Prospectus

Safe and Sustainable Fleet Management with Data Analytics and Training
(Technical Topic)

A Human-Centered Approach to Sustainability: Empowering Behavioral Change in the Transportation Sector
(STS Topic)

By

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December 1st, 2020

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Eco-Driving

Every day, hundreds of millions of individuals from all walks of life get into their vehicles and drive to their respective destinations, unaware that their actions are emitting greenhouse gases and are moving humanity closer to our imminent destination: the irreversible destruction of our global environment. Consider just the United States of America (USA), the country with consistently the second greatest contribution of total annual carbon dioxide emissions, the terms "carbon dioxide emissions" and "greenhouse gas emissions" are used interchangeably since carbon dioxide accounts for more than 75% of greenhouse gas emissions, in the world (Union of Concerned Scientists, 2020). In 2018, the USA alone produced 6.7 billion metric tons of CO_2 equivalent with the largest source, 28.2%, of anthropogenic greenhouse gas emissions stemming from the combustion of "fossil fuels for cars, trucks, ships, trains, and planes" (United States Environmental Protection Agency, 2020). The transportation industry must swiftly acknowledge and remedially act to curb their carbon dioxide emissions or jeopardize escalating the adverse effects of climate change. One strategy often overlooked yet has proven immediate reductions in fuel usage and subsequent emissions by approximately 5 to 20% is eco-driving: the set of human behaviors and driving styles that characterizes fuel-efficient driving (Rakotonirainy *et al.* 2011). The behaviors which comprise eco-driving include avoiding harsh accelerations, minimizing rough braking, reducing excessive idling, evading harsh cornering and curtailing speeding (McIlroy & Stanton, 2016).

When addressing sustainable advances in the transportation sector at-large, an auspicious syndicate for the execution of eco-driving are commercial fleets of vehicles. The University of Virginia's Facilities Management Fleet Team (FMFT) is one example which operates roughly 260 vehicles ranging from light weight pickup trucks to heavy duty truck cabs. While the UVA FMFT has recently been accredited as a "Sustainable Fleet" by Calstart and the National Association of Fleet Administrators through the replacement of less-efficient diesel vehicles with electric and hybrid vehicles, operations management does not have a systematic methodology for analyzing driver performance in terms of fuel usage, emissions and crash risk (GF Staff, 2019). To reduce UVA FMFT carbon dioxide emissions, the technical project aims to leverage data-driven analytics and implement a personalized eco-driving training pilot program for targeted drivers. To address UVA FMFT safety concerns, the technical project will involve tracking and evaluating improvements to safety scores from a deterministic safety scoring methodology before-and-after education and feedback. If the project meets its objectives, UVA FMFT operations management will have a driver assessment tool which can be utilized to monitor fuel efficiency and safety hazards.

The STS research paper aims to analyze programs of actions which can be embedded into the technological artifact of the automobile to empower humans to enforce positive behavioral change in their driving habits. Because the technical deliverable will provide data-driven insights evaluating an eco-driving training pilot program at a local-level, and the STS paper will evaluate ways to technologically mediate sustainable driving behaviors, the projects will collectively offer a foundation to better understand the value of human-centered design strategies, specifically eco-driving, as an approach to realizing environmental sustainability for UVA FMFT and the transportation industry.

Eco-Driving at UVA

Over the past several years, UVA FMFT has begun to install in-vehicle telematic Internet of Things (IoT) sensors with the objective of using the data collected to track aggregate trends in performance and pinpoint ways to improve the productivity of their vehicle fleet. These in-vehicle sensors constantly collect and compile a broad range of driver performance metrics such as harsh acceleration, hard braking, hard cornering, speeding, fuel consumption and seat belt usage. This data is then stored on a server and management can pull all of the raw data directly or choose to produce scorecards which highlight the number of incidents that occurred based on specified criteria and thresholds. These incident counts are then normalized based on distance driven and standardized to be between zero and one hundred (Geotab, 2018). Finally, a weighting system is applied to these metric scores to obtain a single vehicle score that can be used to classify and compare the performance of different vehicles.

