

Sweden's Thirty-year Experience with Tractor Rollovers

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Abstract

The purpose of this study was to analyze Sweden's experience of farm tractor rollover injuries over three decades during which policy requirements for safety features on tractors were first introduced and then later strengthened. The incidence of fatal and nonfatal tractor rollover injuries was compared with the proportion of farm tractors with and without rollover protective structures (ROPS) at different times from the late 1950s up to 1990.

From the period 1957-1964 to the period 1986-1990 rollover fatalities decreased from 12 to 0.2 per 100,000 farm tractors. During that same period, the total number of Swedish farm tractors rose by 275% and the proportion of those tractors equipped with ROPS increased from 6% to 93%. The Swedish approach for prevention of fatal and nonfatal tractor rollover injuries was successful, emphasizing the value of public policy requiring ROPS on farm tractors.

Keywords. Farm tractors, Tractors, Agricultural injuries, Tractor rollover, Rollover Protective Structures, ROPS.

Farm tractors are associated with fatal and nonfatal injuries, especially when tractors roll over and drivers are trapped underneath the vehicles. The mounting of a protective frame or crushproof cab (known as rollover protective structures or ROPS) can prevent personal injuries to the driver of a tractor. Karlson and Noren (1979) emphasized that voluntary safety standards claiming such a protection failed to reduce the problem. Related issues have been discussed in several Swedish and U.S. papers. The idea of rollover protection started during the 1920s, as tractor rollovers became prevalent in the agricultural community (Ross and DiMartino, 1982). Homemade cages and roll bars were mounted on the tractors. In 1939 the Dooley safety device, an engine cutoff switch, was introduced, but the device reacted too slowly and did not stop the rollover movement. Rollover protections of sufficient strength were developed by agricultural and military institutions (McCollum, 1984). However, users of tractors did not accept such protections and the intervention was delayed (Springfeldt and Thorson, 1987; Etherton et al., 1991; Kelsey and Jenkins, 1991; Kelsey et al., 1994, 1996; Centers for Disease Control, 1993, 1995).

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Beginning 1 July 1959, the Swedish National Board of Safety and Health (NBOSH) required ROPS on all newly manufactured farm tractors (NBOSH, 1959). This standard was intended to be a passive, rather than active measure and, thus, would be effective regardless of the purchaser's initiative (Haddon, 1974). Despite opposition by farmers, Swedish regulations were later expanded to all existing tractors so that from 1965 it was required that all employees be protected by ROPS regardless of the tractor's age. In 1970 the standards were further expanded to require rollover resistant cabs on new tractors. By 1981 safety cabs were mandated for all tractors. Cabs provide better protection to the driver during overturning than ROPS alone, since the operator may not always be secured with a seat belt. That is, the cabs do not resist rollovers per se, but protect the occupant from ejection during a rollover. Because of effective policy enforcement by Sweden's central and local authorities, the regulations were extensively followed. By the 1990s it was estimated that about 93% of Swedish tractors in use were equipped with ROPS (National Central Bureau of Statistics, 1992).

Objective and Scope

The aim of this study was to describe fatal and nonfatal injuries associated with farm tractor rollovers in relation to the proportion of farm tractors equipped with ROPS in Sweden from 1957 to 1990.

In the study the following terms are defined:

- Farm tractors—wheeled vehicles used in agricultural, forestry, and related work.
- Farm owners—owners of the agricultural enterprise including adult male relatives.
- Farm laborers—full-time, part-time, and seasonal hired workers.

Method

The number of Swedish farm owners, hired laborers, and registered farm tractors at four intervals over 30 years was obtained from official government reports. The numbers of tractors in farming and other occupations are reported in the Central Vehicle Register (National Central Bureau of Statistics, 1992). Registered tractors were recorded as being operational, but there is the possibility that some of these tractors were not being utilized. After 1972 it was possible to differentiate the primary use of the tractor when used for agricultural work only (in contrast to combined forestry and farming use prior to that time).

The proportion of farm tractors with ROPS in sequential four-year intervals was estimated from statements on time of manufacture and claims on ROPS, which are based on rules of compulsory registration at the National Central Bureau of Statistics, a system that is used for all motor vehicles. Furthermore, sales of ROPS for mounting on old tractors are reported for government records.

Sweden's fatal and nonfatal tractor rollover injuries from 1957 to 1990 were obtained with data from NBOSH and other authorities (Karlson and Noren, 1979; Springfeldt and Thorson, 1987; Springfeldt, 1993; NBOSH, 1972, 1992). Injury statistics were compiled related to tractors used in agriculture and forestry from 1957 through 1971 and tractors used solely in agriculture from 1972 to 1990. Rates of fatal and nonfatal rollover injuries per 100,000 tractors were calculated during these same two time intervals (1957-1971 and 1972-1990).

