

CRITICAL ISSUES IN EVALUATING
USER ACCEPTABILITY OF
ADJUSTABLE ROLLOVER PROTECTIVE STRUCTURES

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Ergonomists should be involved in the design of new safety devices to ensure that the proposed design will meet basic ergonomic design criteria for function and safety, as well as being acceptable to users. This paper describes an ergonomic design methodology employing a Likert-type questionnaire for evaluating user acceptance of adjustable ROPS designs. A Likert-type questionnaire is presented that can be used to probe for attitudes about the use of ROPS and possible indications that an adjustable ROPS would be more acceptable to farm tractor owners.

INTRODUCTION

Between 1980 and 1985, farm tractor rollovers fatally injured a conservative annual average of 132 people while they were working (Etherton et al., in press). The rate of tractor overturn fatalities in the U.S. in 1987 was estimated at 5.6 deaths per 100,000 tractors in an estimated U.S. tractor population of 4.44 million tractors (National Safety Council, 1988). These fatalities contribute to making work in agriculture one of the most dangerous occupations in the U.S. (Division of Safety Research, 1989). Rollover Protective Structures (ROPS) that can be adjusted down and out of the way when they might otherwise interfere with tractor operations may offer a solution to the tractor rollover fatality problem which is acceptable to farmers.

Strategic thinking about how to reduce the death toll among farm tractor operators has led to a focus on retrofitting older tractors with ROPS (Stallones, 1989). But there is some doubt that farmers will actually use retrofit ROPS. Ross and DiMartino (1982) indicate that the acceptability of ROPS to tractor users was an important factor in early efforts to get ROPS installed on farm tractors. In their opinion, acceptability implies trade-offs by the user/customer, and the single most influential trade-off was between rollover protection and operator convenience. In other words, farmers will probably use a retrofit ROPS if it is convenient for them to do so.

There are a wide variety of ways to design retrofit ROPS (two post, four post, adjustable, fixed, ...). Voluntary standards for ROPS for farm tractors have been written in such a way that the process of designing better or equally effective ROPS is not constrained. What is expected from any design, however, is that it perform its protective function by deflecting within safe limits during loading tests (ASAE, 1988). Determining whether farmers will use retrofit ROPS should consider whether differences in design will have a significant effect on acceptability and therefore on use. Retrofit ROPS should be treated as a multidimensional, not a one dimensional, variable in agricultural safety research. This paper will address whether particular design configurations for retrofit ROPS are more or less convenient and consequently more or less likely to be used by farmers.

In an earlier paper on the need for ROPS retrofits (Etherton, 1990), an adjustability feature in ROPS retrofit designs was discussed as one possible way to make ROPS use more convenient and therefore more acceptable to users. It is postulated that acceptability for the adjustable ROPS would derive from its capability to be moved down and out of the way for tractor operations where the height of the ROPS would normally interfere with the work.

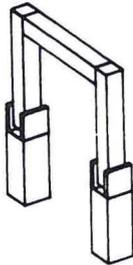
There are currently two approaches to ROPS adjustability: the folding approach (Figure 1) and the telescoping approach (Figure 2). Lowering an adjustable ROPS of either type requires a person (normally the tractor driver) to remove the fasteners that hold the ROPS in the up position, lower the ROPS to the down position, and attach the fasteners in the down position. To return the ROPS to its raised position, the driver must remove the fasteners holding the ROPS in the down position, lift or raise the ROPS to the up position, and insert and secure the fasteners in the up position.

Before expending scarce injury-prevention resources on initiatives to promote the design and fabrication of adjustable retrofit ROPS for older tractors, fundamental questions about the user acceptability of this safety device need to be addressed. One such question is: Is the lowering procedure measurably convenient enough to make the adjustable ROPS an acceptable alternative to no ROPS for the user who needs to drive the tractor in places where a fixed ROPS could not be used? The purpose of this paper is to discuss early work in the development of models to help answer this question. The proposed models would predict the degree of acceptability for alternative adjustable ROPS features based on quantitative measures of user performance in tasks like those in adjusting a ROPS and subjective responses relating to the convenience of the adjustment.

