MAKING THE MOST OF CURB SPACES IN A WORLD OF SHARED AUTONOMOUS VEHICLES: A CASE STUDY OF AUSTIN, TEXAS

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ABSTRACT

With the recent developments of connected and autonomous vehicles (CAVs) as well as technologies in traffic and transportation systems, CAV applications – like shared autonomous vehicle (SAV) systems - will have the ability to radically change the urban grid system and challenge urban planners to repurpose existing public infrastructure. As CAV technology matures and shared autonomous vehicles (SAVs) account for higher proportions of the operating traffic, parking demands are likely to fall greatly in central business district centers. Curbside parking spaces may be given back to pedestrians, repurposed for active transit users, or removed entirely to create additional roadway capacity.

This paper researchess Austin's parking supply and offers case study examples for curb-parking repurposing. The potential implications of SAVs enable more utilitarian uses of curb-parking and offer an empirical study into repurposing this public area, providing municipalities the ability to develop the means to eventually liberate this public land from parked vehicles and repurpose it for a larger community benefit. The supply and demand for these alternative spaces is provided here for developing the decision support system, as well as their physical location, attributes, and pricing regimes. This analysis offers recommendations for future usage of existing curb spaces and ways to ensure curb-parking is ready for SAV-using settings. The suggestions offered here may serve as a model for other cities and may be valuable in long-term city development and planning.

Key Words: Parking Provision, Shared Autonomous Vehicles (SAVs), Connected and Autonomous Vehicles (CAVs), Curb Parking

INTRODUCTION

The rapid urbanization and the desire for the urban lifestyle throughout age-groups have highlighted the need to provide a higher quality of life. Urban residents and their quality of life depend upon thoughtful urban planning and a transportation system to mobilize its citizens. Growing urban populations want streets to serve not only as corridors for the conveyance of people, goods, and services, but often as playgrounds and public spaces. Ideally, city streets are safe, sustainable, resilient, multi-modal, and economically beneficial, all while accommodating travelers. In response to these unprecedented demands, cities around the world are attempting innovative solutions through technology, automation and a shifting emphasis on active transit amenities.

Mobility is a key factor in urban quality of life and connected and autonomous vehicles (CAVs) have the potential to upend our current transportation system. CAVs are predicted to be one of the greatest technological advances in daily traffic service, with a promising future of safer and more convenient transportation (Fagnant and Kockelman 2015, Schoettle and Sivak 2014). CAVs are now within reach and may soon become a daily mode of transport for hundreds of millions of people (Bansal and Kockelman 2016). Many major companies, like Google, Toyota, Nissan, and Audi, are developing and testing their own autonomous vehicle (AV) prototypes (Anderson et al. 2014). Past transport transformations, like Henry Ford's mass-produced Model T, helped shape our modern-day traffic systems. Our existing urban traffic systems are now being called into question, in terms of whether they can optimally support the needs and aspirations of a world increasingly dependent on more automated vehicles and traffic managment systems.

Vehicle ownership costs and the freedom that SAVs offer travelers may lead to rapid adoption of shared autonomous vehicles (SAVs). SAVs, also known as autonomous taxis or aTaxis (Kornhauser et al. 2013), offer short-term, on-demand rentals with self-driving capabilities, enabling members to call up distant SAVs using mobile phone applications, rather than searching for and walking long distances to an available vehicle. SAVs may overcome the limitations of current car-sharing programs, such as vehicle availability, due to their ability to offer door-to-door service as well as effective connectivity to exist transit facilities. Therefore, one might expect the early integration of SAVs to cater to the shift in urban living where vehicle ownership is the most expensive and cumbersome. Martin and Shaheen (2011) estimate that 9 to 13 vehicles may be replaced for every non-automated shared vehicle. Burns et al. (2013) found that in mid-sized urban and suburban settings, each shared vehicle could replace 6.7 privately owned vehicles. Spieser et al. (2014) modeled a fleet of shared self-driving vehicles in Singapore in the absence of any private vehicles, and found that each shared vehicle can replace three privately owned vehicles and serve 12.3 households.

Douglas (2015) uses Kornhauser et al.'s (2013) base model proposal to size a SAV fleet for a 5-mile by 5-mile subset of the New Jersey model and found that at least 550 SAVs would be needed to serve the trip demand with reasonable wait times. The International Transport Forum (2015) applied SAVs to serve Lisbon, Portugal, and found that with ride-sharing enabled, each SAV could be expected to replace approximately 10 privately owned vehicles while inducing about 6% more vehicle-miles travelled (VMT) than the city's baseline. Without ride-sharing in Lisbon, each SAV was expected to replace about 6 privately owned vehicles but deliver 44% more VMT, which could easily gridlock that city. Fagnant and Kockelman's (2014) 10 mi x 10 mi simulations of relatively short trip-making patterns indicated that each SAV may be able to replace 11 conventional, privately owned vehicles, while generating up to 10% more VMT. When the simulation was extended to a 12 mi x 24 mi case study of Austin (Fagnant 2015), with relatively low market penetration (just 1.3% of all person-trips in early test scenarios), each SAV was estimated to be able to replace 9 conventional vehicles while generating about 8% more VMT (due to unoccupied travel. Chen et al. (2016) utilized 2009 NHTS trip distance and time-of-day distributions indicate that fleet size is sensitive to battery recharge time and vehicle range, with each 80-mile range SAEV replacing 3.7 privately owned vehicles and each 200-mile range SAEV replacing 5.5 privately owned vehicles, under Level II (240-volt AC) charging. With Level III 480-volt DC fast-charging infrastructure in place, these ratios rise to 5.4 vehicles for the 80-mile range SAEV and 6.8 vehicles for the 200-mile range SAEV.

