Cost Analysis of a PTO Driveline Shielding Program: Are Effective Programs Cost-Effective?

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HIGHLIGHTS

- This article describes a cost assessment of a PTO driveline shielding intervention.
- Considerations for effective occupational safety interventions beyond reductions in injuries or fatalities are described.
- The financial viability of combining various on-farm services to reduce intervention costs is discussed.

ABSTRACT. *PTO entanglements are a primary injury concern on U.S. farms, affecting adults and children. These events often lead to severe injury and permanent disability but can be prevented with proper use of PTO shielding. A promising strategy for increasing PTO shielding on farms has been the introduction of user-friendly shielding options by qualified safety specialists. This study looks at the cost-effectiveness of this approach. The cost-effectiveness of this PTO shielding strategy was calculated based on program-related costs, the PTO shield cost, the lifespan of PTO shields, and the number of PTO shields needed to prevent an entanglement. The cost per entanglement prevented was then calculated by dividing the total costs by the number of entanglements prevented in several cost-estimate scenarios. Costs were adjusted for inflation to 2019 dollars. Costs per entanglement prevented ranged from a low of $921,544 (assuming a 10-year PTO lifespan and using 12,487 as the number needed to treat, i.e., to prevent a PTO entanglement, referred to as the NNT) to a high of $18,583,492 (assuming a three-year PTO lifespan and 67,119 as the NNT). The cost per entanglement prevented at the median PTO lifespan of five years and median NNT of 39,802 was $6,612,244. Based on our estimates, the cost-efficacy of increasing PTO shielding using qualified safety specialists differs widely based on the shield lifespan and the number of shields needed to avoid one entanglement. However, if the cost of introducing PTO shields in on-farm visits is coupled with other on-farm services that defray these costs, then the cost-efficacy increases considerably.*

Keywords. *Cost-effectiveness analysis, PTO entanglements, PTO injuries, PTO interventions, PTO shields.*

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Public health research aims to develop and implement solutions that are beneficial to the health, safety, and wellbeing of the public. These solutions may involve education, behavior change programs, engineered solutions, or other types of innovations. In assessing the uptake of such solutions, cost is often a primary consideration and a barrier to sufficient implementation (Cidav et al., 2020; Sohn et al., 2020). This includes costs to the end user as well as costs to intermediaries, such as organizations that administer public health interventions. A cost analysis, as presented in this article, can be used to weigh the costs and outcomes of an innovation. For decision makers, cost analyses are particularly important for prioritizing efforts and budgeting, as cost analyses promote fiscally informed comparisons between solutions to the same or competing problems.

Within the agricultural industry, numerous solutions to everyday safety and health problems exist, including shielding for power take-off (PTO) drivelines. This shielding is necessary to prevent equipment operators from becoming entangled in a PTO driveline should they come into contact with it during operation. Research has identified augers, elevators, and conveyors as the implements most often involved in driveline-related injuries and fatalities (data from 1970 to 2003) (Beer and Field, 2005). An estimated 60% of PTO entanglements are non-fatal, with two-thirds of non-fatal entanglements resulting in amputations (Beer and Field, 2005). Driveline-related fatal and non-fatal injuries are a particular concern for children, with nearly one-fourth occurring to children under the age of 18. In cases of entanglement involving children, nearly 50% resulted in amputation (Beer et al., 2007). Such severe injuries result in lifetime disability, diminished quality of life, and often an inability to continue farming.

PTO driveline shields are necessary for preventing injuries, unless alternative methods for powering PTOs are employed (Thomas and Buckmaster, 2003). However, barriers to maintaining adequate shielding are well-known among farmers. Past studies have demonstrated that maintaining PTO shielding has historically been both cost- and time-prohibitive (Weil et al., 2014). Estimates of the percentage of properly shielded PTO drivelines in New York in 2014 ranged from 90.2% (phone surveys) to 56.7% (in-person farm machinery audits) depending on the method of data capture (Chapel et al., 2015). In Kentucky, Future Farmers of America student inspections of farm tractors showed similar percentages of shielding compliance, with the entire shield missing on 39% of inspected tractors (Cole et al., 2009). While newer PTO shield styles address these barriers, distribution of them has been challenging, with little change despite employing a number of interventional strategies (Tinc and Sorensen, 2019; Tinc et al, 2021; Sorensen et al., 2017).

