Undergraduate Thesis Prospectus

A Strive to Net-Zero: Layered Insulation

(technical research project in Mechanical Engineering)

A Battle for the Road: Motorcyclists' Quest to Legalize Lane Splitting

(sociotechnical 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 may system efficiencies be improved?

Repair is naturally built into the reliability and performance of all systems and designs. It is used to meet system requirements, rather than improve systems. If a certain reliability is desired or known, "it is a routine matter to determine permissible values for the mean time to repair and the mean time to failure of each component" (Barlow & Hunter, 1960). This indicates a natural preference for predictability in system efficiencies. Performance is often sacrificed to guarantee the reliability of a system. In order to improve system efficiencies, system designs must look beyond routine repair and into the risk of performance orientations.

A Strive to Net-Zero: Layered Insulation

How can a building afford its occupants comfort without powered heating and cooling systems?

While the U.S. commercial sector tries to become more environmentally conscious and friendly, the residential sector lacks progress. According to the Office of Energy Efficiency and Renewable Energy, houses built since 2000 consume more energy than houses built in the 1960's (OEERE, n.d.). Heating and cooling accounted for 55% of energy consumption in U.S. homes in 2015. This number is projected to grow as the world becomes increasingly invested in electronic devices demanding power. The residential sector, responsible for 21% of the total energy consumption in the U.S., has ignored environmental considerations.

The capstone project of Mechanical Engineering will convert an existing building to a net zero energy footprint. The University of Virginia Architecture School's Initiative reCOVER building, located at Milton Airfield in Charlottesville, VA, was approved for this project. The building was initially designed for the 1.3 million people left homeless after Haiti's 2010

earthquake (Ford, 2010). It is not equipped to handle Virginia's diverse and seasonal climate. Our team, consisting of Cathryn Palmer, Amelia Kokernak and Jack Pazin, will optimize the insulation of the building to reduce heat loss and conserve energy. Harsha K. Chelliah, a professor in Mechanical and Aerospace Engineering, will supervise our efforts.

The goal is to design a layered insulation system that outperforms and replaces the existing system. The performance will be based on the system's thermal resistance, also known as the R-value. A larger R-value indicates better resistance and less heat loss. The design will also be evaluated on its cost, use of recycled materials, fireproofing and moisture proofing. Due to various climates across the nation, the design will only be applicable to houses in region four (fig. 1).

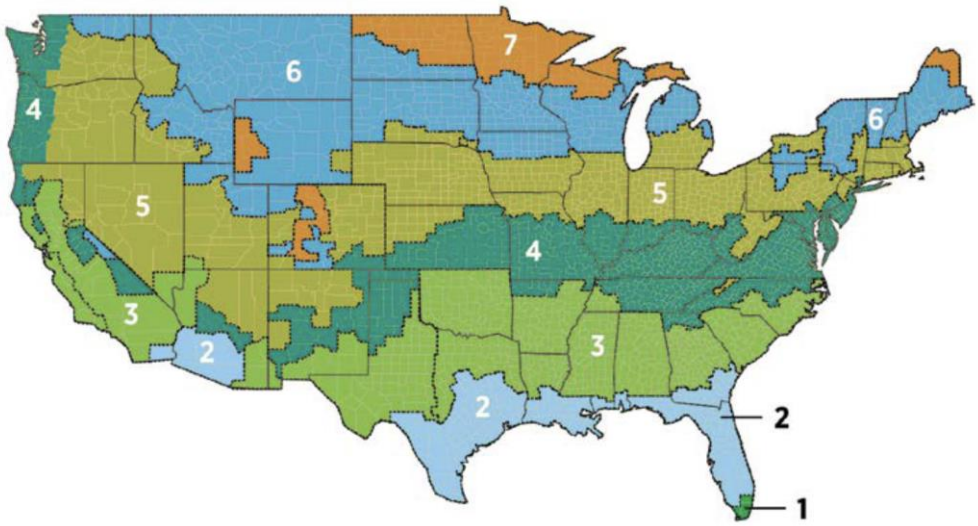


Figure 1. Climate Zones in the United States (OEE, n.d.)