This work relates to the investigation of the parking provisions in downtown Austin, which will be shortly followed by the downtown Austin Alliances commissioned study. A basic spatial distribution for the environmental impact analysis of CAVs is postulated. This estimation model builds off additional works mentioned as well as incorporating CAV technologies to repurpose parking amenities and capture the effect on traffic and commuting patterns. In summary, the contributions of this paper include:

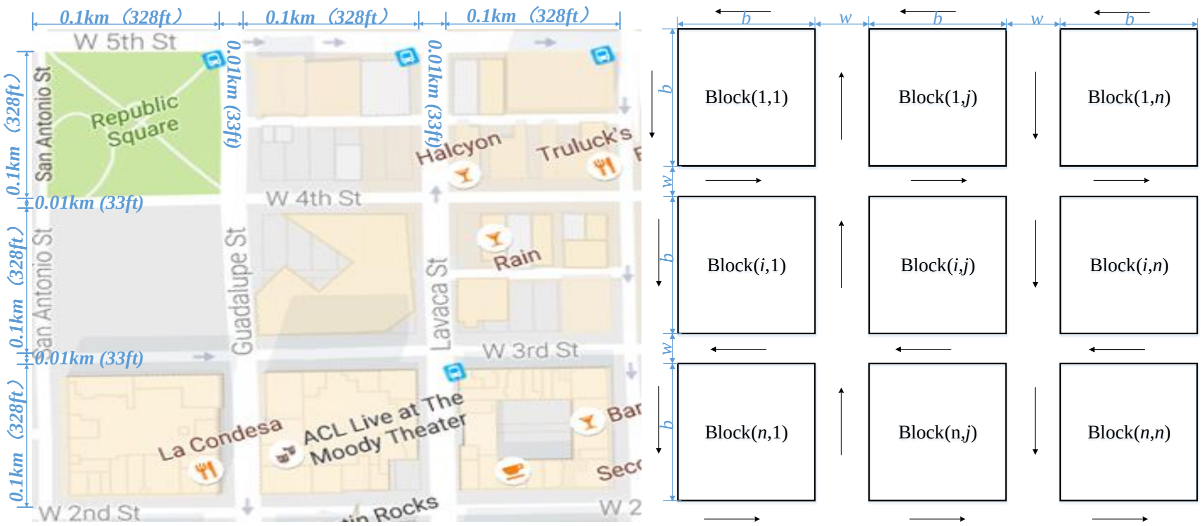
- The first analysis on real-time dynamic sharing of parking spaces in downtown Austin. A basic spatial distribution for an environmental impact analysis of CAVs is formulated within the paper.
- An estimation model, which updates the parking provision to avoid affecting traffic and commute time. The re-configuration of the curb parking provision will greatly impact the already packed traffic in the urban core, which is an inevitable problem during the transition period from private-cars to shared-vehicles.
- Extensive research which validates that re-planning parking spaces improves both comfort and convenience of life downtown through the implementation of SAVs.

The value of curb parking for other utilitarian uses should encourage city officials to begin discussions about how to utilize emerging infrastructure to allow for dynamic changes.

Spatial Model Analysis

The following illustrates a spatially symmetric road network structure of Austin's downtown area, and will highlight the benefits seen as urban environments expand. Thus, essential assumptions of this model are made, such that all transit has enabled CAV technology and all parking is on-street. All trips are the same, and entail driving a fixed distance over downtown streets directly to a destination, followed immediately by having the vehicle park if a vacant parking spot is available and otherwise will search until a vacancy is found. The demand for trips is inversely related to the full trip price, which includes time and capital costs. Downtown corridors and the adjacent parking provisions rely upon adjacent land-uses, street width, and the proportion of the curbside allocated to parking. Vehicular travel and the proportion of vehicles in transit searching for parking makeup a significant proportion of the travelling public in downtown areas when analyzing parking availability and turnover. Within the model, the drop-off and pick-up of citizens from vehicles present the biggest opportunity to improve traffic, as cars cruising for parking greatly slow down traffic. Traffic equilibrium conditions are also affected by policy decisions, including management and design pricing and the designated use of curbside parking.

Spatial symmetry is assumed to simplify the analysis according to the survey of the blocks and road network. There are n×n blocks in the network, numbered as {Block(1,1), Block(1,2), . . . , Block(i,j), . . . , Block(n,n)} and illustrated in Figure 1(b). Blocks are square with sides of length b, streets are of width W, and those blocks are connected to the automobile network by four roadway links. The capacity parking of each block is expressed as the total of the maximum possible number of on-street parking spaces per roadway link. The paper ignores the complications that arise from the indivisibility of lanes.



