Role of Social Context in Technological Advancement

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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

Dense urban areas are often met with traffic congestion and seemingly scarce parking options. In the United States, the population is estimated to increase by 70 million by 2060 (Vespa, Medina, Armstrong 2018). With an increase in population, research has indicated a parallel increase in urbanization (Cilluffo, Ruiz 2019). The urban areas will face immense infrastructure issues if the problem remains unsolved. A solution to both traffic congestion and parking scarcity is implementing a smart parking system. Smart parking is a vehicle parking system that helps drivers find a vacant spot. When a driver is able to find a parking spot faster, it mitigates the need to circle around the area to find a parking spot, thereby reducing traffic congestion in that area. Smart parking systems can have varying design implementations depending on city requirements and local infrastructure.

The parking industry is worth over $100 billion annually in the United States (Chatterjee 2019). The smart parking industry is rapidly growing and is projected to increase the worth of the parking industry. The United States is a country that runs by cars and has a rich historical culture behind it. Investing time to research the design and implementation of smart parking is relevant.

Where2Park is a smart parking capstone project that is aimed to be released in Charlottesville, Virginia. Charlottesville houses the University of Virginia and all its components (i.e., UVAHealth, UVAResearch Park, etc.) as well as long term residents unaffiliated with UVA. Where2Park is a battery-powered Internet of Things (IoT) project aimed for deployment in parking garages. It relies on a series of sensor nodes embedded in the concrete beneath parking spots. The network was designed to interface with a centralized application that features

a map of the parking spaces that indicates their availability and updates in real time. In theory, a system such as Where2Park will reduce traffic congestion and increase parking availability. However, there are concerns associated with this technology. The sensor itself would have to be embedded into the concrete and parallel to the parking spot, or alternatively encased in a hard resin at the center of the parking spot. There would have to be significant labor and resources used to make this change to existing parking locations. The cost of this project is another concern for implementation. The University has an endowment of $9.9 billion dollars and has a history of infrastructure initiatives. In stark contrast to the University hub, 24.1% of unaffiliated Charlottesville residents live under the poverty line. While the University may have sufficient funds for the project, the greater Charlottesville area may not.

Social acceptance of a new parking system is another concern for the project implementation. Many implementations of smart parking systems involve payment for parking. While traffic congestion and parking are issues that need solutions, a solution that involves added costs to users will be met with resistance. In addition, smart parking may introduce new cultural difficulties that the infrastructure may not be able to solve. For example, smart parking may influence residents to take public transportation instead of driving. Added costs may price out residents, which will cause public dissatisfaction.

Using the smart parking Where2Park project as the technology being discussed, the focus of this thesis is: how does social acceptance, context and design implementations impact the value and progress of technological advancements?

## Literature Review

Smart parking systems take a variety of different implementations and have different impacts on societies. Several scholarly sources have investigated the social impact and application of smart parking. Smart parking data encompasses social impacts, changes in public infrastructure and changes in transportation behavior. The following analyses focus on the roles of social context, design implementation and social acceptance on smart parking.

Research done by Amalendu Chatterjee raises social issues with the implementation of smart parking. As stated in the research, smart parking is more focused on city business centers, and has “vendor specific products that have no interface for connectivity”. There is a “monopoly attitude and reluctance overhaul due to political financial influence” (Chatterjee 2019). This means that developers who created the product are in charge for future development and adhere to political influences moving forward. Because smart parking focuses on city business centers, it has a more heightened focus on urban centers. Any addition to urban development, heightens the disparity between rural and urban infrastructure. However, there are benefits to having a smart parking system. One is that it prevents unnecessary city land development for parking spaces. If the smart parking system can tell users which spots are free, it will enable more spots to be used and lessen the need for more spaces. Additionally, more efficient parking that increases the uses of these spaces increases parking revenue. Historically, parking has been operated through a legacy of outdated technology and regulations. Having a smart parking system enables there to be more environmentally friendly monitoring systems and user-friendly systems. The benefits and disadvantages of having a smart parking system is inevitably dependent on social acceptance and the level of development of surrounding infrastructure

Researcher Kontokosta and Hong raise social issues with the context of smart cities. Much of the governance and decision-making in smart cities and smart parking are data driven (Kontokosta, Hong 2020). Even though the intention is to improve efficiency and collect data holistically, there is an issue of bias in the collection methods. In the data collection methods, there is a lack of understanding and or omission of social equity. A popular design implementation of smart parking is charging for the use of a spot. Certain areas where there is noncompliance with payment may have more attention than others if the residents of those areas are predominantly minorities. It exacerbates the social issue of regional bias and bias that the monitoring party may have.

