Quantifying the Benefits of Mindful Driving Training in Safety and Sustainability

Rebecca Dollahite[1], Michael Duffy[2], and B. Brian Park[1,3], *Senior Member, IEEE*
[1]Department of Systems & Information Engineering, University of Virginia
[2]Facilities Management, University of Virginia
[3]Department of Civil & Environmental Engineering, University of Virginia
{red5zk, med7p, bp6v}@virginia.edu

Abstract — **While automobiles are essential for enabling the daily lives of many Americans and businesses, they have caused significant public health concerns, including over 31,785 fatalities in 2022 from traffic crashes and generating 27% of the United States' greenhouse gas emissions in 2020. It has been shown that mindful driving training reduces aggressive driving behaviors, which is expected to reduce crashes, fuel consumption, and greenhouse gas emissions.**

In this research, we work with the University of Virginia (UVA)'s Facilities Management (FM) group which monitors over 280 vehicles through GPS tracking software. The FM group started mindful driving training in March 2021 and has since completed training for nearly half of drivers. We started collecting and analyzing these vehicles' performance data, including harsh braking, hard acceleration, speed violation, seatbelt violation, fuel consumption, and idling time. We quantified the impacts of mindful driving using before and after analysis. The safety impact was assessed using delta changes in harsh braking, speed violation, seatbelt violation, and number of relative crashes and the sustainability impact was based on the changes in hard acceleration, fuel economy, and idling time. Our analyses showed that mindful driving training greatly improves sustainability with reduced fuel consumption and safety with reduced occurrences of safety-related violations.

Keywords – Mindful Driving, Sustainability, Safety, Fleet Management

I. INTRODUCTION

The University of Virginia's (UVA) Facilities Management (FM) houses more than 280 vehicles and supports 18 million square feet of the UVA Academic and Health Systems. FM is essential for ensuring daily life at the University runs smoothly [1]. The transportation industry accounts for the largest contribution to greenhouse gas emissions in the United States [2]. As climate change has begun to create detrimental, lasting effects, there is an increased urgency for transportation to become a more conscious and sustainable industry.

FM aims to reduce costs and improve vehicular safety while maintaining a commitment to the environment. FM management monitors infractions, rules, regulations, and provides training. Their commitment to environmental excellence has led to the development of an eco-driving-based curriculum. Eco-driving "attempts to change drivers' behavior through advice such as driving more smoothly by anticipating changes in traffic" [3]. It is a low-cost driving technique that can be implemented immediately [3]. Two previous research teams, working alongside FM at UVA, explored the effect of an Eco-driving-based training program. The previous teams found that regularly administered training significantly improved most behavioral metrics measured and reactive training significantly reduced speeding occurrences.

It is expected that Eco-driving and FM's training program improve drivers' mindsets concerning safety and sustainability, reiterating its importance to the greater fleet and to the University. In addition, it is also expected that a correlation between sustainability metrics and fuel economy will ultimately act as a future source of cost-reduction for FM. Thus, our objective in this research is to quantify the safety and mobility benefits from the FM's mindful driving training. By doing so, we expect that FM's training become a foundational program, one which will become incorporated into orientation for all new employees and act as a refresher to existing staff going forward.

The remainder of this paper is organized as follows. Section II discusses the background of this research, including previous works. Section III delves into the methodology in quantifying training benefits, including vehicle and division selection as well as data collection. Section IV analyzes the results of training, both in safety and sustainability metrics, followed by the conclusions and future works in Section V.

II. BACKGROUND

FM is responsible for adhering to UVA's 2020-30 Sustainability Plan. Some of the most ambitious and relevant goals include a commitment to achieving carbon neutrality by 2030 and being completely fossil fuel free by 2050. FM has long term plans to phase out gasoline vehicles and invest in electric vehicles, with 28 electric and hybrid vehicles already a part of its fleet [1]. FM has also introduced eco-driving as a short term, easily implemented solution. Eco-driving is a proven cost-effective strategy that leads to both improved driver safety and a reduction in emissions, however there is little research examining the long-term benefits of Eco-driving. [3].

A. Previous Works

FM has previously invested resources into eco-driving, as over the past two years, teams at UVA have conducted similar research with the FM Fleet, concerned with developing effective, informational training material and analyzing the effects of reinforcement training.

