Installing a Cost-Effective Rollover Protective Structure (CROPS): A Cost-Effectiveness Analysis

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Abstract. *Cost-effective rollover protective structures (CROPS) are tractor model-specific rollover protective structures (ROPS) that are as effective as existing ROPS retrofits (passed standardized structural static testing such as SAE J2194), but less costly (less than one-half the cost of existing ROPS retrofits). This study estimated the expected effects and costs at a per-tractor level for two options: No-CROPS and Install-CROPS. Expected injuries per tractor were 0.00169 with no CROPS and 0.00016 with CROPS installed, resulting in 0.00153 injuries prevented per tractor over a 20-year period. Expected costs were $457 and $248 with and without CROPS, respectively, over the same time period, giving the cost per injury prevented as $136,601. Comprehensive sensitivity analyses indicated that the probability of an overturn is one of the most important variables. When the cost of intervention ($1,000 for purchasing, shipping, and installation of ROPS retrofit) is used in the analysis, the cost-effectiveness ratio is $497,000 per injury prevented over the 20-year period. Thus, installing CROPS instead of existing ROPS retrofits improved the cost-effectiveness ratio substantially, with a 73% reduction in the net cost per injury prevented.*

Keywords. *Cost-effectiveness analysis, CROPS, Decision tree, Dominance, Net savings, ROPS, Sensitivity analysis.*

Tractor overturn continues to be the leading cause of occupational injuries in the agricultural industry. According to the U.S. Department of Labor, more than 1,000 deaths have resulted from tractor overturns between 1992 and 2004 (USDOL, 2004). A rollover protective structure (ROPS) is the major intervention and has been proven to have an estimated prevention rate ranging from 75% (CDC, 1995) when seatbelts are not used to 99% (Morgan et al., 2002) when seatbelts are used. The ROPS is a component attached to the tractor to provide a protective zone around the driver in the event of an overturn. It is estimated that about half of the 4.8 million tractors in the U.S. do not have ROPS installed (Reynolds and Groves, 2000; Myers and Snyder, 1995), and this poses an occupational safety and health problem. In making a decision about the extent to which society's resources are to be expended to address this problem, decision makers need to have reliable information on the costs and effects of this intervention.

A previous cost estimate of ROPS retrofitting, including shipping and installation, was $1,000 (Scharf et al., 1998). It is expected that if the cost of intervention is reduced,

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then the adoption rate would increase substantially. To achieve this, Harris et al. (2002) developed and evaluated CROPS (weld-free ROPS constructed with common structural elements and fasteners). CROPS designs are tailored to specific tractor models. Currently, prototypes for two popular models (Ford 3000 and Ford 4000) have been tested successfully, according to the static testing procedures of ROPS consensus performance standard SAE J2194 (Harris et al., 2005). The estimated cost to commercially produce these CROPS was $290 in 2003 (no shipping or installation cost included). Additionally, designs developed to date can be installed by one person (Harris et al., 2005) in about an hour (expert opinion from engineers working on the CROPS project, March, 2006). Hence, this component is aptly referred to as "cost-effective ROPS" to imply that it is as effective as existing ROPS, but less costly.

Previous Studies

Pana-Cryan and Myers (2000) reported that retrofitting all non-ROPS tractors with ROPS would cost $489,373 per injury prevented if compared to a do-nothing scenario over a 23-year period. In their cost benefit estimates, Pana-Cryan and Myers concluded that a nationwide intervention to retrofit all non-ROPS tractors would result in a net benefit of $1.5 billion. Myers et al. (2004) studied a ROPS intervention campaign for two counties in Kentucky. They concluded that the campaign was effective in influencing farmers to retrofit their tractors with ROPS. They reported a cost of $172,657 per injury prevented over a 20-year period.

