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Economic Analysis of Onboard Monitoring Systems in Commercial Vehicles

Kelly Pitera, Linda Ng Boyle, and Anne V. Goodchild

Onboard monitoring systems (OBMSs) can be used in commercial vehicle operations to monitor driving behavior, with the goal of enhancing safety. Although improved safety produces an economic benefit to carriers, understanding how this benefit compares with the cost of the system is an important factor for carrier acceptance. In addition to the safety benefits provided from the use of OBMSs, operational improvements may have economic benefits. This research provides, through a benefit–cost analysis, a better understanding of the economic implications of OBMSs from the perspective of the carrier. In addition to the benefits of reduced crashes, the benefits associated with reduced mileage, reduced fuel costs, and the electronic recording of hours of service (HOS) are considered. A sensitivity analysis demonstrates that OBMSs are economically viable under a wide range of conditions. The results indicate that for some types of fleets, a reduction in crashes and an improvement in HOS recording provides a net benefit of close to $300,000 over the 5-year expected life span of the system. Furthermore, when additional benefits, such as reduced fuel consumption and reduced vehicle miles, are explored, the operation-related benefits can be upward of seven times more than the safety-related benefits. This research also shows that net positive benefits are possible in large and small fleets. The results can be used to inform policies that motivate or mandate carriers to use such systems and to inform carriers about the value of system investment.

Technological advancements have improved the safety monitoring and support for commercial drivers. Some examples include lane departure warning systems, drowsy driver detection systems, and electronic onboard recorders that record hours of service (HOS) (*1–3*). These onboard monitoring systems (OBMSs) are designed to monitor driving performance, inform commercial drivers of safety-critical situations, provide feedback, and record trip information. Previous research has shown that targeted driver feedback is effective at reducing driver-related crash risk factors and enhancing driver performance (*4, 5*). However, there are costs to the implementation of such systems, and as is to be expected, the systems' economic viability needs to be considered. As these systems become more prevalent and policies regarding their use begin to be considered, it will be important to understand the value and economic sustainability of such systems. A framework for a benefit–cost analysis (BCA) is considered in this paper to examine the safety- and non-safety-related benefits of OBMSs. The BCA considers the uncertainty that exists with these benefits and the extent to which the benefits can be quantified. The results provide the context for when the system is economically feasible.

The objective of a BCA is to determine the net economic benefit of a new program or project. BCAs are common within the transportation sector, and many are focused on programs that either incorporate technology into operations or improve safety. Although the safety of operations is important to carriers, most investment decisions are related to the additional profit that can be generated. Carriers operate within low margins; therefore, the initial and recurring costs of these systems must be compared to the safety benefits and efficiencies gained (*6*). Existing research, industry knowledge, and carrier consultation were used to develop the basis for a BCA of the use of OBMSs. The safety benefits of OBMSs are reductions in crashes and HOS violations. It was advantageous to also consider non-safety-related factors, such as a reduction in fuel consumption and improved routing, as these factors have to potential to provide significant economic benefits. Although BCAs have previously been used to study the economic impacts of other onboard safety systems (*1, 7–13*), most studies have centered on the safety benefits of these systems and considered very few (or no) non-safety-related benefits, which can have a larger impact on carrier costs.

ANALYSIS ASSUMPTIONS

A standard BCA methodology was used (*14, 15*); the methodology included the quantification of the benefits and costs attributable to OBMS implementation, the calculation of the net present value (NPV), and a sensitivity analysis to address uncertainty and generalize the BCA. A regional carrier was consulted in the study to provide information about the operational procedures and costs associated with HOS recording and crashes. Additionally, one terminal was examined in detail, and the characteristics of the fleet in this terminal formed the basis of the fleet examined in the base case. The fleet used in the base case consisted of 62 vehicles that traveled approximately 7,900,000 total miles per year. Although the base case served as a basis for comparison and discussion, the analysis was not meant to be specific to the carrier consulted and did not solely rely on data from the carrier. Data gathered from the carrier and data from other sources were identified as such in the analysis description. Although the carrier consulted in this study had multiple terminals, on the basis of conversations with the carrier and the OBMS supplier, and given the structure of the analysis, it was determined that it was reasonable to study each terminal as

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an individual entity because there were limited economies of scale associated with OBMS use.