The research team two years prior, who developed training material, intended to create "an interactive data-driven training program" to provide information concerning "the fleet's holistic driver performance historically," which is referenced as FM training [4]. The team measured similar metrics as used in this paper such as harsh acceleration, harsh braking, speed violation, seatbelt violation, and idling. The team did not analyze fuel economy (mpg), which we included due to its association with greenhouse gas emissions. FM training intended to reduce incident counts of non-compliance behaviors and fuel consumption-related metrics; however, the team only had a short time frame to conduct analysis, specifically between a month prior and following the training date. FM training led to a significant decrease in harsh acceleration, hard braking, speeding violations, seat belt violations, and idling as compared to the control group, adequately "addressing both behavioral and compliance elements within [the] training group" [4]. There is currently a lack of analysis on the long-term effects of FM training.

In 2022, the team assessed the success of reinforcement training, additional scorecards, and manager conversations. Training was administered both proactively and in reaction to an increase in driver violations, testing if either proved to be effective. Training was administered on a shop level basis, using the same six identified metrics as the 2021 team. The team only found a statistically significant decrease in speeding violations due to reactive training, however found no other statistical significance in metrics for both reactive and proactive training [5].

III. METHODOLOGY

Certain factors had to be taken into consideration when conducting the analysis. With over 280 vehicles as a part of FM, vehicles and drivers had to meet a minimum criterion in regards to quantifying FM training benefits. Not all vehicles were eligible for analysis.

A. Division Selection

FM groups all its vehicles into six divisions: Capital Construction and Renovation (CC&R), Utilities, Operations, UVA Health Operations, OP SVP Operations, and Management Services. Each division is made up of individual shops that house vehicles and drivers. We chose to analyze a single division which trained all drivers to hold certain variables relatively constant such as management, vehicular task, and idling requirements/habits. It is noted that Don Sundgren, the Associate Vice President, and Chief Facilities Officer in 2020, committed to support the research of two previous Capstone Projects at UVA conducted with FM. The outcome of a successful initial project resulted in a request for an entire division(s) to undergo FM training to provide further data. Mark Stanis, the Director of FM's CC&R division, volunteered his group to be completely trained. CC&R was the first division in FM to be entirely trained as part of ongoing research.

Vehicle training began as early as March 2021, as conducted by the previous research team in 2021, and has been ongoing for additional divisions and vehicles as recently as January 2023.

B. Vehicle Selection

Within FM, vehicles serve vastly different purposes and have a variety of vehicular habits. Vehicles drive and work on both urban and highway roads and carry variable load sizes, with no distinction of this made within the dataset; each drives a variable difference, both between months and in comparison to other vehicles. FM's large fleet works primarily in a small, central area, with 82% of vehicles driving less than 4,000 miles per year and 11 vehicles driving more than 9,000 miles per year. Each vehicle serves a different purpose, and variable factors result in massive fuel economy disparities.

In analyzing the sustainability assessment of FM's training, vehicles, even within the same division, could not be averaged and accurately represent the effects of a training program due to the large disparities in vehicular habits. Certain vehicles within CC&R were selected for the sustainability analysis and were then analyzed as a representative sample of CC&R vehicles who had undergone FM training. This is also further expanded to act as an estimate for all FM vehicles, regardless of division. Selected vehicles must be within the CC&R division, must have accessible data, and must not be administrative vehicles used by management. Of these contenders, we selected V0*28, V0*33, V0*33, V0*62, V0*61, and V0*22 based on their relative consistency between variables (Table I. Selected Vehicles and Descriptions).

TABLE I. SELECTED VEHICLES AND DESCRIPTIONS

Vehicle Name	***Description***
V0*28	Class 1 Cargo Van, 2-wheel drive
V0*33	Class 1 Cargo Van, 2-wheel drive
V0*33	F-250 truck, 2-wheel drive, works in cabinet (carpentry) shop
V0*62	F-150 truck, 4-wheel drive
V0*61	E-250 Cargo van, 2-wheel drive
V0*22	F-250 truck, 2-wheel drive, works in masonry shop

All trained CC&R vehicles were used in regard to safety analysis. This is because safety, on the other hand, depends on the driver themselves and is necessary during all tasks.

