) system operation.

- The cost for system investigation is mainly working time. Benefits occurring already at this stage are incremental changes and that people participating in the investigation often get a good training.
- Implementation costs include investment for equipment, installation, design, documentation, training. Benefits which may occur during this phase are mainly concerned with potential improvements in design of operations also from a production point of view.
- When the system is in operation costs may involve a slower working procedure, there may also be more maintenance called for. Benefits are fewer and less severe accidents and illnesses, reduced risk for production disturbances and other risks and a generally improved workplace design which stimulate individuals to increase productivity and quality.

Costs and benefits to systematic improvement of work environment

Case	A		B		C	
Activity Estimate	Low	High	Low	High	Low	High
System investigation						
Costs						
- Investigation						
Benefits						
+ Replaced activity						
+ Education						
Sum investigation costs						
Implementation						
Costs						
- Investment						
- Time delay						
Benefits						
+ Implementation						
+ Time saved						
+ Design process						
Sum investigation + implementation costs						
System in operation						
Costs						
- Reduced Production						
- Other demands						
Benefits						
+ Reduced illness						
+ Reduced accidents						
+ Production system						
+ Work situation						
Sum of benefits per year						

Investment criteria through ill-health cost scenarios.

During 2001-2002 a material concerning illness costs among machine operators in Swedish forestry was developed by the worker protection agency and three labour unions. Five cases were investigated. Identified cost categories included lower operator performance, loss of production through machine stand still, overtime payment, damage to machinery, rehabilitation, job switching, administration and recruitment/training. It is considered that it takes three years to reach full productivity for a new harvester operator, involving costs for lost production to a value of 500 000 SEK (60 000€).

Four different illness cost scenarios were then developed. The first scenario involves remaining personnel working harder to recuperate for the absence of their colleague, a possible solution in the short run but not sustainable for a longer period. A next scenario involves production loss which cannot be recuperated. In a third scenario the absence is considered to be filled in by a replacement. In a fourth case there is a low demand for timber and no irredeemable costs occur. Illness scenario costs are then used as "critical values" showing possible investment volumes for specific ergonomic investments.

Costing is simplified compared to the methods put forward by Oxenburgh and Harms-Ringdahl. To account for the cost of production loss standard concepts are used. Production value is equal to the price paid for the harvesting or forwarding service, the profit contribution is equal to the production value less variable costs. A standard for accounting for production loss looks like the following.

	Costs of lower performance at work due to illness
Profit contribution (PC) (Production value-variable costs)...	€/hour
Lowered production due to illness	%
Cost of lost production (PC*decreased production*number of hours)..........................	€
Other replacement costs, e.g. overemployment (€/hour*hours applicable)..................	€
Total costs (production loss+other replacement costs)	€

A machine stand still due to illness without replacement means losing the full profit contribution (100%). Total salary costs are calculated as nominal salary multiplied with supplementary charges. The model is further developed to include cases when there is a replacement worker filling in. However, in this study personnel costs vary according to Swedish standards (e.g., no compensation (or salary) paid for the first sick day, 80% of the salary paid by the company for the first two sick weeks). To account for operators being at home sick therefore depends on during what time the operator is sick and also involves calculating the difference between decreased ordinary salary costs and costs for overtime. Additional costs may involve rehabilitation, repairs for machinery, administration.

The five "case costs" and additional calculations of costs for machine stand still due to illness or overtime costs are then used to illustrate the funds which are available for ergonomic investments in e.g., training, work organisation, health monitoring etc.

Literature review on cost and benefits implications to ergonomic investments in forest harvesting

Work related illness

Work related illness may be far more frequent than is shown by official statistics, as indicated by worker reporting rates of MSD symptoms of only 9-45% of the true extent. There may be a number of reasons for not filing for compensation, including fear of reprisal, a belief that pain is a normal reaction from work and a lack of management response on earlier reports. Effects of the illness will also in many cases remain long after the patient has been declared healthy, and there is danger of a repeated illness. Work related illness may therefore be far more costly on company level than indicated by summary statistics.

Profitability of ergonomic investments

The scientific review identified many cases of positive benefit/cost ratios for ergonomic investments, usually in manual work in manufacturing and service industries. Pay-back times generally ranged between four months and two years. The positive benefit/cost ratio was frequently heavily influenced by substantial productivity gains in the new production systems, covering the costs. These production benefits may be difficult to reach in modern mechanised forest operations

Company models

Three models for the accounting of costs and benefits of ergonomic interventions on company level were identified. The productivity model (Oxenburgh, 1991; 2004) serves primarily to analyse single investments. To include costs also for monitoring another way of costing ergonomic intervention could be by following the cycle of (old) system investigation, system improvement and (new) system operation. Costs occur primarily during the first two phases, benefits largely during the third phase (Harms-Ringdahl, 1990). A last model estimates the costs of work related illness in forest machine operation based primarily on costs for lost production and increased salary costs (Arbetarskyddsnämnden, 2002). Case experience and scenario costs are then used to illustrate the available room for ergonomic investments.

Abstracts and summaries

Andreoni, D. 1986

The costs of occupational accidents and diseases. International Labor Office: Geneva. 142 pp.

The book contains a summary of the thinking and state of the art of costing of occupational injuries and their prevention at the time. Methodological section on methods of calculating and allocating cost. Separate sections dealing with costs for workers, costs for enterprises, administrative and governmental costs and national costs. Extensive reference section.

Arbetarskyddsnämnden. 2002

It’s all about us. Stockholm. (Mimeo; in Swedish)

The mimeo provides an overview of how to account for costs related to work related accidents and illness in forestry. Costs may include abuse of machinery and production losses as well as sick leave and rehabilitation. During 2001-2002 a material concerning illness costs among machine operators in Swedish forestry was developed by the worker protection agency and three labour unions. 5 cases were investigated concerning primarily MSD, musculoskeletal disorders (neck and shoulder pains) but also one accident. The illness cases were documented for production loss, different illness and treatment costs, machine damage, rehabilitation and training and working with other tasks than machine operation. Total company costs for illnesses including e.g. lost production, rehabilitation, switching to new tasks, recruitment of supporting personnel varied between 3 000 and 180 000 Euro. Different illness scenarios were then developed and ensuing costs calculated. Illness scenario costs are then used as “critical values” showing possible investment volumes for specific ergonomic investments.

Ashford, N. 1997

The importance of taking technological innovation into account in estimating the costs and benefits of worker health and safety regulation. in: Costs and benefits of occupational safety and health. Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health, The Hague, 1997. 69-79.

Regulation of worker health and safety is acknowledged to result in better health benefits to workers and economic costs to employers. However, the history of OHS regulation in the United States during the last twenty years reveals that this is a simplified view which neglects the important role that technological innovation plays in 1) reducing the actual costs of compliance, 2) yielding a benefit in terms of saving material, water, and energy costs and 3) changing the nature of process and product technology. It has been found that 1) technological innovation has been pushed by stringent regulation and 2) traditional cost-benefit assessments performed prior to a standard’s implementation failed to anticipate significant economic benefits accruing to the innovating industrial firm.

Beevis, D. 2003

Ergonomics: costs and benefits revisited. Applied Ergonomics 34, 491-496.

An earlier review reported a dozen cases where ergonomics applications had resulted in cost savings. A large number of publications which refer to the topics of the cost-effectiveness and cost-benefits of ergonomics can now be found. However, data showing the value of ergonomics applications remain scarce. Cost-benefit and cost-effectiveness studies are difficult to conduct for a number of reasons. While it is unlikely that the general case for the value of ergonomics can be proven, ergonomists must be in a position to discuss the potential costs and benefits of their work with clients. The Business case model is suggested as one way to structure an analysis of where a potential ergonomics application might reduce the risks to costs or the possibility of lost benefits.

Biddle, J., & Roberts, K. 2004

More evidence of the need for an ergonomic standard. American Journal of Industrial Medicine 45, 329-337.

In 1999, the Occupational Safety and Health Administration (OSHA) proposed regulations designed to reduce work related inquiries by limiting worker exposure to ergonomic risk factors. Congress subsequently overturned the regulations. We provide additional evidence on earnings losses attributable to musculoskeletal disorders (MSDs), and thus on the need for an ergonomic standard. Regression techniques are used to analyze data from a survey of injured workers that has been matched to employer-reported earnings data covering pre- and post-injury periods, and to workers’ compensation claims records. MSDs lead to large and persistent earnings losses. Cost estimates used by OSHA to justify the 1999 EPS are corroborated. Losses are greatest among workers who file workers compensation claims, but nonclaimants also have losses. Earnings losses and lost productivity associated with work-related MSDs are substantial and an ergonomic standard could be cost effective.

Boden, L. I., & Galizzi, M. 1999

Economic consequences of workplace injuries and illnesses: Lost earnings and benefit adequacy. American Journal of Industrial Medicine 36, 487-503.

This is the first study based on individual data to estimate earnings lost from virtually all reported workplace injuries and illnesses in a state. We estimated lost earnings from workplace injuries and illnesses occurring in Wisconsin in 1989-90, using workers' compensation data and 6 years of unemployment insurance wage data. We used regression techniques to estimate losses relative to a comparison group. The average present value of losses projected 10 years past the observed period is over $8 000 per injury. Women lose a greater proportion of their preinjury earnings than do men. Replacement of after-tax projected losses averages 64% for men and 50% for women. Overall, workers with compensated injuries and illnesses experienced discounted pre-tax losses projected to total over $530 000 000 (1994 dollars), with about 60% of after-tax losses replaced by workers' compensation. Generally, groups losing over eight weeks' work received workers' compensation benefits covering less than 40% of their losses.

Costa, J., & Verborgh, A. 1997

Stress among European workers. in: Costs and benefits of occupational safety and health. Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health, The Hague, 1997. 299-306.

Dembe, A. 2001

The social consequences of occupational injuries and illnesses. American Journal of Industrial Medicine 40, 403-417.

Most outcome studies of occupational injuries and illnesses have tended to focus on direct economic costs and duration of work disability. Rarely have the broader social consequences of work-related disorders or their impacts on injured workers' families, coworkers, and community been investigated. This paper examines a wide range of social consequences including workers' psychological and behavioral responses, vocational function, and family and community relationships. Complex and multifactorial relationships are described whereby occupational injuries and illnesses produce a variety of social consequences involving filing and administration of workers' compensation insurance claims, medical care experiences, domestic function and activities of daily living, psychological and behavioral responses, stress, vocational function, rehabilitation and return to work and equity and social justice. A research agenda is proposed for guiding future investigations in this field.

Harms-Ringdahl, L. 1990

On economic evaluation of systematic safety work at companies. Journal of Occupational Accidents 12, 89-98.