NPV is a commonly used BCA metric because it is straightforward and provides consistent results. The benefits and costs over the life of a project are calculated in terms of the present value. The following standard NPV formula was used for the BCA:

$$\text{NPV} = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

where

B_t = total benefits that arise in year t ($t = 0, 1, 2, \ldots, T$),
C_t = total costs that arise in year t ($t = 0, 1, 2, \ldots, T$),
T = life span of the project, and
r = discount rate.

The benefit value (B_t) is the sum of all the individual benefits (from the reduction of crashes and HOS violations, as well as the non-safety-related benefits, as defined later). When the NPV of a project or program is greater than zero, the project is considered economically beneficial.

Benefits Associated with Reduced Crashes

The monetary benefit of crash reduction that resulted from monitored driving behavior was determined from the number of crashes that occurred before OBMS use, the estimated crash reduction rate attributable to system use, and the cost of such crashes.

Number of Crashes

Data from the U.S. Department of Transportation's NHTSA, compiled from both the Fatality Analysis Reporting and General Estimates Systems, provide statistics on crash trends and involvement rates for specific classes of vehicles, including large trucks, in relation to vehicle miles traveled (VMT) (*16*). From an examination of 10 years of data (2000 to 2009), it was determined that large trucks (single-unit trucks and truck tractors) were involved in crashes at the following rates: 138.8 property damage only (PDO) crashes per 100 million VMT, 35.4 injury crashes per 100 million VMT, and 1.96 fatality crashes per 100 million VMT. Some carriers were inherently safer than others; therefore, varying crash rates were considered within the sensitivity analysis.

Crash Reduction Rate

A proxy measure was used to estimate the number of crashes avoided through the use of onboard safety systems. To determine a crash reduction rate attributable to OBMS implementation for use in the BCA, numerous existing studies were examined. All of the existing studies indicated that OBMSs reduce crashes, but to varying degrees.

In existing research, a series of field operational tests and simulations on lane departure warning systems, forward collision warning systems, and roll stability control systems for commercial vehicles considered two measures: the exposure of a vehicle to driving conflicts that could lead to crashes and the prevention of crashes when a vehicle was in a driving conflict (*1, 7, 8*). The results from these studies were incorporated into three follow-on studies that each conducted BCAs (*9–11*). All three BCAs incorporated system efficacy findings from the previously described research, as well as information gathered from motor carriers that provided estimates for crashes prevented within those carriers' own fleets. Hickman and Hanowski used commercial vehicle drivers, employed by two carriers, and trucks equipped with OBMSs to evaluate the efficacy of such systems (*17*). Safety-related and severe safety-related events were identified within the experiment to determine whether onboard safety monitoring systems would reduce such events. Wouters and Bos examined several fleets of vehicles to better understand the impact on safety of the monitoring of driver behavior and feedback (*18*). Reductions in crash rates were determined through a comparison of the actual crash rates before and after the intervention and between experimental fleets and a comparable control fleet. Table 1 summarizes the results of these studies.

A crash reduction rate of 21%, which corresponds to the first quartile of these reduction rates, was used within the base analysis. The total number of crashes reduced by system use was calculated by multiplying the crash reduction rate by the number of crashes per year (without system use).

