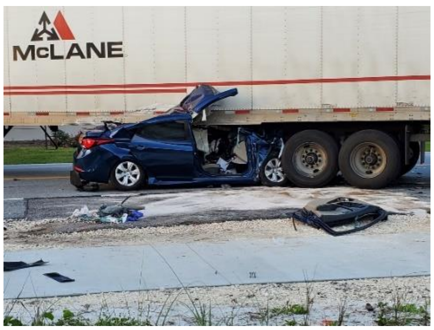
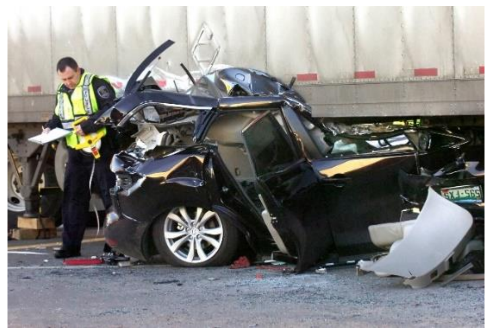
AngelWing ™


SafetySkirt ™



# Using Cost-Benefit Analysis to Evaluate the Economic and Societal Benefits of Side Underride Guards for Semi-Trailers


Abstract

This report estimates the economic effects of implementing a regulation mandating side underride guards on new semi-trailers to evaluate the estimated benefits from a reduction of fatalities and serious injuries in relation to the costs of the guards. The cumulative 15-year societal benefits of installing side underride guards on new semi-trailers would save at least 3,560 lives and prevent 35,598 serious injuries. The cost of guards would be fully offset by the estimated benefits, providing a minimum annual Net Present Value of $53,057,724,800 to $79,238,494,800. A regulation for side underride guards is considered cost effective because the public safety benefits from installing side underride guards on semi-trailers substantially outweigh the costs.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May 25, 2022

Since 1993, the U.S. Department of Transportation (USDOT) 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. This USDOT guidance ensures that the economic costs and benefits of road safety measures can be monetized and compared, leading to informed decision making. In this report, estimates of costs to the trucking industry from the installation of side underride guards (SUGs) on new semi-trailers are quantified and compared to the anticipated associated benefits. This report examines the economic impact of fatalities and serious injuries, and the related financial costs resulting from side underride motor vehicle crashes to the benefits of reducing the severity of these collisions. The purpose of presenting the benefits and costs is to place in perspective the economic losses and societal harm that result from side underride crashes, and to provide information to evaluate the effect of the USDOT mandating SUGs to reduce or prevent these impacts.

An "underride" occurs when a vehicle collides with a semi-trailer even at low speeds, due to the height differential, bypassing the 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 semitrailer, resulting in death or severe injuries for the occupants. Side underride guards engage a vehicle's airbags, crumple zones, crash avoidance sensors, and other safety features to minimize fatalities and reduce the potential for serious injuries to occur (Brumbelow 2012, Insurance Institute for Highway Safety (IIHS) 2017, Mattos *et al*. 2021). Side underride guards are a solid or flexible metal frame or cable/nylon webbing that can be affixed onto the sides of semi-trailers to prevent vehicles from going under the semi-trailer.

Crash victims, their families, employers, and society are all affected by vehicle side underride crashes. For example, the cost of medical care is often borne by the victim in the form of payments for insurance, deductibles, uncovered costs, and uninsured expenses. There are also significant costs associated with the lost productivity experienced by an individual and others when the victim dies prematurely or experiences a short or long-term disability from serious injuries.

The USDOT provides cost estimates for injuries and fatalities resulting from vehicle crashes (USDOT 2021a, 2022). For fatalities, the estimate includes the average cost of a crash in which at least one person was killed. The costs reflect the value of remaining life-years lost by the victims of the crash, in addition to the other costs associated with the crash such as treatment of injured victims, property damage, congestion delays, etc. (e.g., see Federal Motor Carrier Safety Administration (FMCSA) 2008, USDOT 2021a, 2022). For injuries, the estimate includes the average cost of a crash in which at least one person was injured and includes medical treatment and rehabilitation costs as well as quality of life losses for injured individuals who suffer long-term disability from the crash. These estimates include costs to society that result from a crash, with the exception of pain and suffering for family and friends of crash victims (FMCSA 2008).

