A Comparison Study of Smart Parking Infrastructure Between Shenzhen and Charlottesville

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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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STS Thesis

Introduction: Fable of Tomorrow

In a distant, bustling city, the sound of an automated robot could be heard from a nearby parking garage. Having received the proper QR code and password, the robot deftly navigated itself to an Audi located on the sixth floor. The Audi sat on top of a generous 30-degree angle diagonal platform. Extending itself around and below the Audi, it gently loads the car onto itself and brings it down to the owner. Not even two minutes had passed before the owner drove off with his Audi.

Soon after, the robot received an instruction to park a car that was just arriving. Having already reserved and paid for a parking spot through an app, the owner simply parks in front of the robot, turns off his car, and walks away while the robot took care of placing the car on its designated diagonal platform. The convenience and safety that the parking garage provided immensely boosted its popularity and demand, and all spots were booked well in advance. The diagonal parking allowed the parking garage to have a larger capacity. And the automated parking guaranteed that the cars would be protected from any accidents or thieves.

These visions are quickly becoming a reality in advanced smart cities around the world. Yet different cities have found varying levels of success while using the same implementations, causing some parking garages to thrive and some to not. The root cause of the differences is a very complicated problem due to the numerous factors that tie into the parking problem. Whether it's the city's population size or the city's use of private transportation, it is important to analyze what factors will impact the implementation of a smart parking system.

Introduction: Research Questions

Parking within a city is often overlooked for the bigger and more global issues, such as pollution and energy, that plague a city. However, parking is a major problem in nearly every major city due to increasing vehicle ownership and lack of efficient parking solutions. Free parking spots are quickly taken when they become available and often have time limits attached to them. Paid parking, including parking meters and parking garages, quickly racks up fees and many people are reluctant to use them because of it. It is impossible to know when parking spots will be available and how much it will cost if it requires payment. The current parking situation in Charlottesville deters many local community members from even going to downtown Charlottesville. "'The cost and hassle of parking is one thing that prevents me from going to the [Downtown] Mall,' said Ashleigh Crocker, who said she lives too far away to walk or use transit" (Tubbs, 2015).

Smart parking is often a major pillar in the development of smart cities because it supports transportation and mobility around a city. Parking promotes community engagement by allowing parking to become much more efficient. While this may suggest that smart parking is a simple solution to any urban parking problems, there are many different ways that smart parking could surface itself. For example, smart parking could mean drastic infrastructure changes with how parking garages and on-street parking is handled, or it could simply mean a controlled system of managing the prices of parking spots to fulfill the city's goal, such as reducing overall car emissions while minimizing the impact on car owners. With smart parking, one of the many barriers to community engagement will be removed while reducing unnecessary stress and allowing for residents to waste less time looking for parking. Removing this barrier allows for the Charlottesville economy to benefit as well, as local residents are reluctant to travel or work in

areas with contested parking due to the inconvenience and time consumption. "'It could help us with employment downtown,' Benford said. 'People don't take jobs downtown because there's a parking fee they might have to pay'" (Tubbs, 2015). Many downtown businesses are concerned over increases in parking fees as that will deter potential customers. Charlottesville currently has very limited infrastructure in place to support parking. Mostly all that Charlottesville currently does is maintain a few parking garages and patrol street parking.

On the other side of the world, Shenzhen, a large Chinese city, has already implemented various smart parking elements to large degrees of success. "When addressing parking in Chinese cities the first step is to manage and price it right to ensure drivers are able to find a parking spot. Dealing with this challenge which includes higher on-street parking price, getting rid of free parking in central locations and better enforcement of illegal parking can help open up more parking spaces" (How China is Solving, n.d.). Shenzhen is aiming to target their parking problems with multiple angles and solutions in order to create a structured, meticulous plan to ensure that their implementation will be successful. "The revenue will be collected through a branch of the municipal government to avoid the loss in revenue that was documented in Beijing and Shanghai where fee collection was contracted to an outside company. The government is working on making it easy to pay for parking through popular apps such as WeChat and Alipay and connecting the parking system with people's mobile phones to give them notice before time expires" (How China is Solving, n.d.). Shenzhen has shown that it is learning and adapting to previous smart city implementations, including itself, in order to become a more efficient and successful smart parking model.