Trends in ROPS-related events were calculated by analyzing rates of fatal and nonfatal rollover injuries per 100,000 farm tractors and per 100 million driving hours. In Sweden there are government records of all registered tractors which denote the status of each vehicle as a primary or secondary (reserve) tractor. For example, in the late 1950s about 8% of tractors were a secondary vehicle; then, by 1978 there were nearly 300 000 registered tractors of which 40% were reported as secondary tractors. Driving hours of Swedish farm tractors have previously been estimated from statements on fuel purchase. Records regarding use of fuel on farms were used to estimate that primary tractors were driven 500 h and secondary tractors were driven 100 h annually (Johansson, personal communication; Persson, personal communication; Springfield, 1993; Lundqvist and Springfield, 1989). Tractor rollover fatalities per 100 million driving hours were calculated based upon reports of the proportion of primary and secondary tractors during seven different time periods from 1957 to 1990 (refer to "NOTE on method for calculating fatalities per million driving hours").

Results

Over three decades, the work force on Swedish farms diminished notably. The number of farm owners dropped by 65% and the number of farm owner spouses declined by 78%. Meanwhile, the number of hired farm laborers increased. The total number of owners, spouses, and laborers on farms was reduced by nearly one-half. During the same period, the number of farm tractors increased by 275% (table 1). The proportion of tractors equipped with ROPS increased from approximately 3% in 1951 to an estimated 88% in the 1980s (table 1) and up to about 93% by the 1990s (National Central Bureau of Statistics, 1992).

The continuous decrease of fatal and nonfatal rollover injuries in farming is shown in table 2. From 1957 to 1964, there was an average of 23 fatalities annually

Table 1. Swedish farm operators and farm tractors per Swedish government inventories for the years 1951, 1961, 1972, and 1981

Year	1951	1961	1972	1981
Farm owners*	369,000	263,000	167,000	130,000
Spouses of farm owners	304,000	193,000	94,000	68,000
Hired farm laborers	69,200	148,200	169,000	190,000
Farm tractors	NA	194,000	248,000	303,000
Estimated proportion of tractors with ROPS	3%	26%	68%	88%

* Includes adult male relatives.

NA = not applicable.

Table 2. Occupational injuries associated with farm tractor rollovers according to reports from the Swedish Labour Inspectorate (forestry and farming data were combined before 1972, only farming data were used from 1972-1990)

Period	Average Number of Injuries			Average Number of Tractors		Fatalities per 100,000 Tractors		
	Fatal	Non Fatal	Total	Farming	Forestry & Farming	Fatal	Non Fatal	Total
1957-1964	23	19	42		190,000	12	10	22
1965-1971	9	10	19		246,000	4	4	8
1972-1977	6	8	13	177,000		3	4	7
1978-1983	1	5	6	190,000		0.5	2.6	3
1984-1990	0.4	4.6	5	196,000		0.2	2.3	2

associated with tractors used in farming and forestry. Three decades later, Sweden reported less than one tractor-related fatality per year. The annual number of nonfatal tractor rollover injuries during those three decades declined by nearly 90%.

Analysis of fatal and nonfatal injury rates revealed there were 12 fatal rollover injuries per 100,000 tractors in forestry and agriculture during the period 1957 to 1964, which decreased to 4 in the period 1965 to 1971 (table 2). The combined fatal and nonfatal rollover injury rate decreased from 22 to 4 per 100,000 tractors during that time. In later years, when details on farm tractors alone were available, it was calculated there were three fatal rollovers per 100,000 farm tractors between 1972 and 1977. This frequency decreased to 0.2 in the period 1984-1990. In total, the fatal and nonfatal farm tractor rollover injuries decreased from seven to two per 100,000 farm tractors from 1972 to 1990.

As noted in table 3, side flips were nearly four times as common as rear overturns. However, the latter were more dangerous. Nearly half the 488 rollovers from 1959 through 1978 were fatal. Side flips were associated with 88% of the nonfatal injuries and 72% of the fatalities. Yet, when a rear overturn occurred, the outcome was likely to be fatal 68% of the time, compared with 44% of the time with side flips.

