Advanced Cabin Design

How to Improve Comfort and Performance by Progressive Cabin Design

Robin E. Bronkhorst

Michiel P. de Looze

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Cover photo:
In co-operation with the public transport enterprise RET in Rotterdam and the manufacturer of the tram, TNO developed a cabin that provides all drivers with a safe and comfortable working environment. This could only be achieved by designing the tram from scratch. The adjustments involve more than just the adjustment of the chair and the range of the controls.

This publication can be ordered at:
TNO Work and Employment
P.O. Box 718
2130 AS HOOFDDORP
The Netherlands
Fax: +31 23 554 93 94
E-mail: receptie@arbeid.tno.nl
Price: 20 euro, excl. VAT

ISBN 90-5986-113-2

Editors:
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Print:
PlantijnCasparie Amsterdam

1 Major Challenges in Cab Design

Liesbeth Groenesteijn, Michiel P. de Looze

This chapter addresses the current problems in cab design. Although a lot has improved over the past years, operators still recognize a number of aspects that need further improvement. In addition, the currently available health figures are clear: operators of various vehicles are at increased risk for developing back and neck pain. Specifically, the machines where operation requires a near vertical view (cranes, sweepers, straddle carriers) form a major problem area. Here, the finding of a comfortable and healthy body posture is the major challenge for cab designers. Some new ideas for future cab design are presented in this chapter.

1.1 Current cabin design and comfort

Over the recent years, the design of cabins of all kinds of vehicles has strongly developed. Not only forms and dimensions of the cabins have evolved, also the seat comfort and the climate control, for example, have improved in the past few years. Comparing 'less than four years old' to 'more than four years old' wheel loaders and excavators Kuijt-Evers et al. (2003) found that the general opinion of operators about the comfort of the cabin was clearly higher in the newer machines.
However, the same study indicates that operators can easily think of a number of aspects that need further improvement. An important aspect that is mentioned by wheel loader operators, is the comfort of the seat. Excavator operators specifically consider the cabin dimensions, the outside view, the reliability of the machine and the climate control as factors to improve.

A main question in this respect is: do we need further improvement? Is it a luxury or is it an unambiguous necessity to make comfort improvements?
Obviously, people are currently used to a high level of comfort, not only at work but also at home, in their private cars and so on. As developments in related branches are on-going, comfort is a relative understanding, but it is obvious that expectation levels with regard to cabin comfort are continuously increasing.
It can also be argued that comfort would improve the operators' performance. A comfortable cabin is a cabin where (among other issues) the seat can be optimally adjusted to the driver, where handles, joysticks, pedals are always within

reach, where the inside view (on panels) and the outside view are not obstructed and don't require awkward body postures (trunk twisting, neck extension, and so on) and where the climate can be optimally controlled. It is likely that all these features may directly or indirectly, i.e. by an improved operator's motivation, increase the working speed.

Finally, a comfortable cabin is likely to promote health. Comfortable cabin design should be aimed at the reduction or elimination of risk factors for work-related health complains like neck and shoulder pain and low back disorders. In the next paragraph the currently known, hard figures about the health of the operators of various machines are presented.

For now, the conclusion is that comfort is a necessity. This is underlined by the increasing numbers of cabin manufacturers recognizing comfort as an important selling factor.

1.2 Health of vehicle operators

In the past, a lot of studies about the physical conditions of the operators in their cabins have been conducted all over the world. The results from these studies are described below and summarized in Figure 1.1.

Zimmerman et al. (1997) gathered the numbers of operators reporting neck/shoulder and back pain for various machines, namely bulldozers, forklifts, power shovels and earth moving machines. More than half of the involved bulldozer operators reported neck and shoulder pain, while over one third of these operators reported an episode of low back pain over the last year (see Figure 1.1). For forklift truck drivers the extent of the health problems is even higher and for the power shovel operators quite similar to the bulldozer operators. The back problems for the operators of earth moving machinery seem even worse: two third reported low back pain over the past year.

In another study (Burdorff et al., 1993) the occurrence of back problems among crane and straddle carrier drivers was studied. The percentages of drivers reporting the occurrence of back problems over the past year were 50% and 44%, respectively. Massaccesi (2003) found high numbers of neck and back pain for street cleaning machine drivers: about 80% of the questioned operators report pain in the neck and back. Other papers show the scores of low back pain for truck drivers, namely 50% (Miyamoto et al., 2000), and neck/shoulder pain for logging machine operators, namely 60% (Axelsson and Pontèn, 1990).