The anticipated benefits of SUGs reduce the likelihood of fatalities and serious injuries and are expected to be proportionally phased in over a 15-year period as the semi-trailer fleet is replaced. The benefits measure the reduction of fatalities and serious injuries as well as the economic value that is reasonably expected to result from the installation of SUGs on new semi-trailers. These estimates are compared to the anticipated costs of SUGs related to manufacturing, installing, and maintaining new SUGs, including the potential impact of weight or payload displacement. The analysis uses estimates of incremental costs on a per trailer basis to calculate a 15-year cumulative cost, the expected period covering fleet replacement. Following the initial 15 years to replace the current fleet of semi-trailers, full economic benefits would be realized annually. It is anticipated that aerodynamic skirts would be installed over SUGs due to the increasing rate of adoption of this technology and proven solution to significantly save fuel, one of the highest operating-costs faced by the tractor-trailer industry (North American Council for Freight Efficiency (NACFE) 2020). Consequently, savings from the installation of aerodynamic skirts are estimated by using a 1 and 5 percent improvement in fuel efficiency (NACFE 2020). This report also identifies sources of data, values of key parameters, and reference materials for SUGs. Calculations are also included (see Appendix A; Excel Spreadsheet).

The analyses assumed that the baseline risk of between 200 and 1,000 annual fatalities and between 1,000 and 5,000 annual serious injuries would remain constant from underride crashes in the absence of SUGs. Testing and modeling demonstrate that SUGs are expected to be highly effective and reduce the risk of annual fatalities and serious injuries by up to 89 percent (Brumbelow 2012, IIHS 2017, Mattos *et al*. 2021, National Transportation Safety Board (NTSB) 2014). For example, IIHS (2017) crash tests demonstrate that SUG technology is a simple solution to the known risk of side underride collisions. Side underride guards would prevent almost all underride collisions at a speed differential of 40 mph (note: SUGs prevent underride occurrences when the vehicle and semi-trailer are travelling at highway speeds, because their speed differential would almost always be less than 40 mph) (IIHS 2017). Therefore, SUGs offer significant benefits to society by reducing the risks and associated costs of semi-trailer and vehicle crashes.

Side underride guards will mitigate the main risk factor in underride collisions: a geometric height difference between passenger vehicles and semi-trailers. Underride protection will not avert collisions; rather, SUGs will prevent or diminish passenger compartment intrusion and the devastating and costly effect of fatalities and serious injuries. A SUG is designed to withstand the force of a crash and prevent the car from sliding under the semi-trailer and provide an effective point of impact that will activate the car's safety features to protect the occupants.

The general methodology used to calculate the benefits and costs of SUGs is discussed and demonstrated below. These methods could also be used to evaluate the cost-benefit analysis of SUGs for single unit trucks.

1. Estimate the annual cost of fatalities and injuries from underride crashes.
    a. Use the Fatality Analysis Reporting System (FARS) database and literature to estimate the average number of fatalities per year from semi-trailer side underride collisions (additional analysis should also consider single unit trucks);
    b. Due to the documented undercounting of FARS data, bracket this estimate to examine and capture a range of fatalities of vehicle-trailer collisions that would be prevented by SUGs (additional analysis could also include motorcycle, pedestrians, and bicyclists);
    c. Estimate the annual cost of fatalities from semi-trailer side underride crashes using the USDOT valuation by multiplying the average number of fatalities per year and a range of fatalities (USDOT 2022);
    d. Use literature to estimate the average number of injuries per year from semi-trailer side underride crashes (additional analysis should also consider single unit trucks);
    e. Estimate the annual cost of serious injuries from semi-trailer side underride crashes using the USDOT valuation multiplied by the average number of injuries (USDOT 2022); and
    f. Use a range of values for the effectiveness of SUGs for reducing serious injuries;

2. Estimate the annual number of SUGs installed on semi-trailers to turn over the fleet in 15 years (additional analysis should also consider single unit trucks).

