Cost-Benefit Analysis of Side Underride Guards on Semi-Trailers: Assessing the Economic Impact and Safety Benefits

Abstract

This research paper examines the economic and societal benefits and costs associated with implementing side underride guards on semi-trailers. Side underride crashes involving semi-trailers lead to a significant number of fatalities and serious injuries each year, resulting in substantial costs to society. By estimating the prevention of fatalities and serious injuries, as well as the costs associated with side underride guards, this study assesses the potential impact of mandating their installation on new semi-trailers.

In the absence of side underride guards on semi-trailers, side underride crashes result in a minimum annual baseline of between 200 to 400 fatalities and 200 to 400 serious injuries, which annually costs society between $2,670,920,000 and $5,341,840,000. Side underride guards are highly effective in reducing crash severity of a passenger vehicle into a semi-trailer. The benefits of installing these guards include an annual prevention of between 50 and 150 fatalities, as well as an annual reduction of between 50 and 150 serious injuries. The costs associated with side underride guards encompass the installation and maintenance expenses ranging from $1,000 to $3,000 per semi-trailer, along with a fuel impact of 0.25 percent due to the additional weight of 500 pounds.

Subtracting the costs from the benefits of side underride guards, the study estimates a minimum annual net present value of between $540,242,339 and $1,385,702,339. Moreover, the installation of aerodynamic skirts on semi-trailer side underride guards can yield additional annual benefits of $746,426,163, resulting in a total net present value of $2,132,128,502. These additional benefits are achieved through fuel savings of 714 gallons of diesel per semi-trailer, assuming a conservative 5 percent reduction in fuel consumption.

The positive net present value demonstrates that the benefits of installing side underride guards on new semi-trailers exceed and fully offset the costs. Therefore, mandating the installation of side underride guards through Federal regulation is considered cost-effective.

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Since 1993, the U.S. Department of Transportation (USDOT 2023) has issued cost-benefit guidance on valuing the reduction of fatalities and injuries by regulations or investments. A cost-benefit analysis provides estimates of the anticipated benefits that are expected to accrue over a specified period and compares them to the anticipated costs. The USDOT (2023) guidance ensures that the economic costs and benefits of road safety measures can be monetized and compared, leading to informed decision making. The current research evaluates the National Highway Traffic Safety Administration (NHTSA) mandating side underride guards (SUGs) on new applicable semi-trailers by comparing the anticipated costs and benefits associated with their installation.

Side underride crashes involving passenger vehicles and semi-trailers result in fatalities and severe injuries due to the difference in height between the vehicles. Because of the height difference, underride crashes bypass the passenger vehicle's safety features because the point of impact is the passenger compartment, not the front bumper. Frequently, the vehicle goes partially or completely under the semi-trailer causing the passenger compartment to be crushed when it contacts the semi-trailer, resulting in death or severe injuries for the occupants. Side underride guards are safety devices that can be affixed to the sides of semi-trailers that lowers to the point of impact and prevents passenger vehicles from sliding underneath trailers during collisions.

Side underride guards are a solid or flexible metal frame or cable/nylon webbing that can be affixed onto the side of a semi-trailer to prevent a passenger vehicle from going under the semi-trailer. As a passive safety device, side underride protection guards do not affect the risk of a crash, but evidence confirms that these guards would have a large a reduction in crash risk severity, as measured through the preventing fatalities and serious injuries, and the associated property damage (Brumbelow 2012; National Transportation Safety Board (NTSB) 2014, 2023; Insurance Institute for Highway Safety (IIHS) 2017, 2017a, 2023; Mattos *et al*. 2021; NCSA 2023). A SUG is designed to stop a passenger vehicle from a direct impact (i.e., a 90-degree crash angle) by preventing the car from sliding under the semi-trailer and providing a point of impact that will activate the car's safety features to protect the occupants (Brumbelow 2012; Ponder 2020; Kiefer 2018; Wilson 2017; Utility Trailer Manufacturing Company (UTM) 2022). A SUG is also designed to contain and redirect the passenger vehicle when the crash occurs at an oblique angle (where the vehicles collide at an angle that is not perpendicular or 90 degrees); thus, not all the energy of the vehicle must be dissipated by the SUG (NHTSA 2018). Crash tests have successfully demonstrated that a SUG can stop a 90-degree crash angle of a passenger vehicle traveling up to 40 mph (IIHS 2017), whereas simulations have established that SUGs will redirect a passenger vehicle in an oblique angle crash traveling up to 50 mph (NHTSA 2018; Mattos *et al*. 2021).