A simple model was developed for cost-benefit evaluation of safety improving measures at companies. Economic values were estimated for a number of items, which fall in three main categories. These are system investigation, implementation of measures, and the effect on the improved system. A description of the application is given in four case studies. One study concerned the application of accident investigation. In three studies safety analysis was applied on work places at factories. The economic calculations gave positive economic results in all cases. In the case of accident investigations a reduced number of accidents gave a good economy. In the other studies a major part of the benefits came from production improvements. One conclusion is that the model worked practically for the estimation of costs and benefits for safety work. However, there are large uncertainties in the estimations, which make it advisable to present both high and low value results.

Helander, M. G., & Burri, G. J. 1995

Cost effectiveness of ergonomics and quality improvements in electronics manufacturing. International Journal of Industrial Ergonomics 15, 137-151.

This paper describes the increasing emphasis on ergonomics in the manufacturing plants of IBM. Since 1978, 250 000 engineering hours have been devoted to ergonomics training. As a result a systematic approach to ergonomics improvement of manufacturing facilities has been implemented. This involves an analysis of the production environment including equipment, processes, ambient factors and job procedures. Information is collected through interviews of management, operators and first-line supervisions and complemented thorough field measurements of ergonomic parameters. Individual workstations as well as processes are analyzed with the purpose of modifying processes, reallocating tasks between automated devices and human operators and optimizing workstation design. Four case studies of industrial improvements are presented and analyzed in terms of improved productivity, quality and reduction of injuries. All four studies proved to be good investments. Since its implementation around 1978, it is estimated that ergonomics improvements have resulted in cost savings of approximately $130 million.

Hendrick, H. W. 2003

Determining the cost-benefits of ergonomics projects and factors that lead to their success. Applied Ergonomics 34, 419-427.

Managers usually can justify financially supporting a proposed ergonomics project only when it is supported by a sound cost-benefit analysis. The factors to consider and sources of information for calculating the costs and benefits of proposed ergonomic projects are described. Based upon his experience and review of numerous ergonomics projects, the common characteristics of successful ergonomics interventions gleaned by the author are described and then illustrated by actual documented cases.

Johnson, W. G. 2000

Outcomes in work-related upper extremity and low back injuries: Results of a retrospective study. American Journal of Industrial Medicine 37, 400-409.

A mailed, self-report survey measuring multiple dimensions was conducted. Identified through the New Hampshire Division of Workers' Compensation First report of injury database, a sample of workers with injuries to their lower back (60%) or upper extremities (40%) a year prior to the study were surveyed. Response rate was 80% (N=169; upper extremity cases=70; low back cases=99). Most (82.8%) were working one year post-injury. Over half reported residual effects of the injury on work or activities of daily living. Many working subjects reported persistent injury-related anxiety and pain at the end of the work day, worse in those with low back pain compared to those with upper extremity injuries. Almost 40% of those who returned to work suffered a reinjury. 44% of respondents suffered significant injury-related financial problems, which were worse in those who had been out of work for longer periods. Occupational musculoskeletal injuries do result in significant, long-term adverse physical, economic, and psychological consequences, as demonstrated in self-reported surveys.

Lehmann, E., & Thiehoff, R. 1997

What answers do we have? A presentation of cost-benefit studies. in: Costs and benefits of occupational safety and health. Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health, The Hague, 1997. 36-46.

National economics perspectives are compared to business economics perspectives. Comparisons are based on theoretical reflection and German, Danish and Swedish national statistics on e.g., absenteeism, production losses are compared. Business examples include a case from Volkswagen.

McLean, J., & Rickards, J. 1998

Ergonomics codes of practices: The challenge of implementation in Canadian workplaces. Journal of Forest Engineering 9(1), 55-64

Despite a reduction in the workplace injury rate for most industries in Canada, the number of compensation claims for the Canadian forest industry is not declining at a comparable rate. While mechanisation, particularly of tree harvesting operations, has improved injury rates in the last 5 to 7 years, the forest industry, along with similar labour-intensive industries such as mining, construction, and agriculture, continue to have unacceptable health and safety records. This review of ergonomics codes of practice focuses on the issue of implementation, as perceived by the three major stakeholders, management, employees and their unions and government. Barriers to implementation and successful programs are discussed, as is the use of benefit/cost analysis as one measure of success. Three examples of successful ergonomic interventions in Canadian forestry (maintenance shops for forestry equipment), manufacturing and healthcare are detailed to illustrate the effective use of benefit/cost analysis as a measurement tool, and as the potential path to the implementation of universal codes of practice.

Mossink, J. 1997

Costs and benefits of occupational safety and health. in: Costs and benefits of occupational safety and health. Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health, The Hague, 1997.

Occupational health is an economic factor. At the macro level there is an effect on total economic efficiency, losses (or availability) of resources and financial costs. There is an influence on the distribution of financial revenues and costs between individuals, companies, insurance and society. At the sector and company level, compliance with regulations and standards may pose a cost factor for certain sectors, this may affect international competitiveness. Within companies preventive policies have both costs and benefits. Costs may consist of preventive action and corrective costs (damages to health, absenteeism, or legal damages). Benefits can be monetary (reducing the corrective costs) but can alsobe expressed in terms of morale, productivity or quality gain. The employees are directly affected by ill health in many economic and other ways. The international perspective is important.

Oxenburgh, M. 1991

Increasing productivity and profit through health and safety. CCH international. 309 pp.

A cost-benefit analysis method of calculating the cost of employment and ill health is elaborated (see abstract for Oxenburgh, 1997 below). The method is then applied in 61 case studies where different work situations and stations in different industries are studied and evaluated from both production, profit and health perspectives. The work considered is usually manual work. Direct calculations of monetary costs and benefits are sometimes included.

Oxenburgh, M. S. 1997

Cost-benefit analysis of ergonomics programs. American Industrial Hygiene Association Journal 58, 150-156.

A cost-benefit analysis method for calculating the cost of employments is described. The purpose is to portray, in financial terms, the benefits to health, productivity, and quality brought about by improved working conditions. The analysis can be used to measure the financial benefits after the completion of changes to working conditions, or it can be used to show the potential value of proposed expenditure (improvements to working conditions) and thus compete for resources on an equal footing with other enterprise proposals. The cost-benefit analysis may also be used as a sensitivity analysis to detect areas of high labor costs (e.g. high injury absences) and/or productivity losses (e.g. low quality of service or product) and thus direct workplace improvements toward these areas, if appropriate.

Oxenburgh, M., Marlow, P., & Oxenburgh, A. 2004

Increasing productivity and profit through health and safety: The financial returns from a safe working environment. CRC Press: Boca Raton, FL.

This is an updated version of Oxenburgh (1991). The methodology remains essentially the same. The economics section has been enlarged. There is an increased focus on management and decision making. A productivity assessment tool, which is an expanded version of the former cost-benefit analysis methodology, has been formalised and developed into an electronic tool. The cases still focus on manual tasks such as cleaning, lifting, welding, but modern sectors such as call cntres have also been added.

Punnett, L. 1999

The costs of work-related musculo-skeletal disorders in automotive manufacturing. New Solutions 9, 403-426.

Seeley, P. A., & Marklin, R. W. 2003

Busines case for implementing two ergonomic interventions at an electric power utility. Applied Ergonomics 34, 429-439.

Ergonomics analysis of line workers in the electric power industry who work overhead on utility poles revealed some tasks for which less than 1% of the general population had sufficient strength to perform. During a 2-year study, a large Midwestern US electric utility provided a university with a team of represented workers and management. They evaluated, recommended and monitored interventions for 32 common line worker tasks that were rated at medium to high magnitude of risk factors for musculoskeletal disorders (MSDs). Two of the recommended ergonomic interventions – the battery-operated press and cutter – were selected by the team as having the greatest potential for reducing risk factors of MSDs. Only overhead distribution line worker tasks were evaluated. A business case was formulated that took into account medical injury and illness statistics, workers’ compensation, replacement worker and retraining costs. An outline of a business case formulation and a sample intervention payback calculation is shown. Based on the business case, the utility committed over $300 000 to purchase battery-operated presses and cutters for their overhead distribution line crews.

Washington State Department. 2003

Cost benefit analysis of the ergonomics standard. Web publication. http://www.lni.wa.gov/wisha/ergo/default.htm. Accessed 04/04 2003.

The cost to society from work related musculoskeletal diseases (WMSD) is sizable. The department estimates the total cost of WMSDs to the employees and employers of the state at $1.56 billion per year. To counteract WMSD, the time and cost requirements for businesses to comply with an ergonomics rule have been calculated. Total annualized compliance costs for all businesses in the state were estimated at $80.4 million, or $37.77 per employee. The social benefits from the ergonomics rule are the cost savings associated with the decrease in WMSDs that follow the reduction of WMSD hazards in the workplace. It is estimated that the ergonomics rule will prevent 40% of WMSD injuries and 50% of WMSD costs once all programs are fully effective. It was estimated that the annualized present value of compliance costs for the ergonomic rule is $80.4 million and the annualized present value of social benefits is $340.7 million. Comparing the costs and benefits of the rule demonstrates that the benefits to society greatly exceed the costs of compliance: A benefit-cost ratio of 4.24 to 1.0.

Weil, D. 2001

Valuing the economic consequences of work injury and illness: A comparison of methods and findings. American Journal of Industrial Medicine 40, 418-437.

This paper compares methods of economic valuation, focusing in particular on how different methods diverge to varying degrees from measuring the true economic costs of injuries and illnesses. In so doing, it surveys the literature that has arisen in the past 25 years to measure different aspects of economic consequences. Estimates of the costs of injuries and fatalities tend to understate the true economic costs from a social welfare perspective, particularly in how they account for occupational fatalities and losses arising from work disabilities. Although data availability often makes estimation of social welfare costs difficult, researchers should attempt to more fully integrate such approaches into estimation procedures and interpretation of their results.

Zangenmeister, C. 1997

Health management, efficient planning, evaluation and implementation of occupational health using multi-level cost-effectiveness analyses. in: Costs and benefits of occupational safety and health. Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health, The Hague, 1997. 345-355.

A model is proposed whereby the management of occupational health and safety measures could be handled within a total quality management framework. A target frame for the OSH measures will then be decided by corporate policy. The one-dimensional method of purely monetary profitability analysis is discarded in place of a multidimensional system-analytical solution. Methodological instruments to use are cost effectiveness analysis in combination with a relevance tree. The methodology proposed has not been put to practical testing.