A holistic approach that takes into account total costs and effects of retrofitting all non-ROPS tractors with CROPS would be ideal. However, this is not feasible for three reasons: (1) at present, estimates of the numbers of non-ROPS tractors for the models for which CROPS have been designed and successfully tested (Ford 3000 and Ford 4000) are not available, (2) the development of CROPS for other models is still in progress, and (3) CROPS designs might not be feasible for some models due to inadequate axle housing geometry or structural strength. For these reasons, this study is conducted from a societal perspective, but at the per-tractor level. This study considers the installation of CROPS on a tractor and estimates the expected costs and effects over a 20-year period. The result is compared with installing existing ROPS retrofits to determine how much the cost-effectiveness ratio is improved.

It is hoped that the results of this study will complement and boost the efforts being made in the research and design of CROPS for existing non-ROPS tractor models. A ROPS is effective when used in combination with seatbelts, and the intervention proposed in this study includes the use of seatbelts. Nonetheless, a sensitivity analysis was conducted to account for the reduced effectiveness of CROPS due to non-use of seatbelts on CROPS-equipped tractors. At the same time, as recommended by tractor manufacturers (Deere, 1994), it is assumed in this study that non-CROPS tractor drivers do not use seatbelts.

Methods

The alternatives considered in this study are: No-CROPS (do nothing) and Install--CROPS. For each option, the tractor driver may die (fatal injury) or survive following an overturn. Surviving drivers may be injured (non-fatal injury) or not (healthy). If there is no overturn, the driver remains healthy. Figure 1 shows the decision tree with two alternatives and the final health outcomes. TreeAge software was used to compute the annual expected costs and injuries for the two alternatives using the associated probabilities of occurrence. Excel was used to compute the expected costs and injuries over a 20-year period.

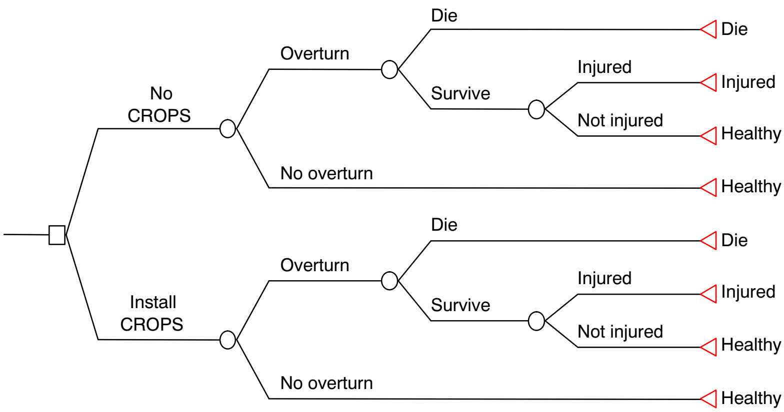

Figure 1. Decision tree with two alternatives.

Following Weinstein and Staton (1977) and Haddix and Shaffer (1996), a cost-effectiveness ratio is computed by dividing the net cost of the intervention by the net effect (difference in the resulting fatal and non-fatal injuries). Net cost is the total cost of the intervention minus the savings attributable to the intervention, i.e., the cost of intervention minus the cost of fatal and non-fatal injuries prevented. Because only two alternatives are being compared, cost-effectiveness ratio (CER) and incremental cost-effectiveness ratio (ICER) are used interchangeably in this study.

Data

Actual values for the analysis do not exist, so this study uses estimates from already published literature, ROPS manufacturers, and expert opinion on CROPS installation time. Sources and values that need clarification and the rationale for using them are presented below.

Analytic Horizon

The analytic horizon is essential because the effects of the intervention accrue over this time period and as such affect the ratio substantially. A 20-year period is used in this study for two important reasons:

- The average age of a tractor in the U.S. was 26 years in 2001, and some non-ROPS tractors have a life expectancy of 50 years or more (Myers, 2003), which implies that an analytic horizon up to the year 2025 is reasonable.
- It is expected that 20 years into the future is a time horizon within which a major technological change (such as all existing non-ROPS tractors being retrofitted with ROPS) is not likely.

Because some of the non-ROPS tractors may be nearing their useful life span while others may be in use well over 25 years from now, the sensitivity analysis was conducted from 5 through 30 years.