The study on the implications of changing an existing system to a smart parking system introduced more aspects to the implementation of smart parking. When the system is changed and there is a cost associated with parking, there are new costs that need to be explored. For example, there are meter maintenance costs, networking assets operating costs, licensing fees and telecommunications fee, credit/debit transactions fee and revenue collection fees (Dey, Dock, Patterson 2015). If there is not a payment associated with parking, there are still maintenance costs and networking costs. The study takes a look into the District of Columbia when they introduced a new smart park system and notes the consumer satisfaction rates. Initially, the new system caused frustration among consumers and the city noted many broken meters. The District Department of Transportation noted that the Chinatown area that was the location of the smart park system had a 55% positive experience with service in 2009, the year it was implemented.

A study done by Dr. Ngo and Dr. Krishnamurthy was on the effects of demand-responsive parking on transit usage and congestion. The evidence that was presented was from

the smart parking pilot program, SFPark in San Francisco, California (Ngo, Krishnamurthy 2017). The SFPark program involved a parking meter at public parking spots all across the city. The meters included a sensor that was able to detect the presence and absence of a vehicle. The local government was then able to price fix the meters based on which times the spots had a high occupancy rate. The aim of this program was to decrease traffic congestion and ensure that all parking spots were utilized. The research done showed that the program did in fact decrease traffic congestion and increased parking availability. However, on times and days that the parking rates were high, the usage of public transportation increased. It is important to note however, larger cities have a better-defined public transportation infrastructure in place.

In small cities like Charlottesville, public transportation is primarily social, whereas in larger cities like San Francisco, it is the vitality of the city (Vuchic 2007). In a smaller city like Charlottesville, if a demand-based pricing system was a design implementation of the smart parking system, more people would opt to use public transportation. For residents that live paycheck to paycheck, the price of parking may deter them from driving. Public transportation in small cities serve people who don't have cars, do not drive or do not want to drive (Vuchic 2007). With a large increase in users, the public transportation infrastructure would have major functionality issues. With more users, current residents who rely on public transportation for their jobs would have a harder time to get to their workplaces. It is also worthwhile to note that the size of cities can correlate to how developed the public transportation infrastructure is. In larger cities, the size of the population heightens the issue of traffic congestion and parking space limitations. In a small city like Charlottesville, it may be less of an issue comparatively.

Smart parking is an example of technologically advanced infrastructure featured in smart cities. A smart city is a model that aims to improve the living conditions and quality of life of

residents. Researchers Vasuanunchita, Vongmanee and Rattanawong raise important concerns over technological advancements. In an effort to advance technologically, the researchers state that the smart city model neglects the immediate and more pervasive needs of society (Vasuanunchita, Vongmanee and Rattanawong 2018). Many cities face homelessness, poverty and a range of other humanitarian issues. Decision makers need to consider the opportunity costs of investing in smart cities to ensure that these investments don't come at the expense of disadvantaged residents.

When creating a product that is going to be designed for public use, the product should be up to safety standards. The NEMA safety standard uses various grades of electrical enclosures typically in industrial applications. Each has ratings on hazardous parts and additional type-dependent designated environmental conditions (NEMA, n.d). In addition to safety standards, IEEE standards have been developed to have green and clean technologies to protect and improve the quality of the environment and the earth. The application to smart parking is how the sensors are created and whether or not they require maintenance (IEEE, n.d).

Bosch is a company that has created a parking sensor quite similar to Where2Park. The difference is that Where2Park uses a launchpad to create a mesh network rather than a star network. A launchpad is a hardware device that allows connectivity interfaces between low level hardware and software. A mesh network involves all aspects of the system to be completely connected and a star network involves connections to one hub. A star network is generally more cost effective and thus the sensor is more marketable. However, data from the singular hub is accessible by Bosch and is reliant on Bosch to allow functionality on a daily basis. This service of constant monitoring is expensive to sustain (Bosch, n.d.). While considering that Bosch is a Company based on technological innovation, they have the resources to invest in projects such as

smart parking. The social context of this sensor is broadened over a global audience and is viewed as a general advancement. Bosch has yet to implement any of its sensors in the United States and has not yet had to question the societal acceptance to this technology.