3. Estimate the unit cost of an SUG to be installed on semi-trailer (additional analysis should also consider single unit trucks);
    a. Use a range of cost estimates to evaluate, for example, the effect of mass production of a SUG by a semi-trailer manufacturer and other possible costs to the consumer.

4. Estimate the annual amount of fuel used by an average loaded tractor and semi-trailer by using the reported industry data of average annual miles driven divided by the average mpg fuel economy for a loaded tractor and semi-trailer.

5. Use the reported industry data of average annual mpg fuel economy for a loaded tractor and semi-trailer;
    a. To determine the percent miles-per-gallon reduction from the potential weight impact on fuel economy (i.e., 0.5%–0.6% per 1,000 lbs); and
    b. To determine the percent miles-per-gallon saved from the potential benefit of an aerodynamic skirt on fuel economy.

6. Estimate the effect of installing an SUG with an aerodynamic skirt using the average annual mileage driven by a loaded tractor and semi-trailer mileage divided by the difference between the potential fuel savings and potential weight on the overall mpg;

a. Compare this estimate to number 4 to determine the fuel savings; and
b. Estimate the benefit by multiplying the savings by the average cost of diesel fuel.

7. Calculate the Return on Investment using the estimated Net Present Value (NPV) minus the estimated unit cost of an SUG divided by the estimated unit cost of an SUG multiplied by 100.

**Parameters**:

1. Annual Cost of Fatalities and Injuries from Underride Crashes.
    a. Average Number Fatalities/Year: 500[a,b,c,d,m]
    b. Range of Fatalities/Year: 200 – 1,000[a,b,c,d]
    c. Cost of Average Truck-Involved Fatality: $12,837,400[e]
    d. Average Number Injuries/Year: 1,000, 5,000[f]
    e. Cost of Average Truck-Involved Injury: $302,600[e]
    f. Effectiveness of preventing fatalities and injuries: 50, 89 percent[a]
2. Annual number of semi-trailers manufactured and sold: 300,000[h]
3. Average annual number of semi-trailers with SUGs to turn over the fleet in 15 years: 513,300
4. Unit cost of an SUG to be installed on semi-trailer: $1,000, $2,000, $4,000
4. Average annual tractor semi-trailer fuel economy (miles per gallon): 6.6[i]
5. Average tractor semi-trailer pounds of operating weight (2019): 63,000[i]
6. Average tractor semi-trailer moving speed (mph): 51[i]
7. Average annual tractor semi-trailer mileage driven: 105,041[j]
8. Percent Miles-per-gallon reduction from weight: 0.0025 – 0.003 (500 lbs); 0.00375 – 0.0045 (750 lbs)[j]
9. Percent Miles-per-gallon saved with an aerodynamic skirt: 0.01 – 0.05[k]
10. Average cost of diesel fuel: $5.62[l]

**Results and Discussion**

Using Brumbelow's (2012) estimate of 89 percent effective rate for SUGs with an average annual proportional fatality rate (i.e., calculated as the proportion of guarded to unguarded trailers) of 500 fatalities, the 15-year cumulative monetized estimate from installing SUGs is $45,701,144,000 by saving at least 3,560 lives (societal benefit), plus the reduction of an average of 5,000 annual serious injuries by preventing 35,598 serious injuries over the 15-year cumulative estimate and saving of $10,771,954,800 (societal benefit). The 15-year cost of $7,699,500,000 for SUGs (cost for trucker drivers or trucking companies) was subtracted from this estimate to calculate the NPV benefit of $48,773,598,800 (Table 2). As demonstrated below, the addition of an aerodynamic skirt would save an additional $4,284,126,000 (1 percent of fuel) to $30,464,896,000 (5 percent of fuel; benefit to trucker drivers or trucking companies) and *fully offset* the entire cost of SUGs to provide a minimum NPV 15-year cumulative benefit of $53,057,724,800 to $79,238,494,800. For a lower-end injury comparison, the societal benefit was also calculated using a reduction of an average of 1,000 annual serious injuries to prevent 7,220 serious injuries over provide a minimum NPV 15-year cumulative benefit of $44,386,689,000. After the Nationwide semitrailer fleet is replaced in 15 years, the annual estimated benefit from SUGs is $3,643,839,000 to $29,824,609,000 attributed to 445 lives saved and the reduction of 4,450 serious injuries, plus 1 to 5 percent fuel savings respectively. Please also see additional computations below for the full range of estimates (Appendix 1). The Return on Investment is estimated to be 489 percent.