TABLE 1 Crash Reduction Rates from the Literature

Literature	Crash Reduction Rate (%)	Description
Orban et al. (*1*)	17–23	Lane departure warning system
Battelle (*7*)	21–28	Forward collision warning system
Battelle (*8*)	20–33	Roll stability control system
Houser et al. (*9*)	23–53	Lane departure warning system
Murray, Shackelford, and Houser (*10*)	21–44	Forward collision warning system
Murray, Shackelford, and Houser (*11*)	37–53	Roll stability control system
Hickman and Hanowski (*17*)	37–52	Onboard safety system that considered hard cornering, braking or acceleration, collision, and rough or uneven surface
Wooters and Bos (*18*)	20–31	Onboard data recording system (type of data recorded and feedback received varied among the fleets in the study)

Crash Costs

The carrier consulted within this study provided crash cost data for the period from September 2009 to November 2011. Cost data were provided from carrier records for individual crashes and represented the true cost of each crash for this carrier. These cost values included only direct costs, such as liability, cargo, and collision repair costs. The cost of PDO crashes varied between $0 (for not at fault crashes) and $8,500 per crash, and injury crashes varied between $50,000 and $81,000 per crash. No costs were provided for fatality crashes as none occurred within the analysis time frame. The studies sponsored by FMCSA identified higher crash cost ranges because the studies included many indirect costs, including replacement labor, worker's compensation, environmental cleanup, and labor costs, that were not reported in the carrier-provided costs (*9–11*). To account for these differences (between direct and indirect cost estimates), mid-range crash costs were used in the base case analysis: $5,000 per crash for PDO crashes, $50,000 per crash for injury crashes, and $500,000 per crash for fatality crashes (*1, 7, 8*).

Benefits Associated with Electronic HOS Recording

The OBMS examined within this study was also able to record HOS through electronic onboard recorders. This feature was not included as part of the other electronic safety systems discussed but has several economic benefits (*1, 7–12*). First, there is a benefit associated with the cost reductions attributed to the electronic recording of HOS information as compared to paper recording (*19*). Second, there are both internal (time and extra training) and external (fines and out-of-service penalty) cost reductions associated with reductions in HOS violations. Third, there are potential benefits associated with fewer fatigue-related crashes with greater adherence to HOS regulations. This last benefit is difficult to quantify because it is not always clear that a crash is fatigue-related and that the fatigue is a result of HOS noncompliance. Although police crash reports may indicate whether a crash was fatigue-related, these reports rarely provide information about HOS violation, and it is difficult to attribute crashes directly to HOS violations or to determine a crash reduction benefit specific to the use of an electronic system. Given the challenges associated with the estimation of this type of crash reduction, this benefit was not quantified.

Another concern with the use of electronic onboard recorders is whether these systems negatively impact productivity. Information gathered from case studies indicates that carriers report decreased productivity but note that operational managers receive improved data on driver hours and compliance, which improves planning and dispatching (*20*). In fact, other carriers also noted the benefits of electronic onboard recorders beyond HOS recording, commenting that the recorders give the carrier more knowledge of operations, improve the efficiency of management, help in making better use of available driver hours, and quickly highlight compliance problems. Within this analysis, the changes in productivity, as a result of stricter adherence to HOS regulations, were not captured.

Benefits from Recording Process

The benefits gained from switching from a paper-based HOS recording process to an electronic process come from the reduced costs associated with employee time and materials. The use of an electronic system to record HOS reduces the time required by administrative personnel and drivers to record and store HOS information. Previous research has indicated that the time required by administrative personnel for HOS-related tasks can be reduced by 1 min per day per driver or 20 min per month per driver (*13, 21*). The assumption is that drivers are paid by the mile or by the trip and that the burden of time spent recording HOS falls on the driver. Therefore, the carrier does not necessarily observe a benefit from the time reduced for the driver in this process. In addition to the recording time saved, there is also a cost saving based on the number of paper log books that no longer need to be purchased.