The first source authored by Amalendu Chatterjee confirms that technological advancements depend on social context. The place in which the technology is discussed needs to have proper societal contexts in order to be beneficial. Kontokosta and Hong highlight in their paper that technology applied without context has harmful biases associated and can incur social injustices. It is necessary to understand all aspects of technology to fully understand the scope of its impact.

**STS Frameworks**

An appropriate framework for discussion is the distinction between appropriate technology or advanced technology. The distinction between the two being that a technology is appropriate to the setting or if it is too advanced in the setting and somewhat out of place. This is a concern when considering the Charlottesville community as a whole. The Charlottesville community can be divided into affluent residents of the community, impoverished residents and UVA. The greater Charlottesville area would consider smart parking as advanced technology because there are other important issues that need to be considered first. Public welfare programs, road development and etc. are issues that can take precedence. With these prominent issues, it is considered advanced technology. However, when we consider the parking sensor in the UVA circle, it can be considered appropriate. Charlottesville's wealthier residents might consider this an appropriate technology because there is less of a need for social welfare and infrastructure in their day to day lives. Another relevant subgroup are the residents dependent on

tourism, as Charlottesville is widely known to be a popular tourist destination. An added technology would serve to enhance the tourist experience and reduce infamous parking barriers. To Charlottesville residents reliant on tourism, this feature would fit in well with Charlottesville's reputation. Finally, the other important subgroup is UVA students, many of whom come from urban backgrounds. To many students, limited parking is a source of frustration. Additionally, a large majority of students have positive views on the integration of technology into their daily lives.

Though the levels of appropriateness differ among different groups in Charlottesville, it is likely that there won't be a sufficient level of social acceptance. The use of public funding going towards a technology that does not immediately benefit the social welfare of its disadvantaged residents will create a larger divide in social equity. In light of the current pandemic, nonessential spending such as technological advancements can be seen as wasteful, disrespectful and blind to the heightened needs of Charlottesville residents whose financial situations have worsened. To those residents, investments made in welfare and infrastructure will be considered money better spent. The moral question would be is it appropriate to keep building on the UVA circle without considering the needs of the greater Charlottesville area.

This moral question can be further discussed using the political-social-cultural roots of engineering ethics. When considering the University's mission to provide a wealth of innovation and knowledge to its students, impressive technology will undoubtedly be produced. However, there is a substantial difference in technological advancement between Charlottesville and UVA. The outcome of only considering the scientific background that the Engineering department has, then the parking sensor would most definitely be allowed on UVA parking spots. However, considering the advanced technology in Charlottesville, the parking sensor might be pushed back

on the list of projects the city would like to take on. The question now is a dilemma between pushing the scientific boundaries and helping the city develop along with the institution.

Smart parking is unique in that it can affect many stakeholders while also appearing simple. A few social groups that follow the SCOT framework are the local government and the general public. The local government can have a wish to have more of the public to use the public transportation to develop the infrastructure of the city. Based on this information, developers can add garage/spot price information and the ability to check the predictions for spots at a given time. This may allow the user to decide if public transportation is a better alternative. This is an example of a desired human action and technology that is shaped based on it.

A social group to consider is the general public. Depending on public sentiment and social context, a smart parking system may seem superfluous. Almost one fourth of the Charlottesville  population live under the federal poverty line. Current initiatives targeted at these residents include public transportation improvements, public infrastructure, security and employment. However, Charlottesville has several groups of people that would consider smart parking as appropriate. Social acceptance and context would suggest that smart parking is a technology that would have to be reconsidered in Charlottesville.

Another social group are the Hardware Companies. Many companies, such as Bosch, create their own sensors. To create such hardware, they usually follow a list of specifications given by a third party without social context. In the case of an in-house invention, companies have to follow a set of engineering standards. For example, they must follow NEMA, IEEE Environmental Engineering standards and Electronic Code of Federal Regulations. These

standards regulate what a company can do with user data and make sure that no user gets hurt. In the event that a third party sends in a list of requirements, the company builds upon it accordingly, keeping the standards in mind.

An important group to note when considering the widespread implementation of Where2Park, is the private parking owners. Realistically, not all parking is publicly owned. Therefore, implementing a smart parking system would be hindered by any reluctance by this group, especially if they are expected to contribute financially. Solutions that exclude parking garage owners limit the adoption rates, which would exacerbate disparities between public and privately owned spaces.