Cost of Intervention

In 2003, the cost of CROPS was quoted as $290 ($300 in 2004 dollars) plus the average cost of packaging and shipping ($140). There was no estimate of the cost of installation. However, because a CROPS can be installed by one person in one hour, the opportunity cost of farm labor is used as the cost of installation. The average hourly wage rate for U.S. farmers reported by the USDA (2005) was $9.23 in 2004, bringing the total cost of intervention to approximately $450 in 2004 dollars. Because seatbelts may have to be installed on some tractors, the sensitivity analysis was conducted on a cost of intervention up to $1000.

Probability of Overturn

The overturn probability values used in this study were derived from those reported by Pana-Cryan and Myers (2000) and Cole et al. (2000). The probability reported by Cole et al. (2000) was based on data from Kentucky, which has a higher predisposition to overturn due to the topography, and was therefore higher than the nationwide estimate obtained by Pana-Cryan and Myers (2000). Both studies computed probabilities based on annual tractor operation of 2000 hours. However, Myers and Snyder (1995) reported annual operation time estimates of 238 hours for non-ROPS tractors and 402 hours for ROPS-equipped tractors. These estimates were used to calculate the probabilities based on the estimated operation time using the Poisson probability formulas provided in the TreeAge software package. It was assumed that annual operation time for CROPS--equipped tractors is the same as for ROPS-equipped tractors. Therefore, based on the expected operation time, the probabilities of overturn were different for the two alternatives (ROPS and non-ROPS). The formulas used and the results are summarized in table 1.

The calculations show that the probability of overturn of non-CROPS tractors increases by a scale factor of 1.69 after installing CROPS. Thus, for the sensitivity analysis of overturn probability, the values were changed simultaneously to maintain the scale factor. Myers et al. (2005) also reported that ROPS-equipped tractors in Kentucky have a substantially longer annual operation time than those without ROPS (816 vs. 464 hours per year). From these studies, there is strong evidence to support the existence of a difference in operation time between ROPS and non-ROPS tractors, which affects the probability of overturn. Therefore, this research conducted an additional sensitivity analysis on the scale factor specifically to account for the potential change in the difference in probabilities of overturn with and without CROPS. Conceivably, the number of hours of operation may not change for some tractors, while others may change substantially. In view of this, the scale factor was varied from 1 through 3: from no difference to a three-fold increase in probability of overturn after installing CROPS. Although reports do not show three-fold increases, it was used in this study to see how sensitive the CER is to the relative change in overturn probability.

Social Discount Rate

Discount rates determine how society values current costs and benefits over future costs and benefits. Therefore, it plays a crucial role in the decision making process. This research used a discount rate of 4% to maintain consistency with the discount rate used for the costs of injuries estimated by Leigh et al. (2000) and with previous cost-effectiveness studies conducted on ROPS (Myers et al., 2004; Pana-Cryan and Myers, 2000).

Table 1. Calculation of annual overturn probabilities adjusted for actual operation time.[a]

Annual Probability (2000 h)	Convert Probability to Rate: -Ln(1-prob)/time	Convert the Resulting Rate to Probability: 1-Exp(-rate*time)	
		Non-ROPS Equipped	ROPS Equipped
0.00145	0.001451052	0.000172692	0.000291704
0.007604	0.007633058	0.000907921	0.001535422

[a] Ln is the natural log, and Exp is exponential. Time is equal to 1 in the second column, 238/2000 or 0.119 in the third column and 402/2000 or 0.201 in the fourth column.

Sensitivity analysis was conducted for values from 0% to 10%. Because the analysis essentially performs a trade-off between money and healthy years, health outcomes and costs are discounted using the same discount rate. However, the cost of the intervention is incurred at the beginning of the first year and is therefore not discounted.

Cost of Injuries

National costs of fatal and non-fatal injuries estimated by Leigh et al. (2000) were used as the cost of injuries, while the cost of injuries estimates for the agricultural industry (Leigh et al., 2001) was used as the lower bound estimates for the sensitivity analysis. All costs were adjusted to 2004 dollars.