Side underride guards are readily available. For example, Utility Trailer Manufacturing Company (2022), the largest semi-trailer company in the United States, sells a SUG (Side Impact Guard), which has undergone extensive testing and can be installed as safety option at the factory during semi-trailer manufacturing. Side underride guards are also offered as an aftermarket safety option (AngelWing (Airflow Deflector 2020); SafetySkirt 2020). The

AngelWing, Safetyskirt, and Wabash SUGs have similarly been successfully crash-tested by stopping a passenger vehicle from underriding a semi-trailer (Ponder 2020; Kiefer 2018; Wilson 2017). In addition, Wabash holds three patents (issued in 2012, 2020, and 2021), Vanguard holds one patent (issued in 2019), and Great Dane holds one patent (issued in 2021) for SUGs.

Aerodynamic skirts could also be installed over SUGs to significantly save diesel fuel, one of the highest operating-costs faced by the tractor-trailer industry (North American Council for Freight Efficiency (NACFE) 2020; Galipeau-Belair *et al*. 2014). Consequently, cost savings from the installation of aerodynamic skirts on SUGs are estimated using a 5 percent improvement in fuel efficiency (NACFE 2020; also see UTM 2022, 2023).

This study is consistent with the USDOT's cost-benefit guidance, which estimates the economic value of reducing fatalities and serious injuries resulting from vehicle crashes (USDOT 2021, 2023). Following USDOT's Cost-Benefit Guidance (2023), the Net Present Value (NPV) is estimated because it is the most straightforward measure of benefits and costs. The estimates include the willingness of individuals to pay for improved safety, incorporating the Value of a Statistical Life (VSL) to measure the costs associated with the reduction of risk through the prevention of loss of life and serious injury (USDOT 2023). The benefits measure the reduction of fatalities and serious injuries as well as the economic safety value reported by NCSA (2023) that is reasonably expected to result from the installation of SUGs on new semi-trailers. The estimated benefits are compared to the anticipated costs of SUGs related to manufacturing, installing, and maintaining SUGs.

The estimated benefits and costs are reported in present value 2023 dollars and are reported using a 3 and 7 percent discount rate to emulate a 1-year lag between NHTSA proposing a rule for SUGs in 2023 and a final rule in 2024.

The annual baseline risk (see Office of Management and Budget 2003; USDOT 2023) is likewise calculated using between 200 and 400 fatalities and between 200 and 400 serious injuries, which would remain constant from side underride crashes in the absence of SUGs (i.e., NHTSA takes no action and does not issue any regulation regarding the adoption of SUGs). Benefits of side underride guards were estimated using the annual prevention of between 50 and 150 overall fatalities and 50 and 150 overall serious injuries.[1,2] Costs were estimated using between $1,000 and $3,000 per SUG installed on a semi-trailer and the potential impact 0.25 percent fuel impact associated with the combined weight of a 500-pound SUG. All sources of data, values of key parameters, and reference materials for SUGs are identified.

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[1] IIHS (2023, 2023a) estimated that 159-217 fatalities could be addressed by a side underride guard standard.

[2] NHTSA (2023) proposed automatic emergency brake (AEB) systems on passenger vehicles that would detect and apply brakes at speeds up to 100 km/h (62 mph) when manual braking is applied and up to 80 km/h (50 mph) when no manual braking is applied. In conjunction with SUGs, these AEB collision avoidance speeds would reduce the severity of side underride crashes, preventing *additional* fatalities and serious injuries.

