

## Computer-aided evaluation of the safety aspects of materials handling

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Approximately one-third of all industrial accidents are the result of malfunctions in materials handling systems (3). The demands for more design-oriented and formal safety assessments have been stimulated by the rapid increase in new technologies in materials handling. Accident data are often very scanty or totally lacking when novel installations are introduced into production. Prophylactic activity must therefore be built on a diagnosis of normal operation and symptoms rather than on one of sickness and injury.

The evaluation of alternative materials handling solutions is based essentially on how well each alternative is expected to meet the overall goals of the firm and the task. Several formal evaluation procedures have been developed for the analysis of the time, cost, space, and capacity characteristics important for production (1, 6, 11). Unfortunately, safety is commonly regarded as an intangible factor that cannot be reduced to quantitative measures (6). Thus there is a need to make safety assessment more tangible.

### Safety evaluation

Two distinct activities are required in safety evaluation, ie, measuring risks and judging their acceptability (8). Consequently safety evaluation is a mixture of objective and subjective factors. In addition to the measurable values of physical properties, the values and opinions of people are part of safety analysis (2, 4).

Risk is a function of the frequency and severity of the accidental outcomes of a system. As accident data are scarce or even nonexistent, there is need to look for the risk characteristics of the machines, tasks, goods, and environment. Hazards and error-inducing factors, as well as the potential for failures and disturbances, must therefore be analyzed. Safety evaluation should also cover the quality of accident prevention within a system, ie, the degree to which the risks have been coped with (figure 1).

Due to the multidimensional nature of safety, a single quantitative output is seldom received from a safety evaluation. The attributes to be measured have mostly an intermediate nature, and their relationship with safety remains vague.

The following two problems of safety evaluation can be distinguished in the design of materials handling

systems: (i) is the system already selected safe enough and (ii) which of the given alternatives has the highest safety level? In the first case, there is usually only a single solution to be assessed. The second problem involves a set of solutions to be evaluated and compared with each other.

### Computer-aided safety evaluation

Checklists are traditional tools in safety assessment when compliance with safety standards is a major concern. The first step in computer-aided evaluation could be a checklist within a microcomputer. A programmed checklist compels the evaluator to respond to every single question systematically. During the course of evaluation one can receive information, eg, on safety standards. Danger points and safety hints may be visualized by graphics. Summary statistics can be presented, eg, on the number of "yes" or "no" answers. A checklist for the evaluation of fork-lift trucks (10) was constructed for a microcomputer with the use of the PASCAL code.

Multicriteria evaluation techniques are used when a set of solutions is to be compared (2). Then an evaluation matrix is constructed which is a table with the criteria in rows and the solutions in columns. Each criterion-solution element includes the degree of satisfaction of the solution as to the criterion in question. The degrees of satisfaction are multiplied by weighting values of criteria indicating their importance for total safety. The end result is a ranking list of solutions in terms of safety characteristics.

Most spreadsheet programs are suitable for constructing and calculating evaluation matrices. In a project in which access systems of tractor cabs were evaluated, a BASIC program was developed to yield a multicriteria evaluation for seven makes of tractors. A total of 50 safety criteria was included on the basis of the measurable dimensions, physical properties, and data on simulated use experiments and user opinions. The same data set was also run by the Lightyear(C) decision modeling software including a graphic output of results (4).

Figure 2 presents the set of rules governing tractor access design according to Finnish safety regulations in the format in which they were dealt with in the Lightyear program. One can easily convert the safety requirements into rules to be automatically considered