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Scientific review of controlling and monitoring systems

W. M. Jones, C. Saunders & J. D. Neil

Abstract

The health of harvesting machine operators is not only affected by the ergonomics of machines, but also by the ways in which work is organised and managed. Once having decided upon specific means of organisation and management to best meet the needs of a particular organisation, company or job, those decisions have to be implemented and then the effects should be monitored and controlled to ensure the changes are achieving the required results.

This scientific review was to identify the various factors affecting operator health which specifically require monitoring and controlling systems, the priority of each of the elements requiring control, factors affecting effective control and problems with achieving control.

The factors which were identified as being of particular concern, require management and which should be considered for inclusion into operator health monitoring and controlling systems were: Work scheduling and organisation, including length of hours worked, job rotation, shift working; working environment including co-worker relationships, communication styles and stress management; crew and operator selection processes; training and education processes; factors affecting machine procurement and maintenance.

The factors considered to be of particular significance in achieving effective implementation of monitoring and controlling systems were found to be: Open and inclusive communication between all levels within the organisation and others with influence e.g. customers; effective support systems including development of long term plans and management commitment; adequate resourcing (financial, time, etc.) and external expertise provision where required; appropriate training at all levels; effective staff selection processes; health monitoring and reporting systems sensitive to the concerns of operators that reporting any of their health problems may be detrimental to their continued employment or earning capacity.

Monitoring should include factors other than health to ensure the effects of implementation of any changes, on all aspects of organisational performance e.g. profits, efficiency, customer satisfaction etc.), are taken into account.

Introduction

This report is one of the scientific reviews undertaken for ErgoWood – Ergoefficient mechanised logging operations. The other elements of the scientific review deal with a) Factors influencing the machine operators health; b) Machine ergonomics including standards (ISO, CEN, etc.) and ranking of measurement methods and needs for development; c) Work organisation; d) Implementation and intervention.

The objective of this particular scientific review may, to some extent, overlap with the interest of the other parts. However, it is the intention of this report to:

- Identify those elements of the various factors affecting operator health which specifically require controlling systems
- Attempt to identify the priority of each of the elements requiring control

- Identify factors affecting effective control and problems with achieving control
- Identify recommendations from previous studies with regard to systems of control

It is appreciated that considerable guidance and regulation (e.g. ILO, CEN, national Health and Safety Organisations guidance) is already available with regard to the management of Health and Safety at work in general and Health and Safety in forestry work in particular. It is not the intention of this report to develop new systems or standards where such guidance fully meets requirements. These general standards and requirement will be mentioned in this report and where appropriate the particularly relevant elements of such guidance will be identified. The main body of this report deals with scientific papers, which will enhance the guidance available from the more general guidance as described above.

Factors considered in the review

See Appendix 6.1.

Scientific papers considered

49 papers were initially sourced (see references) of which 22 were considered to be of particular relevance to this review. These are listed in Appendix 6.2 with summaries for each.

Of those considered of particular relevance, 9 were reviewed in some detail as follows:

Managerial and operational characteristics of "safety successful" harvesting contractors

Reisinger, Sluss, & Shaffer. Forest Products Journal 44(4), 72-77. 1994. (English)

Level of development or application of controls

Team work and delegation of responsibility to crew and operators in order to reduce the need for supervision to maintain standards was considered to be important to a high proportion of safety conscious crews.

Management commitment to safety was recognised in those teams, which were safety conscious.

Specific aspects identified as being important

Resourcing of crew/operator compensation/benefits
There was recognition that in order to retain experience and skilled crews, competitive wages and benefits had to be paid (paid holidays, transportation to job, health insurance etc.). Some believed hourly payment was better than payment by output but this association was not found in the study.

Machine selection
Contractors believed that the use of mechanised equipment reduced the frequency of accidents but no views were produced in this report on specific machine selection.

Crew/operator selection
Crew/operator selection was identified as a very important factor in maintaining a stable crew and operating safely.

Safety and training
Very few had a formal safety program for meetings or training. It was expected that all aspects of health and safety were a normal part of the operation of a well managed harvesting business not a separate or distinct component.

Discussion

This report was based on an interview of 26 successful loggers in the eastern United States and provides reasonably robust findings.

Although no information was available on specific controlling or monitoring systems, it does help to identify what aspects of management style, resourcing, operator selection and training they considered to be particularly relevant to high standards of health and safety. This is helpful in informing the project on where controlling systems would be of particular benefit.

New ergonomic problems in mechanised harvesting operations

Axelsson & Pontén. International Journal of Industrial Ergonomics 5(3), 267-273. 1990. (English)

The structure of communicating and support systems

It is important to evaluate effects of changes on other performance factors (outputs, quality, efficiency etc.).

Three main areas affect the working environment – technical, organisational and individual.

Level of development or application of controls/advice support

Increasing motivation and involvement of all parties involved is necessary.

Individual prescriptions are appropriate (i.e. exercise regimes are recommended etc. and the support of a physiotherapist is recommended).

Individuals have different limits and therefore appropriate standards can differ between individuals. This in conjunction with the fact that different organisations and jobs can have different requirements results in the need to tailor controls and standards to individual circumstances.

The aspects of management which require control

Working limits or risks result from the combination of various factors which all should be considered as a whole.

Individuals have different working limits depending on physical and sociological status. This limit can be changed by environmental conditions (e.g. cold or fitness level (training could increase limit)).

Work organisation has possibly the highest potential for improving the situation e.g. length of working shift, work tasks and responsibilities, job rotation, team work, motivation and payment systems.

Machine selection
The improvements in newer machines had not been enough to relieve the operators of symptoms or to prevent the development of new ones.

Shift working
The introduction to a 3-hour shift working pattern did not lead to the expected decrease in health complaints. It was considered that this could be due to operators working more intensively during the 3 running hours.

Discussion

This study used a high number (1 174) of machine operators in total (although sub-groups are often much less) and results are therefore robust. The above suggests that controlling systems and application of standards should take account of individual needs and local conditions and not be rigid rules applied to all in the same way or using the same standards or limits.

Controls should recognise the effects on other performance measures and not just health.

Controls should recognise the need for holistic approach to health management and not concentrate on individual aspects.

Commitment and co-operation at all levels is necessary. Any control system needs to take this into account seriously.

Motivation of the machine operator is important to ensure he maximises his influence on his situation. This would infer that good education of operators with regard to health risks and management plus good support from management and their recognition of the importance are also important.

Ergonomics codes of practice: The challenge of implementation in Canadian workplaces

McLean & Rickards. Journal of Forest Engineering 9(1), 55-64. 1998. (English)

The structure of communicating and support systems

Appropriate epidemiological monitoring should be performed and the public kept aware of the magnitude of the problem.

Benefit and cost analysis is an important element each time ergonomic intervention is made. This must be passed on to all levels for successful implementation.

Legislation can be passed once evaluation above has been completed.

Strategy should follow legislation.

Ergonomic standards are more easily applied incrementally particularly using cost-benefit examples.

Open communication between employers and employees is required where high risk is identified.

Level of development or application of controls or advice/support

Employees should be provided with sufficient education to identify the risks.

Employees should be involved in all phases of programme implementation.

The aspects of management which require control

Work organisation
Employees should not be told specifically how to perform tasks, as different techniques may be equally efficient. They should be simply able to identify those tasks, which have significant associated risk.

Health monitoring
Workers can be discouraged from reporting problems if there is a concern of loosing their jobs.

Employers can be reluctant to enforce change as it could incur costs.

Discussion

This is essentially a review of implementation of the codes of practice as perceived by the major stakeholders: Management, employees and their unions, and government.

It draws on work done by other researchers.

No specific systems are discussed but some principles of communication and provision of supporting information to encourage the implementation of standards by both employers and employees are given.

Exploring “stress among loggers”

Parker, Tappin, Ashby, & Moore. Report. LIRO: Roturua, New Zealand. 2002. (English)

The structure of communicating and support systems

A good remuneration system was important in controlling stress.

Workers from different companies differed significantly in their responses to questions about satisfaction. This indicates that individual analyses of actions required to monitor and control health are likely to be important.

Good co-worker relationships were important.

Level of development or application of controls or advice/support

A good supervisory style was important in reducing stress.

Job autonomy and flexibility was important in reducing stress.

The aspects of management which require control

Long working hours was a negative influence on stress.

Pressure to meet targets was a negative in managing stress.

The scale was found to be a useful predictor of intended job turnover, absenteeism, illness and injury, including musculoskeletal pain and psychosomatic symptoms in loggers.

Discussion

The forestry stress scale developed, which measures the incidence and extent of stress of loggers, could be useful as a monitoring tool.

The scale was developed using interviews from 56 loggers initially who highlighted issues and then 259 other workers responded to a questionnaire developed from the interview results. The results are therefore robust but their relevance to countries other than New Zealand would need to be verified.

The scale was found to be a useful predictor of intended job turnover, absenteeism, illness, and injury, including musculoskeletal pain and psychosomatic symptoms in loggers.

The findings of the study also could be helpful in recruitment selection.

The findings are also useful in identifying aspects of management style which affect stress (e.g. good supervisory style, need for co-operation, and relationships between staff and co-workers).

Documentation of hazards and safety perceptions for mechanised harvesting operations in east central Alabama.

Bordas, Davis, Hopkins, Thomas, & Rummer. Journal of Agricultural Safety and Health 7(2), 113-123. 2001. (English)

The structure of communicating and support systems

Dissemination of information was found to be a problem. None of the crews indicated that they used the internet to acquire safety information or were aware of the OHSA website. Information should be disseminated via companies, insures and academic activities.

Dissemination of information directly to operators was considered to be important, particularly regarding lessons learned information; i.e. identification of problems and solutions.

The information collection system should be non-punitive to encourage frank reporting.

However this is rather at odds with the additional finding that a fine/penalty system would encourage compliance of safety rules.

A user friendly image should be developed by the use of professional harvesting conferences, activities, and harvesting manager training.

The use of experience managers and operators with good records was considered to be a means of developing appropriate training.

Level of development or application of control or advice/support

The current level of penalties (low) was insufficient to motivate to comply with regulations.

Supervisors should visit sites more regularly.

Harvesting managers had insufficient knowledge of effective means of information dissemination or training for operators and crews.

The effect of implementation of new standards on productivity should be covered and the positive trade-offs emphasised.

The aspects of management which require control

Operator and crew training are currently of insufficient depth or breadth or not conducted at all.

Discussion

The sample used for the survey was from a limited area and not meant to be representative of the country. Values and attitudes to health and safety standards can vary considerably from country to country. However the findings could be used to give some guidance to those situations where the improvement to health and safety standards is trying to be attained.

Survey of the health and wellbeing of workers in the New Zealand forest industry

Thomas, Bentley, & Ashby. Report 2(5). Centre for Human Factors and Ergonomics, LIRO: Roturua, New Zealand. 2001. (English)

The structure of communicating and support systems

Self-perception of level of health did not correspond with the amount of sick leave taken. Any health monitoring programme should therefore recognise this and be objective.