Summary

A summary of the variables used in this study and their description is provided in table 2. Values in parentheses were used for the sensitivity analysis.

Results

This study estimates the expected effects and costs at a per-tractor level for two alternative choices: No-CROPS and Install-CROPS. Expected injuries per tractor are 0.00169 without CROPS and 0.00016 with CROPS installed, resulting in 0.00153 inju-

Table 2. Variables and sources of estimates used in the study.

Variable	Values	Source
Analytic horizon (years)	20 (5-30)	Assumed
Cost of intervention	$450 ($1000)	Manufacture and installation time (assumed)
Cost of fatal injury	$843,207 ($491,432)[a]	Leigh et al., 2000 (Leigh et al., 2001)
Cost of non-fatal injury	$39,836 ($14,453)[a]	Leigh et al., 2000 (Leigh et al., 2001)
Annual discount rate	0.04 (0.00-0.10)	CDC recommendation
Effectiveness to prevent a fatal injury	0.988 (0.758)	Springfeldt et al., 1998 (Pratt and Hard, 1998)
Effectiveness to prevent a non-fatal injury	0.758 (0.60)	Cole et al., 2000 (assumed)
Probability of fatal injury without CROPS	0.09593 (0.4)	Cole et al., 2000 (CDC, 1993)
Probability of fatal injury with CROPS	0.00115 (0.0024)	Springfeldt et al., 1998 (Pratt and Hard, 1998)
Probability of non-fatal injury without CROPS	0.69 (0.83)	Cole et al., 2000 (Myers and Pana-Cryan, 2000)
Probability of non-fatal injury with CROPS	0.17 (0.34)	Sprinfeldt et al., 1998 (Myers and Pana-Cryan, 2000)
Probability of overturn without CROPS	0.000172692 (0.000907921)	Computed from estimates by Myers and Pana-Cryan 2000
Probability of overturn with CROPS	0.000291704 (0.001535422)	Cole and Westneat, 2001
Scale factor of probabilities	1.69 (1-3)	Computed (assumed)

[a] Adjusted for inflation.

ries prevented over the 20-year period. Expected costs were $457 (i.e., cost of the intervention plus the cost of associated injuries) and $248 (i.e., cost of injuries) with and without CROPS, respectively, over the same time period. Thus, the CER is $136,601 per injury prevented.

Sensitivity Analysis

Given the uncertainty surrounding events in nature, coupled with the substantial disparities in estimates obtained from previous studies, a comprehensive sensitivity analysis (SA) was done to assess the sensitivity of the estimated CER to the extreme values of the estimates. One-way SAs were conducted for all the variables used, and two-way SAs were conducted for three variables that were found to exert the most influence on the CER. When an intervention is both less costly and more effective (i.e., the ICER is negative), it is referred to as the dominant alternative. In other words, there is net savings when that intervention is adopted.

One-Way Sensitivity Analyses

Table 3 provides a summary of the estimated CERs obtained from the one-way sensitivity analyses.

Sensitivity to the probability of overturn. The benefits of CROPS rest in its ability to prevent injuries when there is an overturn. Therefore, it was expected that high probabilities of overturn would result in high savings resulting from a high number of injuries prevented. The values used in this study converted the values reported to probabilities based on the actual operation time, as shown in table 1. The scale factor of 1.69 was maintained in the SA. CERs ranged from $136,601 to a net savings of about $124,000 per injury prevented as the probability of overturn of non-ROPS tractors increased from 0.00017269 to 0.000907921, while the probability of CROPS-equipped overturns increased from 0.000291704 to 0.001535422 simultaneously. The SA also indicated that when the probability of overturn of non-CROPS tractors is more than 0.00032 (0.000541 for CROPS-equipped tractors) per year, the Install-CROPS option dominates.

Sensitivity to the scale factor for probability of overturn. The preceding SA assumed a constant scale factor of 1.69. In other words, when a tractor is retrofitted with

Table 3. Summary of one-way sensitivity analyses results.