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 a skirt (NACFE 2020). In fact, trailer skirts offer 1 to 5 percent and possibly higher fuel savings than non-skirted trailers (NACFE 2020). Ponder (pers. comm. 2017) reported that an AngelWing SUG with an aerodynamic skirt increased fuel efficiency by 8.3 percent. The addition of a 250-pound aerodynamic skirt (total weight of 750 pounds with an SUG plus a skirt) would increase the average of 6.6 mpg by 1 to 5 percent to achieve an annual fuel reduction savings of 99 to 704 gallons ($556.00 to $3,954.00 using $5.62/gallon) of diesel fuel. Using a 5 percent increase in fuel efficiency, an SUG with an aerodynamic skirt would offset the entire cost to truck drivers or trucking companies within the first year of installation. In fact, some aerodynamic skirts (e.g., Windyne Fairing System 2022) claim to save significantly more fuel (2,094 gallons per year; saving $11,769 per trailer per year). If fuel prices rise or fall, the savings would correspondingly differ.

Brumbelow's (2012) evaluation of the potential benefits of SUGs strongly suggested that they would also reduce injury severity. Of passenger vehicle occupants with serious to fatal injuries attributed to side impacts with semi-trailers, 89 percent were considered injuries that could have been mitigated by SUGs. As a passive safety device, underride protection guards do not affect the risk of a crash, but evidence shows that these guards would have a large a reduction in crash risk and severity of accidents as measured through the preventing fatalities and injuries, and the associated property damage from collisions (e.g., Brumbelow 2012, NTSB 2014, IIHS 2017, Mattos *et al*. 2021). Future analysis should strongly consider the additional benefits of reducing property damage using the estimated cost per vehicle crash (e.g., USDOT 2022, Table A-2) and preventing fatalities and serious injuries of vulnerable road users (Volpe 2021).

For example, Brumbelow (2012) estimated that 530 passenger vehicle occupants died each year during 2006–2008 in two-vehicle collisions between passenger vehicles and the sides of large trucks. Brumbelow (2012) and Hein et al. (2021) also reported that deaths and injuries from side underride collisions into heavy trucks and trailers are a significant public health issue. Side underride guards are designed to engage car safety systems (e.g., airbags, crumple zones, seat belts) during a collision to reduce the degree of passenger compartment intrusion (Mattos *et al*. 2021). Significant expenses went into developing these car safety systems, but without a SUG these systems are rendered useless.

Following USDOT's Cost-Benefit Guidance (2022), the NPV is estimated because it is the most straightforward measure. Benefits are estimated in present dollars tallied over a 15-year period, phasing out semi-trailers without SUGs to achieve full turnover of the semi-trailer fleet. Costs are also estimated in present dollars tallied over a 15-year period and are subtracted from the estimated benefits to yield an NPV.

The benefits of SUGs would be phased in and not fully accrue until the current fleet of semi-trailers without guards has been replaced. The average semi-trailer is replaced every 12.8 years; however, the average age of semi-trailers is 6.2 years (Williams and Murray 2020). Because of significant cost savings, some fleets are replacing semi-trailers every five to seven years through leasing programs, which are gaining in popularity, as opposed to legacy practices of operating them for 10 years (Straight 2019). Based on these data, by year 6 many of the semi-trailers on the road would have SUGs, with the current fleet of semi-trailers replaced by year 12. Nevertheless, to be more conservative in the length of time to fully penetrate the semi-trailer fleet (i.e., older trailers are replaced by newer trailers), costs and benefits were estimated using a 15-year phased approach (Table 4).