Despite the fact that fleetwide data has been gathered and stored over the past year, UVA FMFT does not have a suitable method for utilizing the driver performance data metrics to pragmatically improve fleet safety and sustainability by altering driver behavior. Additionally, a leading cause of complacency identified by the UVA Facilities Management operations team was the lack of a comprehensive driver training program (Duffy, personal communication, 2020). The development of a comprehensive driver education program must be supported by relevant prior research, a preliminary focus group consisting of FMFT drivers and an extensive analysis of UVA-specific driver performance data. “Performance” in this context can be understood as the extent to which a driver complies with safety laws and engages in sustainable driving behavior. Facilities Management has specified that vehicle drivers must comply with seatbelt laws and speed limits at all times (ibid). As such, driver compliance will be measured by the frequency of speeding and seatbelt misuse incidents. As a result, driver safety will be measured by both the degree of driver compliance along with the frequency of harsh acceleration, hard braking and cornering incidents. In terms of measuring sustainability, or “eco-driving”, extreme speeding and idling have been shown to be among the most crucial metrics to consider in regard to fuel consumption (Huang et al., 2018). Furthermore, the training program will be partitioned into two modules: safety, educating on behavior and compliance which reduces crash risk, and eco-driving, aligning good driving habits to sustainable values.

Our technical project will involve the development and validation of a deterministic classification model which measures, assesses and categorizes the safety and environmental impact of each driver. The model will apply thresholds for the three distinct classes of vehicles (passenger cars, trucks/cube vans, heavy duty vehicles) determined through transportation expert accounts and literature reviews. The model will categorize both a safety score and a sustainability score into the ordinal groups: low, mild, medium and high risk. To aid in the construction of this model, Transportation Operations and Fleet Manager, Mike Duffy, is providing the project team with raw and feature engineered datasets of the driver behavior, geographic location, and seat belt usage across the past year which enables a detailed, historical analysis of fuel efficiency and safety indicators by vehicle. Once developed, the model results will be utilized to summarize and detect vehicles with a distinguished influence on the fleet, in terms of vehicles with highest risk and vehicles with greatest impact on the fleet at-large. Additionally, results will provide input to identifying behavioral metrics which present significant opportunities for improvement and should be focused on in the design of a personalized driver feedback and training program.

In order to evaluate the efficacy of a personalized training program, a multi-week pilot test will be conducted with a selection of UVA FMFT drivers. Our approach to driver selection will be limited as the driver is not directly mapped to the vehicle at each instance that a data point is collected, so driver selection will be established based on at-risk vehicles, the driver’s frequency with driving relevant vehicles and the driver’s availability to participate in the pilot. Driver performance will be measured before, during, and after the implementation of the feedback and training program. The results of the pilot test will be compiled and analyzed with the intention of improving the training program through further iterations. Furthermore, the technological solution will be a fully developed driver behavior risk classification model and training program that could be implemented across UVA Facilities Management's entire vehicle fleet to improve the fleet's safety compliance and eco-driving behavior.

A Human-Centered Approach to Sustainability

Although it may be tempting to deploy technologies that decouple human behavior from environmental impacts, the demand for a fundamental re-evaluation of the relationship between technological innovation, human consumption and the environment is critical to ameliorate the harmful impacts of climate change (Latour, 2015). The paper will explore a human-centered approach to sustainability in order to understand how technology can be inscribed deliberately to empower behavioral change in human actors. This approach fundamentally challenges traditional belief systems with the notion that small changes to behavior incrementally aggregate to significant impacts and that technology should be designed to make behavioral programs of action easy to achieve (Harvey, 2013). Furthermore, the paper will investigate examples of sustainable driving behavioral programs of action and their effectiveness on reducing emissions for commercial fleets of vehicles, like the UVA FMFT. In order to understand the connection between human, social and technical elements with regards to driver behavior in vehicle fleets, the topic will be explored through actor-network theory and the limitations of strictly socially-driven and technologically-driven strategies will be addressed in light of resolving environmental issues.