One strategy that appears promising is the distribution of shields through an existing on-farm safety program (Sorensen et al., 2017). The New York Center for Agricultural Medicine and Health (NYCAMH) is a grant-funded organization that provides free, on-farm safety training and safety consultations for farmers and farmworkers. In an effort to distribute PTO shields and other personal protective equipment (PPE), which is available at cost (no retail markup) through NYCAMH, safety trainers educate farmers about the use of appropriate PPE and PTO shields and hand-deliver PTO shields to farmers who purchased them during on-farm service visits (Carrabba, 2012). A typical on-farm visit includes training on various specific farm hazards, safety walk-throughs in which safety specialists identify hazards on the farm and provide technical assistance for addressing these hazards, and fit-testing of respiratory PPE for farmworkers. A survey of 81 farmers who had received PTO shields through NYCAMH indicated that 97% felt the PTO shields were cost-effective and 92% felt the shields were easy to install (Carrabba, 2012).

The success of this PTO shield distribution method is supported in the literature as a common marketing strategy called "liking" (Cialdini, 2007). This marketing strategy indicates that people are more likely to engage in a behavior if it is promoted by someone they like and have a positive relationship with (Cialdini, 2007). In addition, this strategy is supported by the "place" principle of social marketing, which highlights the importance of making products easily accessible through strategic distribution (Andreasen, 2006).

The aim of this study is to assess the cost-effectiveness, defined as the cost per entanglement prevented, of distributing PTO driveline shields through the on-farm safety services offered by NYCAMH.

Methods

This analysis includes several key components, including (1) the program-related costs associated with the on-farm visits during which many of the PTO shields are sold, (2) the cost for each PTO shield purchased by farmers, (3) the duration of treatment, as measured by how long PTO shields remain in place, and (4) the number of PTO shields needed to treat (i.e., to prevent a PTO entanglement). Each component of the analysis is described here. All costs were adjusted for inflation to 2019 dollars using the U.S. Consumer Price Index (BLS, 2021).

Program Description

NYCAMH offers farmers access to PPE through the NYCAMH PPE program, which provides technical assistance and the opportunity to purchase safety equipment over the phone or through online orders. Equipment can either be shipped to farms or delivered by NYCAMH safety specialists when conducting on-farm visits for safety training. In addition to this option, safety specialists also bring some PPE inventory with them during on-farm visits for safety training or safety walk-throughs. PTO driveline shields are offered through the NYCAMH PPE program and are a primary example of the PPE inventory that is featured and delivered in on-farm visits.

On-Farm Services Costs

Work plans from grant budget reports from 2011 to 2019 were used to calculate the proportion of each budget for on-farm service activities. Because PTO shields are typically distributed in person during scheduled on-farm services conducted with adults, PTO-related services conducted off the farm or with youth were excluded from these cost estimates. The total on-farm service costs (OSC) were calculated as follows:

$$OSC = PC + TE + OE \quad (1)$$

where

PC = Personnel costs, in full-time equivalent (FTE), associated with on-farm services.
TE = Travel expenses, including mileage, hotel costs, and meals, for travel to farms to provide on-farm services.
OE = Operating expenses, including secretarial, administrative, and supply costs (promotional materials, brochures, installation information, etc.).

Personnel costs were calculated as the percentage of total salary costs dedicated to on-farm services. These amounts were based on the reported percentages of time spent conducting on-farm services for full-time (range 70% to 91% per year) and contract staff (range 30% to 59% per year). These percentages varied annually based on priorities,

availability of staff, and funding stipulations. Personnel costs also included prep work (e.g., scheduling, materials development) done by full-time staff for on-farm services. This was calculated separately, with 92% of prep work dedicated to on-farm services annually. Contract staff are scheduled by full-time program administrative staff and are provided with materials; thus, no additional prep time is paid for these individuals.

For certain years where data were missing, it was necessary to impute total costs (i.e., to create values for specific data items that were missing) using linear regression. More specifically, a linear regression of the actual total costs was created based on the planned total costs for the year where planned costs were available but actual costs were missing.

PTO Shield Costs

Costs of the PTO shields sold through NYCAMH were obtained for the same time period as on-farm service costs (2011 to 2019). These dollar amounts included the cost of the shield, as well as shipping costs, and ranged from $67 for the least expensive shield to $91 for the most expensive shield over the time period included in the study.