The focus of the research topic is a comparative study between Shenzhen and Charlottesville; it is important to look outward to other solutions that have already been

implemented in order to apply it to Charlottesville. The smart parking implementations and social constructs in Shenzhen should be analyzed and understood in order to properly apply them to Charlottesville's unique circumstances successfully. China has already been experiencing increasing demand for private transportation and already has several models of successful smart parking implementations. This allows us to study the various human and non-human actors within the smart parking network that Shenzhen has utilized and apply it to Charlottesville's current parking crisis.

Literature Review

Private car ownership in China is constantly on the rise, and China has been continuously running into problems with finding enough space to all of the new cars. As part of the solution, China developed several parking applications in attempt to appease the problem. However, these smart technologies may bring significant benefits, but they also bring notable drawbacks with them, including information insecurity, privacy leakage, information islands, and digital divides (Ma, Lam, & Leung, 2018). This demonstrates the social construction of technology in that Chinese citizens are shaping where their technology goes. The increased demand for parking lead to the development and usage of smart parking.

One of the challenges of developing smarter parking is the evolving transportation methods available. Stakeholders may be hesitant to invest in parking for just cars because in ten or twenty years, cars may be irrelevant or completely autonomous. Zuev highlights the problem of other transportation options competing with cars for both the road and parking. "The situation with E2Ws in China and their role in low-carbon transition is still not very clear but the relationship between the ever-increasing number of cars and e-bikes in Chinese urban and

suburban space is becoming more and more conflictual on the road, in the parking lots and in the family space, where everyday mobility decisions have to be made" (Zuev, 2018).

The increase in demand for parking has led to significant increases in the technological capabilities of parking garages. In Nanjing, the robotic parking garage implements Internet of Things technology to automate many of the parking garage functions, including parking and storing vehicles. "An automated platform then lifts the vehicle and moves it to an available diagonal port. Diagonal carports save space and are more efficient compared to vertical/horizontal/perpendicular ports. Robotically maneuvering a vehicle is also easier in diagonal ports due to the elimination of sharp turns" (Gautam, 2019). Automating the entire parking process reduces the chance of accidents and allows drivers to save time by simply dropping their vehicle off. The automated parking process only takes a few minutes and has measures in place to reduce theft, damage, and vandalism. The parking garage is capable of holding 60% more cars, which is a significant amount considering the large population and density of Nanjing.

In a different take on making parking garages more efficient, the Beijing Airport started a trial to use intelligent robots that are responsible for handling the parking process for drivers. Similar to Nanjing, almost the entire process is automated. "The robots can carry up to 3.5 metric tons… produce zero emissions and can work for up to six hours on a single charge, before automatically making their way to their charging station. Sensors enable the robots to dodge obstacles, including other robots and cars, which reduces the risk of cars getting dents or scratches from parking lot mishaps" (Chan, 2019). Parking robots handle many of the difficulties that come with parking, and drivers can instantly know whether the parking garage is full or not

thanks to the automatic system in place. To collect the car, the driver can simply scan a parking ticket or enter their plate number and the car will be delivered within a few minutes.

In the bigger picture, the expected integration of autonomous vehicles into cities is further complicating the conversation around parking. Although there are crucial steps in advancing Charlottesville's parking infrastructure, it is important to keep in mind that simply changing the infrastructure is not the only solution. In order to tackle the root of the problem, many other factors will have to be evaluated and analyzed to determine the best way forward. For example, autonomous vehicles are just around the corner, and they may complicate the parking situation even more. "Considering AVs could serve multiple users during the day and therefore remain parked much less than regular cars, or AVs could move back home or to cheaper parking areas designated by the city as less impactful to the overall traffic" (Duarte & Ratti, 2018). This is just one example of how a technological advancement could single handedly affect the parking crisis, and it will remain to be seen what exactly will happen in the future.

STS Framework

The framework used to analyze this research question is the Actor Network Theory (ANT). This theory highlights that there are many actors, both human and non-human entities, that work together to become more than the individual parts by themselves. Within the smart parking system, the human actors are easily identifiable as two groups: the car owners and the government, whether it's the local or federal level. The non-human actors are more difficult to identify; however, the primary non-human actors are the specific parking implementations and social constructs for the area being investigated.