Variable	Range of Values[a]	Estimated CERs ($ per injury prevented)
Probability of overturn (without ROPS)	0.000915548 - 0.00017269	-124,000 - 136,601
Scale factor	1 - 3	129,000 - 152,000
Analytic horizon	30 - 5	-74,000 - 742,000
Cost of intervention	$450 - $1,000	136,601 - 497,000
Discount rate	0.00 - 0.10	44,000 - 312,000
Probability of fatal injury without CROPS	0.4 - 0.09593	-212,000 - 136,601
Probability of non-fatal without CROPS	0.83 - 0.69	109,000 - 136,601
Cost of fatal injury	$843,207 - $491,432	136,601 - 189,000
Cost of non-fatal injury	$39,836 - $14,453	136,601 - 158,000
Probability of fatal injury with CROPS	0.00115 - 0.0024	136,601 - 138,000
Probability of non-fatal with CROPS	0.17 - 0.34	136,601 - 157,000
Effectiveness to prevent a fatal injury	0.988 - 0.758	136,601 - 137,400
Effectiveness to prevent a non-fatal injury	0.758 - 0.60	136,601 - 150,000

[a] For consistency, some of the ranges in this column have been reversed to reflect the best (low CERs) to worst (high CERs) values in the "Estimated CERs" column.

CROPS, the relative change in hours of operation remains constant. Thus, an SA was conducted to account for a change in the probabilities by changing the scale factor from 1 to 3. The initial probability of overturn for non-CROPS tractors was used, and only the probability of overturn for CROPS-equipped tractors was changed. Although the probability of overturn increased the number of injuries prevented (denominator), the total cost of injuries associated with the intervention increased at a faster rate in the numerator. Therefore, it is expected that a higher scale factor would increase the CER. Using the initial value for probability of overturn, the CER varied from $129,400 to $152,000 as the scale factor increased from 1 to 3.

Sensitivity to analytic horizon. Because the intervention prevents injuries every year, and these are summed over the entire period, the net effect of the intervention increases with the analytic horizon. Incremental cost-effectiveness decreased from $742,000 to a net saving of $74,000 per injury prevented as the analytic horizon increased from 5 to 30 years.

Sensitivity to cost of intervention. The price of CROPS is unstable due to unstable steel prices and other exogenous factors. It is conceivable that if the adoption rate increases due to enhanced national campaigns, then demand would also increase. Without a proportionate increase on the supply side, the price of CROPS might increase. In addition, the cost of shipping, packaging, and installation (which may include seatbelt installation) may also increase. Therefore, sensitivity analysis was conducted on a total cost of intervention from $450 to $1,000. The cost of the intervention is in the numerator of the ratio; therefore, it is expected that the higher the cost, the higher the CER. The ratio increased from $136,601 to $497,000 per injury prevented as the cost of intervention varied from $450 to $1,000.

Sensitivity to discount rate. High discount rates imply low valuation of future costs and benefits. Although discounting is applied to both the numerator and denominator of the ratio, it discounts the numerator at a faster rate than the denominator because the value being discounted is higher and negative. Thus, high discount rates increase the ratio. Therefore, it is expected that the ratio would increase as the discount rate increases. The CER increased from $44,000 to $312,000 per injury prevented as the discount rate increased from 0% to 10%.

Sensitivity to probability of injury without CROPS. A high probability of fatal injury without CROPS implies a relatively high effectiveness for the use of CROPS. In view of this, it is expected that the higher the probability of fatal injury without CROPS, the greater would be the relative effectiveness of CROPS, resulting in lower CERs. As the probability increased from 0.09593 to 0.4, the CER decreased from $136,601 to a net savings of about $212,000. The Install-CROPS option dominates when the probability of fatal injury is greater than 0.21. Similar to the probability of fatal injury without CROPS, a high probability of non-fatal injury without CROPS also implies a relatively high effectiveness for the use of CROPS. Therefore, it is expected that the higher the probability of non-fatal injury without CROPS, the greater would be the relative effectiveness of CROPS, resulting in lower CERs. As the probability increased from 0.69 to 0.83, the CER decreased from $136,601 to $109,000.