PTO Shield Lifespan Estimates

An important element in cost-effectiveness analysis is treatment duration. A few studies have looked at how many drivelines are shielded on farms. However, knowledge is lacking on how long a PTO shield typically lasts, once it is installed on farm equipment. There are few formal assessments of PTO shield life, but it is clear that, in practice, a large percentage of farm equipment is missing such shields (Chapel et al., 2015). This suggests that the expected lifespan of a shield is relatively short. Anecdotal evidence from discussions with farmers suggests that PTO shields are often damaged in use or removed, and these shields are often not replaced during routine maintenance (Tinc et al., 2015).

To determine how long a PTO shield lasts, a short survey was conducted in September 2020 with farmers who had purchased PTO shields in the prior year. In addition, farmers who called to order PTO shields while the survey was being conducted were also asked to complete the survey. Attempts were made to contact 61 farmers via telephone. These attempts continued until completed surveys were obtained from 35 farmers, a response rate of 57%. Two additional surveys were obtained from farmers who contacted the NYCAMH PPE program to obtain shields. Not surprisingly, there was wide variation in the survey responses. Rather than selecting one number, the cost-effectiveness analysis was conducted using the 25th percentile (3 years), median (5 years), and 75th percentile (10 years) of the survey responses.

Number Needed to Treat (NNT) to Prevent a Single PTO Entanglement

Data on the number of PTO shields needed to prevent a single entanglement fatality (number needed to treat, NNT) similarly has not been thoroughly explored in previous studies. One of the few studies (Sorensen et al., 2017) shows a very wide range of possible NNT values, ranging from a best-case NNT value of 12,487 shields versus a worst-case NNT value of 67,119 (Sorensen et al., 2017). In that analysis, the authors used estimates of the number of unshielded PTO drivelines in New York State (an estimated 107,391 unshielded implements on 35,560 farms), PTO entanglement fatality data from the northeast, and agricultural driveline-related incident data from Beer et al. (2007) to develop their best-case and worst-case NNT calculations. The cost-effectiveness analyses presented below used both of these estimates, as well as a mid-range NNT value of 39,802.

Cost-Effectiveness Analyses

Due to the wide range of data, separate cost-effectiveness analyses were conducted for different combinations of PTO shield lifespan (3, 5, and 10 years) and NNT (12,487, 39,802, and 67,119). With three PTO shield lifespans and three NNT values, a total of nine analyses were conducted.

PTO shield service years were estimated by multiplying the total number of shields sold over the eight years (2011-2019) of the study (1,274 shields) by the different expected PTO shield lifespans (3, 5, and 10 years). Therefore, the total PTO shield service years for the three scenarios were 1,274 × 3 = 3,822; 1,274 × 5 = 6,370; and 1,274 × 10 = 12,740. The number of entanglements prevented (NEP) was estimated by:

$$NEP = NNT/SYE \quad (2)$$

where NNT is the number needed to treat, and SYE is the service years expected for the PTO shields. The cost per entanglement prevented (CPE) was then calculated as:

$$CPE = OSC/NEP \quad (3)$$

where OSC is the total costs of on-farm services (eq. 1), and NEP is the number of entanglements prevented.

Results

A total of 1,274 PTO shields were sold over the eight years (2011-2019) of the NYC-AMH PPE program, with annual sales ranging from 66 shields to 408 shields. The years of service expected from the 1,274 PTOs purchased by farmers through this program ranged from 3,822 (if a PTO shield lasts an average of 3 years) to 12,740 (if a PTO shield lasts an average of 10 years) (table 1). The number of PTO entanglements prevented therefore ranged from 0.06 to 1.02, depending on the NNT. For example, if the NNT is 67,119 and the PTO shields last 3 years, then only 0.06 entanglements would be prevented, while 1.02 entanglements would be prevented if the NNT is 12,487 and the shield lasts 10 years.

As stated in the Methods section, it was necessary to impute the total cost of the program for four of the program years for which data were missing. Using linear regression of the planned program costs on the actual program costs, the resulting equation was:

$$ITC = \$22{,}793 + 0.710 \times TBC \quad (4)$$

where ITC is the imputed total cost, and TBC is the total budgeted cost.