The appropriate frequency of monitoring depends upon circumstances and local OSH branches can give useful advice.

Level of development or application of control or advice/support

Employers and others should place greater emphasis on providing sufficient and relevant information on hazards, their effects and controls.

The aspects of management which require control

Long hours are recognised as having health implication as well as efficiency implications but this is drawn from previous work rather than this study.

Discussion

The survey used a restricted sample size (274 employee questionnaires over 12 months) and non-random sample, i.e. where forestry inspectors were located.

The survey also had a limited number of employees over 44 years, which could indicate that older employees find the work too difficult or start developing health problems and leave. Any monitoring system therefore should include ex employees and reasons for leaving. This would also ensure that younger employees who leave because of health problems are included in the monitoring process.

Monitoring requirements can vary and the use of local health and safety organisations can be of assistance in advising.

Forest worker safety and health in Finland

Jokilouma & Tapola. Unasylva 44(175), 57-33. 1993. (English)

The structure of communicating and support systems

This paper identified the key principles of forest worker safety programmes in Finland:

- Constructive co-operation between all parties concerned at the national level and at the workplace
- Respect of the interests of all parties concerned
- Sustainable forest management and long term planning
- Effective training. Incorporating safety and health aspects at all levels
- Training of safety specialists and labour protection delegates, managers and committee members
- Up-to-date legislation and guidelines

- A competent and effective labour protection administration, emphasising advice and using enforcement as a last resort
- Research on effective and safe work methods, technology, machinery and equipment
- Continuous improvement in the design of machinery and equipment

The aspects of management which require control

The report emphasised that skills and knowledge are key factors in effective and safe work.

Discussion

The paper is essentially a review of the approach taken in Finland to the improvement to health and safety standards in Finland. The following areas were considered particularly: Skills and training, legislation, special regulations for forestry, a labour inspection for forestry, co-operation at all levels and an awareness of the economic implications of the standards.

RSI in forest machine operators in Scandinavia

Erikson. Redogörelse 4. Skogforsk: Uppsala. 1995. (Swedish)

The structure of communicating and support systems

The paper identifies that a comprehensive programme of preventative measures are needed to safeguard operators – technical measures alone will not be enough. These measures – technological, personal and organisational – must be employed based on a holistic and long-term action programme.

The aspects of management which require control

Machine selection and maintenance

The following were identified as being of particular significance (and therefore should be particularly considered for control and monitoring):

- Fine tuning the hydraulic system for smooth jerk-free operation of controls.
- Fitting of mini joystick controls
- Automation of crane and function unit control
- Measures to improve operator vision and posture

Work patterns

The following were identified as being of particular significance (and therefore worthy of particular consideration for control and monitoring):

- Regular breaks and a relaxed working technique (bio-feedback is a useful tool to improve technique)
- Physical exercises – also active relaxation can be useful therapy for existing RSI-related complaints (identifies the need for health monitoring and identifying appropriate remedial action)
- Job rotation is an excellent way of countering problems of sedentary work and repetitive movements – particularly important in intensive machine operation such as a harvester

The above may require the consideration of change in job description and possibly include work previously done by the supervisor. This would require organisation of work in the form of machine-based teams.

Discussion

The report draws on much previous research with the support of considerable data and the conclusions are therefore very robust.

The emphasis is placed on a holistic approach to health management covering all relevant aspects ultimately influencing the health of the operator not just those directly affecting health. Those aspects suitable for specific attention are identified.

With regard to machine selection and work organisation, some useful areas appropriate for high priority for control and monitoring are identified.

Physical stress can be overcome

Pontén. Resultat 12. Skogforsk: Uppsala. 1992. (Swedish)

The structure of communicating and support systems

Help from outside the organisation is a good means of exerting pressure emphasising the significance of the measures being taken and can be used both at the start of programmes as well as throughout the programme to maintain the momentum of change.

Symbolic actions are important to show the level of commitment by the organisation.

Systems for improvement need to take into account a range of actions and not single actions/changes.

Change will be progressive building upon the various different improvements applied.

Stress injuries should not be regarded as an issue which can be solved in isolation but is one piece of the programme of improvement or change which take into account all changes and developments to working methods and to the organisation. Effects on costs/profitability should be considered.

Level of development or application of control or advice/support

All links in the organisational chain should be included in any plan/programme.

There should be a shared vision in the organisation and the change must be managed in the ranks.

Everyone should understand the implications for others and therefore be prepared to change if it is for the overall benefit e.g. operators should not refuse to get out of the machine in order to help alternate jobs.

Personal development interviews between managers and colleagues are a good way of being firm about personal and team development.

The aspects of management which require control

Work techniques
Bio-feedback as an educational aid to make the operator aware of problems and therefore improving techniques are mentioned. This needs to be supported by a physiotherapist to identify what the operator can do to improve technique and reduce the possibility of stress.

Discussion

The above identifies the need to have a programme of implementation and a system to monitor the improvements achieved and also this would be beneficial in identifying when to take action to improve implementation if it is not succeeding.

The changes required for the improvement of health should be taken in context of all changes to working methods and the organisation. The planning of control, monitoring and actions to take as the result of feedback should take this overall picture into account.

Once again, it is emphasised that all levels need to understand and be involved in the total process of change and be aware of the reasons for it.

It is emphasised that overall tactics should be supported by management of each individuals' support to colleagues and teams.

The use of external organisation to advise and support the change is emphasised.

Common factors identified during review

Factors identified as being of significant concern to operator health

Machine selection

The improvements in machine design were not found to relieve operator symptoms or prevent the development of new ones (Reisinger et al., 1994).

Fine tuning of hydraulic systems for smooth jerk-free operations of control (Erikson, 1995).

Fitting of mini joystick controls (Erikson, 1995).

Automation of crane and function unit control (Erikson, 1995).

Measures to improve operator vision and posture (Erikson, 1995).

Work scheduling and organisation

Work organisation has possibly the highest potential for improving the situation e.g. length of working shift, work tasks and responsibilities, job rotation, team work, motivation and payment systems (Axelsson & Pontén, 1990).

Individuals have different working limits depending on physiological and sociological status. This limit can be changed by environmental conditions and individual prescriptions are appropriate (Axelsson & Pontén, 1990).

The introduction of a 3-hour shift working pattern did not lead to the expected decrease in health complaints. It was considered that this could be due to operators working more intensively during the 3 working hours (Axelsson & Pontén, 1990).

Long working hours has a negative effect on stress (Parker et al., 2002).

Long hours are recognised as having health implications as well as efficiency implications (Thomas et al., 2001).

The following were identified as being of particular significance:

- Regular breaks and relaxed working technique (Erikson, 1995).
- Physical exercises and active relaxation (Erikson, 1995).
- Job rotation (may require revision of job description) (Erikson, 1995).

Working environment
Pressure to meet targets was a negative in managing stress (Parker et al., 2002).

A good supervisory style was important in reducing stress (Parker et al., 2002).

Good co-worker relationships were important in reducing stress (Parker et al., 2002).

Crew/operator selection and training
Crew/operator selection was identified as very important in maintaining a stable crew and operating safely (Reisinger et al., 1994).

Safety and training – very few had a formal safety programme for meetings or training (Reisinger et al., 1994).

Factors affecting effective control and problems with achieving control

The structure of the communicating and support systems

Team work
Team work and the delegation of responsibility to crew and operators – in order to reduce the need for supervision to maintain standards, was considered to be important to a high proportion of safety conscious crew (Reisinger et al., 1994).

Increasing motivation and involvement of all parties involved is necessary (Axelsson & Pontén, 1990).

Resourcing
Resourcing of crew/operator compensation/benefits was important in retaining experienced and skilled crews (including wages and other benefits) (Reisinger et al., 1994).

Factors other than health affecting change
It is important to evaluate effects of changes on other performance factors (outputs, quality, efficiency etc.) (Axelsson & Pontén, 1990).

Employers can be reluctant to enforce change as it could incur costs (Lofroth & Pettersson, 1982).

A good remuneration system was important in controlling stress (Parker et al., 2002).

The COHSE forestry stress scale was found to be useful in identifying aspects of management style, which affect stress (Parker et al., 2002).

Level of development or application of controls

Involvement of management and other levels
A management commitment to safety was recognised in those teams, which were safety conscious (Reisinger et al., 1994).

Increasing motivation and involvement of all parties involved is necessary (Axelsson & Pontén, 1990).

Factors other than health to be considered
Controls should recognise the effects on other performance measures, not just health (Reisinger et al., 1994).

Specific aspects identified as being important to controlling systems

Controls should recognise the need for a holistic approach to health management and not concentrate on individual aspects (Axelsson & Pontén, 1990).

Operator selection
Crew/operator selection was identified as a very important factor in maintaining a stable crew and operating safely (Reisinger et al., 1994).

Training/education
Very few had formal programmes as it was considered that it should be an integral part of all aspects of a well managed harvesting business not a separate component of meetings on safety (Reisinger et al., 1994).

Dissemination of information was found to be a problem. Use of Internet was rare (Bordas et al., 2001).

Harvesting managers had insufficient knowledge of effective means of information dissemination or training for operators and crews (Bordas et al., 2001).

Operator and crew training are currently of insufficient depth or breadth or not conducted at all (Bordas et al., 2001).

Skills and knowledge are key factors in effective and safe work (ILO, 1992).

Health monitoring
Workers can be discouraged from reporting problems if there is a concern for loosing their jobs (Lofroth & Pettersson, 1982).

The information collection system should be non-punitive to encourage frank reporting (Bordas et al., 2001).

Self-perception of level of health did not correspond with the amount of sick leave taken. Any health monitoring system should therefore recognise this and be objective (Thomas et al., 2001).

Recommendations from previous work with regard to systems of control

The structure of communicating and support systems

Controls should recognise the need for a holistic approach to health management and not concentrate on individual aspects (Axelsson & Pontén, 1990).

A comprehensive programme of preventative measures is needed to safeguard operators – technical measures alone are not enough. These measures include technical, personal, and organisational factors employed on a holistic and long-term action programme (Erikson, 1995).

Help from outside the organisation is a good means of exerting pressure, emphasising the significance of measures taken, and can be used both at the start of programmes as well as throughout to programme to maintain the momentum of change (Pontén, 1992).

Systems for change and control need to take account of a range of actions, not single actions or changes (Pontén, 1992).

Effects on cost/profitability should be considered (Pontén, 1992).

Benefit/cost analysis is an important element each time ergonomic intervention is made – this must be passed on to all levels for successful implementation (Lofroth & Pettersson, 1982).

