An Automatic Parking Lot Sensing and Management System
(Technical Paper)

The Role of Sociocultural Values in Parking Lot Design and Administration

(STS Paper)

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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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Introduction

The invention of the automobile drastically changed the American economy and lifestyle by effectively shrinking the nation and bringing citizens closer together. For example, the advent of the suburbs. No longer bound to live where they work, city-dwellers flocked to the suburbs and commuted to their places of business. During this colossal lifestyle shift, motor vehicles became more than transportation and took on roles as symbolic cultural icons. Today the enormous cultural significance of automobiles is manifested in popular activities such as road trips, in the performance-driven subculture of sports cars and car modification, and in the socioeconomic status symbols automobiles represent. In the United States there are an estimated 240 million passenger vehicles and another 10 million commercial vehicles (Chester et al., 2011), all of which spend 95% of its lifetime parked (Nourinejad et al., 2018). To provide parking for all of these cars, Chester et al. estimate that parking areas constitute approximately 0.7% of the area of the United States: almost 27,000 square miles of land- greater in area than the state of West Virginia (2011). Even parking lots themselves hold cultural significance; according to Neely & Marone they often serve as points of confluence in which people of different backgrounds interact, participate in rituals, and convey information and lore to one another (2016). This practice is evident in the American tradition of tailgating before a football game and in the parking lots of jam band concerts, popularized by the Grateful Dead. In this research paper, I seek to understand what sociocultural values are reflected in the design and administration of parking lots and how an understanding of this can benefit society.

Managing the huge number of parking lots in the US is very important; mismanagement of parking lots reduces the efficiency of urban land use and necessitates the construction of more parking lots which results in greater environmental damage (Rushton, 2001). My team's Capstone project is a parking lot monitoring and administration system comprised of wireless beacons which mount to users' cars, and sensors in each parking spot which can detect the presence and identity of a vehicle. This allows a central computer to gather statistics on parking lot usage and to enforce permit-only parking.

Currently parking enforcement is done either by manual inspection of cars for decals, by permit-enforced gating, or by license plate recognition systems. There are also parking systems which use distributed sensor networks to measure capacity and to provide digital signage accordingly (Smart Parking Limited, 2020). This system is very useful and advanced, but is not capable of authenticating users and reporting unauthorized vehicles in specific spots. E-ZPass is a popular electronic road toll collection system which uses active RFID transponders mounted in users' vehicles to identify them as they pass through the toll plaza. In 2019, there were nearly 42 million active transponders which made 3.7 billion transactions (E-ZPass Group, 2020). This technology is effective for vehicle identification, but not for detecting the location of a vehicle, and as such does not have an application in parking lot management. The most common vehicle presence detection method is the inductive-loop sensor, which uses a coil of wire in the pavement to sense a change in inductance due to conductive metals in the vehicle above (Klein, 2006). These systems are all limited in their capabilities for either connectedness or ability to identify vehicles. Our project differs from these existing technologies by using Bluetooth Low Energy (BTLE) technology to identify every vehicle in each parking spot in a lot or garage, to

track occupancy of that garage, and to authenticate whether vehicles are permitted to park there. This provides much more information than existing systems and makes detection of parking permit violators far easier and more automated than manual verification.

There are essentially two parts to the system: one is the sensing device beside the parking spot, and the other is the Bluetooth beacon mounted on the user's vehicle. The sensing device is polled at regular intervals by the controlling computer, this prompts the oscillator to power on and begin to oscillate. If the spot is empty, then the oscillator will output a known frequency determined by the values of the components in the circuit. The sensing device will report this to the computer and then power off until it is polled again. However, if there is a vehicle or another very large metal object in the parking spot, then the properties of one component, the inductor, will change and the oscillator will output a frequency different from the baseline value. If a certain threshold deviation is met, then the sensing device will begin to scan for Bluetooth beacon signals. When it finds one, it will read the identifier unique to that beacon and relay it back to the computer. The computer checks this Bluetooth address against the authorized addresses for that particular spot; if the address is in the database, then the time and Bluetooth ID are logged. If the address is not in the database, then a warning message is thrown to the administrator detailing which spot is occupied.