Another relevant framework to consider is Mediation Theory. Mediation Theory is the investigative nature of the mediating role of technologies. In other words, it is the study of the relationship between humans and technologies. Smart parking aims to show the user which parking spots are taken and improve traffic congestion. Analyzing the impact of smart parking on human behavior is also the focus of technical mediation (Voordijk, Dorrestijn 2021). Smart parking has extensive information systems that collect and organize digital information (Voordijk, Dorrestijn 2021). When the system is implemented, there will exist a new expert only system for decision support and management. Knowledge about smart parking and how it works will be more accessible to those with technical backgrounds. This excludes the general public from discussion about design implementation and further uses. The perception of technology in smart parking initiatives is dependent on the integration of systems, infrastructures and services, all mediated through enabling technologies (Voordijk, Dorrestijn 2021). Technology is not neutral or passive. The social context and acceptance influence the course of technological advancements.

## Method

Data collection methods included a combination of field studies and casual conversation. Due to the COVID-19 pandemic, the interview size was not large. In a normal scenario, there should be interviews done with local government leaders, construction companies, construction employees, local business owners, UVA personnel and a larger size of students and residents. The interviewees consist of 2 UVA students and 2 Charlottesville residents. The interview questions asked about the impact smart parking could have in the area and what the benefits could be. The general consensus about the parking app is that it is a step to achieving a smart city. The opinion was that it would be nice to have, but if resources were put elsewhere for the current moment, it would have better uses. This can be due to the fact that Charlottesville residents have priorities to invigorating their communities. A resident mentioned that having an improvement on social welfare and public transportation would be more beneficial. These conversations were humbling and concluded that smart parking is a step that may have to come later in time but is something residents  view as a luxury. nice to have, certainly, but too costly to be realistic anytime soon.

While observing parking infrastructure in a vehicle around Charlottesville multiple times to observe the spaces for potential design implementations, the conclusion is that the city has many different suburban sections and rural sections. While surveying the central downtown area, lack of sufficient parking is apparent. There are a few spots for the cars to gain access to Downtown. Many of the inaccessible off-street spots contain parallel parking spots and are mostly occupied by local business vehicles. The main parking garage a few minutes from downtown is where most people park. In terms of design implementation, the parking garage has sufficient structures in place to support the current parking sensor. The parking garage has

concrete headers that can be broken and have the sensors embedded within. The garage is also a paid service, this would allow immediate deployment as the technology does not yet include payment options. Another central location that was observed was the Barracks Shopping Center. It has mass parking availability. However, the spots are close to each other and small. It would be difficult to embed the sensor into the concrete as one spot is immediate to another. The current design implementation would have to be made relevant to the location. The final location that was observed was the UVA campus. Universities are notorious for parking inaccessibility; UVA is no exception. It is almost impossible to find parking spots on the UVA campus. The spots are scattered all around the campus. Many of the spots are off street and are immediate to other parking spots. The University also has a number of garages for employees, visitors and students. The design implementations for the University campus vary on the ease of embedding the sensor in concrete. Another important factor with design implementation is that parking spots vary in size due to location and have different shapes. The common denominator is that each spot is at least large enough for a compact sedan.

**Data Analysis**

The interviews with Charlottesville residents and UVA students provided important data on how to contextualize smart parking in Charlottesville.

| Survey Objectives | Conclusions |
|---|---|
| Understand whether smart parking is beneficial and applicable | It is applicable and beneficial to groups of people who feel that traffic congestion is a main concern |
| Understand design implementation drawbacks to the system | It has the potential to be used against the consumer when considering isolated spots and payment |

Figure 1: Survey results summary

UVA students mentioned that it would be beneficial to know where spots are within the campus and would reduce the traffic congestion around popular college areas. Charlottesville residents mentioned that most people would rather park in a parking garage because the spots that are in the open and parallel are most susceptible to car theft and robbery and garages have sufficient parking available. The resident feels that traffic congestion is not a concern with parking garages since that is where most residents park anyway. They also mentioned that in high-crime areas, it would not be beneficial to know which cars are not surrounded by other cars. When analyzing the responses of the interviews, it is clear to see that there are socially contextual differences between the UVA circle and the greater Charlottesville area.

When analyzing the overall parking spots around the Charlottesville area, many spots would require different design choices. Many of the off-street parking are narrow and are one-way streets. Where2Park involves a sensor being embedded into concrete. Many of the off-street spots are simply not able to have work done on them without significant labor and expense. To properly implement a smart park system, the sensor would have to be able to be embedded in meters or lay on the spots directly. The Bosch sensor mentioned in the literature review has the functionality to be placed in the middle of the spot and does not need to be embedded into the

concrete. However, these options include a completely different sensor design and have a significant increase in expenses. To detect the car in the respective spot, a specific type of detector must be used. If an ultrasonic sensor is used, soiling could result in the misidentification of a parked car. To prevent common deviations, a metal detector is the best option. The fruition of technological advances is directly impacted by expenses and context.