According to investigations in agriculture and forestry, the life span of Swedish tractors in active use is about 15 years. Previously they were used for 20 years (Lundqvist and Springfield, 1989). Assuming a 15-year life span for farm tractors, 1 per 388 was involved in a fatal rollover injury during 1957-1960 (Springfield, 1993). Corresponding figures were 1 per 21 505 during the period 1986-1990. As noted in table 4, annual tractor rollover fatalities decreased from 25 to less than 1 from 1960 through 1990 which corresponds to a drop in the fatality rate per 100 million driving hours from 25 down to 0.3. Meanwhile, between 1957 and 1990

Table 3. Occupational fatal and nonfatal injuries associated with farm tractor rollovers in the years 1959-1968 and 1969-1978 according to reports from the Swedish Labour Inspectorate (forestry and agriculture data were combined before 1972 and only agriculture data were used from 1972)

Period	Side Flips			Rear Overturns			Side and Rear Events Combined		
	Total	Fatal	(% Fatal)	Total	Fatal	(% Fatal)	All Total	All Fatal	(% Fatal)
	1959-1968	298	131	44	64	43	67	364	174
1969-1978	93	41	44	33	23	70	126	64	51
Total	391	172	44	97	97	68	488	238	49

Table 4. Farm tractor rollover fatalities, number of tractors, and exposure

Period	Average Number of Farm Tractors	% with ROPS	Average Number of Fatalities		
			Official Statistics	Per 100,000 Farm Tractors	Per 100 million Driving Hours
1957-1960	169,787	6*	25	15	25*
1961-1965	214,451	26*	20	9	2.1*
1966-1970	248,838	49*	9	3.6	9*
1971-1975	253,544	68*	9	3.5	10*
1976-1980	289,620	80*	4	1.4	4*
1981-1985	311,913	88*	2	0.5	1.3*
1986-1990	336,785	93*	0.2	0.1	0.3*

* Estimation.

the number of farm tractors in use per each fatality rose from 388 to more than 21,000 tractors.

Figure 1 depicts the trends in total injuries, fatalities and proportion of tractors equipped with ROPS. The four different years during which new policy requirements for ROPS and cabs were implemented are also noted. The trends illustrate a remarkable decline in fatal and nonfatal tractor rollover injuries concomitant with a marked rise in the proportion of tractors equipped with ROPS. In 1959 when there were no safety regulations for tractors, Sweden had 12 fatalities per 100,000 farm tractors. By 1968, when about half the tractors had ROPS, fatalities were down to four per 100,000 tractors. After 1981 when safety cabs were mandated on all tractors, the rate dropped to 0.2 fatalities per 100,000 tractors.

Discussion

Fatal and nonfatal tractor rollover injuries are strikingly associated with tractors without ROPS. In Sweden the increase in the number of ROPS-equipped tractors and simultaneous decrease of fatal and nonfatal rollover injuries was observed. When the Swedish authorities first announced plans to introduce mandatory regulations on ROPS for all tractors, there was strong resistance from farmers. However, the authorities supported the new regulations. Through effective enforcement by the Labour Inspectorate, the goal of the 1959 policy, and the following strengthened ones, was achieved and nearly all tractors are now equipped with rollover resistant cabs. The Swedish society did not provide any economic compensation to farmers that directly related to the increased costs of protected tractors. Indirectly, this policy

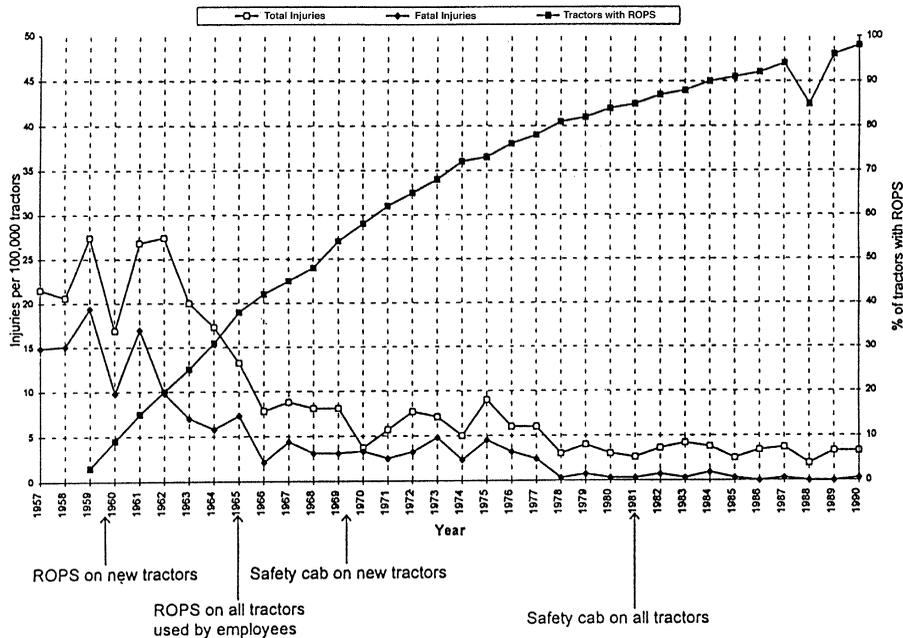


Figure 1–Rollover injuries per 100,000 tractors 1957-1990. Years during which new regulations were introduced are marked. The drop in the curve in 1988 is associated with a structural change in agricultural work.

saved money for farm owners and society by reducing costs associated with adverse outcomes of tractor rollover events.