The slope of the regression line was marginally significant ($p = 0.096$), and the coefficient of determination (percentage of variability explained) was 54.2%. Other modeling strategies were attempted to improve the predictive strength of the model, but those methods did not yield greater accuracy.

Table 1. Expected number of entanglements prevented based on shield lifespan and NNT.[a]

Expected PTO Shield Lifespan			Entanglements Prevented Based on Three NNT Estimates		
Expected Service Years	Average PTO Shield Lifespan	Service Years for 1,274 PTO Shields	12,487	39,803	67,119
3 years (25th percentile)	3 years	3,822	0.31	0.1	0.06
5 years (median)	5 years	6,370	0.51	0.16	0.09
10 years (75th percentile)	10 years	12,740	1.02	0.32	0.19

[a] NNT = number of PTO shield service years needed to prevent a single entanglement.

The average cost of an on-farm service visit, calculated as the total annual budget divided by the total number of visits (regardless of whether or not the visit resulted in the sale of a shield), was modestly low at $280 (in 2019 dollars). However, the total program costs incurred over the eight fiscal years (FY, defined as April 1 to March 31) included in this analysis (FY 2011-2012 to FY 2018-2019) was $1,058,211, which consisted of $940,216 in NYCAMH operating costs and $117,995 in farmer PTO shielding costs.

Costs per entanglement prevented ranged from a low of $921,544 (assuming a 10-year PTO lifespan and 12,487 NNT) to a high of $18,583,492 (assuming a 3-year PTO lifespan and 67,119 NNT). The cost per entanglement prevented at the median PTO lifespan of 5 years and median NNT of 39,802 was $6,612,244. Tables 2 through 4 list the overall estimated costs to prevent an entanglement given total NYCAMH and farmer costs of $1,058,211.

Discussion

As discussed previously, the data on PTO driveline-related injuries indicate that these events account for a significant percentage of injury-related costs on farms and often lead to permanent disabilities for both adults and children. Of the injuries that can occur on farms, machinery entanglements, including PTO entanglements, are among the most common (Hard et al., 1999). Prior studies on the prevalence of shielding on farms have indicated that a significant percentage of PTO drivelines are not properly shielded (Chapel et al., 2015; Cole et al., 2009), while other studies have documented barriers to PTO driveline shielding that have historically impacted the willingness of farmers to follow-through on this essential safety activity (Sorensen et al., 2017; Tinc and Sorensen, 2019; Weil et al., 2014). Fortunately, many previously identified barriers have been addressed with new PTO driveline shield options, but encouraging farmers to try these new options has been difficult (Tinc et al., 2021).

One potentially promising method for increasing the replacement of missing or broken shields has been the introduction of new, user-friendly options by trained safety specialists who have a working relationship with farmers (Sorensen et al., 2017). Although other strategies have been tested (such as social marketing and principles of influence campaigns) (Sorensen et al., 2017; Tinc and Sorensen, 2019), the introduction of these devices by

Table 2. Cost per entanglement prevented if 12,487 treatments were needed (2019 dollars)

Expected Service Years	NYCAMH Cost	Farmer Cost	Total Cost
3 years (25th percentile)	$3,071,816.00	$385,507.08	$3,457,323.09
5 years (median)	$1,843,089.60	$231,304.25	$2,074,393.85
10 years (75th percentile)	$921,544.80	$115,652.13	$1,037,196.93

Table 3. Cost per entanglement prevented if 39,802 treatments were needed (2019 dollars)

Expected Service Years	NYCAMH Cost	Farmer Cost	Total Cost
3 years (25th percentile)	$9,791,582.63	$1,228,825.06	$11,020,407.68
5 years (median)	$5,874,949.58	$737,295.04	$6,612,244.61
10 years (75th percentile)	$2,937,474.79	$368,647.52	$3,306,122.31

Table 4. Cost per entanglement prevented if 67,119 treatments were needed (2019 dollars)

Expected Service Years	NYCAMH Cost	Farmer Cost	Total Cost
3 years (25th percentile)	$16,511,349.25	$2,072,143.03	$18,583,492.28
5 years (median)	$9,906,809.55	$1,243,285.82	$11,150,095.37
10 years (75th percentile)	$4,953,404.78	$621,642.91	$5,575,047.69

qualified safety specialists has been the most successful strategy for generating interest in PTO shielding.