(a) Investigation of blocks and roads **(b) Geometric model from road network**

FIGURE 1 Geometric model of road network in downtown Austin.

Suppose each Block(i,j) has a capacity of P_{ij} spaces and its parking fee is f_{ij}, and the time horizon is discretized into T time periods, {1, 2, . . . , T}. Then the $f_{ij}(t)$ and $P_{ij}(t)$ represents respectively the dynamic parking fee and the number of effectively occupied spaces in Block(i,j) at time t. Obvisely, $P_{ij}(t) \le P_{ij}$, here, $\forall i \in \{1, 2, . . . , n\}, \forall j \in \{1, 2, . . . , n\}, \forall t \in \{1, 2, . . . , T\}$. If travelers departing from the same origin and using the same block choose the same roadway route, then, Figure 1(a) can be transformed into the graph shown in Figure 2.

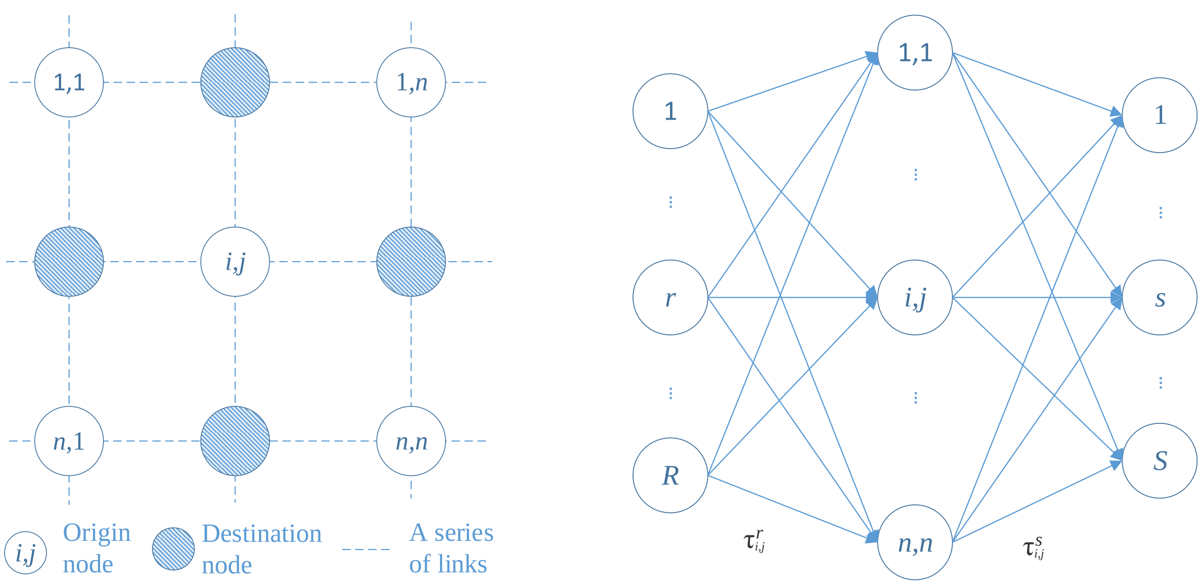


FIGURE 2 A general roadway network

Figure 2 is a representation of an average trip, if each traveler departs from an origin, chooses a block to park, and then walks to the destination. As shown in Figure 2, there are |R| origin nodes and |S| destination nodes in the road network, where R and S are the set of origin nodes and destination nodes, respectively. Here $\lambda_{ij}^{rs}(t)$ is defined as the traffic demand departing the origin r at time t heading for destination s and choosing the parking Block(i,j), ∀r ∈ R, ∀s ∈ S, ∀i ∈ {1, 2, . . . , n}, ∀t ∈ {1, 2, . . . , T}. The composite travel time $\tau_{i,j}^{rs}$ denote the sum of the time from his origin r to Block(i,j) and the walking time to the destination node s. Thus,

$$\tau_{ij}^{rs} = \tau_{ij}^{r} + \tau_{ij}^{s} \tag{1}$$

The real-time occupancy information helps travelers choose the parking location that yields the lowest travel cost in real time, which ensures a stabilized traffic flow pattern. The current parking space is occupied by travelers whose arrival time to the parking Block(i,j) is prior to t. The real-time effective occupancy is exactly the cumulative arrival rate to the Block(i,j). The lot arrival rate Φ have the closed form by following the definition of the traffic demand directly,

$$p_{ij}(t) = \sum_r \sum_s \sum_{m=\tau_{ij}^r+1}^{t} \lambda_{ij}^{rs}\left(m - \tau_{i,j}^r\right) \tag{2}$$

$$\lambda_{ij}(t) = p_{ij}(t) - p_{ij}(t-1) = \sum_r \sum_s \lambda_{ij}^{rs}\left(t - \tau_{ij}^r\right) \tag{3}$$