Reduction in HOS Violations

The reduction in violations is difficult to quantify because it is not possible to establish the true compliance rate before system use. Carriers and drivers are not likely to voluntarily disclose noncompliance. Although FMCSA identifies some violations during inspections and reviews, many others go undetected. Therefore, FMCSA-detected violations from roadside inspections and carrier reviews were used and provided a conservative estimate of the number of drivers who operate out of service; this assumption was consistent with a previous FMCSA study (*21*). Between 2008 and 2010, FMCSA identified (through roadside inspections and carrier reviews) an average of 518,513 acute HOS violations and 168,170 critical HOS violations per year (*22*). Given an average annual commercial VMT of 295,090 million between 2008 and 2010 (*23*), the average violation rates are 1.76 acute violations per million VMT and 0.57 critical violations per million VMT. In FMCSA's *Regulatory Impact Analysis of Electronic On-Board Recorders,* it was assumed, with experiential knowledge, that a 50% reduction in HOS violations was reasonable (*24*). Industry studies have also verified this assumption to be sound (*25*). Varying reduction rates were considered within the sensitivity analysis to address the uncertainty in these estimates.

Violation Costs

The cost savings associated with reduced violations are observed from the reductions in the time spent addressing violations (both administrative and driver time), the time spent out of service, and fines. Undetected violations do not directly result in costs for the carrier; therefore, the carrier benefits were based on the reduction of known violations. It was assumed that the administrative time required to address HOS violations was 30 min per acute violation and 2 h per critical violation; these assumptions were based on communication with the carrier. Carrier-required remedial driver training, whenever a critical violation occurred, was considered to have a cost of $27 per violation and was included in the base case. It is more difficult to quantify the penalty costs associated with HOS violations because fines and out-of-service penalties vary greatly depending on the severity of the violation and the past violation record. The HOS regulations state that carriers may be fined between $1,000 and $11,000 for violations (*26*). Because of the wide range of violations and the difficulties in determining the costs (direct and indirect) associated with drivers being out of service, these penalties were combined into one value of $6,000 per critical violation for the base case.

Costs

The OBMS provider consulted within this study supplied cost data that were fairly consistent with other studies (*9–12*). The costs associated with OBMS implementation included equipment ($3,500 per vehicle), installation ($100 per vehicle), and training ($1,500 per terminal). Previous studies used costs that ranged from $1,000 to $2,500 for equipment, installation, and maintenance combined. However, these previous studies were single-function systems; the OBMS considered here had multiple features that encompassed several of the other systems' components. The cost of maintenance ($175 per vehicle per year) and training per driver ($36) and per manager ($264) were also considered; previous studies did not include these costs at the terminal or manager level.

ANALYSIS

The analysis period and expected life of the system (T) was 5 years, as suggested by the system provider and validated by previous BCAs (*9–12*). Present value benefits and costs were computed with a discount rate (r) of 3% and depicted in 2011 dollars. The U.S. Office of Management and Budget requires a more conservative discount rate of 7% (*27*), but a 3% discount rate is recommended by economists in the public and private sectors and represents the social discount rate, or rate of return, at which society is indifferent between a benefit now and a greater benefit in a future year (*28*). This rate is an estimate of the after-tax rate of return to private capital. The costs and benefits that resulted from reductions in cost were also adjusted for inflation at the rate of 3% per year.

RESULTS

The BCA was performed to provide insight into how factors such as fleet characteristics, carrier operations, and the use of the system impact the economic viability of OBMSs. The analysis indicated that OBMSs can, as a result of a reduced number of commercial vehicle crashes, produce economic benefits that average approximately $65,000 per year, with initial system and training costs of approximately $228,000 (one time over the life of the system) and average maintenance costs of close to $8,500 per year. When only the benefit attributable to a reduction in HOS recording costs and violations is considered, the costs would remain the same, with an average yearly benefit of just over $45,000. When the benefits are compared with the costs, the NPVs for reduced crash benefits only, reduced HOS benefits only, and both crash and HOS benefits are $54,853, –$43,088, and $281,625, respectively (Table 2).