Actor-Network theory, proposed by Bruno Latour, is the theory that situational programs of action, goal-directed behavior for human beings to function through artifacts, are not accomplished from a strictly human actors or technological artifacts, but through a collective effort between technology users, behavioral aids embedded in the technology and behavior-enforcing allies within the operating network (Schulz-Schaeffer, 2006). In the case of a commercial fleet with the goal of improving eco-behavior, the three types of actors in the vehicle drivers (users), in-vehicle eco-driving systems (behavioral aids) and fleet managers (behavior-enforcing allies). Latour argues that there are “missing masses” which lie within our socio-technical actor-networks and must be identified in order to realize how to enforce programs of action and subsequently fight anti-programs, actions which conflict with the aforementioned programs (Latour 1992). Latour’s reasoning supports the argument that that technological and social actors must work together interconnectedly to drive environmental impacts. This analysis will be employed to better understand the effectiveness of engineered inscriptions in the fleet vehicle system, ranging from eco-driving training programs to in-vehicle feedback systems to fiscal incentives, in supporting fuel-efficient programs of action and subsequently restricting anti-programs, or poor driving behavior in this case. Large vehicle fleets, such as UVA FMFT in particular, are distinguished in the analysis as ideal for the social learning of fuel-efficient driving behaviors because it is easier to spread knowledge within social units as opposed to large numbers of individuals learning independently, as shown in Figure 1 (Slater & Robinson, 2020).

In order to understand the programs of action, or “scripts”, Latour uses an analogy surrounding a network with a hotel customers as the user, hotel manager as the behavior-enforcing ally and the Berlin key as the technological artifact. The Berlin key has a design which forces visitors to close and lock doors, further mediating a relationship between the human actors and allies to shut their door at night. Nevertheless, the technological design of a system cannot fully encompass every potential program of action, and therefore socio-technical actors and behavioral aids are necessary to perform scripts (Latour, 1992). For example, every hotel customer who is given the key knows they must return it upon leaving, but the key alone is not enough to fulfill the program of action sought out by the manager. In order to incentivize hotel customers to return their key after use, the manager employs successive strategies including oral notices, written notices and weights on keys as seen in Figure 2 (ibid). This analogy is useful in understanding the complex relationship between technological artifacts, human actors, and allying components in manipulating behaviors directly.

In the context of this topic, surveys have identified that a majority of people, roughly 85%, are consciously aware of eco-driving and have a positive attitude towards it, however knowledge of and consequent performance of fuel-efficient behaviors which compose eco-driving are generally low (McIlroy & Stanton, 2016). Furthermore, neither pro-environmental attitudes nor a predisposition to perform eco-driving behaviors are actually indicative of performance signifying that human actors are not capable of innately making eco-friendly decisions when driving. On a different note, complex technical solutions in sustainability, such as the implementation of electric vehicles or development of renewable energy infrastructure, act to sustain nature as humans prefer it, for industry and the prolonging of continued human consumption, rather than sustaining nature "in itself" (Butman, 2016). While physical technology is often seen as the only necessary accelerator of fuel efficiency progress, "… a solely technological response to climate change does not question the social, political, and cultural tenet of infinite material growth, one of the root causes of climate change" (Karwat, Eagle, Wooldridge, & Princen, 2015). So, while electric and hybrid vehicle technology exists, relationships between humans, environment and driving practices need to be thoroughly investigated, interconnected and assessed for actionable behavioral change as society continues to push the eco-modernist agenda (Latour, 2015).