The NPV should be considered minimum estimates because they do not incorporate additional potential benefits to the trucking industry such as lower legal and court costs (e.g., Sievers 2020), insurance cost reductions on premiums and settlements, or less workplace impacts (e.g., Walsh 2021 such as PTSD for drivers). When the USDOT conducts a cost-benefit analysis for SUGs, qualitative measures of benefits or costs that are difficult to quantify, but nevertheless essential, should also be considered (Executive Order 12866). Further, in choosing among regulatory approaches to underrides, the USDOT should select those approaches that maximize net societal benefits (including potential economic, environmental, public health and safety, and other advantages).

The cost-benefit calculations used the anticipated cost of $1,000 for each semi-trailer pair of SUGs, but also evaluated $2,000 and $4,000 per installed SUGs to account for the possible range of costs related to purchase price, maintenance, or other potential costs (e.g., aerodynamic skirt; Appendix 1). For example, if the maximum unit cost of an SUG is $4,000, with 500 annual fatalities, an 89 percent effective rate, and a 1 to 5 percent fuel efficiency from an aerodynamic skirt, the NPV is estimated to be $29,959,224,800 to $56,139,994,800. As a result, the highest cost could also account for any additional expenses possibly borne by the consumer. Ranges of estimates were also used in the cost-benefit analysis to account for under-reporting of data (e.g., a range of 200 to 1,000 fatalities per year; and 1,000 or 5,000 serious injuries per year). Future analyses could also explore unclear market responses (e.g., considering how fewer deaths and injuries to the traveling public affect insurance premiums for trucker drivers and trucking companies).

The most common trailer type is the standard dry van or box trailer, which is enclosed and can haul most types of mixed freight (Environmental Protection Agency (EPA) 2016). One specialized type of box trailer is the refrigerated van trailer (reefer). This is an enclosed, insulated trailer that hauls temperature sensitive freight, with a refrigeration unit or heating unit mounted in the front of the trailer powered by a small (9-36 horsepower) diesel engine.

Together, the standard box vans and reefers are the likely types of trailers for SUGs and make up greater than 70 percent (7.7 of 11 million) of the registered semi-trailers (EPA 2016).

The general rectangular shape of these trailers allows operators to maximize freight volume within the regulated dimensional limits. For semi-trailers, the majority of freight hauled in semi-trailers cubes-out (is volume-limited) before it grosses-out (is weight-limited) (EPA 2016). Federal Highway Administration (2000) estimated that about 80 to 90 percent of "cubes out before it weighs out". This means that cargo space in a semi-trailer usually fills before reaching the 80,000 pound limit. Indeed, Williams and Murray (2020) reported that the average operating weight of a tractor and semi-trailer in 2019 was 63,000 pounds, leaving 17,000 pounds on average before reaching the weight limit. The average weight of a SUG is currently about 500 pounds; however, other braided cable or nylon webbing designs are about half of this weight (Vanguard 2019, Wabash 2012, Fortier 2019, Kiefer 2020, and Fontaine 2021). Similar advances with rear underride guards (Stoughton 2020), future engineering improvements of SUGs will undoubtedly bring about further innovations in reducing the weight of guards, leading to additional savings.

Regardless of loading configuration of semi-trailers, the addition of any weight to a semi-trailer has the potential to negatively affect the fuel consumption of the tractor unless the increase in fuel consumption is offset by a sufficient reduction in aerodynamic drag by the device itself. For example, approximately 40 percent of new box trailers are sold with aerodynamic side skirts (NACFE 2019). Still, the current aerodynamic skirt designs leave a portion of the semi-trailer underbody uncovered and exposed to air currents that affect fuel efficiency. SUGs cover the entire area exposed under a semi-trailer and the addition of a skirt to cover this area would improve the aerodynamics and save additional fuel likely even higher the estimates below (Table 3). Aerodynamic-device-equipped semi-trailers can also reduce drag by improving air flow around the truck and semi-trailer, which also helps reduce splash and spray generated by trucks in wet weather (NACFE 2019, 2020), which could offer additional safety benefits to the traveling public.