The powerful impact of an engineering design modification is illustrated by a 93% reduction of rollover-related fatalities from 12 to 0.2 per 100,000 tractors over a 30-year period. Rear overturns accounted for 12% of nonfatal rollover injuries but 28% of the fatalities. Thus, rear overturns were more fatal than side flips (table 3). This finding suggests implications for engineering as well as educational interventions in countries where ROPS are not presently required.

Rollover fatalities per 100 million driving hours decreased to less than 1% when 93% of the tractors were protected (table 4). While data on fatalities per driving hours were derived from proportions of primary and secondary tractors, the Swedish proportions of newer versus older tractors differ from tractors in the U.S. (Kelsey et al., 1996). According to a telephone survey of randomly selected New York farmers, the investigators found that older tractors were only slightly less likely to be used primarily for fieldwork than the newest tractors (with ROPS). In the New York study, one third of tractors in use were more than 20 years old and 4% or less had ROPS. Compared with U.S. farm tractors, the oldest Swedish tractors without ROPS are very few and might be more aged than those used on U.S. farms.

This analysis supports the principle that passive or automatic safety measures are highly effective for reducing injury (Springfeldt, 1993; Haddon, 1974). Rather than rely on educational approaches to inform tractor owners of the value of ROPS, the country of Sweden passed legislation affecting tractor manufacturers and retail dealers. The original ROPS in Sweden were rollover frames, and since 1981, all farm tractors must have rollover resistant cabs. The Swedish policy does not require seat belts on tractors, but all Swedish tractors must have a cab.

Certain limitations of this study should be noted. Given that the primary sources for injury data were government reports, the validity of annual calculations was not verified. While Swedish routines for reporting tractor rollover injuries are strict, especially for fatalities, it is possible the variance between actual and occurred events could be 10% or more. The process for reporting occupational injuries is connected with the insurance system. Compensation from the compulsory injury insurance is paid out solely on condition that the injury is reported to the authorities. Under reporting of occupational injuries sometimes occurs, especially with injuries of a temporary nature. As of 1977, farm owners had weaker insurance protection for themselves than for employees and, thus, are less likely to report their own injuries. The system is more reliable for serious injuries than minor ones. All fatalities are reported. Studies in agriculture in 1987 demonstrated that 68% of occupational injuries with one or more sick days were reported and 82% of injuries requiring one month absence from work were reported (NBOSH, 1992).

Another issue for consideration is the possible influence of factors other than ROPS on tractor rollover events. For example, tractor design modifications, operator behaviors, or environmental conditions could account for improved safety. Newer tractors have a lower center of gravity than older models and, thus, are more stable. Over the years, tractor operators were likely to have increased opportunities for education and training in avoiding rollovers. Dangerous field and road conditions may have been modified over time. Clearly, these factors could have contributed to the reduction in fatal and nonfatal tractor rollover injuries. Yet, the primary and consistent intervention experienced in agricultural work during that time period was the requirement for ROPS on all tractors.

Summary

The Swedish approach for preventing farm tractor rollover injuries was an implementation of the passive method, i.e., ROPS on newly manufactured tractors followed by mandatory rollover resistant cabs on all tractors. This is compared with active approaches that rely on personal choices, such as noted in the U.S. and other countries. The passive approach has demonstrated a major impact on the protection of tractor operators from fatal and nonfatal rollover injuries.

NOTE on Method for Calculating Fatalities per Million Driving Hours

For the years 1971-1975 it was reported that 34.6% of 253,544 tractors were secondary tractors, used about 100 h per year ($253,544 \times 0.346 \times 100 = 8.8$ million hours). The 65.4% primary tractors were used 500 h per year ($254,544 \times 0.654 \times 500 = 81.5$ million hours). Totally, the farm tractors were used $8.8 + 81.5 = 90.3$ million hours on an average during that period. The average number of fatalities was 9. Then $9 \times 100 \text{ million} / 90.3 \text{ million} = 9.97$ or 10 fatalities per 100 million driving hours. In other periods the proportion of secondary tractors was 9% (1957-1960), 17% (1961-1965), 27% (1966-1970), 35% (1976-1980), 39% (1981-1986), and thereafter 40%.

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