C. Data Collection

Our research intended to analyze the long-term safety and environmental effects of mindful driving training previously implemented by a group of researchers working alongside FM at UVA [4,5].

Comprehensive data was collected from three different datasets provided by Geotab, an AI-driven platform used by FM to offer insights into fleet driving behaviors. The three datasets cumulatively formed a monthly vehicle scorecard, with safety statistics such as harsh braking score, speeding score, percentage of time seat belt is worn, and environmental measures, including harsh acceleration score, percentage of total engine time spent idling, and fuel consumption (miles per gallon). These metrics, along with a binary variable determined by FM to indicate if a vehicle requires idling, were the basis of our data analysis.

Within our analysis, the scorecard was derived from monthly data. Counts and total times utilized in score calculations were derived from a total month.

Geotab calculates scores for vehicles such as hard acceleration score, harsh braking score, and speeding score based on the number of occurrences in each respective category as represented with the following formula:

$$Score_{iv} = max(100 - \frac{1000*occurrences_{iv}}{total\ miles\ driven_v}, 0) \qquad [1]$$

where the variable i represents a specific score (acceleration, braking, and speeding) and v represents a vehicle.

A hard acceleration occurrence is counted when an acceleration exceeds a threshold value of 0.38 G. Similarly, a harsh braking occurrence is counted when a deceleration exceeds -0.56 G. Speeding comprises an instance in which the driver exceeds 5 mph above the speed limit. Utilizing a score-based metric as opposed to an occurrence-based metric allows the data to become normalized by total miles driven, since each vehicle does not necessarily drive the same distance between months and when compared to vehicles.

The percentage of time a seat belt compares the driver(s)' proportional time wearing a seat belt to the amount of time the vehicle is driven. The percentage of time a vehicle is idling works similarly and compares the proportional time a vehicle is spent not changing location with its engine running to the amount of time a vehicle's engine is on. Fuel economy is measured in miles per gallon and divides the total number of miles driven by the gallons of gasoline consumed.

IV. RESULTS

To assess the sustainability impacts due to training, we analyzed the six selected vehicles as a representative of the entire CC&R division. We hypothesized that FM training would decrease unnecessary idling time and increase a vehicle's acceleration score, a metric which correlates a higher score to less hard acceleration violations, which would correlate to an improved fuel efficiency and equate to less greenhouse gas emissions.

A. Sustainability Assessment

Since each vehicle has a different make, model, and vehicular task, we assessed each correlation by vehicle. All selected vehicles had a negative Pearson's Correlation Coefficient between idling duration and fuel economy, with vehicles V0*28 and V0*62 having the strongest correlation of the six. This aligns with our hypothesis, as the percentage of time spent idling is linearly related to a vehicle's fuel economy (Fig. 1. Correlation of Fuel Economy and Idling Duration by Vehicle). As a vehicle idles for less proportional time, its fuel economy tends to improve.

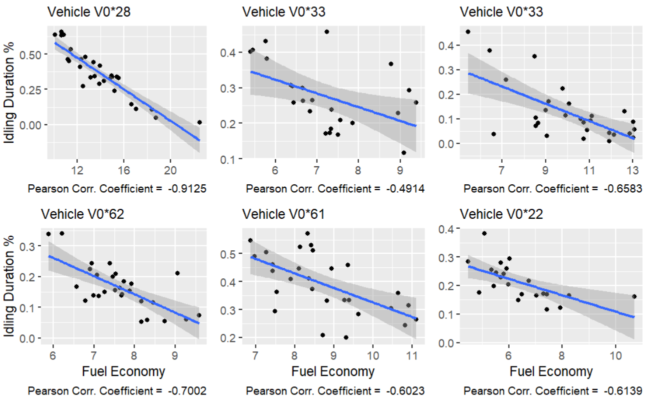

Fig. 1. Correlation of Fuel Economy and Idling Duration by Vehicle

Vehicles drive relatively few miles per month, meaning there tend to be minimal hard acceleration violations per mile driven. For the CC&R division, consisting of months before and after training, there is an average of 3.5 hard acceleration violations per month compared to an average total miles driven of 155.8 miles per month. This equates to roughly 1 violation for every 44 miles driven. As a result of this small quantity, the correlation between hard acceleration score and fuel economy is not as apparent as that between idling duration and fuel economy. This excludes vehicles V0*33 and V0*62, both of which show some sort of correlation between variables (Fig. 2. Correlation of Fuel Economy and Hard Acceleration Score by Vehicle).

