Undergraduate Thesis Prospectus

Production of Biodiesel and Coproducts from Algae

(technical research project in Chemical Engineering)

Different Conceptions of Autonomous Vehicle Safety

(STS research project)

by

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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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General Research Problem

How can transportation be more sustainable?

Transportation is crucial to the economy, contributing up to 9% of the United States' gross domestic product, but has environmental, health, and social equity implications (BTS, 2018). Transportation produces 29% of greenhouse gas emissions in the United States, of which 82% is from gasoline and diesel cars and trucks (EPA, 2019). Globally, traffic deaths are the eighth highest cause of death, killing 1.35 million people each year; low-income regions and non-driving road users disproportionately affected (World Health Organization, 2018). Air and noise pollution further degrade quality of life and public health (EEA, 2016).

Production of Biodiesel and Coproducts from Algae

How can biodiesel be profitably produced from algae?

This is a team capstone project under Eric Anderson of the Chemical Engineering Department, with Amna Tahir, David Vann, Jack Pagan, and Schuyler Dineen.

In the United States, the most common biofuels are bioethanol, from corn, and biodiesel, from soybean and canola oil. The U.S. produced 16.1 billion gallons of bioethanol and 1.83 billion gallons of biodiesel in 2018 (U.S. Energy Information Administration, 2019). Algae-based biofuels represent a potential significant advancement. Algae grows quickly, can be rich in oil, and is the only biofuel source able to meet more than half of U.S. fuel demand since it uses land efficiently (Chisti, 2007). Algae can be grown in many conditions and can be genetic engineered for different strain characteristics (Gomiero, 2015; Hannon et al., 2010). Additionally, algal biofuels do not compete with food for land, a concern with current biofuels (Ajanovic, 2011).

Several approaches have been developed to commercialize algal biodiesel, but attempts have failed because of cultivation difficulties. Open ponds and closed photobioreactors have been used for cultivation. Open systems are cheaper but difficult to control, vulnerable to contamination, and can have issues with light penetration (Saad et al., 2019). Closed systems have higher yields, are controllable, and save water, but are expensive and difficult to scale up (Saad et al., 2019). The company Solazyme engineered its algae to not require sunlight, with the algae grown in standard fermenters containing a sugar substrate (Biello, 2013); however, the use of sugar is expensive, competes with food production, and increases environmental impact. For photosynthetic algae, poor light penetration can cause low cell density and lower production than theoretically possible; still, productivity is much higher than typical biofuel sources (Dassey & Theegala, 2013; Li et al., 2008). Low cell densities, the small size of algal cells, and high water content make harvesting and drying algae expensive (Li et al., 2008).

These costs make processes producing solely biodiesel uneconomical. An analysis of algal biodiesel production found a selling price of $8.52 per gallon is needed to be profitable (Davis et al., 2011). Without an increase in oil prices or a breakthrough in algal cultivation, algal biodiesel will not be economically competitive with fossil fuels on its own. The proposed solution to this problem is the design and development of an integrated algal biorefinery to produce coproducts in addition to biodiesel. The aim is to be able to sell algal biofuels at a lower price than what would be profitable if producing biodiesel alone. While the high value coproducts could be produced by themselves, combined production with biofuels decreases total fossil fuel consumption.

Data will be found from literature to design the major unit operations of the process. Data needed includes: algal growth, algal composition, harvesting (i.e. flotation) kinetics, transesterification kinetics, and kinetics for coproduct processes such as cellulose pretreatment and fermentation. Other unit operations will be designed using heat and mass transfer fundamentals, along with chemical properties and process-flow modeling from Aspen Plus software. Annual revenue, operating costs, and capital costs will be determined by material prices and unit operation design specifications.

Conceptions of Autonomous Vehicle Safety

How do social groups disagree about the safety implications of autonomous vehicles?

According to the National Highway Transportation Safety Administration (NHTSA), human error is the critical reason for 94% of traffic fatalities (Singh, 2015; Koopman, 2018). Self-driving cars may prevent many errors of this kind. Proponents claim autonomous vehicles (AVs) will also increase productivity, reduce traffic, and reduce emissions (CFM, 2019). However, AVs must prove their safety before such benefits can be realized. Proving the safety of AVs is difficult due to the randomness of machine learning, low frequency of accidents and edge-cases, and unhelpful metrics like “disengagements” (Koopman & Wagner, 2016; Marshall, 2018). AVs cannot be tested or deployed at a large scale without trust and public understanding of the technology.