Vacuum insulation panels (VIP's) are the leading insulation performers with an R-value of approximately 50 per inch of material (Thermal Visions, n.d.). In comparison, a traditional insulation material like fiberglass has an R-value between 3.7-4.3 per inch (EcoStar Insulation, 2019). VIP's consist of a multilayer envelope that encloses an open-porous material, forming a

vacuum inside the core to increase thermal resistance (Gangåssæter et al., 2017). VIP's propose a risk of failure due to puncture as well as a difficulty to adapt the panels to a building's structure.

Aerogels trail VIP's with an R-value of 10-20 per inch (Kahn, 1991). They consist of a silica gel where all liquid components are replaced by air using a complex drying process, producing a nanoporous structure (Gangåssæter et al., 2017). Aerogels propose a challenge in insulation due to their low density and fragility.

To begin the design, a sensitivity analysis will identify the most influential thermal or physical property of an insulation system. Optimizing this component will be the focus of the design. A one-dimensional heat transfer analysis will derive an equation for the R-value of a single layer insulation system. Since layered insulation systems are arranged in series, the R-values of each layer can be summed to yield the total R-value. This calculation will be expedited with a Matlab code and used to evaluate the performance of each design. Experiments will occur in three-dimensional Solidworks simulations due to ease of setup and control, but physical experiments and prototyping will occur time-permitting.

If successful, a layered insulation system will reduce the heat loss and conserve energy in the reCOVER building. The building will be suitable for residents in a climate it was not constructed for. Next steps will include removal of the existing system and installation of the new design.

A Battle for the Road: Motorcyclists' Quest to Legalize Lane Splitting

In the U.S., how have advocates and opponents of motorcycle lane splitting advanced their respective agendas?

In lane splitting, motorcyclists ride between lanes through congested traffic. The technique is also known as lane filtering, lane sharing, whitelining and stripe-riding, though each individual, organization or government agency may define them differently. Lane splitting affects all motorists on the road through the interactions and perceptions between motorists and motorcyclists. Although there is national discussion and activity, lane splitting is only legal in California since 2016. The National Highway Traffic Safety Administration (2019) found that 7 percent of motorcycles involved in two-vehicle crashes were struck in the rear. This percentage has remained constant for the last two decades. Advocates of lane splitting hope to reduce this number by permitting motorcyclists to ride between cars at traffic stops and slow speeds to avoid rear-end collisions. Opponents believe lane splitting will have no benefit on crash statistics and traffic culture.

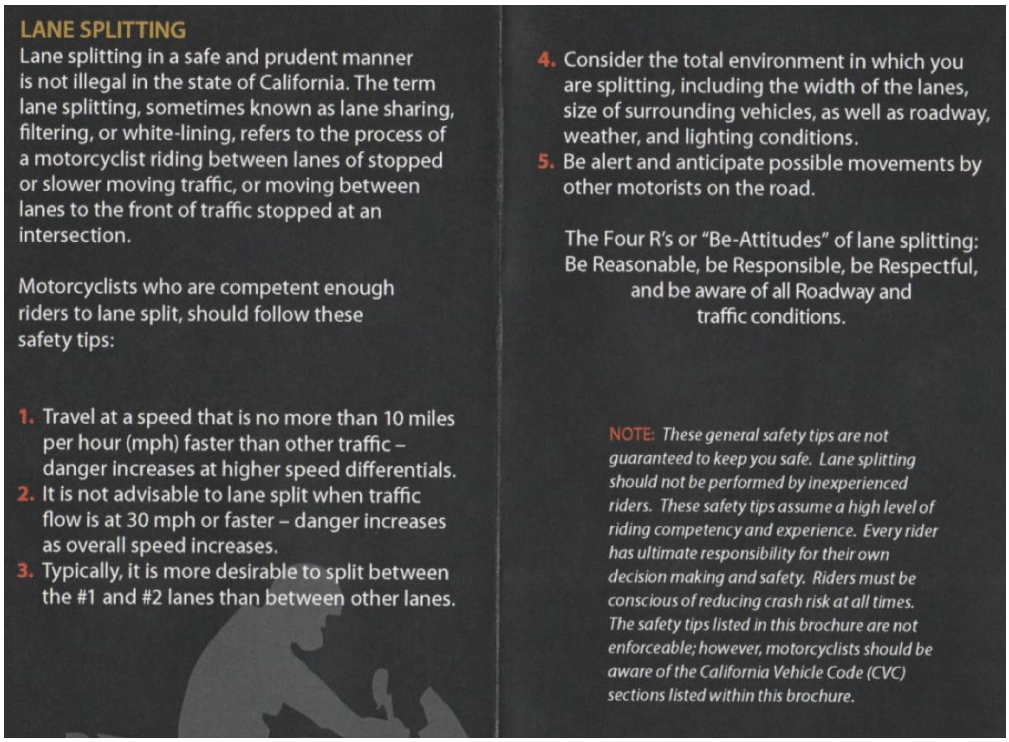
Hamann and Peek-Asa (2017) found that bicyclists in Melbourne, Australia (right-hand traffic) had the fewest safety-relevant events (crashes, near crashes, errors and traffic violations) when positioned on the left side of a lane. The next safest lane positions were sidewalk/sidepath/not applicable, center, and right, respectively. Cycling safety was dependent on the proximity to vehicle drivers in adjacent lanes.

