Parking Reservation for Managing Downtown Curbside Parking

Zhibin Chen, Yafeng Yin, Fang He, and Jane L. Lin

This paper discusses a smartphone-based parking reservation system that manages a finite number of curbside parking spaces located at various places in a downtown area. Parking reservation schemes are designed to minimize the total social cost of parking, which is assumed to be a weighted sum of the cruising times for drivers to travel from their current locations to allocated parking spaces and the walking times from parking places to final destinations. With the assumption of perfect information on cruising and walking times, a simple reservation scheme to achieve an optimum allocation of parking spaces is presented. However, although the locations of drivers can be retrieved from their smartphones, it is shown that drivers have an incentive to misreport their final destinations for their own benefit, which compromises the system benefit. Thus, the Vickrey–Clark–Groves mechanism is applied to determine the allocation of parking spaces and parking fees to minimize the total social cost while ensuring that all drivers report their final destinations truthfully. Last, a revenue redistribution scheme to reduce drivers’ financial burden further and increase public acceptance of the reservation system is discussed.

Because of increasing car ownership, parking has become a major problem in many large cities and downtown areas worldwide. Cruising for parking is time-consuming and frustrating for drivers, and it makes traffic congestion more severe by slowing down through vehicles and increasing the traffic volume on roads. For example, it was reported that in some major European cities and in Boston, Massachusetts, more than 50% of downtown traffic during peak hours is made up of vehicles searching for parking (1), and in 11 major cities 30% of traffic congestion can be attributed to vehicles cruising for parking (2). Assuming a cruising time of 3 min, an average cruising speed of 10 mph, and a turnover of 10 vehicles a day, Shoup estimated that cruising for curbside parking yields 1,825 vehicle miles each year (3).

Advanced parking management, including parking pricing (4–6), parking information provision (7, 8), parking guidance (9–11), and parking reservation (12), aims to help drivers find parking spaces quickly and reduce the deadweight loss associated with cruising for parking. Of these parking management innovations, parking reservation has scarcely been implemented. However, the proliferation of advanced smartphones [the number of smartphones is forecast to triple to 5.6 billion globally by 2019 (13)] has made parking reservation more practical and accessible. Drivers now can use smartphone parking applications to view the availability of parking spaces and make reservations virtually anytime and anywhere. A number of parking reservation applications, such as SpotHero, ParkWhiz, ParkNow, and Parking Panda, have emerged on the market.

In contrast to the large body of reservation research in other areas, such as airlines (14), highway trips (15–17), downtown spaces (18), and hotels (19, 20), the literature on parking reservation is rather limited, with a few exceptions. Teodorović and Lučić proposed a parking reservation system for revenue management, which makes online decisions on whether to accept or reject a new driver’s request for parking, considering uncertain future vehicle arrivals and parking space availability (12). Integer programming was used to develop the best parking strategies for various patterns of vehicle arrivals. Specific fuzzy logic rules were derived for decision making as a result of learning from these strategies. Yang et al. pointed out that because of the insufficient parking supply in a downtown area, retaining some spaces for reservation while keeping the remaining spaces for competition can smooth out traffic arrivals to a highway bottleneck leading to the downtown area and thus reduce traffic congestion (21). Liu et al. further showed that expirable parking reservations can even the traffic arrival pattern at the bottleneck to reduce traffic congestion (22). Liu et al. developed a tradable parking permit scheme to implement parking reservations when commuters are either homogeneous or heterogeneous in their values of time (23).