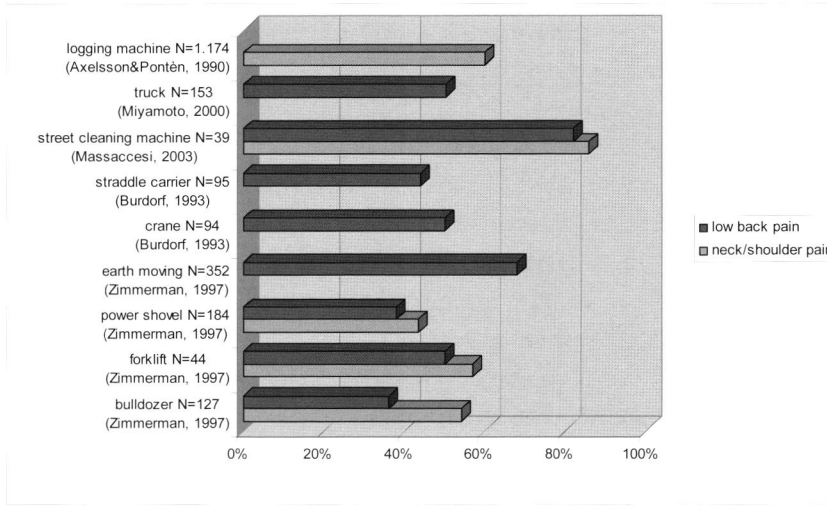

Figure 1.1 The percentages of cabin operators reporting the occurrence of an episode of neck/shoulder and back pain over the past year for various kinds of machinery. N reflects the total number of people for each kind of machine that were involved in this study. When there is just one bar it means that either back or neck problems were recorded and not both

Although the above studies are not exactly comparable because of different subject numbers of different populations and because they don't use exactly the same definitions for health disorders, they all indicate health problems for operators in cabins. Figure 1.1 shows that many operators suffer from health problems in the back and neck/shoulder regions. An important question in this respect is how the observed rates of health problems among cabin operators relate to the rates of other working populations. The health problems of cabin drivers can only be defined as 'work-related', in case the rates of health problems of cab drivers are significantly higher compared to other workers.

Table 1.1 Odds ratios for back and neck pain for the operators of various machines

operators of machinery type	back pain	neck/shoulder pain
cranes	2.7[1]-3.6[2]	3.3[1]
straddle carriers	2.5[3]	
forestry		3.4[4]
trucks	2.0-2.4[5]	
forklift trucks	2.3[6]	

[1] Piccinni et al., 1992.
[2] Burdorf and Zondervan, 1990.
[3] Burdorf et al., 1993.
[4] Hagen et al., 1998
[5] Miyamoto et al., 2000.
[6] Zimmerman et al., 1997.

Table 1.1 shows the odds ratios (OR) for the operators of various machines. The OR indicate the odds for the occurrence of back or neck/shoulder pain in relation to a reference group. The reference groups vary from blue collar workers in the same company without cabin operator tasks to administrative/office workers, also known as white collar workers.
The risk for vehicle operators of getting back or neck/shoulder pain is sometimes more than three times higher than for the reference group (Burdorff et al., 1990; Piccini et al., 1992; Hagen et al., 1998). All the studies in the table show an OR of at least two or more. That means that the chance of getting back or neck problems is at least double for operators of the these machines in relation to the control group. The average is even two point five to three times higher. This shows that the problems of cabin operators are work-related. The direct work environment is one of the aspects which can influence the operators' health. So cabin design potentially helps to reduce back and neck complaints and must be improved.

1.3 Main factors in cabin design

Having said that cabin design may well reduce the health problems among operators, the question is: what aspects should be specifically addressed? Hereto, we need to know the major risk factors of neck/shoulder and back pain.

Ariëns (2001) systematically reviewed the general scientific literature on the work-related risk factors for neck pain. From this review the following factors could be unambiguously defined as increasing the risk for neck pain: (fixed) sedentary postures, twisting and bending of the trunk, neck flexion, high arm force, fixed arm posture, hand-arm vibrations, long duration of sitting and bad workplace design. Another review (Hoogendoorn, 2001) established the main risk factors for back problems. These are: twisting and bending of the trunk, sedentary postures and vibrations.
In general, many of the above risk factors are present in the work of machine operators. In order to prevent the back and neck/shoulder problems, which may even lead to permanent disability to work, it is clear that the above factors are the ones to address in the design of future cabins.