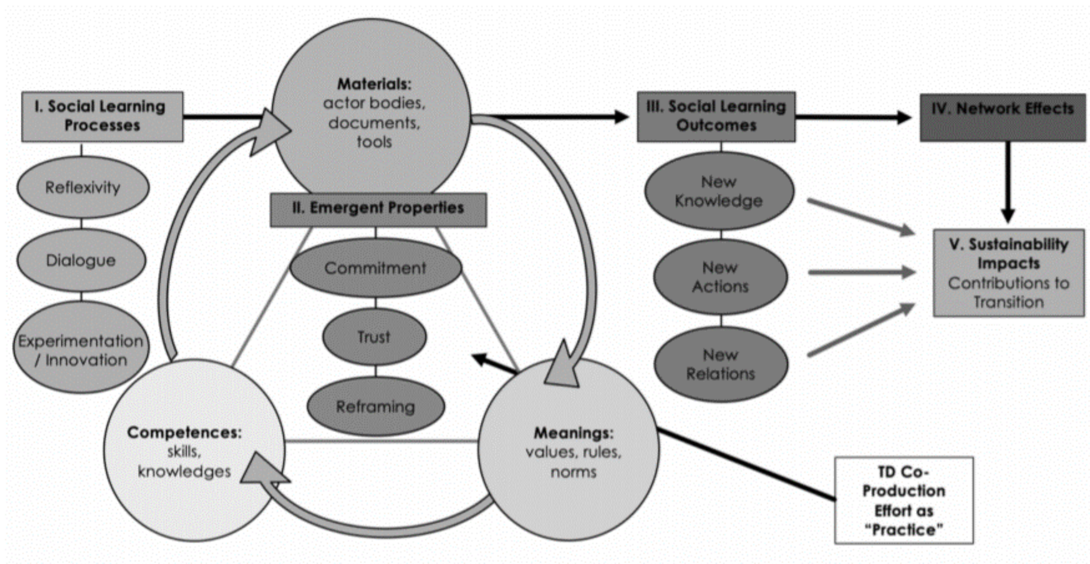

Figure 1: Process of Social Learning in Transdisciplinary Co-production for Sustainability Transitions (Slater & Robinson, 2020).

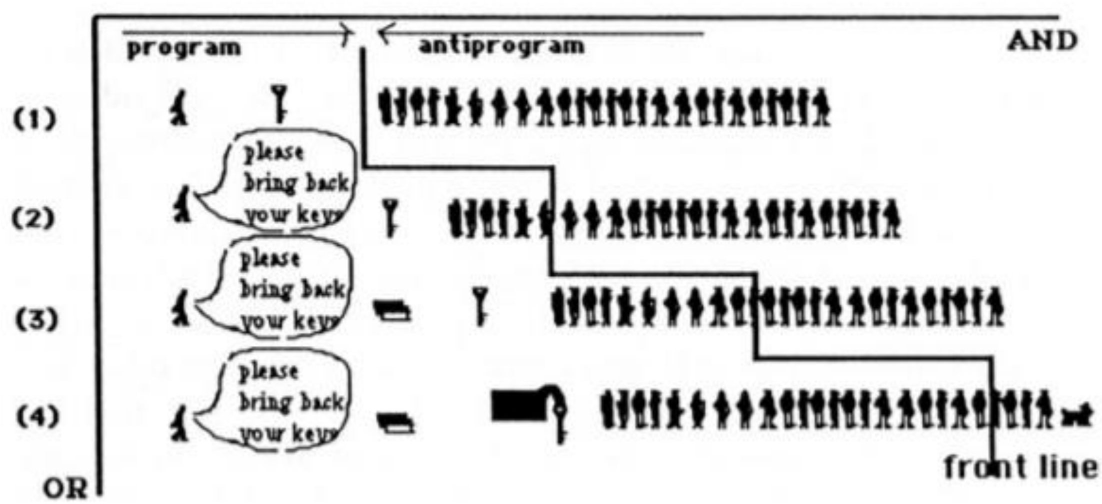

Figure 2: Sequential components used by a hotel manager to modify the attitudes of hotel customers to returning their key; Berlin Key Analogy (Latour, 1992).

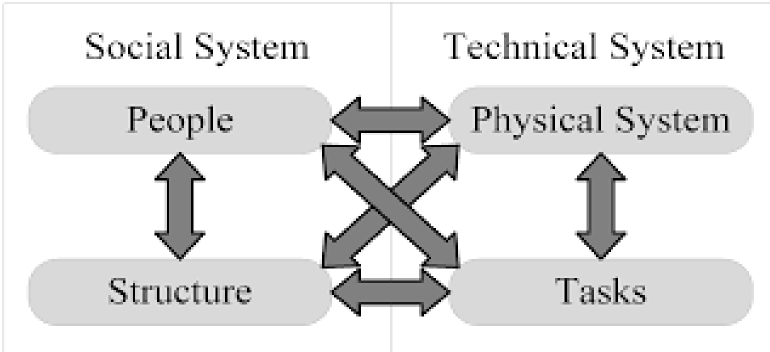

Figure 3: Socio-Technical System Components (Ibl & Capek, 2017).