The charged parking fees are generally not considered (mainly are system optimal price schemes) in the total cruising time. The total system cost (TSC) is the travelers' total composite travel time. The minimal total cost of the optimization parking pricing is calculated by the following optimization equation,

$$\widehat{min} TSC = \alpha \sum_{r\in R} \sum_{s\in S} \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{t=1}^{T} \left(\tau_{ij}^r + \tau_{ij}^s\right) \lambda_{ij}^{rs}(t) \tag{4}$$

Where, *a* denotes the time average of the traveler population. If let $d_{i,j}^{rs} = \tau_{i,j}^r + \tau_{i,j}^s$, then

$$\widehat{min} TSC = \alpha \sum_{r\in R} \sum_{s\in S} \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{t=1}^{T} d_{ij}^{rs} \lambda_{ij}^{rs}(t) \tag{5}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{n} \lambda_{ij}^{rs} = \sum_{t=1}^{T} \lambda^{rs}(t)\,, \forall r, s \tag{6}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{n} \lambda_{ij}^{rs}(t) = \lambda^{rs}(t), \forall t, r, s \tag{7}$$

$$p_{ij} = \sum_{r\in R} \sum_{s\in S} \sum_{t=1}^{T} \lambda_{ij}^{rs}(t)\,, \forall i, j, r, s, t\ p_{ij} \le P_{ij},\ \lambda_{ij}^{rs}(t) \tag{8}$$

The Block(i,j)-based parking pricing scheme{$P_{i,j}$(t)} should satisty that ∀t∈{1,2,…,T}, travelers choose from Block(i,j) to Block(x,y) ∀i, j, x, y ∈ {1, 2, . . . , n}, for the parking. If the rs is a pair of between Block(i,j) and Block(x,y), and there exists $\tau_{ij}^{rs} > 0, \tau_{xy}^{rs} > 0$, then the pair rs of OD is a go-return route.

$$p_{ij}\left(t + \tau_{ij}^r\right) - p_{xy}\left(t + \tau_{xy}^r\right) = a\left(d_{ij}^{rs} - d_{xy}^{rs}\right) \tag{9}$$

where, $p_{ij}\left(t + \tau_{ij}^r\right)$ means the real-time occupancy at the arrival time $t + \tau_{xy}^r$. Consider the differentiate both sides with respect to t,

$$p_{ij}^*\left(t + \tau_{ij}^r\right) - p_{ij}^*\left(t + \tau_{ij}^r - 1\right) = p_{xy}^*\left(t + \tau_{xy}^r\right) - p_{xy}^*\left(t + \tau_{xy}^r - 1\right) \tag{10}$$

where p_{ij}^* denotes the optimal solution, the result shows that the optimal price change is negative relativity with own real-time occupancy. This is because the travelers' parking choice could change according the provision of parking information and the parking price, which may serve as an effective way for traffic manage and control. The parking price and the occupancy information should be balance out and work jointly for the best system performance.

Renewal of Parking Spaces

Emerging CAVs will grow out of a need to correct modern city car-sharing inefficiencies. The connected and autonomous ride-sharing service will create more-efficient travelling options for the public money while reducing the amount of traffic and burden on the environment. The research conducted strategically reorganizes the existing parking provision, aiming at reducing the need for land occupancy, which has significant potential to improve urban life.