Without context, technologies meant for advancement can be harmful. The data in the literature review add to the claim that context is important when designing and developing technology. It also suggests that social acceptance impacts the connotation of the technology and impacts its further development. If smart parking is met with resistance, there is less likely to be more development on its technologies. For example, data from the literature review, suggests that a design choice to include payments was met with consumer dissatisfaction and thus had a halt in smart parking development.

The data also suggests that implementing a smart parking system where it is appropriate, the UVA hub, would create a larger disparity in social equity between the different types of residents in Charlottesville. In the literature review, the study done by Chatterjee aligns with the claim that social equity will be impacted when there is an issue of advancing in a bubble. The smart parking system increases the disparity between rural and urban development. With the scale of smart parking, there can be other more pressing issues solved. Research done by Kontokosta and Hong also suggest that when developing new technologies, there is a lack of understanding and omission of social context. The technology being developed needs to have relevance in order for it to be beneficial. When analyzing that statement further, if the project were to take place, hundreds of spots would have to be redone with a sensor embedded into the concrete. There would also be significant monitoring costs. In order for the investment into smart

parking, Charlottesville may need to make it paid to recoup in investments to justify not using funding on other issues such as welfare. Considering the local economy of Charlottesville is still recovering from the ongoing pandemic, smart parking would not be feasible, even if UVA were to help financially.

**Discussion**

Social context and social acceptance are important factors in the development of technology. They are often forgotten as a criterion for innovation. Parking sensors were developed for ease of parking and to decrease traffic congestion. With certain design implementations, such as a payment system, there is a shift in social acceptance. It is interesting to note that while an overall idea may have social acceptance, the design implementations and context impact the connotation. Using smart parking as an example, the idea is often met with excitement but when put into the local context, it can have a negative sentiment.

Smart parking is a component to a smart city. There are smart cities growing in the United States as urbanization increases. It is important to note that the rate of urbanization is not similar all across the country (Cilluffo, Ruiz 2019). The divide between urban and rural impact the decisions made regarding technological advancements. The frameworks discuss in detail the potentials of technological advancement in different scenarios. An urban city will most likely have the support, resources, and time to dedicate to technological advancements as it may be a potential solution to a relevant issue. While continuing to use smart parking as an example, large cities have large populations, increasing the chances that a resident will own a vehicle. While residents move around in the city, parking becomes a necessity. While trying to find a parking spot, residents may circle around the area and thus increase the traffic congestion in that area.

With a rural location or even a less populated city, traffic congestion is less of an issue. It still exists, other issues take precedence.

The difference in urgency impacts the likelihood of the smart parking system or other similar technological advances. It is important to note however, that even though an advancement of technology is not feasible at the current moment, innovation and design can still occur. Using social context and acceptance, innovative ideas can turn into technological advancements. An advancement that wasn't feasible before can definitely be feasible in the future.

**Conclusion**

Social acceptance, context and design implementations determine the timeline of appropriate technological advancements. Research done in literature review and frameworks conclude that context should be considered as a main design requirement of an applicable technological advancement. The smart parking system can be applied to the Charlottesville area, however given the context and social acceptance, it would not be beneficial enough to society to outweigh the opportunity costs. Smart parking is a technological advancement that few cities have the luxury of considering. Having context as a design factor can invite innovation for applicable solutions and designs.

Where2Park is an Internet of Things smart solution to facilitate parking. When a parking space is vacated or occupied, a sensor node will send a signal to a central application that displays a map of the parking lot, indicating which spots are empty and which are full. It was aimed to be released in the Charlottesville area. The design implementations had room for payment options, however it was not yet tested. Even though the design implementation has a

more user-friendly impact, the overall system may not. In research, data collection and analysis, this technological advancement does not meet the needed positive social acceptance or appropriate context.

Applying concepts such as social acceptance and context allows a scientist to critically innovate with a group in mind. The benefits from having technological advancements that are socially accepted and within context include more awareness of innovation, an increase in the quality of life and the potential for more funding for future projects. A technological advancement is beneficial only when it meets the requirements of social acceptance and has relevant context.

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