SENSITIVITY ANALYSIS

A sensitivity analysis was conducted to observe the elasticity of each factor considered in the BCA. To capture the effects of fleet characteristics and uncertainty in the system effectiveness, the sensitivity analysis examined the impact of changes to the input components of the BCA analysis. This examination allowed insight into how variables and changes to variables were related to the analysis output and which variables had the largest impact on the economic viability of OBMSs. Numerous scenarios were considered within the sensitivity analysis; the most pertinent results are highlighted below.

TABLE 2 NPV: Crash and HOS Benefits

BCA Computation Consideration (2011 $)	NPV ($)
Crash benefits only Benefit from crash reduction (over 5 years), 324,713 One-time equipment and training cost, 227,724 Maintenance cost (over 5 years), 42,136	54,853
HOS only Benefit from HOS improvements, 226,772 One-time equipment and training cost, 227,724 Maintenance cost (over 5 years), 42,136	–43,088
Crash and HOS Benefit from crash reduction (over 5 years), 324,713 Benefit from HOS improvements, 226,772 One-time equipment and training cost, 227,724 Maintenance cost (over 5 years), 42,136	281,625

Varying Rates of Crash and HOS Violation Reduction

Any variations in the reduction rates for crashes and the HOS violations that result in an NPV greater than zero were considered economically feasible. Figure 1 shows the combinations of crash and HOS violation reduction rates that resulted in conditions in which OBMSs were economically beneficial (NPV > 0).

With an HOS violation reduction rate of zero, a crash reduction rate of 16% would be required to make OBMS use economically feasible. Conversely, with a crash reduction rate of zero, an HOS violation reduction rate of 61% would be required to make OBMS use economically feasible. As previously mentioned, existing research has indicated crash reduction rates between 17% and 53%; therefore, even with greater uncertainty regarding HOS violation reduction rates, there is a high likelihood that fleets will have crash and violation reduction rates within the economically feasible zone, as shown in Figure 1.

Fleet Variations

The base case BCA included a fleet of 62 vehicles and an average (fleet) VMT of 7,900,000 per year. Fleet sizes can vary from fewer than 10 vehicles to several thousand vehicles. The analysis indicated that even single-truck fleets (owner operated) could have an economic benefit from the use of OBMSs, given the reduction rates provided by the base case (62 vehicles). When all other factors (e.g., VMT, HOS rates, crash reduction rates) remain fixed, the NPV for a fleet of one is $2,821, which is a smaller total benefit than the per-vehicle NPV of $4,542 for a fleet of 62 (i.e., $4,542 × 62 = $281,625, as shown in Table 2).

As fleet size increases, the per-fleet cost of training does not change, and the per-vehicle share of this cost decreases. In other words, OBMSs have greater economic benefits as the fleet size increases, although this shared cost is quite small and has minimal impact when compared to mid or large fleet sizes. This finding is illustrated in Figure 2, in which variations in fleet size are considered on a per-vehicle basis. Larger fleets see a greater per-vehicle benefit than smaller fleets, but as fleet size increases, there is less incremental increase in per-vehicle NPV.

The average VMT also varies greatly among fleets with greater vehicle exposure and increases the likelihood of crashes and HOS