Improving fuel economy is not only important to reach sustainability goals, but also has the potential to reduce FM's fuel costs. Fuel is an immense expense for FM as many of their vehicles are gasoline powered, costing about $240,000 per year, a number which is projected to increase substantially with the ongoing years.

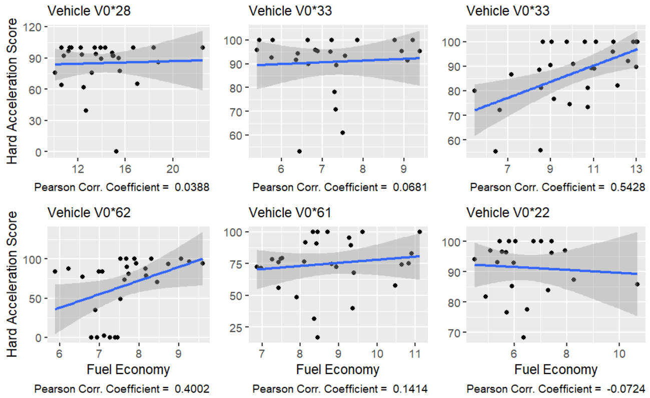

Fig. 2. Correlation of Fuel Economy and Hard Acceleration Score by Vehicle

In calculating the potential money FM can save, we determined the delta difference of variables by subtracting an average monthly fuel economy after training to the same metric before training. It is assumed that the fuel economy before and after training is based on the average values of the six previously identified vehicles (Table II. Delta Difference Between Average Scores Before and After Training) and these numbers can be representative of all vehicles within CC&R and FM as well. It is assumed that, when using 165.5 miles on average are driven per month, data is pulled only from months following the training month to account for abnormalities from COVID-19 and almost an entirely virtual campus. Since this pandemic drastically changed the UVA campus in 2020 and early 2021, these months were excluded when calculating the average miles driven per month. We assumed a fuel price per gallon of $2.75 based on previous conversations with FM.

TABLE II. DELTA DIFFERENCE BETWEEN AVERAGE SCORES BEFORE AND AFTER TRAINING

Vehicle Name	***Difference in Fuel Economy (mpg)***	***Difference in % Idling Duration***	***Difference in Acceleration Score***
V0*61	0.26	-3.76	-1.70
V0*33	2.41	-0.88	10.73
V0*62	0.75	-2.56	34.59
V0*22	1.35	0.66	1.27
V0*28	0.77	-4.06	-8.32
V0*33	0.81	3.45	3.37
Averages	**1.06**	**-1.19**	**6.65**

These assumptions allowed us to quantify FM's monetary savings based on the fuel economy increase. With an average increase of 1.06 mpg (Table II) due to training, FM can expect to save $70 per vehicle over the course of a year and over $19,000 per year in fuel if training extends to all vehicles (Table III. Money Saved in Fuel Due to FM Training).

TABLE III. MONEY SAVED IN FUEL DUE TO FM TRAINING

Category	**Money Saved (Per Year)**
One Vehicle	$70.15
All CC&R Vehicles	$2,665.87
All FM Vehicles	$19,082.04

B. Safety Assessment

FM's mindful training program also promotes safe driving. Working primarily on a closely packed college campus, FM must uphold a standard of safety, despite frequent unpredictable pedestrians and vehicles. Drivers under FM's management have performed considerably well in safety metrics compared to the state average such as seat belt usage, speeding, and number of crashes.

Speeding score is a quantitative measure in which higher scores are associated with fewer speeding violations normalized by total distance driven. Before training began, CC&R was average around a score of 70 and had seen about a 6% increase from September 2021 when training began to March 2022 when training concluded (Fig. 3. Average Speeding Scores vs. Percent of Vehicles Trained (CC&R Vehicles)). We observed a sudden jump between September 2021 and October 2021, which we hypothesize is due to drivers' awareness of the training program, or the Hawthorne Effect [6]. Drivers understand that their performance is being observed, however the longevity and sustained high speeding score indicates that, even if drivers performed better immediately following the training, the training was beneficial for a long-term improvement of safety metrics, in part which can be attributed to the reinforcement and enthusiasm of management.