Parameters:

1. Cost of Fatalities and Injuries from Underride Crashes.
    a. Average number fatalities/year: 200-400[a,b,c,d,m,t,v]
    b. Cost of average truck-involved fatality: $13,046,800[e]
    c. Average number injuries/year: 200-400 citation[f]
    d. Cost of average truck-involved serious injury: $307,800[e]
    e. Effectiveness of preventing fatalities and injuries: 97, 85 percent[a,n,o,]
    f. Fatalities prevented and serious injuries minimized: 50, 100, 150[t]
2. Annual safety benefits per semi-trailer: $640[s]
3. Annual number of semi-trailers manufactured and sold: 245,000[h,r]
4. Unit cost of an SUG to be installed on semi-trailer: $1,000, $2,000, $3,000[q,u,3]
5. Average annual tractor semi-trailer fuel economy (miles per gallon): 6.6[i]
6. Average tractor semi-trailer pounds of operating weight (2019): 63,000[i]
7. Average tractor semi-trailer moving speed (mph): 51[i]
8. Average annual tractor semi-trailer mileage driven: 105,041[j]
9. Percent miles-per-gallon reduction from weight: 0.0025 (500 lbs)[j];
10. Percent miles-per-gallon saved with an aerodynamic skirt: 0.05[k,p]
11. Average cost of diesel fuel: $4.02[l]

Results and Discussion

The NPV ranges from $383,442,339 to $1,228,902,339, depending on the prevention of fatalities and serious injuries and the cost of SUGs (Table 1). The addition of a $640 per semi-trailer safety benefit (NCSA 2023) resulted in an estimated Total NPV of between $540,242,339 and $1,385,702,339 (Table 1). These NPVs are positive, meaning the benefits of installing side underride guards on semi-trailers offset the costs.

Furthermore, installing aerodynamic skirts on SUGs can lead to annual fuel saving benefits of 714 gallons of diesel per semi-trailer or $746,426,163 (total net present value of $2,132,128,502), resulting in additional significant cost reductions for the trucking industry.

In the absence of side underride guards on semi-trailers, side underride crashes result in a minimum annual baseline of between 200 to 400 fatalities and 200 to 400 serious injuries, which annually costs society between $2,670,920,000 and $5,341,840,000 (Table 2).

The NPV should be considered minimum estimates because they do not incorporate additional benefits to the trucking industry such as lower legal (e.g., Sievers 2020) and court costs, insurance cost reductions on premiums and settlements, or less workplace impacts (e.g.,

[3] In 2000, the Strick Corporation estimated the cost to manufacture a side underride guard was $329.82, which is $576.48 adjusted 2023 dollars. This estimate reflects the cost to mass produce side guards during manufacturing of a semi-trailer, rather than an after-market side underride guard like the AngelWing that is only produced in low volumes.

potential jail time or PTSD for drivers; Walsh 2021). Side underride guards also would provide additive safety benefits to vulnerable road users (VRUs; Volpe 2021, 2022) such as pedestrians, bicyclists, and motorcyclists. For example, Epstein (2014), Volpe (2021), and FMCSA (2020) reviewed available information and reported that the safety effectiveness of sideguards to protect VRUs has been well established. Side guards could prevent between 55-75 percent of bicyclists fatalities, and 20-27 percent of pedestrian fatalities (Epstein 2022; FMCSA 2020). Moreover, from 2017-23, an average of 53 pedestrians and bicyclists were killed each year in crashes involving the side of a tractor-trailer whereas, an average of 52 motorcyclists were killed each year from 2017-23 in trailer side impacts (IIHS 2023).

In 2019, the average moving speed of a tractor semi-trailer combination was 51 mph, indicating a high potential for fuel savings when aerodynamic drag is reduced by the addition of an aerodynamic skirt (NACFE 2020). In fact, an SUG with an aerodynamic skirt would increase fuel efficiency for semi-trailers and provide additional significant annual cost savings. For example, UTM (2023) reports that their aerodynamic side skirts are compatible with their SUG and can save an estimated 830 gallons of fuel annually. Saving 700 to 800 gallons of fuel annually, an SUG with an aerodynamic skirt would offset the entire cost of an SUG to truck drivers or trucking companies within the first year of installation. Aerodynamic skirting can also reduce drag by improving air flow around the truck and semi-trailer, which also helps reduce splash and spray generated in wet weather (NACFE 2019, 2020), which could offer additional safety benefits to the traveling public.