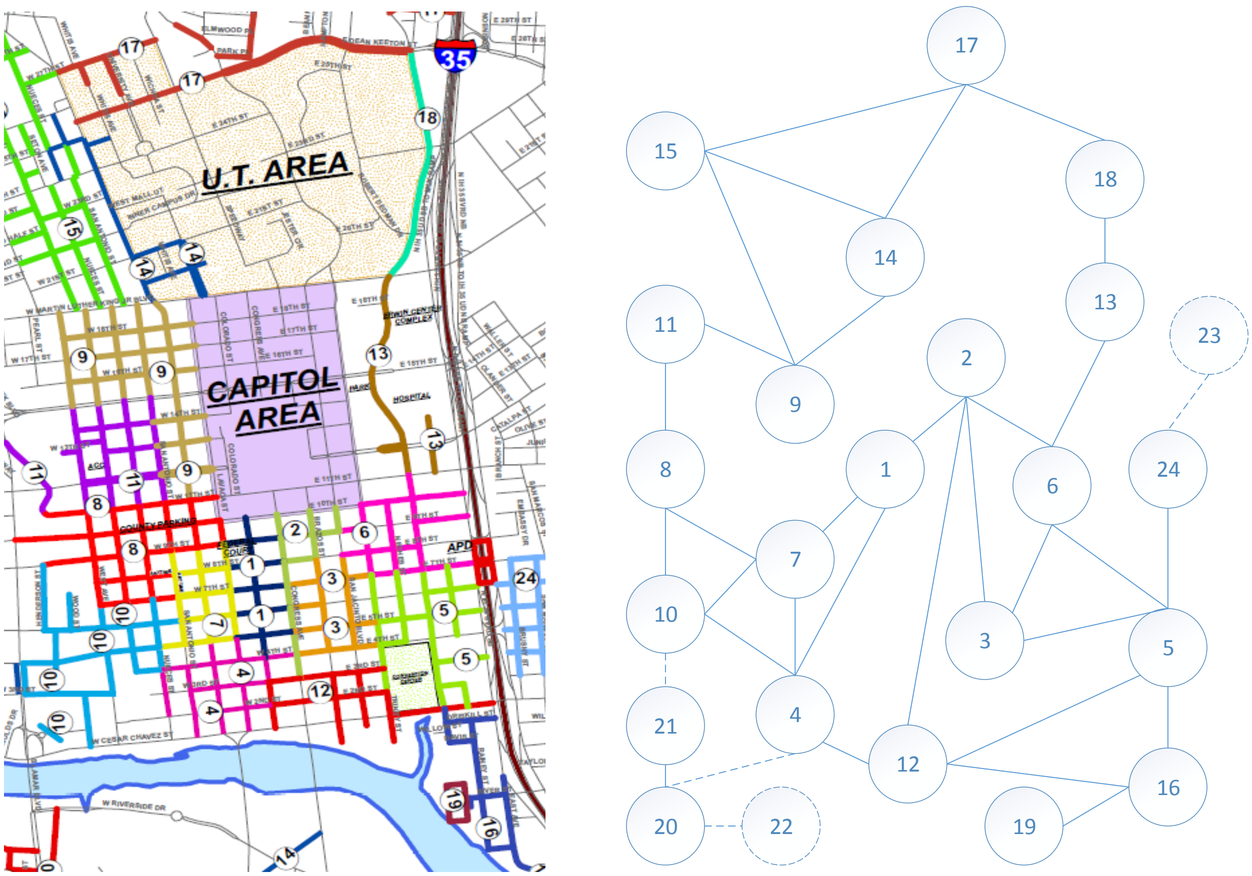
Currently, some major cities have started to convert formerly automobile-only spaces into multi-use spaces for public services, e.g., parklets, a bike lane, a bus-only travel lane, a general purpose traffic lane, extended sidewalks, multi-bus waiting areas, shared-car parking, electric vehicle (EV) battery charging, and truck loading zones. Major redesign of parking spaces requires a variety of considerations since not all streets are appropriate for specific rearrangements, if at all. Some of the ideal land use considerations include traffic flow, parking provision, minimized air pollution, existing pedestrian activity, commercial, high-density building and mixed-use areas. Other considerations include prioritizing parking spaces in rights-of-way, curb parking with low amounts of open space, high open space congestion and environmental transportation demographics. Google Maps and ArcGIS were used in this paper to illustrate one possible way of identifying curb-parking suitable for this study. Additional streets may benefit from the replication of this method or may transform the criteria to account for different local conditions. For full details on this methodology, consult of the following researches.

- 1/4 mile (a 5 minute walk) is considered to be the maximum that most people would be wiling to walk to reach a destination. Beyond this distance, people often bike, drive, take public transportation, or decide not to go to that destination (Nichols 2009).
- The re-plan of parking space prioritized commercial and high-density environments, followed by public service and non-profit institutions, and lastly residential.
- Shared parking will be utilized primarily for adjacent trip attractors and neighboring commercial applications. Therefore, geocoding desirable commercial businesses (restaurants and bars, bookstores, theaters and music venues) and keeping the potential parking locations nearby (within 100 feet) are priorities (ASLA 2011).
- Most residences are within a 1/4 mile walking distance of current parking provisions. In addition, there is a great deal of variety in population density and size of available public space when considering the parking reductions due to the emergence of SAVs technologies. Therefore open space congestion was used (population density combined with open space acreage) as a metric.
- Environmental justice is a consideration in many areas of research, and currently no municipality other than New York City has made it a priority when implementing parklets. Ethnic minorities and those below the federal poverty line are historically disadvantaged populations in terms of open space-and therefore areas with a majority-minority population (>50%) and those with higher levels of poverty are prioritized (Sister 2009).
- Keeping parklets and bike lanes more than 300 meters away from highways is a priority (Brugge 2007) as active transit amenities should not be preferred nearby high speed vehicular facilities.

Re-planning a successful parking provision for a CBD area requires a variety of considerations, as not all streets are appropriate for land use transformation planning. Certain streets and businesses have a higher propensity than others to support a modified parking provision. Along those streets, and despite certain throughput situations, specific blocks may warrant alternative uses, depending upon adjacent land types and means of transportation to reach nearby destinations. The results of the GIS analysis may be used as a basis for discussion with city planners, businesses and residents to supplement parklet location decision-making.

CASE STUDY

A GIS suitability analysis is used here to demonstrate the above method. The downtown-parking provision data were collected from City of Austin files, and suggest significant potential for repurposing and reuse of existing spaces. There are 24 major parking zone located in downtown Austin. The locations of the parking blocks and the traffic analysis zones (TAZ) are shown in Figure 3.



(a) Spatial distribution maps of parking provision (b) Connected state of parking blocks

FIGURE 3 Extraction model based on the parking provision.