Strategy development should follow legislation (Lofroth & Pettersson, 1982).

Ergonomic standards are more easily applied incrementally particularly using cost-benefit examples (Lofroth & Pettersson, 1982).

Open communication between employers and employees is required when high risk is identified (Lofroth & Pettersson, 1982).

The current levels of penalties (low) were insufficient to motivate compliance with regulations (Bordas et al., 2001).

The effects of implementation of new standards on productivity should be covered and the positive trade-offs emphasised (Bordas et al., 2001).

A fine/penalty system would encourage compliance of safety rules (Bordas et al., 2001).

Sustainable forest management and long term planning are a key element of a safety programme (ILO, 1992).

Up to date legislation and guidelines are a key element of a health and safety programme (ILO, 1992).

A competent and effective labour protection administration emphasising advice and support and using enforcement as a last resort is a key element of a health a safety programme (ILO, 1992).

Level of development or application of controls or advice/support

Commitment and co-operation at all levels is necessary. Any control system needs to take this into account seriously (Axelsson & Pontén, 1990).

All links in the organisational chain should be included in any plan/programme (Pontén, 1992).

There should be a shared vision in the organisation (Pontén, 1992).

Change should be managed in the ranks (Pontén, 1992).

Constructive co-operation between all parties concerned at the national level and at the workplace is a key principle of a safety programme (ILO, 1992).

The public should be kept aware of the level of the problem (Lofroth & Pettersson, 1982).

Employees should be involved in all phase of programme implementation (Lofroth & Pettersson, 1982).

Good co-worker relationships were important (Parker et al., 2002).

A good supervisory style was important in reducing stress (Parker et al., 2002).

The COHSE forestry stress scale could be useful to identify aspects of management style affecting stress (Parker et al., 2002).

Supervisors should visit sites more regularly (Bordas et al., 2001).

Everyone should understand the implications for others and be prepared to change if it is for the overall benefit (Pontén, 1992).

The aspects of operations management which require control

Operator selection

Crew/operator selection was identified as a very important factor in maintaining a stable crew and operating safely (Reisinger et al., 1994).

The COHSE forestry stress scale could be helpful in recruitment selection (Parker et al., 2002).

Training/education

Very few had formal programmes as it was considered that it should be an integral part of all aspects of a well managed harvesting business not a separate component of meetings on safety (Reisinger et al., 1994).

Good education of operators with regard to health risks and management plus good support from management and their recognition of its importance are important (Axelsson & Pontén, 1990).

Employees should be provided with sufficient education to identify risks (Lofroth & Pettersson, 1982).

Information should be disseminated via companies, insurers and academic activities (Bordas et al., 2001).

Dissemination directly to operators was considered important, particularly regarding lessons learned (identification of problems and solutions) (Bordas et al., 2001).

The use of experienced managers and operators with good records was considered to be a means of developing appropriate training (Bordas et al., 2001).

Employers and others should place greater emphasis on providing sufficient and relevant information on hazards, their effects and controls (Thomas et al., 2001).

Effective training, incorporating health and safety aspects, are required at all levels – including safety specialists, labour protection delegates, managers and committee members (ILO, 1992).

Personal development interviews between managers and colleagues are a good way of being firm about personal and team development (Pontén, 1992).

Bio-feedback as an educational aid to make operators aware of problems and therefore improving techniques is useful. This needs the support of a physiotherapist to identify what the operator can do to improve technique and reduce the possibility of stress (Pontén, 1992).

Health monitoring

Appropriate epidemiological monitoring should be performed (Lofroth & Pettersson, 1982).

Workers from different companies differed significantly in their responses to questions about satisfaction. This indicates that individual analyses of actions required to monitor and control health are likely to be important (Parker et al., 2002).

The scale (COHFE forestry stress scale) was found to be a useful predictor of intended job turnover, absenteeism, illness, and injury, including musculoskeletal pain and psychosomatic symptoms in loggers (Parker et al., 2002).

Self-perception of level of health did not correspond with the amount of sick leave taken. Any health monitoring system should therefore recognise this and be objective (Thomas et al., 2001).

The appropriate frequency of health monitoring depends upon circumstances and local OSH branches can usefully advise (Thomas et al., 2001).

Work organisation
Employees should not be told specifically how to perform tasks, as different techniques may be equally efficient. They should simply be able to identify those tasks, which have associated risk (Lofroth & Pettersson, 1982).

Job autonomy and flexibility was important in reducing stress (Parker et al., 2002).

Summary of conclusions from scientific reviews

Factors identified as being of significant concern to operator health

The following factors were identified as being of particular concern in potentially affecting operator health and therefore should be specifically considered for inclusion into health control and monitoring systems.

Work scheduling and organisation
This was the area in where most opportunities were identified as being of concern to operator health and where there were the most opportunities for control. The following aspects were covered as being of significance and should therefore be recognised as suitable for prioritising in any system of control and monitoring:

- Long working hours
- Job rotation
- Regular rest breaks
- Physical exercises
- Shift work
- Team working

Working environment
Pressure to meet targets, supervisory style and co-worker relationships were found to be of significance in managing stress.

Crew and operator selection
Having a good selection system was identified as very important to maintaining a stable crew and operating safely. Individuals also have different abilities to cope with particular working environments and therefore optimum selection procedures would assist in reducing vulnerability of crews to health problems.

Training and education
Poor or inadequate operator training or education with regard to the health risks and action to take was identified as increasing health risks.

Machine selection
Improvements in machine design were not found to improve operator health or to prevent the development of new problems (Reisinger et al., 1994). However this may mean either that:

- Improvements to date are insufficient to result in health improvements. This would not mean that they were not a step in the right direction.
- Improvements in machine design alone will not have a significant effect on operator health – without improvements in other aspects of working practice.

The factors to be of particular significance to RSI in machine operators were:

- Fine tuning of hydraulic systems
- Fitting of mini joysticks
- Automation of crane and function unit control
- Measures to improve operator vision and posture

Factors affecting effective control and problems with achieving control

The following factors were considered to be of particular significance in implementing or maintaining effective monitoring and controlling systems.

The structure of communicating and support systems and management factors

The lack of a holistic approach to change and health management was identified to be of concern.

Controls should not only consider health but implications of changes on all other aspects of performance and these should be monitored and appropriate communication made to all levels.

Changes should not be under-resourced. Costs and benefits should be assessed at the start and results monitored.

Management must not be under-committed to the programme of change otherwise it will be likely to fail.

Plans should not be short term. Improvements are likely to be incremental and therefore long-term commitment and planning is necessary.

Lack of expertise or support – external as well as internal – can result in inadequate implementation or failure.

Good communication or education at all levels is necessary to ensure there are no weak links in the application of the new standards.

Factors at crew level which can hinder improvements in practice

Poor crew or operator selection can result in the lack of the necessary skills or a poor team, which would not be effective in working together to support changes.

Training/education
An adequate depth and breadth of all the problems associated with health management and the appropriate actions must be available to all members of crews to ensure full commitment (this applies to all levels within the organisation).

Health monitoring
Crews and operators (even management) can be discouraged from reporting problems if they are likely to be negative effects of such reporting, e.g. if a fine would result in loss of jobs or earnings. These factors should be taken into account when designing monitoring and control systems.

Recommendations from previous work with regard to systems of control

The structure of communicating systems and management issues

A comprehensive long-term programme, which considers technical, personal and organisational input, is required to ensure successful implementation of improved practices.

The effect of the changes on all other aspects of performance – efficiency, costs, outputs, resource requirements, structural changes etc. need to be taken into account in designing and monitoring and controlling the long term plan.

Assistance from outside the organisation will help to support changes and in attitudes/values and practices within the organisation. This can be of value both at implementation and during the process of change to maintain momentum. It can therefore be used both in the monitoring (to assist identification of standards) and controlling (taking action to improve standards).

A philosophy of open communication and commitment throughout all levels is required. Monitoring and controlling systems need to recognise this ensuring that action can be taken where necessary within the organisation following the identification of need through monitoring. Education with regard to risks, standards, and solution finding is a key to effective implementation.

Motivation to change and improve practices is essential and this should be identified in controlling systems. This needs to include the willingness to change for the benefit of overall improvement rather than concentrating on personal interests. However, punitive action for deficiencies can have a negative effect, reducing the willingness to report problems. They should therefore be used only as a last resort.

Blanket prescriptions are generally to be avoided as different circumstances can require different solutions. There can be several appropriate solutions to any problem and appropriate standards may also vary according to individuals and operational circumstances. Guidance may be sought from internal or external expertise. Emphasis should be placed on identifying risk rather than solutions.

The aspects of operations management which requires control

Operator selection
A robust system of operator selection will ensure good team working, selection of people with appropriate skills and willingness to co-operate with the application of best practice.

Training/education
The education and training requirements need to be fully assessed and a long-term programme developed. This should be supported by individual interviews between operators and managers to identify specific requirements and demonstrate commitment to the process.

Education should include awareness of risks and continued development of the change in values required to commit fully to health management programmes.

External support should be sought where appropriate. Advice can be obtained from specialists e.g. health and safety organisations regarding standards and controls and physiotherapists regarding ways to improve operating techniques etc. Bio-feedback can be a useful tool in improving technique.

Health monitoring
Health monitoring should not rely on operator responses but should use other objective techniques (e.g. sick leave records, productive time records, turnover rates and leaving questionnaires) to ensure feedback is not biased.

Individual standards are likely to be appropriate for monitoring and external guidance should be sought for advice.

The COHSE forestry stress scale may be of use in monitoring health.

Appropriate epidemiological monitoring should be performed.

Work organisation
Job autonomy and flexibility are important in reducing stress. The ability to identify risk rather than be prescriptive about solutions is more important.

Team working is seen as important in achieving optimum ability to manage for health and to achieve commitment of the workforce.

With regard to working practices e.g. the length of working hours, shift working, rest periods, job rotation etc. they are all seen as having potential benefits but individual solutions need to be developed for particular circumstances and prescriptive solutions should be avoided. Advice should be sought from specialists – internal or external.

Non-scientific papers and guidance

A list of publications is shown in the end of the references list. The following are considered to be of particular relevance to ErgoWood.