Sensitivity to the cost of injuries. The model is set up such that costs accrue in both alternatives based on the expected number of injuries per year. However, the cost of fatal injuries prevented is negative in the numerator. Thus, it is expected that a high cost of injuries would reduce the ratio. When the cost of fatal injury increased from $491,432 to $843,207, the CER decreased from $189,000 to $136,601. Similarly, if the cost of non-fatal injury varied from $14,453 to $39,836, the CER decreased from $158,000 to $136,601.

Sensitivity to probability of injury with CROPS. Injuries associated with CROPS imply that CROPS is not effective. Therefore, it is expected that high probability of injury with CROPS would result in high CERs. When the probability of non-fatal injury varied from 0.17 to 0.34, the CER increased from $136,601 to $157,000. Similarly, if the probability of fatal injury varied from 0.00115 to 0.0024, then the CER increased from $136,601 to $138,000.

Sensitivity to effectiveness of CROPS to prevent injuries. Effectiveness is measured as the ability to prevent an injury and is measured from 0 to 1. Effectiveness of CROPS affects the CER by changing both the numerator and denominator. When the effectiveness is high, it decreases the numerator (net cost) by increasing the savings (a negative) resulting from the increased cost of averted injuries, and increases the denominator (net effect). Together, the resultant CER is reduced. The non-use of seatbelts in combination with CROPS substantially affects the effectiveness of CROPS. To account for that, an SA was conducted around the effectiveness of CROPS. As the effectiveness of CROPS to prevent non-fatal injuries varied from 0.6 to 0.758, CER decreased from $150,000 to $136,601. Similarly, as the effectiveness of CROPS to prevent fatal injuries varied from 0.758 to 0.99, CER decreased from $137,400 to $136,601.

Two-Way Sensitivity Analyses

The preceding sensitivity analyses assume that while the variable in question is changing, all others stay constant. However, this may not be the case in real life. For instance, the probability of a tractor overturn may vary depending on the topography, and the cost of intervention could change at the same time. For the sake of this study, and given the fact that they were found to have the greatest impact on calculated CERs, probability of overturn, analytic horizon, and cost of intervention are the focus of the following discussion. Only those combinations of variables that indicate dominance of install-CROPS over No-CROPS (negative ICERs) are presented and discussed. The cost of intervention and the analytic horizon did not show any dominant region (i.e., all combinations had positive ICERs) and are therefore not presented.

Sensitivity to the probability of overturn and scale factor. As shown in the preceding analyses, estimated CER is not as sensitive to differences in probabilities (i.e., the scale factor) as it is to the probability of overturn. This is confirmed by figure 2. When the probability of overturn of non-CROPS tractors is greater than 0.00033, there

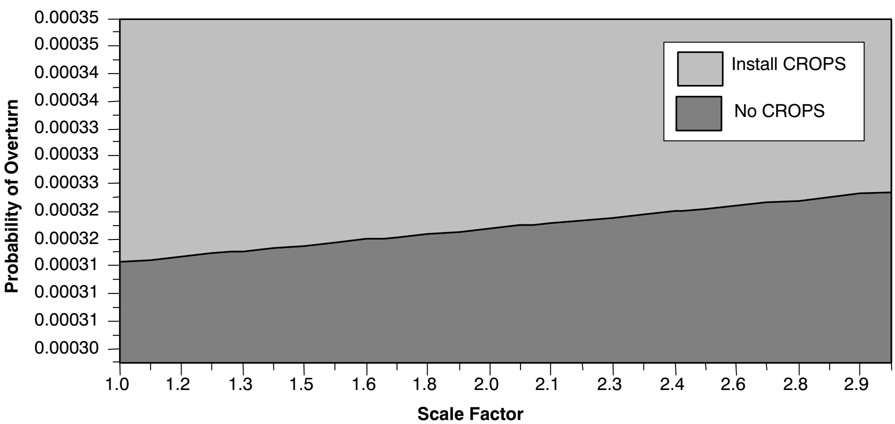

Figure 2. Two-way sensitivity graph for probability of overturn and scale factor.