Table 1.2 The specific risk factors for health complaints for the operators of sweeping machines, forklift trucks, tractors and cranes

sweeping machines (Massaccessi, 2003)	forklift trucks (Brendstrup, 1987; Boshuizen, 1992)	tractors (Kondo, 1986)	cranes and straddle carriers (Piccinni, 1992; Burdorf, 1993)
• neck flexion • neck torsion • trunk flexion • trunk torsion • non-adjustable chair	• sitting a lot • sitting during long periods without interruption • looking back frequently • many working years	• vibrations • sitting posture • frequent pedal operations • poorly arranged working environment	• monotonous and static posture • vibrations • sitting posture • static posture • neck flexion • bended or rotated postures • uncomfortable chairs • uncomfortable controls

Various studies on risk factors have been less extensive, but also more specific, addressing the specific risk factors in specific machines. Table 1.2 presents the results of these studies in terms of risk factors for sweeping machines, forklift trucks, tractors and cranes.

It appears from this table, that nearly all factors got to do, one way or the other, with body posture and movement. It may concern the static and sedentary character of body posture or the repetitive, monotonous character of body movements, or the frequent occurrence of awkward body postures like a twisted trunk and a flexed neck, or cab features like uncomfortable chairs and controls leading to uncomfortable postures and movements. In other words: body posture is crucial in the design of comfortable and healthy cabs.

This is illustrated by the model in Figure 1.2, showing the determinants and effects of the operator's body posture.

Roughly, the operator posture is determined by the cabin design (specifically the seat, but also layout of controls, mirrors and monitors), the task demands (object that must be kept in sight, manoeuvres, around sight and accuracy) and the individual operator properties (like anthropometrics and preferred posture). Further the operator orientation determines the position and movement variation of individual body parts (for instance the degree of neck flexion or trunk torsion), the pressure distribution at the man-machine contact area, the direction of affective forces (shocks, vibrations), the way of operating, the ease of operating of pedals, joysticks and suchlike and the operator's sight. By these factors there is

the effect on physical load , discomfort/comfort, emotional perception, performance and health.

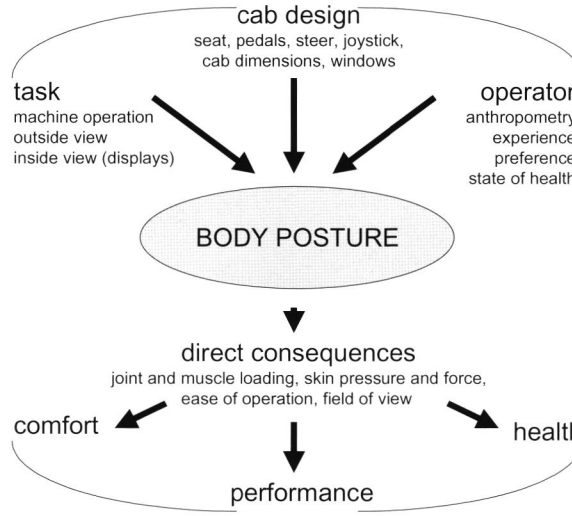

Figure 1.2 The crucial issue of body posture in the design of comfortable, productive and healthy cabins

The crucial role of body posture in comfortable cabin design becomes very clear when considering machines where operators need to look in a near vertical direction. This is the case in sweeping machines, cranes, straddle carriers (see Figure 1.3). Working in these machines mean: static or highly frequent, awkward body postures for long periods of time in combination with frequent body vibrations and shocks in variable directions! Not surprisingly, the rates of injury are high among the operators of these machines, as illustrated before. Optimal solutions, specifically addressing the above problem, do not yet exist. Several ideas are presented in the final paragraph.

Figure 1.3 The body postures in sweeping machines, cranes, straddle carriers, which is forced by the required (near-vertical) viewing direction

1.4 Future challenges

How can we create a healthy posture or, preferably, a number of alternating healthy postures for the crane, straddle carrier an sweeping machine driver. Two solution directions can be distinguished.

First, one may change the required viewing direction. Hereto, mirrors and camera systems might be implemented. In some cases this might work. In Chapter 4 addressing the design of compact sweeping machines gives a good example of the potential power to improve the body posture by implementing a camera-monitor system on a sweeping machine.

The second kind of solution direction might concern a fundamental modification of the standard body posture. Here, we can learn from the experiences with re-

spect to other workplaces where workers adopt for some reason a body posture which is different from normal.

The figures below (Figures 1.4-1.6) show examples of alternative body postures in various industries for a better upward and downward view.