Bonnefon et al. (2016) found people prefer AVs that make decisions which minimize total deaths, even if sacrificing their passengers. However, people would rather purchase AVs that prioritize the passengers' lives over others (Bonnefon et al., 2016). This contention between pedestrians, drivers, and developers is still unsettled. Scheufele & Lewenstein (2005) found the public evaluates innovations within framings supplied by the media. When researchers propose regulations, Corley et al. (2009) found they prioritize risks over benefits, and are prone to political and economic biases. Proponents often acclaim innovations as revolutionary, then retreat in response to public criticism (Rayner, 2004).

Car- and ride-sharing companies are seeking to develop and deploy AVs. Both groups claim that AVs will reduce crashes, emissions, and traffic (GM, 2018; Uber, 2018). Uber claims AVs will be more affordable (Uber, 2018). Both claim AVs will offer mobility benefits for elderly and disabled people (Self-Driving Coalition, 2019). Unlike Uber, car makers have interests in maintaining the personal ownership model of cars as the predominant ownership mode. Lower levels of automation and other safety improvements can serve car makers' interests, while Uber needs full automation for car sharing.

Developers vary in their approach to safety. Telsa's CEO Elon Musk favors rapid transformation: "very, very quickly, maybe even towards the end of this year, … having a human intervene will decrease safety" (Fridman, 2019). Uber is more cautious, grounding it self-driving fleet after the deadly accident in March 2018 (Lafrance, 2018). To promote AVs, the trade association Partners for Automated Vehicle Education (PAVE) publicizes them to the public and policymakers (PAVE, 2019).

Drivers disagree about AVs. Capgemini (2019) found 59% of drivers feel anticipation and 48% feel fear towards AVs. Following Uber's fatal accident, AAA (2018) found 73% of U.S. drivers would be too afraid to ride in a self-driving car. Drivers are most concerned about the possibility of hacking and technical errors in driving, but these misgivings fall with exposure to AVs (König & Neumayr, 2017). Drivers look forward to mobility gains and time savings, however perceived safety remains the largest predictor of use (König & Neumayr, 2017; Zmud et al., 2016). Automated driving systems still require driver vigilance to take over in risky situations (NTSB, 2018; NTSB, 2019). AVs that let humans take control earn more trust, but perceptions of safety can cause complacency, negating safety benefits (König & Neumayr, 2017; Parasuraman & Mansey, 2010; Peltzman, 1975).

Many advocates of walkability and public transit disagree that safety demands vehicle automation, generally preferring better sidewalks, lower speed limits, and buses for safety at lower costs (Amruthapuri & Bartel, 2019). They warn that AVs may impair urban transit, increase traffic demands, exacerbate urban sprawl, and compete with transit (Speck, 2017). They contend the public should be more involved in the implementation of AVs (Amruthapuri & Bartel, 2019). Some non-drivers support AVs; in areas testing AVs, cyclists support them more than the general public, citing predictability and consequent safety sharing the road (BikePGH, 2017).

The U.S. Department of Transportation (DOT) promotes innovation through voluntary advice in safety and transparency. Substantial authority is left to subcommittees and states (U.S. DOT, 2018). The National Highway Transportation Safety Administration (NHTSA), a component of the U.S. DOT, promotes a continuity of existing car safety regulations (King, 2019). Federal regulations, such as the AV START act, have been proposed to standardize testing between states. These bills have failed because they have not satisfactorily accounted for risks and have not provided for sufficient oversight of AV development (Feinstein et al., 2018).

References

AAA. (2018, May 18). American Automobile Association. American Trust in Autonomous Vehicles Slips. https://newsroom.aaa.com/2018/05/aaa-american-trust-autonomous-vehicles-slips/.