Suppose all parking spaces are available for commuters or visitors, and all of parking are set to charge $5 per hour. The driving time and walking time is approximated based on the distance measured in Google Maps. In addition, the time horizon for this analysis is 7:00am-11:00am. Here an initial subset of 100,000 person-trips was randomly selected to imitate a natural 24-hour cycle of travel.The capacities of the blocks are shown in Table 1.

TABLE 1 Total Parking Spaces (Source: Austin Transportation Department, 2016)

Blocks	Meter Spaces	Paystation Spaces	Total Paystations	Total Curb Spaces
1	23	197	31	220
2	29	146	25	175
3	46	232	33	278
4	14	207	25	221
5	54	270	37	324
6	42	385	47	427
7	17	248	36	265
8	56	488	71	544
9	75	399	59	474
10	51	343	48	394
11	43	349	52	392
12	34	126	19	160
13	12	87	15	99
14	39	216	36	255
15	29	463	60	492
16	16	217	24	233
17	23	459	53	482
18	0	37	6	37
19	0	127	4	127
20	16	161	21	177
21	0	195	11	195
22	0	0	30	0
23	0	71	10	71
24	15	812	89	827

Such computations offer planners a conceptual framework for recognizing on-street parking provision and rearrangement of parking spaces under shared-fleet conditions. After a thorough investigation of Austin's downtown blocks and road structure, as illustrated in Figure 1, the block spacing, b + w, is found to be 110 m (361 ft.); the road width, W, is 10 metres (33 ft); and parking spaces typically measure 2.76 metres (9.1 ft.) wide by 6.1 metres (20 ft.) long, on average, with allowance made for crosswalks (2.45 metres or 8 ft.) at the ends of all blocks. As shown in Figure 3, there are 3 types of parking used along downtown Austin's curbs: parallel parking (the most common design), inclined parking, and bay parking. These three types can contain up to 15, 22, and 10 cars, respectively, in a single, average block. Curbside parking on both sides of each block suggests 30, 44, and 20 cars can be parked per block under the 4 parking designs, respectively.

(a) Parallel parking (b) Inclined parking (c) Bay parking

FIGURE 4 Three types of parking in downtown Austin.

The next thing to consider is the amount of roadway surface available for parking space allocation when shared parking is provided for residents, visitors, and businesses. Figure 5 presents the current spatial layout of curb parking spaces in downtown area. A study by Fagnant and Kockelman (2015) indicated that one SAV may be able to replace up to 9 conventional vehicles in the core of a region like Austin, suggesting that the need for any kind of parking spaces may eventually fall by 89%, if all those currently driving shift to SAVs. If one applies this percentage to just curb spots (as listed in Table 1), this liberates 6426 parking spaces, or 0.042 sq.mi (roughly 4 percent of the core downtown's 1.0 sq mi land area), which can be re-purposed for an extra lane of traffic, parklets, bike use, and other public facilities. With this decrease in parking demand, the rational reuse of parking spaces will become an important part of more sustainable transportation system designs.