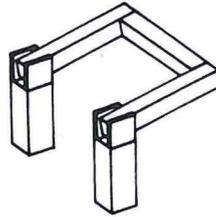
PROTECTIVE DEVICE ACCEPTABILITY

In general, there are two very different categories of users for whom the ergonomist can seek to enhance protective device acceptability: (1) employees who use safety equipment (purchased or developed in-house) as a condition of their employment, and (2) self-employed individuals who obtain safety equipment either as a part of a total product

that they purchase or as a specific product obtained in response to a perceived need for the safety product. Brown (1990) provides insights on participative ergonomics as an approach for gaining safety solution acceptability in labor-management type organizations. Users in the second category are the concern of this paper.

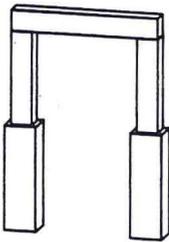


ROPS Up

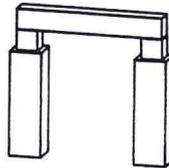


ROPS Down

Figure 1: Folding Adjustable ROPS



ROPS Up



ROPS Down

Figure 2: Telescoping Adjustable ROPS

Berndsen (1990) interviewed users of several devices intended to prevent back injuries among paving workers in Holland who handle heavy materials such as curbs, storm drains, and paving stones. The Dutch government was subsidizing the purchase of some of this equipment. One question addressed was: What are the reasons for not using bought appliances? He found that successful implementation depended on understanding the user and his tasks as well as introducing only well-tested, well-developed, high quality tools that function well.

Feeney (1986) reviewed studies that looked at safety device design factors (factors outside the control of the worker) which influenced the use or nonuse of protective equipment. Important factors identified were poor functional design, discomfort, interference with the work task, and nuisance value. To answer the question of why workers (in this case farmers) would refuse to use

appropriate protective equipment, he suggests that one should first investigate the following four questions:

- Are the workers aware of the hazard?
- Can the protective equipment be obtained easily and conveniently?
- Do the workers believe that the protective equipment is effective in its potential for protection?
- Are there factors in the use of the protective equipment that will inhibit the worker carrying out his work satisfactorily when using the safety equipment?

PROPOSED MODELS FOR TWO ACCEPTABILITY CONSTRAINTS

Determining the probability of use of adjustable ROPS implies developing an understanding of the acceptability criteria of intended ROPS users. The full model for the probability of use of any safety device (Equation 1) is assumed to be an optimization function in which different physical and perceptual aspects of acceptability are considered. The full model for the probability of use of adjustable ROPS retrofits is subject to a variety of constraints relating to many characteristics of the tractor operator interface including: weight to be lifted and lowered, exertion required to loosen and tighten fasteners, perception of the benefit of having the device, difficulty of the task, time to complete the adjustment procedure, number of steps, loose parts vs. captured parts, etc. Some of these constraints, such as the constraint on the amount of weight to be lifted and lowered, can be evaluated using existing models. For others there are as yet no models. Two areas where models are proposed have to do with (1) the exertions required to loosen and tighten fasteners (Equation 2), and (2) user perceptions of the benefit of having an adjustable ROPS on their tractor (Equation 3). These areas for investigation were suggested by observations of people using current adjustable ROPS designs and from comments by experts and in the literature on farm attitudes toward safety equipment.

MAXIMIZE:

$$A = f(E, P^+, A_{i...j}) \quad (1)$$

SUBJECT TO THE CONSTRAINTS:

$$E < MAE \quad (2)$$

$$P^+ > P^- \quad (3)$$

Where:

- A = Probability of Use
- E = Exertion for fastener task
- MAE = Maximum Acceptable Exertion for that Posture and Type of Exertion
- P⁺ = Perceived Acceptability of Using the Device
- P⁻ = Perceived Acceptability of Not Using the Device
- A_{i...j} = Other Aspects of Acceptability

It is proposed that research be conducted to develop and test the models for dealing with the acceptability constraints in Equations 2 and 3. The research on the acceptable exertion constraint should proceed along lines established in the literature on assessment of load handling with regard to unusual postures in maintenance tasks (Selan et al., 1986; Winters, 1986). Planning for that research will be discussed at length in a future paper. The perceived acceptability constraint, a model for it, and a proposed experiment to establish predictor variables and their parameters will be discussed next.