Figure 1.4 Example of an alternative body posture in the assembling industry

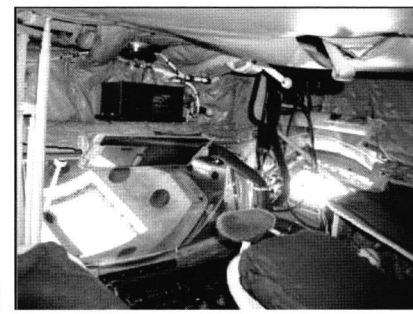

Figure 1.5 Workplace of an operator of a fuel airplane. The operator lays on his ventral side with the chin resting on the small pillow and looks through the small window for refuelling a plane in the air

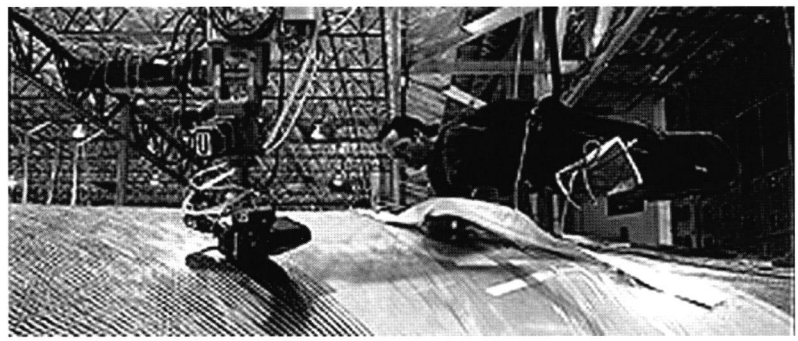

Figure 1.6 Example of an alternative body posture in the sail industry. The person in the photograph is repairing sails

Concepts for new operator body postures for shovel cabins were developed earlier in cooperation between TNO and the University of Delft in the Netherlands. Figure 1.7 shows an example. The shown operator orientation provides the advantages of a better sight, elimination of unfavourable joint postures, an opportunity for variation in posture, less tiredness, more comfort and (through all this) and improved performance.

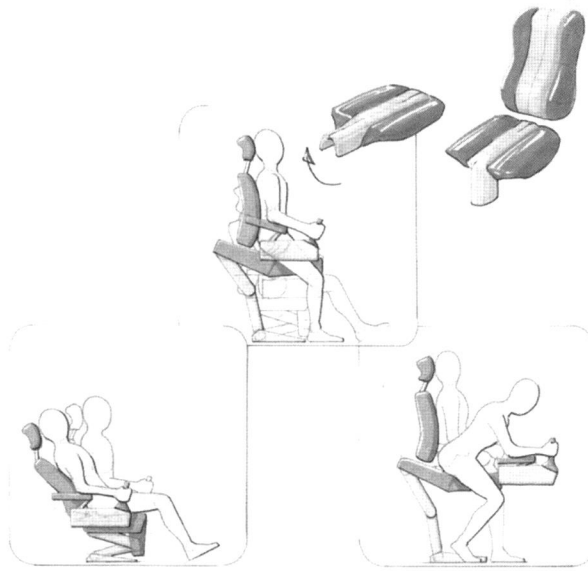

Figure 1.7 An example of alternative operator orientations in a shovel cabin. Particularly the picture on the bottom right shows how the operator could choose to vary between sitting straight up and in 'motorcycle position'

Figure 1.8 shows a good example of an innovative cabin, facilitating a new working posture. The cabin is designed for cranes and harbour facilities. The design of the cabin, the seat and the instruments was specifically aimed to create a comfortably bent forward body posture (like the motor position in Figure 1.7) for the operator who needs to look down in a near vertical direction. Special armrests were designed for upper body support. Chapter 4 in this book pays specific attention to this interesting cabin.

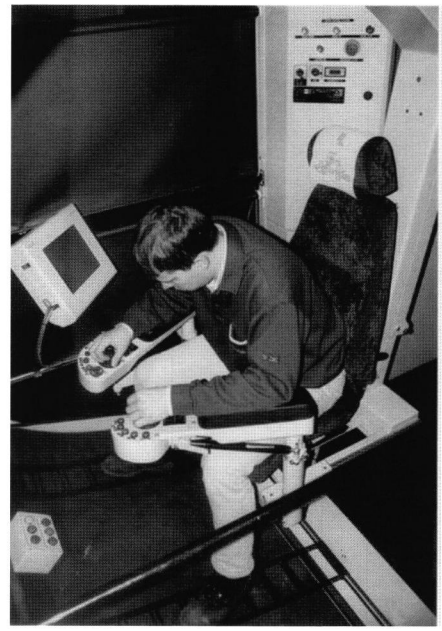

Figure 1.8 Merford's ceiling suspended Ergo-seat specifically aims at supplying more support to the crane operator for a more comfortably bent forward body posture

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