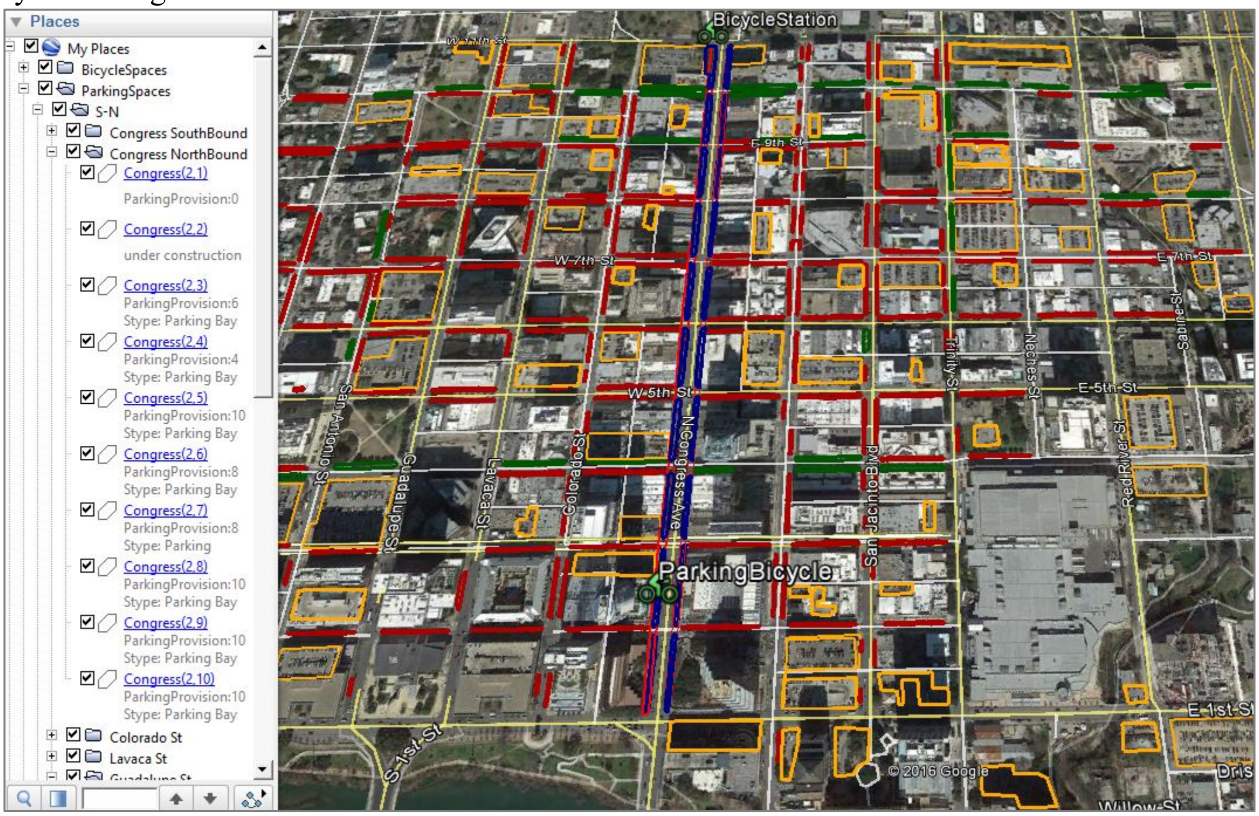


FIGURE 5 Parking provision in downtown Austin.

This pair of equations involves several parameters, whose values may be assumed as follows: t = 2.0 (i.e., in-transit travel distance is two miles), $\alpha$is set to \$23 per hour (approximately the average hourly pay rate on downtown), and parking is provided on just one side of every block (not obth sides). The terminal occupancies are shown in Table 2.

TABLE 2 Terminal occupancies of the TAZs

TAZ	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Capacity	220	175	278	221	324	427	265	544	474	11	392	160
Spots	197	146	232	207	270	385	248	488	399	5	349	126
Percentage	90 %	83 %	83%	94%	83%	90%	94%	90%	84%	45%	89%	79%
TAZ	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Capacity	99	255	492	233	482	37	127	177	195	0	71	827
Spots	87	216	463	217	459	37	127	161	195	0	71	812

Percentage	88 %	85 %	94%	93%	95%	100%	100%	91%	100%	0%	100%	98%

As part of the future urban development, a new parking provision plan and classification method is proposed here, to redefine and prioritize travel modes for each street (e.g., pedestrian and/or bicycle, transit and/or private cars). This plan can be implemented on the basis of existing street designs, land uses, and transportation system operations details, and can be updated as specific projects are funded and community input is obtained.

Existing curbside parking spaces can be completely or partly re-designed in a variety of ways, based on different needs and aspirations. For example, delivery trucks and bus stops can be moved around corners, in many cases, to create an entirely new bike lane or traffic lanes, using spaces in between truck stops for parklets, bike storage, and/or shared-car or SAV storage. The objective is to improve access to, and mobility within, the downtown core, while creating a more balanced and dynamic shared-parking system that supports economic growth and land use intensification, while fostering a high-quality, pedestrian environment and more sustainable travel choices. The optimal solution is shown in Figure 6. It is easily verify that there do not exist any two O-D pairs that use more than one parking block during the entire time horizon.

FIGURE 6 Repurposing downtown parking spaces in Austin (blue for parklets, red for shared parking, purple for extra general traffic lane, green for bicycle lane, and yellow as road axis)

This study seeks to anticipate how much curbside parking may be freed up by used of self-driving shared vehicle fleets, or SAVs. A shift to fleets of shared and self-driving vehicles may improve quality of life for downtown users and visitors, by facilitating all modes of transport by opening up land for more meaningful uses in this highly desirable and busy downtown setting. After conferring with design professionals, local businesses, residents, downtown workers, government officials, and other stakeholders, models of implementation can emerge.

As downtown land space becomes more expensive, vehicles become more automated, shared-fleets become more common, and existing parcels become smaller and less needed for curbside parking, it is important to re-think and re-do parking provision. Since off-street, structured parking is more difficult to re-design (due to sloped floor plans and low ceilings, for example), and cannot support actual travel, curbside slots represent our cities' top opportunity for re-design. A variety of options along each existing corridor should be considered. Instead of single-purpose parking spaces, shared and dynamic automobile and bicycle parking facilities, transit and SAV stops, parklets, and extended sidewalks can emerge.

FURTHER ENHANCEMENTS IN THE URBAN SPACE

With congestion paralyzing many corridors at peak times of day and self-driving (and thus self-parking) cars around the corner, current curb-parking spaces may be repurposed to promote a higher quality of life for the community. Currently, the City of Austin has recently devoted lanes of travel for its bus rapid-transit system routes. Coordination between public and private ride- and vehicle-sharing systems will allow for more sustainable communities, healthier travelers, and more effective land uses. .