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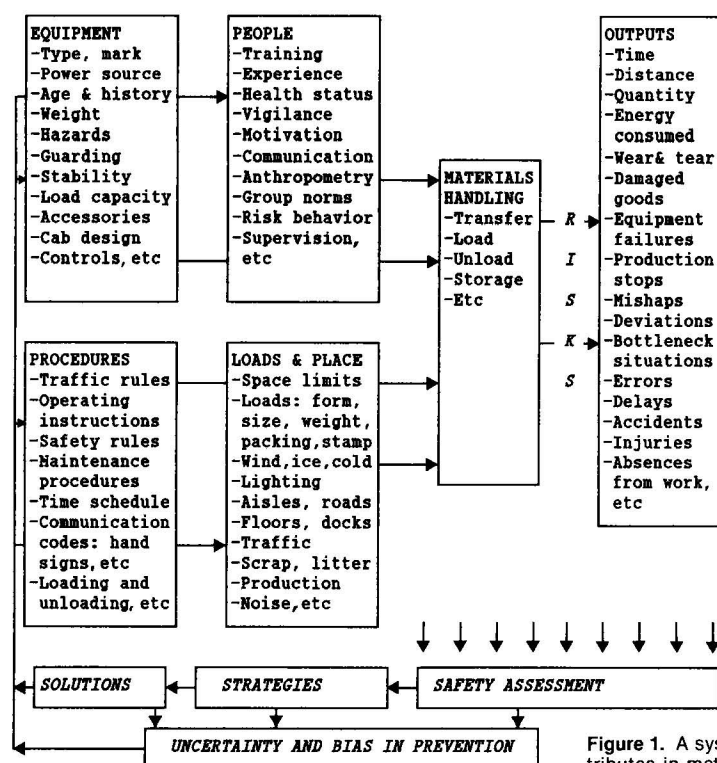


Figure 1. A system model for the evaluation of the safety attributes in materials handling systems.

| RULE NAME     | RULE                                                  |
|---------------|-------------------------------------------------------|
| STEP HEIGHT   | Step height MUST BE AT MOST 550<br>(ELIMINATION RULE) |
| STEP WIDTH    | Step width SHOULD BE AT LEAST 250<br>(WEIGHT = 75)    |
| STEP DISTANCE | Step distance SHOULD BE AT MOST 300<br>(WEIGHT = 75)  |
| STEP DEPTH    | Step depth SHOULD BE AT LEAST 150<br>(WEIGHT = 75)    |
| DOOR HEIGHT   | Door height SHOULD BE AT LEAST 1350<br>(WEIGHT = 50)  |
| DOOR WIDTH    | Door width MUST BE AT LEAST 250<br>(ELIMINATION RULE) |

Figure 2. Set of rules governing the evaluation of tractor access systems according to Finnish regulations in the format dealt with by the Lightyear(C) decision modeling program (dimensions are in millimeters)

| CRITERION: STEP DESIGN |                 |                |
|------------------------|-----------------|----------------|
| ALTERNATIVES           | LEAST DESIRABLE | MOST DESIRABLE |
| A. (Fiat)              |                 | X              |
| B. (Belarus)           | X               |                |
| C. (Zetor)             | X               |                |
| D. (Swed-Trac)         |                 | X              |
| E. (Valmet)            | X               |                |
| F. (Same)              | X               |                |
| G. (Kubota)            | X               |                |
| H. (Ford)              |                 | X              |

Figure 3. Example of graphic input of opinions related to the access systems of tractors (average values of 10 people).

by the program. Then the program can either eliminate the solutions not complying with standards or lower the degree of satisfaction in case of "should" rules.

In addition to the physical variables there is a possibility to incorporate subjective data into the evaluation process. Besides numeric input data, graphic and verbal inputs can also be used in modern decision modeling programs. Thus the qualitative and difficult-to-measure opinions and values of people become more

tangible, and the subjective side of safety is also covered by the evaluation. The graphic input of opinions is demonstrated by figure 3.

A more advanced level of computer-aided decision making is being developed from the artificial intelligence approach. Prototype expert systems have been introduced for the selection of fork-lift trucks (9) and for occupational safety decisions (5, 7). The next few years will certainly see the rise of useful expert systems for the safety evaluation of materials handling. None-

theless, even a sound and efficient use of conventional software in safety evaluation would contribute greatly to better safety decisions. Moreover, the evaluation programs are necessary building blocks for utilizing and understanding expert systems.

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