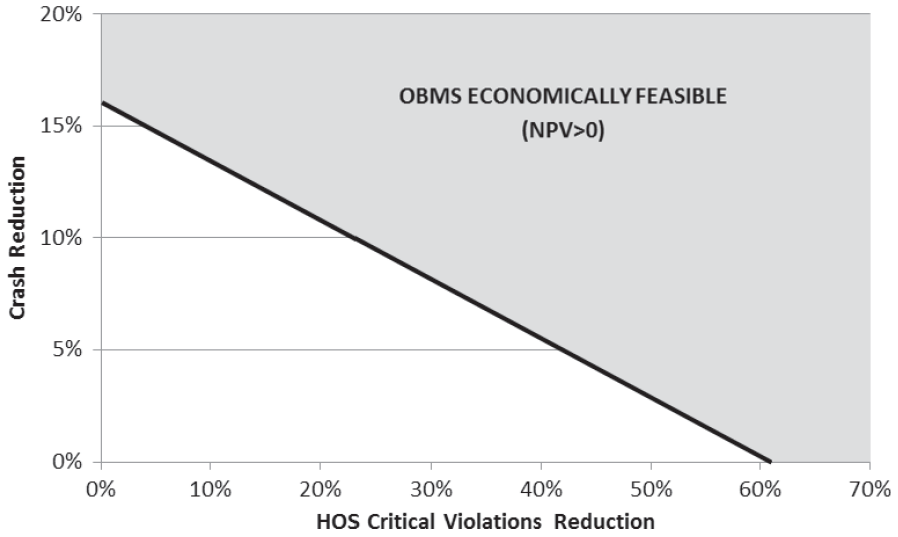

FIGURE 1 Combinations of reduction rates for crashes and HOS violations.

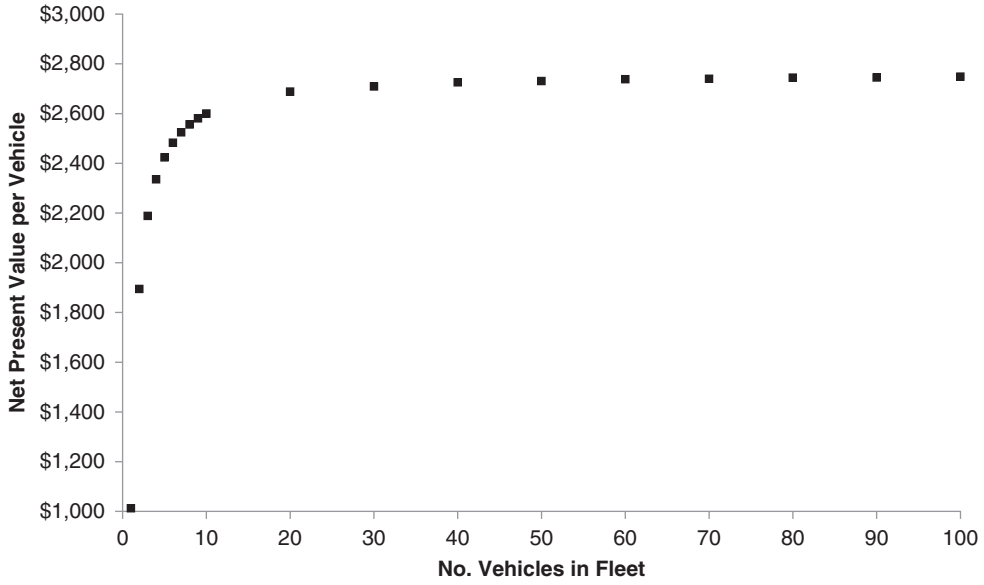

FIGURE 2 Impact of fleet size on NPV (100,000 VMT/vehicle/year; no. = number).

violations. Therefore, consistent with existing studies, VMT values of 60,000 through 180,000 were used in the sensitivity analysis (*9–12*). In terms of benefits, OBMS use is economically beneficial for all fleet size and VMT combinations of more than 84,604 vehicle miles per fleet per year. Table 3 summarizes the results of the fleet variation sensitivity analysis.

TABLE 3 Sensitivity Analysis on Fleet Variation

Parameter	Variation	NPV ($)
Fleet size[a] (vehicles)	62	281,625
	1	2,821
	100	455,625
VMT[b]	127,500	281,625
	60,000	6,771
	180,000	495,986

[a]Using a constant VMT = 127,500 miles per vehicle per year.
[b]Using a constant fleet size of 62 vehicles.

Crash Reduction Rate

The crash reduction rate used in the base analysis (21%) was determined through an examination of the existing literature that also

quantified the impact of onboard safety systems (*1, 7–11, 17, 18*). The highest crash reduction rate observed in the literature was 53% (*8, 11*). At a crash reduction rate of 53%, and with only crash benefits accounted for, the analysis showed that the NPV was $549,654. The smallest feasible crash reduction rate was computed with an NPV of zero. When only crash benefits were considered, a reduction rate of 16% was required to be economically feasible. When crash and base HOS benefits were considered, a 3% reduction rate was necessary.