In order to identify the best course of action for implementing a smart parking system in Charlottesville, the Actor Network Theory will be beneficial by studying other smart parking

implementations and determining the factors that allowed their smart parking implementation to be successful. The government is generally responsible for implementing policies that pioneer the smart parking movement within a city. These policies are identified as different smart parking implementations, whether it is a mobile application, efficient use of parking garages, or managing the prices of parking spots within the parking garages and on the street. The interaction of these smart parking implementations with the local social constructs will determine how successful the smart parking design will be among the car owners.

Method

Although China may be implementing these innovative ideas, it is hard to just copy them here in Charlottesville for several reasons. Charlottesville as a whole is significantly smaller than both Nanjing and Beijing, and thus its parking problem is not as big. Also, funding these automated systems would be impossible for a city as small as Charlottesville. However, this does not mean that there are no takeaways from Nanjing's parking garages and Beijing's parking robots. Both of these examples use extensive Internet of Things technologies through the use of sensors and automation. Even something as simple as displaying where the parking spots are available within a parking garage could pay dividends in the form of saving drivers valuable time and unnecessary frustration. Current Charlottesville parking garages have essentially no data collection or usage which would be the first step in moving towards a smarter city. Connecting this information with a smartphone application and displaying the information there, and even having the ability to reserve parking spots in advance through the app would be greatly beneficial.

Data Analysis

The data collected for this research question will be obtained through surveys with Chinese students attending the Graduate School of Shenzhen Tsinghua University over WeChat, a multi-purpose social media application, after receiving approval from the TA and instructor for the course. The survey questions are located in the Appendix. The purpose of these questions is to initially create an outline what private transportation and parking is like in Shenzhen. Then, the following questions aim to identify the smart technologies surrounding parking and what makes them so popular. Due to the difficulty of contacting and getting survey results from the Graduate School of Shenzhen Tsinghua University, only two data points were collected, as shown in the Appendix.

While the two responses differed slightly throughout the survey, their responses shed enough light upon the smart parking design and circumstances within Shenzhen. According to the results of the survey, China has an extensive public transportation system which they greatly encourage over the use of private transportation. However, private transportation is still very widespread and still causes an increase in demand for better parking infrastructure. China also restricts certain populations from using private transportation through various means such as age and certified documents. To aid in the growing parking needs, Shenzhen has implemented various parking mobile applications to cover high demand areas in dense areas. However, use of these parking applications still varies wildly among the users, and those that use the app tend to use it more often, while those that do not use the app tend to never use it. Interestingly enough, it appears as though the specific advanced features of the parking application does not matter too much, as users can just ignore the features that they do not wish to use. Both the mobile

applications and new parking garage designs could both be expanded upon and improved in Shenzhen and China as a whole.

Discussion

The responses from the survey imply that there is still much work to be done to have the optimal smart parking infrastructure in place. In comparison to Charlottesville's population of 47,902 in 2017, Shenzhen's population was 12.53 million in the same year. It is clear that the two cities are on a whole different dimension. Whereas Shenzhen would need a large smart parking infrastructure to make a difference, Charlottesville would, at most, need a single smart parking garage and a basic mobile application. Even without advanced features, Shenzhen does not seem to need any extra incentive to attract users to their smart mobile applications. However, one key difference is that China's mobile applications can easily connect to Alipay or WeChat to promote the use of smart parking and the ease of transactions. In the U.S., it is significantly more complex to pay through an external software or to even promote a new mobile application.

Conclusion

While having a smart parking infrastructure within Charlottesville is a very desirable and exciting idea, it is most likely to be far too difficult to implement. Charlottesville does not have the same kinds of problems that Shenzhen has, such as overpopulation and lack of land. Rather than looking to implement a new technology within Charlottesville, it would be a more feasible solution to expand on current parking infrastructure, including more parking garages and street parking. The traffic and congestion within Charlottesville are not ideal, but investing resources into an untested implementation while there are more concrete options still available would not be wise. The potential benefits from a smart parking application within the city of Charlottesville

will not be as large as it is for a much larger city. After creating a mobile parking application in Shenzhen, it can be easily expanded and utilized in many different areas across Shenzhen. However, in Charlottesville, only the downtown area is often congested with traffic and would not be worth creating an entire parking application for.