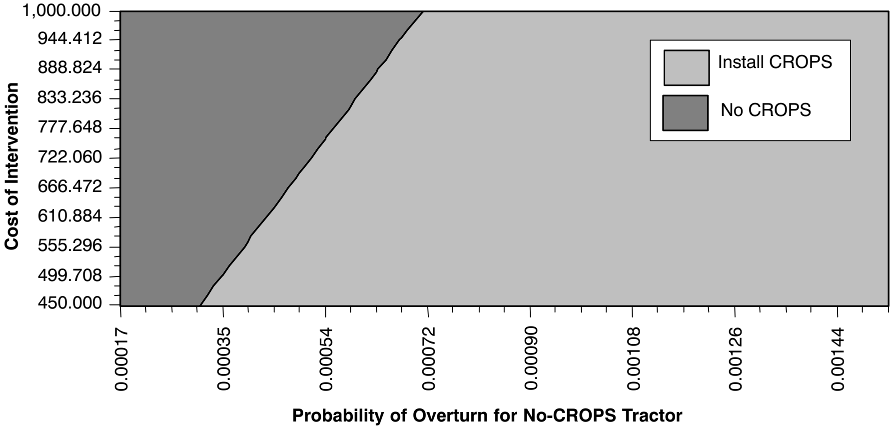

Figure 3. Two-way sensitivity graph for probability of overturn and cost of intervention.

is net savings when the Install-CROPS option is adopted, even if there is a three-fold increase in the probability of overturn after installing CROPS (fig. 2). These results indicate that the estimated CER in this study is not as sensitive to the relative change in probabilities as it is to the probabilities of overturn themselves.

Sensitivity to the probability of overturn and cost of intervention. With the high sensitivity to probability of overturn discussed earlier, the Install-CROPS option dominates No-CROPS over the entire range of the cost of intervention when the probability of overturn is over 0.00072 (0.001217 for CROPS-equipped tractors). Therefore, if the actual probability of overturn per year for non-CROPS tractors is greater than 0.00072, then there is net savings to society even if the total cost of intervention is $1,000 (fig. 3).

Sensitivity to the probability of overturn and analytic horizon. The Install-CROPS option dominates No-CROPS over the entire range of the analytic horizon when the probability of overturn is greater than 0.00095 (0.001606 for CROPS-equipped tractors). This result implies that, if the actual probability of overturn per year is greater

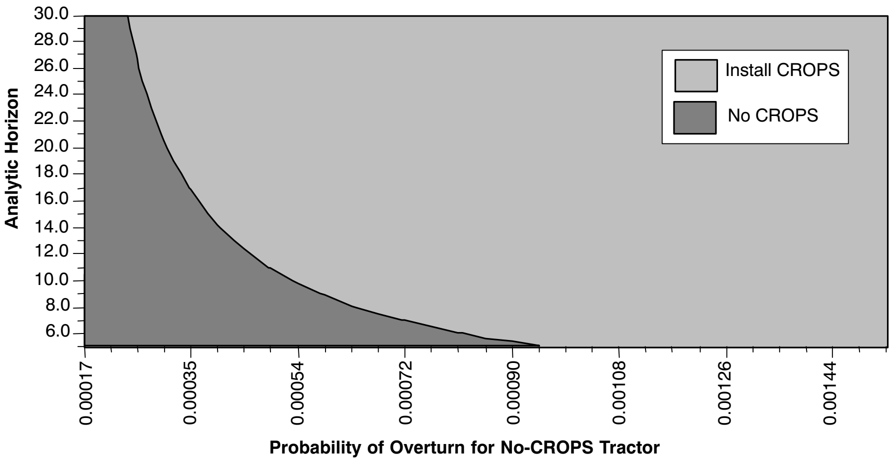

Figure 4. Two-way sensitivity graph for probability of overturn and analytic horizon.

than 0.00095, then there is net savings to society even if the CROPS-installed tractor is in use for as little as five years (fig. 4).