This analysis estimated that the average weight of as SUG is about 500 pounds; however, other braided cable or nylon webbing designs are about half of this weight (Vanguard 2019, Wabash 2012, Fortier 2019, Kiefer 2018, and Fontaine 2021). Moreover, like the engineering improvements of rear underride guards (Stoughton 2020), future designs of SUGs will undoubtedly bring about additional innovations in reducing the weight of guards and safety effectiveness, leading to additional cost savings.

Conclusion

This cost-benefit analysis demonstrates that mandating side underride guards on new applicable semi-trailers is economically justified. The estimated NPVs indicate that the benefits derived from the installation of SUGs on semi-trailers, including the prevention of fatalities and serious injuries, offset the associated costs. Additionally, the potential significant savings in fuel costs by installing aerodynamic skirts further enhances the economic viability of implementing SUGs. Considering the substantial public safety and economic benefits, a regulation by NHTSA for SUGs on semi-trailers is recommended.

Note: This report also includes an unprotected Excel spreadsheet with embedded calculations as recommended by USDOT (2023).

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Appendix 1

Table 1. Estimated Net Present Value (benefits minus costs) of preventing fatalities and serious injuries with side underride guards on semi-trailers using a 0.25 percent fuel impact from the additional 500 pounds.

Parameters	Initial NPV (Benefits Less Costs)	Total NPV (Benefits with a $640 per trailer Safety Benefit Less Costs)	Overall NPV (Benefits Less Costs with a 5% Fuel Savings from Aero Skirts)	Total NPV Discounted by 3%	Total NPV Discounted by 7%
Prevent 50 Deaths + 50 Injuries - ($1000 SUG Cost + Fuel Impact)	$383,442,339	$540,242,339	$1,129,868,502	$524,507,125	$504,899,382
Prevent 50 Deaths + 50 Injuries - ($2000 SUG Cost + Fuel Impact)	$138,442,339	$295,242,339	$884,868,502	$286,643,048	$275,927,420
Prevent 50 Deaths + 50 Injuries - ($3000 SUG Cost + Fuel Impact)	$-106,557,661	$50,242,339	$639,868,502	$48,778,970	$46,955,457
Prevent 100 Deaths + 100 Injuries - ($1000 SUG Cost + Fuel Impact)	$1,051,172,339	$1,207,972,339	$1,797,598,502	$1,172,788,679	$1,12,8946,111
Prevent 100 Deaths + 100 Injuries - ($2000 SUG Cost + Fuel Impact)	$80,6172,339	$962,972,339	$1,552,598,502	$934,924,601	$899,974,149
Prevent 100 Deaths + 100 Injuries - ($3000 SUG Cost + Fuel Impact)	$561,172,339	$717,972,339	$1,307,598,502	$697,060,523	$671,002,186

Table 1 Continued

Parameters	Initial NPV (Benefits Less Costs)	Total NPV (Benefits with a $640 per trailer Safety Benefit Less Costs)	Overall NPV (Benefits Less Costs with a 5% Fuel Savings from Aero Skirts)	Total NPV Discounted by 3%	Total NPV Discounted by 7%
Prevent 150 Deaths + 150 Injuries - ($1000 SUG Cost + Fuel Impact)	$1,718,902,339	$1,875,702,339	$2,622,128,502	$1,821,070,232	$1,752,992,840
Prevent 150 Deaths + 150 Injuries - ($2000 SUG Cost + Fuel Impact)	$1,473,902,339	$1,630,702,339	$2,377,128,502	$1,583,206,154	$1,524,020,878
Prevent 150 Deaths + 150 Injuries - ($3000 SUG Cost + Fuel Impact)	$1,228,902,339	$1,385,702,339	$2,132,128,502	$1,345,342,077	$1,295,048,915

Table 2. Annual baseline societal costs of fatalities[1] and serious injuries[1] from side underride crashes into semi-trailers that lack side underride guards.

200 Annual Fatalities	$2,609,360,000		**400 Annual Fatalities**	$5,218,720,000
200 Annual Injuries	$61,560,000		**400 Annual Injuries**	$123,120,000
Total	$2,670,920,000		**Total**	$5,341,840,000

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