The ILO publications
The particular publications which will need to be referenced when drawing up recommendations for controlling and monitoring systems are:

- Guidelines on occupational safety and health management systems
- Safety and health in forestry
- Technical and ethical guideline for workers health surveillance

The CEN publications
In general the CEN publications will be of relevance to specific standards for factors affecting health rather than controlling and monitoring systems. The following, however, should be referenced when drawing up ErgoWood recommendations with regard to controlling and monitoring systems:

- EC Risk assessment Directive 96/37
- EC Physical Agents Directive

Managing health and safety – Guidance from other countries
Many countries have produced guidance, general and specific to forestry (but little specific to the management of harvesting machine operators) for the management of health. Some of them are listed in Appendix 6.2. They are too extensive to review completely as part of a scientific review. However, they could be used as reference to develop guidelines to inform the seminars, the evaluation of case studies and in the drawing up of ErgoWood recommendations. It is recommended that, if this is considered appropriate, this is undertaken prior to those aspects of the ErgoWood project; i.e. over months 6-12 of the project.

However, it should be considered whether ErgoWood should identify and only deal with those aspects of management which are specific to the needs of harvesting machine operation rather than general health management requirements which are extensive and dealt with in detail by many publications already.

References

Scientific papers identified from CAB review

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List of non-scientific papers and guidance relevant to:

ErgoWood – controlling and monitoring systems

International Labour Organisation guidance:
Fundamental principles of occupational health and safety. ISBN 92-2-110869-4.
Guideline on occupational safety and health management systems. ISBN 92-2-111634-4.
Recording and notification of occupational accident and diseases: Code of practice. ISBN 92-2-109451-0.
Safety and health in forestry: An ILO code of practice. ISBN 92-2-110826-0.
Technical and ethical guidelines for workers health surveillance. ISBN 92-2-110828-7.

CEN directives and guidance:
Machinery directive 98/37/EC.
EC Working time directive 89/391. United Kingdom, Department of Trade and Industry. Employment regulations. Working time regulations.
EC Risk assessment directive 96/37.
EEC Directive: Use of personal protective equipment (PPE) in the workplace 89/656/EEC. Department of Trade and Industry. Personal protective equipment at work regulations 1992. (Adaptations taken from directive 89/656/EEC).
EEC Physical agents directive.
Physical agents (noise) directive 86/188/EEC. Physical agents (vibration) directive (British Standards BS 6841:1987 & ISO 2631:1997).
British Standards, BS 8800:1996. Guide to occupational health and safety management systems.

Other health and safety standards and guidance

United Kingdom – Health and safety guidance:
United Kingdom, Department of Trade and Industry (DTI). The supply of machinery (safety) regulations 1992 (as amended 1999).

The training of first aid at work. 2001. ISBN 07176 1896 X.
First aid at work: The health and safety (first aid) regulations. 1981. ISBN 07176 1050 0.
A guide to reporting of injuries, diseases and dangerous occurrence regulations (RIDDOR). 1995. ISBN 07176 2431 5.
RIDDOR Explained. 1999. HAS 31 (rev 1).
Protecting your health at work. 1996. IND (G) 62L.
Management of health and safety at work regulations. 1992 (updated 1997). ISBN 07176 04128.
Managing health and safety: Five steps to success. 1997. INDG275.
Successful health and safety management. 1997 (2003). ISBN 07176 1276 7.
A guide to measuring health and safety performance. Draft 2001.
Managing health and safety in forestry. 1999. INDG 294.
A guide to risk assessment requirements: Common provisions in health and safety law. 2001. INDG218.
Five steps to risk assessment. INDG 163 (rev. 1).
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Upper limb disorders: Assessing the risks. 1999. ISBN 07176 0751 8.
Work related upper limb disorders: A guide to prevention. 1990. ISBN 01188 5565 4.
Hand/arm vibration. 1994. ISBN 07176 0743 7.
Vibration Solutions. 1997. ISBN 07176 0954 5.
In the driving seat: Advice to employers on reducing back pain and vibration exposure in drivers and machine operators. 1997. INDG242.
Safe use of work equipment: Provision and use of work equipment regulations (PUWER). 1998. ISBN 07176 1626 6.
Safe use of lifting equipment: Lifting and lifting equipment regulations (LOLER). 1998. ISBN 07176 1628 2.

Occupational Safety and Health Administration (OHSA), Canada:
Part 26: Forestry workers compensation act. Workers Compensation Board: British Columbia, Canada.
Part 3/10: Accident reporting and investigation.
Report form (R09/02): Employers report of injury or occupational disease.
Appendices: Safe work procedures (for logging).

Occupational Safety and Health Administration (OHSA), USA:
Appendices: Training and qualifications of loggers.
Appendix A: Musculoskeletal injuries, report form.
29 CFR part 1904: Recording and reporting occupational injuries and illnesses.

Occupational Safety and Health Administration (OHSA), Sweden:
Swedish Work Environment Authority (ADI 560) Safety Delegates: The employer's and employees' co-operation towards creating a better working environment.
Forestry Commission health and safety memorandum 2000(35). Risk assessment: Management of health and safety at work regulations.

Appendix 6.1

Structure of scientific review – control and monitoring systems

General content

The detail of best practice with regard to the various aspects of work organisation and machine selection will not be dealt with within this review as it comes under the remit of other work packages. This review will only deal with the control and monitoring systems appropriate to ensure that best practice can be effectively implemented. It will, however, identify those aspects of machine and operation management, which may require some form of controlling system.

Report structure

The review will be considered from 3 different viewpoints:

- The structure of communicating and support systems
- The level of control
- The aspects of management or operation which require control

The structure of the communicating and support systems.

This will consider:

- Supporting infrastructures and systems – internal and external; e.g. welfare services, sickness benefits, pension benefits, trade union or contractor associations, health and safety organisations/departments
- Structures for information flow
- Structures for the monitoring and controlling processes
- Structures/systems for the identification of priority/problem areas

Level of development or application of controls or advice/support

- External to organisation
- Organisation
- Middle management
- Line manager/supervisor
- Operators

The aspects of management which require control

The following are aspects, which may need to be included in controlling systems, are to be considered during the review:

Machinery aspects

- Machine selection
- Machine maintenance

Work organisation aspects

- Work patterns (shift working, job rotation, length of working day, rest periods)
- Exercise regimes
- Work site management (operation planning, site planning)
- Performance (outputs/costs as well as health and safety performance)

Operator welfare, physiological and competence issues

- Operator selection (qualifications, experience, and health history)
- Operator health monitoring (health and accident recording)
- Training (resources, levels, qualification

Source documents and their relevance to the review

The following sources will be considered during the review:

- Scientific papers
- ILO Guidance
- CEN Directives and Guidance
- Health and Safety Organisations and guidance (various countries)
- Other organisations published guidance

Any guidance or information from the above will be considered in the context of whether it provides:

a) General requirements with regard to the control and monitoring of health and safety at work irrespective of work type.
b) General requirements as at a) but with regard to general forestry requirements or general machine operation.
c) Specific recommendations for the particular hazards associated with harvesting machine operators.

With regard to a) and b), these are generally well documented in various guidelines and this project should ensure any specific guidelines with regard to harvesting machine operations are in accord with these general requirements or guidelines. This scientific review will only identify the relevant documents, which will need to be referred to with regard to these more general requirements.

Where they have specific relevance to harvesting machine operators these will be identified.

Appendix 6.2

Summaries of scientific papers of particular relevance to ErgoWood – controlling and monitoring systems

Anderson, G. 1993.

Shift work patterns for teams. Resultat 2. Skogforsk: Uppsala. (Swedish)

Shift work planning, some ideas to help work teams and their supervisors. There is no universal answer to the question of how the work of logging teams can be best organised. With so many different needs among the workers and within each individual enterprise, it is essential that enough time be set aside to draw up one or more shift work schedules. This issue of Resultat presents some typical shift work schedules, together with a checklist of important items to take into account when planning the work. The purpose is to help stimulate ideas among teams when they draw up their schedules.

Axelsson, S. A. 1998.

The mechanisation of logging in Sweden and its effect on occupational safety and health. Journal of Forest Engineering 9(2), 25-31. (English)

In this study the effect on occupational safety and health of increasing mechanisation and improved ergonomics in Swedish forestry has been analysed by using data on accidents and health hazards for chainsaw operators and logging-machine operators. In 1990 the accident frequency rate was 63 and 17 respectively, indicating a risk reduction of 73% by mechanisation compared to chainsaw-based methods. There have also been significant improvements within each group. Between 1970 and 1990 the frequency rate for chainsaw operators was reduced by 48%, and for logging-machine operators by 70%, the result of improved ergonomics and safety organisation. Health hazards have also been reduced, notably vibration-induced white fingers (VIWF) among chainsaw operators. The increasing number of machine contractors forms a potential risk group. Some 50% of logging-machine operators have symptoms of repetitive stress injuries (RSI). Large-scale prevention programs have been initiated, with the emphasis on development of new work organisation.

Axelsson, S. A., & Pontén, B. 1990.

New ergonomic problems in mechanised logging operations. International Journal of Industrial Ergonomics 5(3), 267-273. (English)

A health risk program for forest work has been developed in order to improve health risk identified by systematic evaluation of relationships between work and health complaints and to create a base for decisions on different actions to reduce the health risk. This paper deals particularly with logging machine operators and the problem of the overload syndrome, characterised by complaints and injuries to the neck, arms, and cervical spine. The result of the health investigations of 1 174 machine operators indicate a prevailing average overload syndrome of 50%, mainly due to one sides, repetitive short cycle working movements with the hand and arms.

The analyses show that a whole battery of measures is needed to radically improve this serious situation. Single measures might be positive, but are not enough. To be effective, the full program of measures must be carried out and adapted individually to each machine operator. Improvements in technology, ergonomics are needed, especially regarding the sitting work posture in the cab, i.e. design of the arms of the chair, controls and instruments. Important factors are working techniques, micro-pauses and physical fitness. New work organisation is the most difficult part of the measures to realise in practise, but also has the highest potential for improving the situation. Examples of issues to address in this area are design and length of the working shift, job rotation, work tasks and responsibilities, team work and motivation and payment systems.

Bean, T. L., & Issacs, L. K. 1997.

Timber harvesting safety. Safety and Health in Agriculture, Forestry and Fisheries, 509-519. (English)

This chapter discusses the high risk associated within the logging industry and the importance of developing effective safety protocols. The unique characteristics of timber harvesting operations, the most common harvesting-related injuries and illnesses and human factors, which contribute to injuries and illnesses, are addressed. The authors present eight components of an effective logging safety program that will help any logging operation be more safety conscious.

We have discussed the special safety issues that must be considered to reduce the incidence of logging related accidents. Logging was identified as a high risk occupation, where massive trauma and head injuries are common due to stuck-by or chain saw accidents. Often multiple factors were involved in contributing to the injury or illness.

In addition, because the logger often works with other crewmembers, his unsafe behaviour may endanger their lives as well. Using the co-operative spirit of the crew, it is suggested that employers implement a formal logging safety program where both management and crew members take an active role in identifying and correcting unsafe work conditions.