Discussion

The results obtained in this study are consistent with those of previous studies, given the substantially lower cost of intervention. Although Pana-Cryan and Myers (2000) used a longer time horizon (23 years), the estimate from this study is 73% lower than the estimate they reported. This difference is attributable to the following:

- The cost of intervention per tractor is about 55% lower ($450 vs. $1000) compared to their study.
- Not all the tractors that were retrofitted in their study were used for the entire period of analysis. Thus, the effects for those tractors were not realized over the entire time period.

Similarly, although Myers et al. (2004) used a higher probability of overturn, the CER found in this study is about 21% lower than they reported. In addition to the higher cost of the intervention per tractor ($647 vs. $450), Myers et al. (2004) evaluated a ROPS implementation program, which incurred other costs. However, the SA in this study showed that when the probability of overturn from their study was used, there is net savings of about $124,000 per CROPS installed over the 20-year period.

Limitations of the Study

Most of the values available for use in this study were from published data, which varied substantially by study. Costs used in the analysis are the lower bounds of the actual economic cost of injuries because intangible costs were not included. As shown in the SA, higher costs of injuries result in lower or negative CERs. In addition, the model is static in the sense that there are no changes in costs, effectiveness, or probabilities over the entire period, which may not represent reality.

There are two important effects in the interventions designed to reduce the burden of injuries and illnesses: prevention and mitigation. While prevention is the ultimate goal, mitigation is also important. However, because data were either unavailable or insufficient, this analysis did not explore the effects of mitigating factors. For example, collateral benefits gained from the reduction in severity of the injuries with CROPS are not captured because the same average cost of non-fatal injuries was used in both alternatives. However, Myers et al. (2005) demonstrated that non-fatal injuries are substantially less severe when a ROPS is used in combination with seatbelt use.

Conclusion

This study estimated the expected effects and costs at a per-tractor level for two alternative choices: No-CROPS and Install-CROPS. The results indicate that the expected number of injuries per tractor is 0.00169 without CROPS and 0.00016 with CROPS installed, resulting in 0.00153 injuries prevented over the 20-year period. In addition, expected total costs were $457 and $248 with and without CROPS, respectively, over the same time period. Thus, the CER is $136,601 per injury prevented. A comprehensive sensitivity analyses indicated that, in addition to the cost of intervention, the probability of an overturn is also one of the most important variables. Using the two extreme values (adjusted to reflect the actual hours of operation) estimated by similar studies, CERs ranged from $136,601 to a net savings of about $124,000 per injury prevented.

The primary objective of designing and developing CROPS is to reduce the cost of purchasing and installing a rollover protective structure, and eventually increase the adoption rate. Essentially, the difference between ROPS and CROPS is the reduced cost; CROPS is designed to be as effective as existing ROPS retrofits. When the estimated cost of ROPS retrofitting (i.e., $1,000, including purchasing, shipping, and installation) is used in the analysis, the CER is $497,000 per injury prevented over the 20-year period. Thus, installing CROPS instead of existing ROPS retrofits improves the CER: the ratio decreased by 73%. This is an important finding because even though the cost of intervention is reduced by 55% ($1,000 to $450), the improvement in the CER is even greater.

The conservative figures used in this study (low probability of overturn, low cost of injuries) as well as ignored collateral benefits are evidence that the benefits of installing CROPS have been underestimated. The results obtained in this study reveal potential for society to save lives when CROPS are installed. These results can help guide policy makers in making critical decisions regarding allocation of scarce financial resources.

Concerns about the assumed values and the published estimates used for the key variables suggest there is the need for further research to:

- Determine actual and more reliable estimates of the probability of events. The high sensitivity of the CER to the probability of overturn underscores this need.
- Assemble detailed information on the injuries that occur before and after interventions. This could help capture the collateral benefits (reduced severity) of non-fatal injuries when they occur with CROPS installed.
- Include intangible costs in the estimated economic cost of injuries.

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