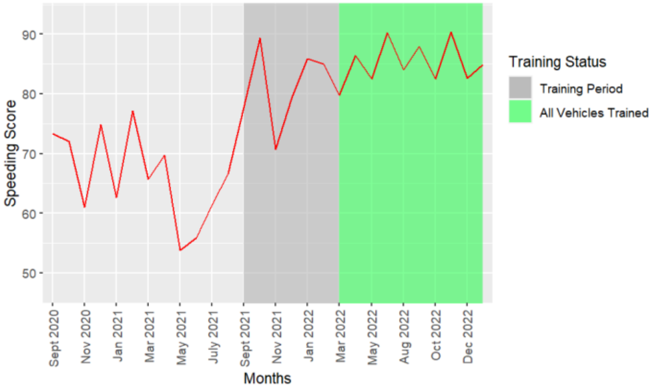

Fig. 3. Average Speeding Score vs. Percent of Vehicles Trained (CC&R Vehicles)

The Virginia state average percentage of time wearing a seat belt is 81.7%, according to Old Dominion University, Virginia Highway Safety Office, and Virginia Department of Motor Vehicles [7]. FM's CC&R division has seen a considerable increase in the percentage of time wearing a seatbelt as coinciding with their training timeline and is now well above the state average, specifically a 12% increase in the time seat belts are worn (Fig. 4. Average Percent of Time Seat Belt is Worn vs. Percent of Vehicles Trained (CC&R Vehicles)).

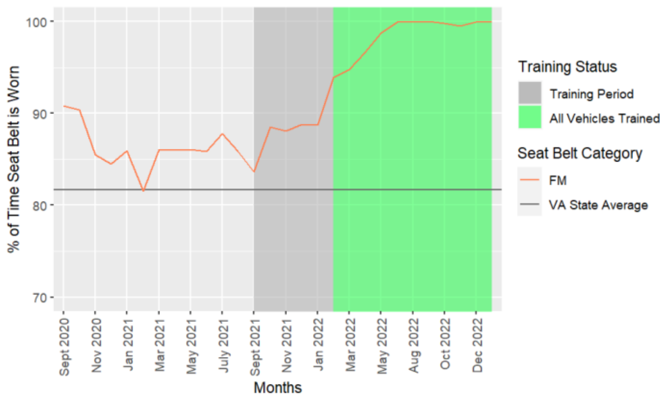

Fig. 4. Average Percent of Time Seat Belt is Worn vs. Percent of Vehicles Trained (CC&R Vehicles)

While the seatbelt and speeding scores went up with FM's mindfulness training, we need to investigate how these scores made an impact on actual safety (e.g., the number of crashes). Fig. 5 shows the number of preventable crashes from FM as well as total reported crashes from the State of Virginia. It is apparent that the number of FM's 2022 preventable crashes reduced by 50% when compared to that of 2021. When compared to the trend on the number of police reported crashes from the State of Virginia, the FM's number of crashes has largely improved in 2022.

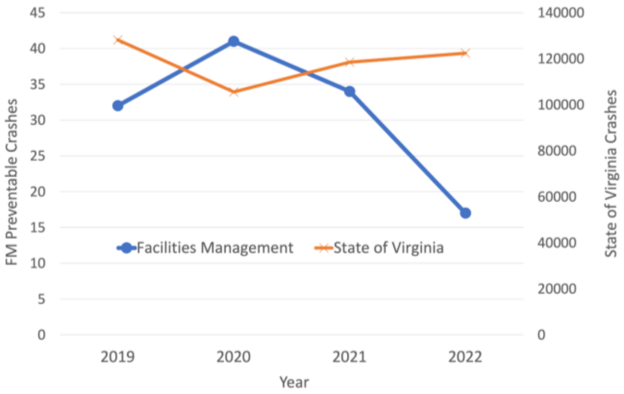

Fig. 5. Yearly Number of Crashes between FM VS State of Virginia

In addition, the State of Virginia crash data, between 2017 and 2021, shows a fatality crash and an injury crash in every 97.4 million miles driven, and every 1.35 million miles driven, respectively [8]. FM's vehicles have driven over 4.5 million miles between 2017 and 2022, with zero crashes involving fatalities or personal injuries. Assuming the State of Virginia average crash rate applies to the FM, an expected number of injury crashes is 3.33. Thus, it is commendable that FM has maintained much better safety than that of Virginia.