USING LIKERT-TYPE SCALES TO ASSESS ACCEPTABILITY

Likert-type scales have been used as a way to assess how features of various products are perceived (Table 1). Osborne and Clarke (1975), in an ergonomics investigation of the comfort of hovercraft passengers, found no significant differences between responses on rating scales with qualitative judgement end values "Pleasant--Unpleasant", "Comfortable--Uncomfortable", "Agreeable--Disagreeable." They also found no significant differences between responses marked on rating lines that were sectioned and unsectioned. Also, the validity of such rating scales was shown in that responses in the field were not significantly different from responses in the laboratory.

A MODEL FOR PERCEIVED ACCEPTABILITY

It is proposed that a measure of perceived acceptability for a particular safety device dimension can be obtained by computing the mean numerical response by a sample of intended users to a five point Likert-type instrument specific to that dimension. In this case there are three dimensions: Fixed ROPS, Adjustable ROPS, and No ROPS. These measures can discriminate between the acceptability of no rollover protection and the alternative acceptability of rollover protection.

$$P = \frac{\sum R}{n} \quad (4)$$

Where:

- R = Individual numerical responses to Likert Instrument for that safety device dimension
- n = Number of subjects

A Likert-type instrument can also be used to evaluate what would be important to users if adjustability were provided as a feature of retrofit ROPS. Equation 5 is a measure of the difference in perceived acceptability between any two safety device dimensions. The two differences, ΔP , of interest for tractor safety are between "No ROPS" and "Fixed ROPS," and between "No ROPS" and "Adjustable ROPS."

$$\Delta P = P_1 - P_2 \quad (5)$$

Table 1. Human factors product evaluations that have used Likert-type scales.

Author	Product Features	Scale	Sample Size	Endpoints
Casey, 1990	Control Handle Locations on 69 Tractors	5 Point	172	1 = Very Unacceptable 5 = Very Acceptable
Drury, 1989	9 Aspects of 2 Cooking Pans	5 Point	32	1 = Strongly Agree 5 = Strongly Disagree
McCrobie, 1989	6 Areas of a Train Rail Car	5 Point	22	1 = Completely Unacceptable 5 = Completely Acceptable
Harrison, Sayer, and Snyder, 1989	48 Aspects of 3 Typewriters	7 Point	40	1 = Hard to Do/Hard to Remember 7 = Easy to Do/Easy to Remember

CONCLUSION

An experiment should be performed to evaluate the model in Equation 4. The segments of the tractor-driving population that are most at risk of rollover fatality are teenagers and farmers age 60 and over (Doss and Pfister, 1974; Karlson and Noren, 1979; Schnieder, 1986). Age-specific relationships on willingness to obtain different types of ROPS should be determined. This would involve comparisons between younger (≤ 60 years) and older (> 60 years) tractor owners. Subjects should be familiarized with the adjustable ROPS concept and should also participate in a psychophysical experiment dealing with determining maximum acceptable exertions (MAE) for the postures associated with adjusting ROPS. The effects of independent variables such as knowledge, experience, and attitudes on the rollover hazard, age, and family status should be evaluated.

Important questions that could be more easily addressed as this research proceeds include: Should resources be expended to design adjustable retrofit ROPS for tractors for

which no retrofit is currently available? Is the inclusion of an adjustability feature in the design of a retrofit ROPS a good predictor of significantly increased acceptability of a retrofit ROPS? If an adjustability feature is included in the design of a retrofit ROPS, do posture and exertion requirements imposed by the type of fastener used and their location significantly effect the acceptability of the retrofit ROPS? What are the non-cost factors that are the best predictors of the acceptability of a retrofit ROPS?

Sleet (1987) says that public health priorities arise from the convergence of:

- a disease (injury) threat,
- public awareness of the threat,
- demand for proper protection from the threat, and
- a body of scientific literature to support the effectiveness of prevention/protection measures.

The first of these is clearly established. Increasing the public health priority of ROPS retrofits for older tractors will depend on agricultural health promotion activities to increase the second and third factors. The research discussed in this paper should increase the fourth. Proceeding with this research will also add to the information that designers have about how adjustable ROPS on new tractors will be used by older drivers.

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