Begus, J., Meved, M., Pogacnik, N., Slavc, J., & Jurc, M. 1997.

Education of private forest owners in the field of safety work in the forest. Znanja za gozd, Zbornik ob 50. Obletnici obstoja in delovanja Gozdarskega instituta, Slovenija 2, 401-418. (Slovinian)

The article deals with education of private forest owners in the field of safe forestry work. The primary motive for beginning this activity was the higher number of accidents during work in private forests. Since 1995 the Public Forestry Service together with the Slovenian Forestry Institute and with Secondary Forestry Scholl Postajna has organised courses for private forest owners on safe forestry work. We analysed the questionnaire filled in by the participants of the course Safety-work with chain saw.

Bordas, R. M., Davis, G. A., Hopkins, B. L., Thomas, R. E., & Rummer, R. B. 2001

Documentation of hazards and safety perceptions for mechanised logging operations in east central Alabama. Journal of Agricultural Safety and Health 7(2), 113-123. (English)

The logging industry remains one of the most hazardous in the nation. Despite more stringent safety regulations and improvements in equipment safety features, the rate of logging fatalities has decreased at a much lower rate than the decrease in the rate of illnesses and injuries in the same occupation. The objective of this research was to identify and assess the hazards associated with logging operations in the Southeast region of the US and propose interventions, taking into consideration the fact that currently, most operations in the region are fully mechanised. Five logging crews in east central Alabama participated in the study and were observed repeatedly during their normal operations. Researchers observed loggers engaging in multiple unsafe behaviours, but none of those led to an injury. The incidents of unsafe behaviours may be due to lack of awareness of the hazards. Results indicated that Occupational Safety and Health Administration (OSHA) regulations appear to have little influence on logging safety. Loggers believe that most safety training recommendations are difficult to implement and negatively impact productivity. Thus, there seems to be fundamental drawbacks in the logging industry regarding effective delivery of safety training to loggers. The present study was a joint venture by the Industrial and Systems Engineering and Psychology departments of the Auburn University, with support from the United States Forest Service (USFS)

Egan, A. F. 1998.

The introduction of a comprehensive logging safety standard in the USA: The first eighteen months. Journal of Forest Engineering, 9(1), 17-23. (English)

In the 18 months since the effective date of the US Occupational Safety and Health Administration's (OSHA) logging standard, 289 logging site inspections have been performed in the US by OSHA personnel. In West Virginia, 25 inspections found 170 violations ranging from incomplete first-aid kits and poor record keeping to hazardous felling areas. Four of these inspections were initiated by accidents that caused serious injury or fatality. The average proposed penalty per citation was $130.59. Approximately ⅔ of West Virginia loggers expressed misgivings about OSHA standard. However, only 36% thought that they had a good knowledge of the OSHA logging regulations. Foresters and loggers in the US should be aware that OSHA regulations pertaining to timber harvesting operations are being enforced and, in some cases, may affect the way forests are harvested and managed.

Erikson, G. 1995.

RSI in forest machine operators in Scandinavia. Redogörelse 4. Skogforsk: Uppsala. 28 pp. (Swedish).

Thanks to mechanisation, much of the heavy physically arduous jobs in forestry have disappeared. Nonetheless, musculoskeletal disorders is still a common complaint among forest machine operators and farm tractor drivers working in forestry. The neck and the shoulders are particularly prone to repetitive strain injuries (RSI) problems. A number of surveys carried out in Scandinavia since the late 1980s have found that more than 50% of machine operators have subjective complaints. Moreover, despite the substantial ergonomic improvements made to forest machinery in the 1980s, the incident of RSI among the machine operators has not declined. RSI causes considerable personal suffering; it is both painful and difficult to cure and often results in long periods of sick leave or even early retirement. Beside the personal financial losses due to lost earnings, sick leave also represents a cost to employers and society at large as a result of lost production and the cost of medical treatment and rehabilitation.

It cost SEK 5 000 000-6 000 000 to recruit and train a new harvester operator, a large part of which represents the cost of lower production levels during training. Over the past few years, medical research has been able to establish the casual relations behind RSI. When a muscle is under tension, circulation and thus oxygenation are reduced, leaving lactic acid and calcium ions in the muscle, resulting in chemical and physiological damage to the muscle cells. In a muscle that is in use, various fibres contract and relax in response to the muscular force called for. The first fibres to be contracted are also the last ones to be relaxed. This means that even if the muscle itself is only moderately loaded, individual fibres can be overloaded. Muscle tension can be triggered by physical and mental causes and repetitive work involved in crane operation is certainly one cause.

Hagberg, J., & Lidén, E. 1991.

Mini-levers decrease RSI. Resultat 24. Forskningsstiftelsen Skogsarbeten: Stockholm, Sweden (Swedish)

Machine operators, who changed from standard levers to mini-levers, were studied. Complaints after 6 months (151 operators) and 12 months (99 operators) were reported. 75% of operators indicated improvement but there were also some new complaints. There was no indication of complaints moving from shoulder to lower arms or hands. Reasons for the new complaints could have been incorrect positioning between the arm-rest, keyboard and mini-levers causing difficult movements. Higher levels of improvement were noted as time with mini-levers increased.

Heil, K. 1996.

Looking for solutions to the problem of personnel not following work safety procedures. Forst und Holz 51(21), 693-703. (German)

In 47 out of 53 fatal accidents common safety rules had been disregarded. If one would know the reasons why forest workers were motivated to engage in forbidden practices one would have the key for measures to improve safe behaviour. When trying to explore the causes of accidents it became obvious that what at first appears like irrational human behaviour is frequently the result of a chain of missions. The list of those responsible for such omissions reaches up to top management. Leadership based on management objectives is a successful principle of modern management. Maintenance of health and safety of employees must be explicitly declared as a management objective. The State Forest Enterprise Thüringenforst has integrated this objective in its mission statement.

The basic requirement for the development of work systems to use safe techniques and fully effective technical safety can hardly be fulfilled in motor-manual forestry work. Forest enterprises in Germany suffer from difficult economic conditions. This results often in giving priority to economic considerations over safety aspects. In future the rule should be: Safety standards rank higher than other preferences; safety comes before economics. Omitting and tolerating are frequently the reasons for accidents. Supervisors omit giving a good example (by wearing a normal hat instead of a safety helmet), organising work adequately etc. They tolerate unsafe behaviour and thus contribute to the fact that this becomes a habit.

In a forest enterprise everybody carries 100% responsibility for his task. Everybody must fulfil his duties and pursue the management objectives. This basic need for safety (according to Maslow), from the forest workers point of view, appears to be satisfied. According to the theory of reinforcement tolerating prohibitive procedures make a habit out of them the more often they are rewarded by success. To avoid such faulty comportment the supervisor should provide assistance. He should neither, based on his authority, forbid dangerous practices nor should he tolerate laissez-faire. The forest worker should be convinced by argument for and against specific ways of doing a job so that he is in a position to independently select the safe solution. When guiding him to apply working habits the philosophy of the rational should be followed.

Jokiluoma, H., & Tapola, H. 1993.

Forest worker safety and health in Finland. Unasylva (English ed.) 44(175), 57-33. (English)

Forest work continues to be a profession with a high risk of physical accidents and illness, but in Finland the accident rate has decreased significantly during the past two decades. A variety of measures have contributed to the improvement of health and safety in forest work in Finland. It is possible to identify some basic features and milestones in the development of a coherent strategy resulting from continuous efforts by all concerned to improve the situation.

One key has been the creation of a strong safety mentality and we feel this is the gain of gold to be preserved when responding to future challenges.

Kirk, P. M., Byers, J. S., Parker, R. J., & Sullman, M. J. 1997.

Mechanisation developments within the New Zealand forest industry: The human factors. Journal of Forest Engineering 8(1), 75-80. (English)

The ergonomic benefits of mechanisation for the forest worker focus around the removal of the worker from the majority of the hazards and severe physical workloads inherent in the forest workplace. However, the characteristics of the current New Zealand forest industry workforce, the lack of trained operators, lack of appropriate training and selection programmes and the high level of turnover in the New Zealand forest industry, are current obstacles to the full achievement of mechanisation's ergonomic benefits. In order for the New

Zealand forest industry to maximise the economic and ergonomic benefits of mechanisation, some formal preparation of machine operators is essential.

Lidén, E. 1996.

Safety and health of contractors. FAO, EC, ILO Seminar on Safety and Health in Forestry, October 1996, Emmental, Switzerland. (English)

Approximately 3 300 machines were used in Swedish industrial forestry during the harvesting season 1992/93. As many as 70% of all machines used were owned by contractors. This percentage is predicted to increase to 79% in the harvesting season 1997/98 according to an inquiry to the forest enterprises.

Thanks to mechanisation, much of the heavy and physically burdensome jobs in forestry have disappeared. Nonetheless, musculoskeletal disorders is still a common complaint among forest machine operators. The neck and shoulders are particularly prone to repetitive stress injuries (RSI). On top of these primarily physical hazards, contractors also might suffer from stress caused by high financial and social demands and vast responsibility for machinery and more often also for employees. According to experiences, RSI must be counteracted with several measures, such as technological, personal and organisational ones.

The group of contractors with one machine and no employees on an average have machines that are almost twice as old as the average company-owned machine. This, of course, means lower ergonomic standards and increased risk of RSI. The increased competition at the Swedish forest market has lowered the profit for many contractors, following that investments in new machinery very often have to be postponed. This adds up to the risks.

The contractors are very aware of the risk of RSI. Half of them comment that they consciously try to operate the machine as relaxed as possible, that they have installed handles to hang on to, to stretch the spine.

Job rotation is an excellent way of countering the problems of sedentary work and repetitive movements of the hands, arms and shoulders. As many as 40% of all employed machine operators used a shift form (K-shift) which facilitates job rotation. Less than 10% of the contractors used this shift form. The development with more and more contractors having employees, although, indicates that K-shift becomes more common also among contractors.

Between harvesting season 1985/86 and 1992/93, the average annual volume of a contractor-owned one-grip harvester used in thinning has been more than doubled. In spite of this, the financial difficulties for the contractors have become more and more severe. During the years 1986 and 1990 as many as 46% of all contractors who quit forestry, made it for financial reasons.

More of the contractors than of the employed operators suffer from psychosomatic complaints and RSI in the shoulders and arms. This is probably caused by the contractors' higher and more intense exposure.

The ultimate consequence of occupational health problems is to quit. During 1986-1990 in total 300 contractors quit forestry, ⅓ of them quit voluntary. Interviews with former contractors pointed out that health problems played an important role.

Lofroth, C., & Pettersson, B. 1982.