Ajanovic, A. (2011). Biofuels versus food production: Does biofuels production increase food prices? *Energy*, 36(4), 2070–2076. doi: 10.1016/j.energy.2010.05.019

Amruthapuri, R., & Bartel, S. (2019, July). Wait, Who's Driving This Thing? Bringing the Public to the Autonomous Vehicle Table. https://www.pittsburghforpublictransit.org/wp-content/uploads/2019/07/PPT-AV-paper.pdf.

Biello, D. (2013, July 25). How to survive as a biofuel-maker: Sell algae to bakers. *Scientific American.* https://www.scientificamerican.com/article/how-to-survive-as-former-algae-biofuel-maker-solazyme/

BikePGH. (2017). Bike Pittsburgh. AV Survey Results 2017. https://www.bikepgh.org/our-work/advocacy/save/survey/.

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, 352(6293), 1573–1576. doi: 10.1126/science.aaf2654

BTS (2018, Dec). Bureau of Transportation Statistics. Transportation's Contribution to the Economy. https://www.bts.gov/sites/bts.dot.gov/files/u796/TET%202018%20Chapter%202.pdf.

Capgemini Research Institute. (2019, May). The Autonomous Car: A Consumer Perspective. https://www.capgemini.com/news/the-autonomous-car-report/.

Chisti, Y. (2007). Biodiesel from microalgae. *Biotechnology Advances*, 25(3), 294–306. doi: 10.1016/j.biotechadv.2007.02.001

CFM (2019). Coalition for Future Mobility. Benefits of Self-Driving Vehicles. https://coalitionforfuturemobility.com/benefits-of-self-driving-vehicles/.

Corley, E. A., Scheufele, D. A., & Hu, Q. (2009). Of risks and regulations: how leading U.S. nanoscientists form policy stances about nanotechnology. *Journal of Nanoparticle Research*, 11(7), 1573–1585. doi: 10.1007/s11051-009-9671-5

Dassey, A. J., & Theegala, C. S. (2013). Harvesting economics and strategies using centrifugation for cost effective separation of microalgae cells for biodiesel applications. *Bioresource Technology*, 128, 241–245. doi: 10.1016/j.biortech.2012.10.061

Davis, R., Aden, A., & Pienkos, P. T. (2011). Techno-economic analysis of autotrophic microalgae for fuel production. *Applied Energy*, 88(10), 3524–3531. doi: 10.1016/j.apenergy.2011.04.018

EEA (2016, Sept). European Environment Agency. Transport and public health. https://www.eea.europa.eu/signals/signals-2016/articles/transport-and-public-health/.

EPA (2019, June). U.S. Environmental Protection Agency. Fast Facts: U.S. Transportation Sector Greenhouse Gas Emissions. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WUHR.pdf.

Feinstein, D., Blumenthal, R., Gillibran, K., Udall, T., & Markey, E. (2018, March 14). Concerns on AV START Act [Letter]. https://www.feinstein.senate.gov/public/_cache/files/f/1/f168c367-bec0-48cc-9220-6a13cbd9dd27/D00752809320841613B5F03BB8517FC2.03.14.2018-av-start-act-letter.pdf

Fridman, L. (2019, April 12). Elon Musk: Tesla Autopilot [Video file]. https://www.youtube.com/watch?v=dEv99vxKjVI.

GM (2018). General Motors. 2018 Self-Driving Safety Report. https://www.gm.com/content/dam/company/docs/us/en/gmcom/gmsafetyreport.pdf.

Gomiero, T. (2015). Are biofuels an effective and viable energy strategy for industrialized societies? A reasoned overview of potentials and limits. *Sustainability*, 7(7), 8491–8521. https://doi.org/10.3390/su7078491

Hannon, M., Gimpel, J., Tran, M., Rasala, B., & Mayfield, S. (2010). Biofuels from algae: Challenges and potential. *Biofuels*, 1(5), 763–784.

King, H. (2019, April 5). SAE Government/Industry Meeting. https://www.nhtsa.gov/speeches-presentations/sae-governmentindustry-meeting.