HOS Violation Reduction

The base case considered violation reductions of 50%, on the basis of previous study estimations, but as noted earlier, this violation reduction rate did not result in a large enough benefit to outweigh the cost of the system when only HOS benefits were considered. Further analysis indicated that when all other factors were kept constant, a 61% HOS violation reduction rate was required for the NPV to be nonnegative. More important, the sensitivity analysis also highlighted that the economic impact of acute violations was generally negligible (around $10 per violation) when compared with critical violations (around $6,100 per violation).

Non-Safety-Related Benefits

In addition to the safety-related benefits, components of the system may allow for operational improvements that result in economic benefits for carriers. OBMSs can reduce fuel consumption as a result of safer driving behavior and a reduction in mileage from the use of a Global Positioning System (GPS) or a fleet monitoring system to improve the efficiency of operations. Although the reduction in fuel consumption that results from changes in driving behavior is likely to occur if the OBMS improves safety, other non-safety-related benefits will only be realized if the carrier has not previously encouraged fuel-efficient driving or the use of a GPS or a fleet management system and is proactive in capitalizing on additional information provided by the OBMS.

Changes in Fuel Economy

OBMSs have the potential to reduce fuel consumption by encouraging more fuel-efficient driving (*20, 29, 30*). Although limited literature focuses directly on the economic impacts of safer driving attributable to OBMS usage, the literature on ecodriving was examined to consider its relevance. Ecodriving initiatives, which focus on improving fuel economy and reducing fuel consumption to reduce emissions, suggest that behavioral improvements, such as maintaining a steady speed, accelerating and decelerating smoothly, and anticipating traffic flow, also contribute to (or result from) safer driving (*31*). Therefore, although the mechanism and motivation behind the behavioral change differs between OBMS usage and ecodriving, similar fuel economy improvements can be expected. Several studies have considered heavy-vehicle drivers and measured changes in fuel economy before and after training (*29, 32, 33*). Within these studies, fuel reductions of up to 30% as a result of changes in driving behavior have been seen, with many results between 5% and 15%.

Improved Routing and Operational Efficiency

Many OBMSs also have fleet management systems and GPS capabilities, which provide information on truck status and location. These GPS capabilities provide information that, when used to its full advantage, allows for increased efficiencies, such as the reduction of empty trips, reduced wait times during loading and unloading, optimized routings, and the avoidance of congestion. The operational benefits associated with OBMS use are only realized in fleets that do not currently use another system for fleet management and GPS routing; these fleets are not likely to receive any additional operational benefits from OBMS use. Existing studies measure efficiency improvements in different ways, including capacity utilization, load factors, and productivity (measured in deliveries per hour) (*34–36*). Improvements to efficiency are dependent on carrier operations and the network; a range of mileage reductions between 5% and 25% was considered within the sensitivity analysis.

Combining Fuel and Efficiency

When reductions in fuel use and mileage are considered, it is evident that these two benefits can have a significant impact. When the economic implications of the individual components of non-safety-related benefits are compared, the NPVs are several orders of magnitude larger than those seen with the safety-related benefits. The economic benefit of a given percentage reduction in fuel use is roughly equal to the economic benefit of that same percentage reduction in miles traveled. When only the contribution of non-safety-related benefits is considered, a 1% reduction in either fuel or mileage is necessary to make the systems economically beneficial. This level of reduction seems reasonably achievable within the constraints of the existing research.

Table 4 summarizes the results of the sensitivity analysis in terms of the benefits of OBMSs. In the table, the benefits are considered independently of one another. The relationship between the crash reduction rate and the HOS violation rate was examined previously in Figure 1, and as mentioned above, the non-safety benefits were so large that their consideration would only improve the economic feasibility of system use.