## Conclusion

As demonstrated, societal benefits exceed and fully offset the overall cost of SUGs to the trucking industry. Using a 5 percent increase in fuel efficiency, an SUG with an aerodynamic skirt would offset the entire cost to truck drivers or trucking companies within the first year of installation. The cumulative 15-year societal benefits of SUGs on new semi-trailers would save at least 3,560 lives and prevent 35,598 serious injuries. The estimated NPV is positive and a regulation for SUGs is considered cost effective because the public safety benefits from installing and maintaining semi-trailers with side underride guards substantially outweigh the costs.

**Note**: This report also includes an unprotected Excel spreadsheet with embedded calculations to allow USDOT reviewers to conduct further sensitivity analyses or update parameters, as necessary and warranted. Sensitivity analysis could be used to help illustrate how the results of the cost-benefit analysis would change if it employed alternative values for key data elements. For example, the estimates use multiple annual fatalities from side underride collisions and variations in the effectiveness of SUGs to conduct a straightforward sensitivity analysis to estimate the benefits under different crash reduction assumptions (USDOT 2022).

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# Appendix 1

Table 1. Estimated benefits of side underride guards for reducing annual fatalities and serious injuries.

| | 50 Percent Effectiveness | 89 Percent Effectiveness |
|---|---|---|
| **Benefit of reducing 200 Annual Fatalities** | $10,269,920,000 | $18,280,457,600 |
| **Benefit of reducing 500 Annual Fatalities** | $25,674,800,000 | $45,701,144,000 |
| **Benefit of reducing 1,000 Annual Fatalities** | $51,349,600,000 | $91,402,288,000 |
| | | |
| **Benefit of reducing 5,000 Annual Injuries** | $6,051,697,400 | $10,771,954,800 |
| | | |
| **Total Benefit Reducing 200 Fatalities and 5,000 Injuries** | $16,321,617,400 | $29,052,412,400 |
| **Total Benefit Reducing 500 Fatalities and 5,000 Injuries** | $31,726,497,400 | $56,473,098,800 |
| **Total Benefit Reducing 1,000 Fatalities and 5,000 Injuries** | $57,401,297,400 | $102,174,242,800 |

Table 2. Net Present Value of Side Underride Guards using $1,000.

| | **50 Percent Effectiveness** | **89 Percent Effectiveness** | **1% Fuel Savings With Aerodynamic Skirt** | **5% Fuel Savings With Aerodynamic Skirt** |
|---|---|---|---|---|
| **Net Present Value of Reducing 200 Fatalities and 5,000 Injuries** | $8,622,117,400 | $21,352,912,400 | $25,637,038,400 | $51,817,808,400 |
| **Net Present Value of Reducing 500 Fatalities and 5,000 Injuries** | $24,026,997,400 | $48,773,598,800 | $53,057,724,800 | $79,238,494,800 |
| **Net Present Value of Reducing 1,000 Fatalities and 5,000 Injuries** | $49,701,797,400 | $94,474,742,800 | $98,758,868,800 | $124,939,638,800 |

Table 3. Net Present Value of Side Underride Guards using $2,000.

| | 50 Percent Effectiveness | 89 Percent Effectiveness | 1% Fuel Savings With Aerodynamic Skirt | 5% Fuel Savings With Aerodynamic Skirt |
|---|---|---|---|---|
| **Net Present Value of Reducing 200 Fatalities and 5,000 Injuries** | $922,617,400 | $13,653,412,400 | $17,937,538,400 | $44,118,308,400 |
| **Net Present Value of Reducing 500 Fatalities and 5,000 Injuries** | $16,327,497,400 | $41,074,098,800 | $45,358,224,800 | $71,538,994,800 |
| **Net Present Value of Reducing 1,000 Fatalities and 5,000 Injuries** | $42,002,297,400 | $86,775,242,800 | $91,059,368,800 | $117,240,138,800 |