However, funding for these services requires investment in staff salaries, travel costs, materials, and the PTO shields themselves. Based on our estimates, the cost-efficacy of this approach is highly dependent on the lifespan of the PTO shield as well as the number of shields that need to be distributed to prevent an entanglement. However, even estimates that are based on a long shield lifespan and a relatively low NNT demonstrate that the program costs versus entanglements prevented is still quite high ($921,544.80 in program costs and $115,652.13 in farmer costs), although this expense is arguably lower than the costs associated with a permanent disability (Karttunen et al., 2017; Sears et al., 2014; Takala et al., 2014).

Regardless, this research shows that as NNT increases and shield durability estimates decrease, even the most successful method for increasing shielding is prohibitively expensive if the sole purpose of the on-farm visit is to encourage shielding. However, given the fact that most NYCAMH on-farm service activities are focused on providing assistance with training, safety walk-throughs, and respiratory PPE fit-testing, combining PTO shielding services requires little additional funding. Given this, our research indicates that the most cost-effective and strategic option would be to introduce new, easier-to-use PTO driveline shielding options with existing farm services.

Another way to consider the cost-effectiveness of the program is to look at the on-farm visit costs and allocate the expense of PTO shielding on a more proportional basis. Using this perspective, if we estimated the average cost for PTO shielding outreach as roughly 10% of the cost of an on-farm service visit, the cost per entanglement prevented would be only 10% of the values reported in tables 2 through 4 and would range between $207,806 to $3.7 million, depending on the years of service and the number of treatments needed.

In summary, these cost analyses provide a compelling illustration of the value of combining multiple interventions during an on-farm visit, such as offering training in combination with access to PTO shields, ROPS, PPE, or other safety technology. In contrast, standalone programs that focus on only one type of intervention can be costly when looked at from the perspective of each event prevented. Given these findings, examining program cost-effectiveness, in addition to program impact, may lead to improvements in health and safety outcomes as well as in the sustainability of effective strategies.

In looking through the literature for other cost assessments of agricultural interventions, we were able to identify only two other examples. Those assessments both examined the costs versus benefits of ROPS interventions and found such programs to be considerably cost-effective (Myers et al., 2018; Sorensen et al., 2010). This is likely due to the comparatively more frequent occurrence of tractor overturns versus PTO entanglements, the long-term viability of ROPS (which only need to be replaced if involved in an overturn), and the relatively low program costs.

Limitations

Conducting this analysis has underscored the need for more data to fine-tune future cost assessments of PTO interventions. Although a few studies have attempted to calculate injury-related exposure, including how frequently PTO shields are missing or broken (Beer and Field, 2005; Beer et al., 2007), more studies should be conducted to confirm existing estimates and explore other influential factors. In particular, additional assessments of PTO

shield prevalence across different types of PTO equipment and hours of exposure would provide more accurate NNT estimates on which to base future cost assessments.

It is also important to mention that these estimates are based on PTO shield purchases made by farmers who requested safety services. Given the proactive safety disposition of this subset of farmers, it stands to reason that they would be more likely to invest in PTO shields and replace missing shields. If that is the case, the results from this study may reflect the cost-efficacy of distributing and increasing PTO shield use on farms that are already safety oriented. This would also mean that our results may not accurately reflect the cost-efficacy of similar programs that include farmers who are less proactive about safety. However, it is also possible that farmers who request on-farm training or safety walk-through services are doing so because they have had accidents. Given these possible scenarios, it is difficult to say how representative our results are of the general farm population. Lastly, our analysis does not include estimates of non-PTO injuries that may have been prevented by on-farm service visits. From this perspective, our results are likely to provide a rather conservative estimate of the cost-efficacy of PTO shielding interventions.

Conclusions

Many evaluations of health and safety interventions look at outcomes (i.e., have injuries and fatalities been prevented?) and ignore the cost-efficacy of these interventions for both the target population and the taxpayer. Our study indicates that combining input from qualified safety specialists and access to user-friendly PTO shield models, coupled with other on-farm services, is the most effective method for increasing PTO shielding on farms. In addition, we conclude that future efforts to improve safety and health should include assessments of program cost-efficacy to both ensure and improve the financial viability and sustainability of these interventions.

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