TABLE 4 Sensitivity Analysis of Safety and Nonsafety Benefits

Parameter	Variation (reduction percentage)	NPV ($)
Crash rate reduction	21[a]	54,853
	16	0
	53	549,654
HOS violation rates	50[a]	–43,088
	61	0
Fuel reduction[b]	1	0
	5	994,007
	15	3,521,740
Mileage reduction[b]	1	0
	5	994,007
	25	6,049,473

[a]Base case.
[b]Not considered in base case.

DISCUSSION OF RESULTS

The BCA showed that OBMSs could be economically viable under a wide range of circumstances. Given the fleet characteristics of the base case, it was determined that crash reduction rates as low as 16%—equivalent to the lowest crash reduction found in existing studies (*1*)—could provide an economic benefit to the carrier. This crash reduction rate was determined for a specific fleet; it did not take into account any other benefits, such as those from electronic HOS recording or non-safety-related benefits. With the inclusion of these additional benefits, crash rates could decrease dramatically yet still provide economic benefits to a carrier. Benefits related to HOS recording are in the order of 70% of the magnitude of the benefits from crash reduction. When both crash and HOS benefits are considered, at a crash reduction rate of 21% (from the base case), additional HOS benefits are not required to make system use economically feasible. When HOS violation reduction rates of 50% (from the base case) are considered, only a 3% crash reduction rate is necessary to make system use economically beneficial.

The base analysis used a fleet of 62 vehicles, each with an average VMT of 127,500 mi per year. To observe the elasticity of the NPV, the variation in fleet size and VMT were considered. Although the economic benefit associated with OBMS use increased as fleet VMT (a function of fleet size and individual VMT) increased, smaller carriers could still gain economic benefits, in part as a result of limited fleet shared costs. In fact, the only component of the BCA in which a fleet of one vehicle did not receive an economic benefit was when HOS recording was the only factor being considered, but this outcome was also noted in the BCA regardless of fleet size. Smaller carriers may also benefit the most from non-safety-related benefits because those carriers are less likely to already be monitoring fuel or using fleet management software (*13, 35*). Additionally, if small carriers are more likely to have higher initial crash and HOS violation rates (*37, 38*), these carriers could actually benefit more from OBMSs on a per-vehicle basis than could larger fleets.

Much of the existing research on the economic impacts of OBMSs only considered the impact of the safety-related benefits of reduced crashes or reduced HOS violations; rarely had these factors been considered together. This analysis moves beyond previous research efforts to also consider non-safety-related benefits, such as reductions in fuel and mileage. Although these benefits are fleet specific and subject to the existing operations of the carrier, these benefits are several orders of magnitude greater than safety-related benefits and should not be overlooked.

Although it has been noted the OBMSs have the potential to benefit carriers in a wide range of circumstances, there are conditions in which system use may not be economically viable. The economic benefit is directly related to the number of crashes and HOS violations observed within a fleet before OBMS use; therefore, a carrier with a consistently high safety rating has the potential to not receive any benefit from system use if only safety-related benefits are considered. Additionally, while the 5-year system life may indicate a short-term investment for larger carriers, many smaller carriers enter and exit the market in smaller time increments. The initial investment required for OBMSs makes these systems impractical for fleets that will not remain in business for the duration of the life of the system. Additionally, issues beyond economic feasibility, such as driver acceptance, also factor into the successful implementation of OBMSs. Although OBMSs can benefit drivers by improving their personal safety and reducing the time required to record HOS, drivers are concerned about privacy and misuse of data (*39, 40*). Although this issue was not explored within this research, it is important for policy makers and carriers to consider when introducing OBMSs into fleets.

OBMSs are used to improve safety by promoting improved driving behavior. Although there is a cost associated with such systems, this research has shown that the economic benefit from their use outweighs the costs in many operational circumstances. Beyond the traditional benefits associated with improved safety, many carriers also have the ability to capitalize on other components of the system to improve operational efficiency and further increase the benefits of system use.

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