König, M., & Neumayr, L. (2017). Users' resistance towards radical innovations: The case of the self-driving car. *Transportation Research Part F: Traffic Psychology and Behaviour*, 44, 42–52. doi: 10.1016/j.trf.2016.10.013

Koopman, P., & Wagner, M. (2016). Challenges in Autonomous Vehicle Testing and Validation. *SAE International Journal of Transportation Safety*, 4(1), 15–24. doi: 10.4271/2016-01-0128

Koopman, P. (2018, June 5). A Reality Check on the 94 Percent Human Error Statistic for Self-Driving Cars. http://safeautonomy.blogspot.com/2018/06/a-reality-check-on-94-percent-human.html.

Lafrance, A. (2018, Mar 26). Can Uber Survive Without Self-Driving Cars? *The Atlantic*. https://www.theatlantic.com/technology/archive/2017/03/can-uber-survive-without-self-driving-cars/520854/

Li, Y., Horsman, M., Wu, N., Lan, C. Q., & Dubois-Calero, N. (2008). Biofuels from microalgae. *Biotechnology Progress*, 24(4), 815−820. doi: 10.1021/bp070371k

Marshall, A. (2018, Oct 29). We've Been Talking About Self-Driving Car Safety All Wrong. *Wired*. https://www.wired.com/story/self-driving-cars-safety-metrics-miles-disengagements/

NTSB. (2018). National Transportation Safety Board. Preliminary Report Highway (Report No. HWY18MH010). https://www.ntsb.gov/investigations/AccidentReports/Reports/HWY18MH010-prelim.pdf

NTSB. (2019, Aug 22). Rear-End Collisiton Between a Car Operating with Advanced Driver Assistance Systems and a Stationary Fire Truck, Culver City, California, January 22, 2018 (Report No. HWY18FH004). https://www.ntsb.gov/investigations/AccidentReports/Reports/HAB1907.pdf

Parasuraman, R., & Manzey, D. H. (2010). Complacency and Bias in Human Use of Automation: An Attentional Integration. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 52(3), 381–410. doi: 10.1177/0018720810376055

PAVE. (2019, March 18). Partners for Automated Vehicle Education. PAVE adds new industry leaders to growing coalition. https://pavecampaign.org/news/pave-adds-new-industry-leaders-to-growing-coalition/.

Peltzman, S. (1975). The Effects of Automobile Safety Regulation. *Journal of Political Economy*, 83(4), 677–725. doi: 10.1086/260352

Rayner, S. (2004). The Novelty Trap: Why Does Institutional Learning about New Technologies Seem So Difficult? *Industry and Higher Education*, 18(6), 349–355. doi: 10.5367/0000000042683601

Saad, M. G., Dosoky, N. S., Zoromba, M. S., & Shafik, H. M. (2019). Algal Biofuels: Current Status and Key Challenges. *Energies*, 12(10), 1920. doi: 10.3390/en12101920

Scheufele, D. A., & Lewenstein, B. V. (2005). The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies. *Journal of Nanoparticle Research*, 7(6), 659–667. doi: 10.1007/s11051-005-7526-2

Self-Driving Coalition. (2019). Our Mission and Members. https://www.selfdrivingcoalition.org/about/mission.

Singh, S. (2015, Feb). Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey. (Traffic Safety Facts Crash Stats. Report No. DOT HS 812 115). Washington, DC: National Highway Traffic Safety Administration.

Speck, J. (2018, May 10). Ten rules for cities about automated vehicles. *Public Square: A CNU Journal*. https://www.cnu.org/publicsquare/2017/10/16/ten-rules-cities-about-automated-vehicles.

Uber Advanced Technology Group. (2018). A Principled Approach To Safety. https://uber.app.box.com/v/UberATGSafetyReport.

U.S. DOT. (2018, Oct). U.S. Department of Transportation. Preparing for the Future of Transportation: Automated Vehicles 3.0. https://www.transportation.gov/av/3/preparing-future-transportation-automated-vehicles-3

U.S. Energy Information Administration. (2019). Monthly energy review (pp. 179–180). https://www.eia.gov/totalenergy/data/monthly/#renewable

World Health Organization. (2018). Global status report on road safety 2018. https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/.

Zmud, J., Sener, I. N., & Wagner, J. (2016). Self-Driving Vehicles: Determinants of Adoption and Conditions of Usage. *Transportation Research Record: Journal of the Transportation Research Board*, 2565(1), 57–64. doi: 10.3141/2565-07