Neck (cervical vertebrae) and arm complaints in logging machine operators: An account of the problems and how to avert them. Redogörelse 7. Forskningsstiftelsen Skogsarbeten: Stockholm, Sweden. 19 pp. (Swedish)

Between 1978 and 1980 there was an increase in the number of logging machine operators suffering from neck and arm complaints. Between 20-30% of all logging machine operators were reporting to have problems which led to their consulting a doctor or an incapacity for work. In this respect, the situation as regards machine operators presents a marked deviation from that applying to other worker categories in forestry. Apart from the personal suffering, the problems have resulted in sick leave and increased costs to the enterprise.

Physicians practising in forestry have issued a job statement on the problem, which in their opinion is attributable to shortcomings in the work environment.

A working group, comprising representatives of enterprise physicians, safety engineers, technicians and researchers has conducted a study to ascertain how the problem can be averted. The working group has examined the experience of similar problems in other sectors, as well as the results of steps taken in forestry sector to get to grips with the problem. On the basis of the combined experience, the group has endeavoured to assess the effectiveness of various measures, the feasibility of implementing the measures in practice and the cost of the measures. On the basis of this assessment, the working group has recommended a campaign of action, to consist in brief of the following.

Operators already suffering from some complaint:

- Training in the correct working technique. A training programme and a slide film have been produced.
- Job rotation and, in some cases, the modification of old machines. Modifications should largely be aimed at providing a better and more flexible operating position.

Preventative work at the enterprise's:

- Job rotation.
- Training in correct operating techniques and the application of ergonomic criteria in machine procurement.

Continued R&D work by the manufacturers:

- The design of operating positions that can readily be adjusted to suit individual operators and which are flexible.
- The development of even better control systems.
- The design of machines that subject the operators to less total-body vibration.

Various parties in the forestry sector have examined the recommended campaign of action and voiced support for it. They include physicians practising at forestry enterprises and the Skogsarbeten advisory group on working environment, logging and logging machine technology.

McLean, J., & Rickards, J. 1998.

Ergonomics codes of practice: The challenge of implementation in Canadian workplaces. Journal of Forest Engineering 9(1), 55-64. (English)

Despite a reduction in the workplace injury rate for most industries in Canada, the number of compensation claims for the Canadian forest industry is not declining at a comparable rate. While mechanisation, particularly tree harvesting operations, has improved injury rates in the last 5-7 years, the forest industry, along with similar labour-intensive industries such as mining, construction and agriculture continue to have unacceptable health and safety records.

This review of ergonomic codes of practices focuses on the issues of implementation, as perceived by the three major stakeholders, management, employees and their unions and government. Barriers to implementation and successful programs are discussed, as is the use of benefit/cost analysis is one measure of success. Three examples of successful ergonomic interventions in Canadian forestry, manufacturing and healthcare are detailed to illustrate the effective use of benefits/cost analysis as a measurement tool and as the potential path to the implementation of universal codes of practice.

Myers, J. R., & Fosbroke, D. E. 1995.

The occupational safety and health administration logging standard: What it means for forest managers. Journal of Forestry 99(11), 34-37. (English)

Equally important, forest managers should assess in advance how their management decisions will affect logging safety.

Incorporating safety into the contract can be done by including a provision that the operator will perform the logging operation in compliance with the OSHA logging standard.

The need to balance safety issues with factors such as environmental regulations, economic goals, biodiversity goals and the other constraints are unavoidable. Forest managers cannot ignore the OSHA standard any more than they can ignore environmental regulations.

Parker, R., Tappin, D., Ashby, L., & Moore, D. 2002.

Exploring "stress among loggers". Report. Centre for Human Factors and Ergonomics, LIRO: Roturua, New Zealand.

A forest stress scale, developed jointly by researchers from COHFE and the University of Auckland, will be useful for highlighting and measuring the incidence and the extent of stress and identifying potential causes of stress and job satisfaction across the logging workforce.

The scale was developed by holding interviews with 56 workers from several crews who highlighted key issues. Then 259 workers from Northland to Invercargill responded to a questionnaire developed from the interview results. The forestry stress scale was shown to be a reliable predictor of intended job turnover, absenteeism, illness and injury, including musculoskeletal pain and psychosomatic symptoms (variable associated in the research literature with occupational stress) in loggers. Interventions to reduce stress in forestry workers could be targeted using the scale. The issues highlighted during the study – turnover absenteeism and injuries and illness – have an enormous negative impact on performance and productivity and are therefore crucial to the forestry industry in New Zealand. The scale may also indicate those job factors likely to prove helpful in recruitment selection and retention of workers.

Pontén, B. 1992.

Physical stress injuries can be overcome. Resultat 12. Skogforsk: Uppsala. (Swedish)

More than half of all logging machine operators in Sweden suffer from neck and shoulder injuries in varying degree of severity. These highly complex stress injuries are caused by the rigid work postures of the operators. Measures to combat the problem must be tailored to the individual and must focus on breaking the one-sided movements, reduce static loads on the muscles and improving operator resistance.

The management of change must be based on a holistic approach i.e. so that technical, organisational and individual measures can be taken. Our findings from a 3-year involvement in managing change at one enterprise are as follows:

- It was possible to implement a complete programme to combat physical stress injury in the forest district concerned.
- Successful implementation is closely linked to a perceived climate among those involved.
- The programme benefited health, job satisfaction and efficiency.

Reisinger, T. W., Sluss, R., & Shaffer, R. M. 1994.

Managerial and operational characteristics of safety successful logging contracts. Forest Products Journal 44(4), 72-77. (English)

Experience has shown that certain logging contractors are effective in promoting safety and maintaining low injury rates on their jobs. Interviews with 26 safety successful contractors in the eastern United States indicated that these contractors had several key characteristics in common that made their operations safer. They were effective people managers who; 1) were able to keep crew turnover to a minimum and maintain a stable crew; 2) hired primarily experienced wood workers; 3) had highly mechanised operations; 4) promoted teamwork; 5) insisted on mandatory use of personal protective equipment; and 6) demonstrated a strong management commitment and safety conscious attitude.

Rey, P., & Bousquet, A. 1995.

Compensation for occupational injuries and diseases. It's effect upon prevention at the work place. Ergonomics 38(3), 475-486. (English)

In Switzerland, as in many other industrialised countries, the nature and extent of prevention at the workplace is determined, at least partially, by known cases of compensated occupational injuries and diseases. At both the national and international levels (ILO conventions), injuries and diseases that fit appropriate lists and definitions are eligible for compensation. It has been found, based upon an investigation of a representative sample (965 subjects) of the working population in the French-speaking region of Switzerland, that this restrictive view does not take into account the fact that a large proportion of injuries and diseases are claimed by the victims to be caused by their job. These injuries and diseases, responsible for at least one month's absence from work, are not considered to be eligible for compensation but must be covered by the patient's own insurance. Moreover, the survey showed that workers considered the ill effects on health and safety to be a consequence less of the physical working environment than of the work organisation and that this category of risks was not recognised. Thus, in addition to the reduction of hazards by the application of industrial hygiene, an informed improvement of the workplace and the work organisation was required. Consequently, laws and regulations on occupational injuries and diseases should be changed in order to emphasise the role of more appropriate preventive tools, which includes ergonomics.

Sullman, M., & Gellerstedt, S. 1997.

The mental workloads of mechanised harvesting. New Zealand Forestry 42(3), 48. (English)

The result from the survey suggests that operating a harvester is more stressful, causes more fatigue and requires more effort than operating a forwarder. Future research measuring the mental workload of forest harvesting tasks will also incorporate an objective measure (such as critical flicker fusion), measure the physical workload (in terms of heart rate), body par discomfort and the workers performance in terms of productivity.

Thomas, L., Bentley, T., & Ashby, L. 2001.

Survey of the health and wellbeing of workers in the New Zealand forest industry. Report 2(5). Centre for Human Factors and Ergonomics, LIRO: Roturua, NewZealand

A sample of forest employees from nine areas of New Zealand were interviewed by OSH occupational health nurses. A large proportion of respondents had been with crews for less than six months, suggesting serious implications for the development of good safety culture and skill retention. Employees reported working long hours in many cases and around ½ reported experiencing some fatigue at work. All but 10% reported their health to be good or excellent, although over ⅓ reported having more than five days off work during the past six months. Over ½ of respondents reported having their health monitored, with monitoring covering skin cancers, hearing, musculoskeletal disorders and vision. The majority of respondents reported good dietary habits but not drinking enough fluid. Many respondents reported environmental hazards affecting their safety at work. Further research looking at several aspects of employee health and its management is required. The New Zealand forest industry must increase its focus on workers health and in particular health monitoring and provisions of relevant information on hazards, their effects and controls.

Warkotsch, P. W., Engelbrect, G. R., & Harker, F. 1995.

The South African harvesting code of practice. Suid-Afrikaanse Bosboutydskrif 174(Nov).

The South African harvesting code of practice is a set of guidelines developed by harvesting specialists to assist the forest industry to select correct harvesting and road construction practices that are consistent with appropriate environmental management principles. The focus is not only on green issues but also on the effects of harvesting on ergonomics (worker's environment), economics, the natural environment and productivity. Environmental auditing is a management tool designed to protect and improve the environment by assisting management in the control of practices which may have an impact on the environment and to assess compliance with company environmental practices. The harvesting code of practice will have an important role to play in setting environmental standards to be documented in company policies.

The development of the harvesting code of practice involved the evaluation of several other international codes, the assessment of local equipment and processes used and an investigation in their possible impacts on the working environment.

Appendix 6.3

List of keywords

List of key words used in the search of literature from the CAB scientific research data base and resulting number of papers identified.

Table 6.1. List of key words used and number of papers identified.

Requested words	Results scientific paper number
Timber	
Timber harvesting	8
Timber harvesting management	10, 28
Ergonomics	2, 34, 42

Table 6.1. (cont.)

Requested words	Results scientific paper number
Ergonomics of timber harvesting	5, 22, 43
Standards	
Timber harvesting standards	
Mechanisation of forest operations	
Operator best practice	
Health monitoring	29, 31
Operator health monitoring	17
Control and monitoring	18
Health controls	
Accident	
Accident recording	46
Accidents	15, 21, 33
Timber harvesting accidents	
Training in timber safety	
Machine training	6, 32
Operator	
Operator training	
Logging mechanism	13
Logging operator health	16, 36, 37, 38, 39
Operator health	12
Operator health and safety	2, 3, 4, 7, 9, 14, 26, 28, 31, 37, 41, 47
Health and wellbeing	
ILO	
Occupational health and safety	11, 46, 49
Contractor health and safety	
Shift work patterns	1, 20, 27, 43
Rest periods	