Research Question and Methods

As society looks towards solutions to reduce transportation-based anthropogenic greenhouse gas emissions, electric and hybrid technologies have come to the forefront of attention for research and development in the U.S., but haven't seen significant progress in taking over market share (Teter, 2020). The adoption of battery-powered vehicles will be gradual and expensive, and the vehicles themselves will only be as clean as the electricity provider (Biello, 2016). Change in driver behavior style corresponding to eco-driving, on the other hand, can be applied to any vehicle regardless of age or size, can take effect across an entire fleet of vehicles immediately at low cost, and can result in savings due to improved fuel efficiency and better safety; however is still frequently overlooked and thought of as too difficult to achieve (Barkenbus, 2010). To that end, the research question I will address is: How will a shift towards human-centered socio-technical solutions to sustainability challenges, embodied in the transportation sector with eco-driving programs of action, be essential for the reduction of U.S. carbon emissions?

There are several methods I intend to utilize for the evidence collection, descriptive analysis and evaluative analysis in order to answer the research question. A comprehensive analysis of eco-driving programs of action in literature and subsequent results of fuel-efficiency improvements will be necessary to compile a ranked list of industry practices compounded and develop a diagram similar to that in Figure 1. A thorough continuation of reviewing literature from scientific and engineering journal articles to books such as Mcllroy's "Eco-Driving: From Strategies to Interfaces" will be useful in further expanding industry knowledge. Using a behavioral design approach to optimizing sociotechnical components and subcomponent relationships conceptualized within actor-network theory as seen above in Figure 3, I plan to facilitate a collaborative interview with the industry experts to cultivate their understanding on vehicle fleets. The interview will be structured towards 1) Developing an understanding of the current state of user behavior and decision-making to reach fleet goals 2) Identifying key enablers or barriers to behavioral changes 3) Proposing an iterative plan for testing solutions and gathering feedback to create a closed-loop system that enables sustained behavioral change (Wordham, Tuff, & Briggs, 2018). From this open dialogue, I hope to understand at a low-level the socio-technical obstacles faced by drivers when adopting eco-driving habits and strategies attempted through research institutes with respect to managing vehicle fleet carbon emissions and promoting sustainable transitions through social learning. Additionally, the technical paper will be used as a case study on UVA FMFT and compared to results of research studies on commercial fleet eco-driving introducing pilot incentives or educational programs, as well as results induced by eco-driving government regulations in the European Union (Reco Drive, 2010). Lastly, a content analysis will be completed using all the evidence collected from prior literature reviews, agency reports, interviews and case studies with the goal of identifying alignment and misalignment with specific methodical programs of action to better understand uncertainty.

Conclusion

Eco-Driving behaviors such as reducing harsh accelerations, curbing braking, and avoiding excessive idling have proven to successfully reduce carbon emissions when implemented throughout a commercial fleet of vehicles. Although eco-driving behaviors are widely known and supported by drivers, evidence has shown that sustained implementation is difficult without socio-technical programs of action in place such as IoT driver performance monitors, education training programs and other socio-technical feedback mechanisms to continuously incentivize drivers to comply over a long period of time (Mcllroy & Stanton, 2017). The STS research aims to evaluate the effectiveness of these programs of action in terms of mediating realistic sustainable behavioral change within the UVA's FMFT vehicles. The expected results from the systems evaluation approach in the STS paper is a better understanding for how to properly translate eco-driving knowledge to drivers in a collective fleet through a human-centered socio-technical methodology, as opposed to emerging socially-driven technologies, to realize necessary reductions in carbon emissions at the local-level of UVA FMFT and throughout the U.S. transportation industry.

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