Table 4. Cumulative lives saved and serious injuries prevented over 15 years, using an average of 500 annual fatalities, 5,000 annual serious injuries, and an 89 percent effective rate, as SUGs are installed on semi-trailers.

| | Trailers Replaced | Remaining Unguarded | Proportion of Trailers with SUGs Replaced to Unguarded | Annual Lives Saved | Annual Injuries Prevented |
|---|---|---|---|---|---|
| **Year 1** | 513,300 | 7,186,700 | 0.066662338 | 29.66474026 | 296.6474026 |
| **Year 2** | 1,026,600 | 6,673,400 | 0.133324675 | 59.32948052 | 593.2948052 |
| **Year 3** | 1,539,900 | 6,160,100 | 0.199987013 | 88.99422078 | 889.9422078 |
| **Year 4** | 2,053,200 | 5,646,800 | 0.266649351 | 118.658961 | 1186.58961 |
| **Year 5** | 2,566,500 | 5,133,500 | 0.333311688 | 148.3237013 | 1483.237013 |
| **Year 6** | 3,079,800 | 4,620,200 | 0.399974026 | 177.9884416 | 1779.884416 |
| **Year 7** | 3,593,100 | 4,106,900 | 0.466636364 | 207.6531818 | 2076.531818 |
| **Year 8** | 4,106,400 | 3,593,600 | 0.533298701 | 237.3179221 | 2373.179221 |
| **Year 9** | 4,619,700 | 3,080,300 | 0.599961039 | 266.9826623 | 2669.826623 |
| **Year 10** | 5,133,000 | 2,567,000 | 0.666623377 | 296.6474026 | 2966.474026 |
| **Year 11** | 5,646,300 | 2,053,700 | 0.733285714 | 326.3121429 | 3263.121429 |
| **Year 12** | 6,159,600 | 1,540,400 | 0.799948052 | 355.9768831 | 3559.768831 |
| **Year 13** | 6,672,900 | 1,027,100 | 0.86661039 | 385.6416234 | 3856.416234 |
| **Year 14** | 7,186,200 | 513,800 | 0.933272727 | 415.3063636 | 4153.063636 |
| **Year 15** | 7,699,500 | 500 | 0.999935065 | 444.9711039 | 4449.711039 |
| **Totals** | | | | 3,560 | 35,598 |

Example calculations from SUG installation (see Excel spreadsheet for others):

1. Estimated benefit = (Number of lives saved using the proportion of guarded and unguarded trailers multiplied by an annual average of 500 fatalities *x* 89 percent effectiveness) *x* (Average fatality cost)

   For example, Year 1 is: ((513300/7700000) *x* (500 *x* 0.89)) *x* (12837400) = $380,595,566.00

2. Estimated benefit = (Number of lives saved using the proportion of guarded and unguarded trailers multiplied by an annual average of 500 fatalities *x* 89 percent effectiveness) *x* (Average fatality cost)

   For example, Year 2 is: (((513300*2)/7700000) *x* (500 *x* 0.89)) *x* (12837400) = $761,636,273.20

3. Estimated benefit = (Number of serious injuries prevented using the proportion of guarded and unguarded trailers multiplied by an annual average of 1000 injuries *x* 89 percent effectiveness) *x* (Average injury cost)

   For example, Year 1 is: ((513300/7700000)) *x* (5000 *x* 0.89)) *x* (302600) = $89,713,040.26

4. Estimated benefit = (Number of serious injuries prevented using the proportion of guarded and unguarded trailers multiplied by an annual average of 5000 injuries *x* 89 percent effectiveness) *x* (Average injury cost)

   For example, Year 2 is: (((513300*2)/7700000)) *x* (5000 *x* 0.89)) *x* (302600) = $179,531,008.10