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Appendix

Survey Questions:

1. What mode of transportation do you use most often, and why?

2020-03-25 12:23	By my foot or subway. Because it's free and convenient. I can take subway to everywhere in Shenzhen
2020-03-25 12:31	underground, because I am liable to carsickness

2. How popular is private transportation, and is it encouraged or discouraged by the Chinese government?

2020-03-25 12:23	In my opinion, in terms of purchase, everyone with enough money can get cars easily. The government only manages the license plates issuance. But in usage, government encourage us to take more public transportation.
2020-03-25 12:31	Private transportation is very popular in our country and the number of the private cars reaches 226,350,000 by December 1, 2019. It is discouraged by our government because too many private cars may bring some problems such as excessive energy consumption, pollution, traffic congestion.

3. How effective are the other modes of transportation besides private transportation?

2020-03-25 12:23	Very convenient. In china, we have a huge public transportation system, bus or subway, almost i can go everywhere.
2020-03-25 12:31	The other modes of transportation is also very effective. For short trip, subway can avoid the delays caused by traffic jams on road. Buses can do this too for that they have their own specific way. For long trip, planes and high speed rails are much faster and can save people time.

4. Do you think that the current parking infrastructure (parking garages, parking apps, parking spot prices, etc.) in China is sufficient for the current parking demands?

2020-03-25 12:23	In the number of that, i think it's enough. But in the quality of that, it's not enough.
2020-03-25 12:31	The current parking infrastructure in China is not sufficient for the current parking demands. It is very common that it's hard for us to find a parking space when going out.

5. Are there any rules for who gets to use private transportation? If so, what are they?

2020-03-25 12:23	Yes. We have a series of administrative regulation of how you use you private transportation.
2020-03-25 12:31	Yes, there are. First, the purchaser must be at least 18 years civilian. Second, he must provide some licenses and certified documents.

6. Do mobile applications for parking exist?

Yes	2	 100%
No	0	0%

7. If yes to 6: How big of an area do these mobile applications cover? Is it the entire city or only dense areas?

2020-03-25 12:23	On in big cities, in huge park lots, there are some supporting apps for parking.
2020-03-25 12:31	The mobile applications can just cover some specific places.

8. If yes to 6: How commonly are parking applications used by private transportation users?

2020-03-25 12:23	It depends on where you live. If you are living Shenzhen, maybe you use them everyday.
2020-03-25 12:31	Less common

9. If yes to 6: What are some features of the parking applications that you commonly use, and what are some features that you rarely use?

2020-03-25 12:23	The mostly use is paying the fee. Apps all connect with Alipay or WeChat. Sometimes i use the finding the car. I don’t remember those features that i rarely use.
2020-03-25 12:31	I haven't used any parking apps till now.

10. If yes to 6: Is there a certain scenario or time frame in which you will use mobile parking applications? For example, only at night, during rush hour, or on weekends.

2020-03-25 12:23	For example, you go to a super-mall. There is a huge parking lot. When you enter it , you must use your phone to scan something to use apps, it you tell you where to park. And when you leave, you must pay online, because there is nobody charging.
2020-03-25 12:31	Yeah, maybe during rush hours and on weekends.

11. If yes to 6: Overall, do you think the mobile parking applications are useful?

2020-03-25 12:23	Yes.
2020-03-25 12:31	There is no doubt that mobile parking apps are very useful but the current parking apps are limited

12. Do parking garages in China have any smart features that improve their efficiency or capacity?

Yes	1	 50%
No	1	 50%

13. If yes to 12: What are the smart features, and how common are they among parking garages in general?

2020-03-25 12:23	To be honest ,i don’t know. Maybe those can push system more quickly running can call “smart” features.
2020-03-25 12:31	Double-decker parking space or multi-decker parking space. They only exist in developed cities now.

14. What other smart technologies are implemented that directly relate to the parking system?

2020-03-25 12:23	5G must can.
2020-03-25 12:31	Online payment