Participants include individual riders who believe lane splitting offers safety and practicality to all motorists on the road. They argue the time savings of lane splitting "will encourage more people to choose to ride motorcycles, further reducing the number of cars on the road" (Pederson, 2015). They claim lane splitting moves motorcycles to a safer position during

slow speeds and red lights. They defend their perspective with evidence by Rice et al. (2015) that lane splitting riders in California are less likely to be rear-ended and suffer head and fatal injuries than non-lane splitting riders (Gish, 2018).

The Motorcycle Safety Foundation (MSF) is a not-for-profit foundation that participates in government relations, provides technical assistance to state training and licensing programs, and is sponsored by the world's leading motorcycle manufacturers. The MSF suggests that lane splitting "may provide a safety benefit" (MSF, n.d.). The American Motorcyclist Association (AMA) is another influential advocate for lane splitting. The AMA recognizes traffic congestion to be "one of the most dangerous situations for any on-highway motorcyclist" (AMA, 2020) and endorses responsible lane splitting for protection and escape routes from traffic.

The California Highway Patrol (CHP), a state law enforcement agency, is an advocate in the only state where lane splitting is legal. Prior to legalization, lane splitting in California was not explicitly legal or illegal. The CHP took a stance by publishing guidelines (fig. 2) for safe lane splitting practice (MacDonald, 2014). Kenneth Mandler, a former California state employee, argued that the CHP had "exceeded its authority by recommending lane splitting" (Fleming, 2014). The Office of Administrative Law later had the CHP remove the guidelines. Mandler's efforts also resulted in the removal of any mention of lane splitting in the California Department of Motor Vehicles' online and printed literature.



LANE SPLITTING

Lane splitting in a safe and prudent manner is not illegal in the state of California. The term lane splitting, sometimes known as lane sharing, filtering, or white-lining, refers to the process of a motorcyclist riding between lanes of stopped or slower moving traffic, or moving between lanes to the front of traffic stopped at an intersection.

Motorcyclists who are competent enough riders to lane split, should follow these safety tips:

1. Travel at a speed that is no more than 10 miles per hour (mph) faster than other traffic – danger increases at higher speed differentials.
2. It is not advisable to lane split when traffic flow is at 30 mph or faster – danger increases as overall speed increases.
3. Typically, it is more desirable to split between the #1 and #2 lanes than between other lanes.
4. Consider the total environment in which you are splitting, including the width of the lanes, size of surrounding vehicles, as well as roadway, weather, and lighting conditions.
5. Be alert and anticipate possible movements by other motorists on the road.

The Four R's or "Be-Attitudes" of lane splitting: Be Reasonable, be Responsible, be Respectful, and be aware of all Roadway and traffic conditions.

NOTE: *These general safety tips are not guaranteed to keep you safe. Lane splitting should not be performed by inexperienced riders. These safety tips assume a high level of riding competency and experience. Every rider has ultimate responsibility for their own decision making and safety. Riders must be conscious of reducing crash risk at all times. The safety tips listed in this brochure are not enforceable; however, motorcyclists should be aware of the California Vehicle Code (CVC) sections listed within this brochure.*

Figure 2. Removed CHP Guidelines (CHP, 2014)

Mandler is one of many individual opponents of lane splitting. Reasons for their resistance might include lack of law enforcement, safety hazards or an unwillingness to change traffic culture. Although advocates of lane splitting won the California battle in 2016 and sparked national discussion and activity, opponents still control the roads in every other state.

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