There was no noticeable difference in harsh braking score between before and after training.

V. CONCLUSIONS AND FUTURE WORKS

In addressing previous works, there are no recorded long-term benefits to FM training. The analysis conducted within this paper indicates that FM training is beneficial on a long-term scale, both in reducing the proportional count of safety-related violations and in reducing the anticipated budget spent on fuel per year. Our analysis consisted of division and vehicle selection, leading us to represent FM's fleet with six selected vehicles from CC&R. Between before and after training, the speeding score and percentage of time a seat belt is worn increased by 12% and 6% respectively. FM can expect to save $2,600 in the CC&R division and, should training be implemented for its entire fleet, save $19,000 on fuel per year. We were able to address safety metrics and savings of sustainability metrics qualitatively and quantitatively.

With a continually growing fleet, FM must be committed to UVA's 2030 Sustainability Plan and mindful driving. We expect, should FM implement training in all its divisions, we expect to see a substantial decrease in the relative cost of fuel by vehicle.

There were certain aspects such as unnecessary versus necessary idling, urban or highway driving, and differentiation of drivers on each vehicle were not addressed within this paper. Since vehicles are incredibly variable in attributes due to their vehicular task, vehicle make, vehicle model, and division, the numerical analysis may not necessarily capture and account for all these features. Vehicles may have multiple drivers as well. Our data collection and analysis could not differentiate between multiple drivers and instead only records data based on a vehicular basis. In order to overcome this, we propose that future research accounts for certain factors such as idling in gear versus park, identifying driving environment based on speed (i.e., classifying above 45 mph as highway, below 45 mph as urban), and identification between drivers for the same vehicle. Both idling and environment classification can be conducted within the software itself. We also propose differentiating between drivers using a key fob or a similar system.

ACKNOWLEDGMENTS

We would like to thank UVA FM staff and leadership for supporting this collaborative effort to propel sustainability and safety for drivers. We would like to thank Don Sundgren, the Associate Vice President and Chief Facilities Officer in 2020, for his financial support in this research. We would also like to thank Mark Stanis and the drivers of the CC&R division for participation in our training program.

REFERENCES

[1] *By the Numbers, 2021-2022 Data*. (2023). Retrieved from University of Virginia Facilities Management: https://annualreport.fm.virginia.edu/2022/by-the-numbers/

[2] *Fast Facts on Transportation Greenhouse Gas Emissions*. (2022, July 14). Retrieved from United States Environmental Protection Agency: https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

[3] Rakotonirainy, A., Haworth, N., Saint-Pierre, G., & Delhomme, P. (2011). Research Issues in Eco-Driving (Queens University of Technology Graduate Dissertation). French Institute in Science and Technology of Transport.

[4] Gresham, T. R., Kim, J., McDonald, J., Scoggins, N., Mostafavi, M., Park, B. B., ... & Smith, S. A. (2021, April). Safe and Sustainable Fleet Management with Data Analytics and Training. In *2021 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE.

[5] Ahmadiyar, R., Chun, J., Fuccella, C., Hrnjez, D., Parzych, G., Weisel, B., ... & Park, B. B. (2022, April). Safe and Sustainable Fleet Management with Data Analytics and Reinforcement Training. In *2022 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 321-326). IEEE.

[6] *Hawthorne Effect*. (2023, April 5). Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Hawthorne_effect

[7] *Virginia Seat Belt Use.* (2022). Retrieved from Old Dominion University: https://www.dmv.virginia.gov/safety/resources/pdf/22-stakeholders-porter.pdf

[8] *2021 Virginia Traffic Crash Facts.* (n.d.). Retrieved from Commonwealth of Virginia: https://www.dmv.virginia.gov/safety/crash_data/crash_facts/crash_facts_21.pdf