The freeing of public land via curbside parking reductions offers an exciting opportunity to promote mores sustainable modes and/or land uses along various corridors. For example, in Austin, Texas, the local transit authority, Capital Metro, has invested in improved bus facilities for a variety of bus routes along Guadalupe Street. To further promote multi-modal travel and transit service levels, the current parking spaces along the downtown section of this corridor can be converted into several services supportive of public transit. These amenities include an extension of the existing bus lane and/or sidewalks, increased bike and car share locations, in concert with queuing spots for buses to prevent traffic buildup during vehicle alighting.

The following corridor case studies offer downtown-Austin examples of how such factors can be used to determine curbside parking's new use:

- San Antonio Street (Average Daily Traffic (ADT): 2,730-2,830 vehicles per day, on average) **Bike corridor** – This corridor runs through downtown to west campus and consists of low traffic neighborhood tree-lined streets. The current corridor has a bike route in place and could be suitable for additional bike traffic. Additional emphasis on this mode of transit would enable other corridors to focus on high capacity transit options. Meanwhile, this street still serves local traffic effectively and presents an aesthetically pleasing area for pedestrians and active transit users.
- Lamar Street (ADT: 32,670-38,480) - SAV prefered corridor - This corridor connects areas of Austin that have been developing rapidly, and the same can be said for the growing transit opportunities along this corridor. Due to the limiting ROW constraints, this corridor would be suitable to encourage high occupancy SAVs to improve and economize the existing infrastructure and serve the multitude of communities adjacent to Lamar Street.
- Congress Avenue (ADT: 7,340-23,260) – Hybrid of amenities for all modes – Congress Avenue has a wide number of bay parking spots that have already been converted to parkelts

where additional pedestrian amenities are needed. Currently, bicycle traffic is mixed in with vehicular traffic decreasing potential throughput capacity. During city wide events and most weekends, large events are planned near the paramount theatre and a dynamic setting to accommodate the stresses of additional pedestrians in the adjacent area should be considered. Additional downtown developments are planned which do not provide parking amenities for its patrons and therefore shared amaneities and transit should be considered around this new development.

- San Jacinto Boulevard (ADT: 4,230-5,980) – Multi-modal transit – San Jacinto Boulevard connects a major university and growing medical center and has high amounts of student traffic on buses, foot, and bike. With the additional roadway space and more centralized parking, more feeder buses should be considered to serve commuters to the university who may park further away. Additionally, to promote active transit and to provide a firnedlier environment for the multiude of events and football games in the area, increased pedestrian and cyclist shade and refuge will help to promote these environmentally friendly forms of transit. Current vehicular access is restricted at most areas of San Jacinto so it is not recommended to encourage additional vehicular traffic.
- Brazos Steet (ADT: 2,880-3,840) and Colorado Steet (ADT: 3,780-4,530) – Shared-parking environment – This corridor is designed to provide shared parking amenities for downtown destinations. This re-designed space allows for quick queuing and alighting times and a space for carpooling and queueing for these vehicles. Current street configuration promotes active transit with newly created pedestrian space and this shared parking environment is already enabled with current bike sharing infrastructure. Additional pedestrian space can be created with this shared-parking environment to relieve some of the urban stresses related to additional density. Neighboring streets with pedicab access should be considered for a pedicab queuing area as well. These streets have a high amount of off-street parking and vehicular traffic should be preferred for these corridors.

CONCLUSIONS

Self-driving technologies may make SAVs a highly competitive mode alternative for many, most, or nearly all person-trips. Around the world, car-sharing is becoming a viable alternative to privately owned vehicles, which helps reduce parking requirements in settings that offer storage for shared fleets. A basic spatial distribution for the environmental impact of SAVs is postulated, liberating curb-parking for other uses. If one SAV can replace 9 conventional vehicles, it seems reasonable to expect that 90 percent or more of Austin’s current downtown curb spaces may be easily liberated (especially since off-street parking can be more challenging to repurpose). That space constitutes about 27 acres of land (or 4.2% of total land) in Austin’s 1.0 square mile downtown, would could be re-purposed for other public uses. This paper provides a variet of re-use suggestions along major corridors, ensuring provision of truck delivery spots and transit stops, while adding bike lanes, extending sidewalks, and providing more general purpose traffic lanes to facilitate various forms of travel and leisure along north-south routes. The goal of this research is to improve access to, and mobility within, a downtown core, creating a more balanced and dynamic shared-vehicle and shared-parking system that supports regional and local growth and densification, while fostering a high quality of life for all those destined to and/or residing in the downtown. As part of any city’s long-term planning efforts, a new parking provision plan, recognizing SAVs’ potential impacts, should emerge. As in this paper, such plans may do well to redefine each street's objectives and priorities (e.g., pedestrian, bicycle, transit and vehicular), to support more active modes, more meaningful land use, and safer and more efficient transport.

Parking provision is a principal factor in shaping the form and character of downtowns everywhere. Although a major goal of many cities is to create sustainable, pedestrian-oriented downtown districts, the lack of many highly well connected, very frequent, and popular transit routes and transit-supportive land use patterns across Austin requires that adequate levels of automobile parking continue to be provided in this particular case study until there are more viable alternatives. SAVs may be the breakthrough that cities like Austin seek, though their overall impacts (on travel distances, location choices, and traffic congestion) remain to be seen.

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