Because of the ubiquitous nature of automobiles and the necessity to park them, parking technologies affects a wide array of people in all reaches of society including tourists (Snider et al., 2015), elderly drivers (Douissembekov et al., 2014), the physically handicapped (Lu et al., 2014), retail consumers and vendors (Robertson, 2007), college students (Sultana, 2015), electric vehicle drivers (Bonges & Lusk, 2016), and the environmentally conscious (Rushton, 2001; Chester et al., 2011; Davis et al., 2010). Entities with greater influence and capitalist incentives typically have enormous influence over parking policy and design and stand to reap the greatest rewards. The parking industry in the US yielded $10.5 billion in revenue in 2019 (Masters, 2020), so there are companies with major financial interests at play who have little incentive to address problems such as environmentally harmful runoff that don't directly affect them or their profit margin. Companies lack motivation to design parking lots for future technologies such as electric vehicles (Bonges & Lusk, 2016) and self-driving automobiles (Nourinejad et al., 2018) and as such they inhibit adoption and dull the potential of these nascent technologies. The environmental cost of inefficient parking is a bill paid by society at large, even people who don't drive or use parking lots. The infrastructure supporting parking as well as the physical lots themselves cause emissions in their construction and maintenance (Chester et al., 2011; Davis et al., 2010), create impermeable land which causes runoff and erosion (Rushton, 2001), and cause microclimates and atmospheric warming due to heat absorption (Asaeda et al., 1996). Parking lots often fall under public jurisdiction and governments issue standards for parking lot characteristics such as dimensions and signage (Urban Land Institute & National Parking Association, 2000) in order to protect drivers and other groups. However, municipalities also have financial interests in supplying parking; both the location and availability of public parking influence consumer spending and satisfaction (Robertson, 2007). Even a falsely perceived lack of available parking can change driver's level of satisfaction (Snider et al., 2015). Conversely, oversupplied parking results in inefficient land use which negatively impacts revenue and lowers

property values (Davis et al., 2010) so businesses and cities often have to choose between a solution which can support the annual flood of holiday shoppers or one that uses valuable land more efficiently. It is also important to understand why drivers choose certain parking spots over others; the culprit is almost always convenience. Improper enforcement and lack of regulation for designated parking spaces allow drivers to park in choice spaces reserved for qualified drivers or vehicles; this negatively affects groups such as the elderly or handicapped (Lu et al., 2014), and owners of electric cars (Bonges & Lusk, 2016) and energy efficient compact vehicles. I will use Bijker's theory on the Social Construction of Technology as a framework to analyze the multifaceted lattice of interactions that occur between groups of people and parking technologies. In their theory, Bijker and Pinch (1984) posit that the phenomenon of interpretative flexibility, which asserts that different groups of people construct different interpretations and meanings for any given technology, facilitates the existence of various problems unique to each group. It is important to consider each of these relevant social groups and to describe their values and the factors which affect their agency with respect to the technology being considered. Once these group have been identified, their problems with the technology that arise can be investigated. These problems and their respective solutions are often in conflict with those of another group and so 'stabilization,' as Bijker calls it, must occur in order to appease a majority of the social groups (Bijker & Pinch, 1984).

Building upon this framework, I will seek to identify how parking lots as a technology affect various relevant groups and what problems arise from these groups' differing characteristics and values. For example, elderly drivers and drivers with injuries or disabilities face the unique problem of diminished sensorimotor skills and physical limitations which make parking more difficult for them (Douissembekov et al., 2014). I will then examine the design principles and considerations that have become normalized by the process of stabilization and which placate not simply the majority groups, but the groups with the greatest agency or influence. Additionally, I will evaluate the problems that are not addressed by parking lot design or regulation. For elderly and handicapped drivers, the codifying of convenient handicapped-only parking spaces is a solution to one of the major problems faced by this group. Finally, I will discuss how parking technologies fit into the larger sociocultural landscape of the United States, and seek to answer my research question: what sociocultural values are reflected in the design and administration of parking lots and how can value-based parking design benefit society? Analyzing the powerful social and political forces at work behind parking design and management will allow me to gain insight into the values behind the decisions made by architects, engineers, and businesspeople as they design, construct, and regulate parking technologies in the United States. Such insight could inform the next generation of designers to meet users' needs as they adapt and create parking technologies according to the changing sociotechnical climate.

Conclusion

My technical deliverable is a parking management and monitoring system which uses a sensing device comprised of an inductive sensor to detect vehicles' presence and a Bluetooth transceiver which will communicate with a Bluetooth beacon mounted to a user's car to identify

and authenticate the car. The hardware development and testing should be complete by mid-November and the software development and integration should be complete by late November; overall I hope to have the technical project complete and functional by December 2, 2020. I aim to have my thesis, in which I will seek to find how parking lot design reflects social values using the theory of Social Construction of Technology and how these values can be used to improve parking systems, complete by May 2021.

The technical and STS aspects of my Capstone project together aim to better society by reducing the various harms that come from uninformed parking design: environmental, social, and economic. The STS component will analyze existing groups of people and how their needs interact with parking lot design and provide insight into the existing social factors affecting parking design so that future designers and parking administrators will be better informed to make decisions that more effectively address the needs of all affected parties. The technical component will provide a means for improving the efficiency of existing parking lots by gathering more information about user behavior in parking lots and by streamlining the parking enforcement process so that the environmental, social, and economic harms which result from sprawling mismanaged parking lots can be minimized.

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