In this paper, a parking reservation system is proposed to manage a finite number of curbside parking spaces located at various places in a downtown area. Drivers who wish to park in the downtown area must obtain a reservation in advance via the reservation system. Otherwise, they can park only outside the area. The goal of this parking reservation system is to minimize the total social cost of parking, which is assumed to be a weighted combination of drivers’ cruising times to parking spaces and walking times from parking spaces to final destinations (24). In this study, it is envisioned that smartphone applications are available to allow drivers to access the parking reservation system. To make a reservation, drivers need to report their final destinations to the system while the system retrieves their current locations from their smartphones. The interest lies in using this information to develop reservation schemes to allocate parking spaces to minimize the total social cost of parking. With the assumption of perfect information about cruising and walking times, a linear program to achieve an optimum allocation of parking spaces is presented. It is then illustrated that drivers have an incentive to misreport their final destinations for their own benefit, which compromises the system benefit. The Vickrey–Clark–Groves (VCG) mechanism is thus applied to determine parking charges to

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ensure that all drivers report their final destinations truthfully. Last, a revenue redistribution scheme to further reduce the financial burden of drivers and increase public acceptance of the reservation system is discussed.

The rest of the paper is organized as follows. The necessity for an optimal parking reservation scheme is illustrated, and the scheme with perfect information about cruising and walking times is outlined. Next, the incentive for drivers to misreport their final destinations is illustrated, and the VCG mechanism is applied on static and dynamic parking reservation problems with private information. A numerical example to demonstrate the performance of the proposed schemes is provided next, followed by the introduction of revenue redistribution to reduce drivers’ financial burden. Last, conclusions end the paper.

PARKING RESERVATION WITH PERFECT INFORMATION

Static Scheme Design

Parking reservations can be simply first come, first served (FCFS), which allows a driver to select and reserve the best parking space from among currently available ones. Without considering the impact of each reservation on the social cost of the system, such a scheme may not be sensible. To illustrate this, a small example is used in which three drivers (V1, V2, and V3) make their parking reservations sequentially; their parking costs (weighted sums of cruising and walking times) to each space are shown in Table 1, in which S1, S2, and S3 represent three parking spaces. On the basis of the FCFS principle, the parking assignment will be (V1, S1), (V2, S2), and (V3, S3), and thus the total social cost is 17. However, another assignment of (V1, S3), (V2, S3), and (V3, S1) yields a social cost of 12, a saving of nearly 30%. In fact, such an assignment is optimal, minimizing the social cost. The question of interest is how to design a reservation scheme to achieve the system optimum.

For simplicity, first consider a static parking reservation problem in which drivers at different locations reserve parking spaces at the same time, or drivers are patient enough to wait until the system receives all requests and makes a final assignment decision. The reservation system can take reservation requests only up to the number of available parking spaces, and then the system decides the space allocation plan. Once a driver is assigned to a particular space, he or she will accept it and cannot make another reservation. In addition, it is assumed that drivers will occupy the spaces for the whole planning horizon, that is, an occupied parking space will not become available again. This assumption can be justified only for situations in which drivers come to the downtown area to work or participate in a full-day event. A future study will relax this assumption to consider different parking durations.

With the above consideration, let I and J represent the sets of drivers requesting parking reservations and the available parking spaces, respectively. Let ei denote the parking cost for driver i to park at space j. Again, the cost is a weighted sum of driver i’s cruising and walking times. Then the system optimum (SO) assignment can be obtained by solving the following linear program (24):

\[
\min \sum_i x_{ij} e_i \\
\text{subject to} \\
\sum_j x_{ij} = 1 \quad \forall i \\
\sum_i x_{ij} \leq 1 \quad \forall j \\
x_{ij} \geq 0 \quad \forall i, j
\]

where \(x_{ij}\) is the variable representing whether space \(j\) is assigned to vehicle \(i\). The first constraint suggests that every driver whose reservation request is accepted by the system should be assigned one and only one parking space, while the second constraint ensures that every parking space can be assigned to at most one driver. Since the matrix associated with the first two constraints is totally unimodular, the optimum solutions are integer.

Dynamic Scheme Design

Nevertheless, in practice, it is unrealistic to require drivers to wait patiently until all reservation requests are in before receiving a reservation decision. Realistically, drivers will send their reservation requests to the system over time and expect a decision within a short period of time. To address that issue, the whole planning horizon is divided into a finite number of short time intervals. At the end of each interval, the reservation system will make decisions on the requests received during the interval. For a reservation decision, drivers can take it or leave it. A dynamic programming approach may be adopted to design a reservation scheme to achieve some form of global optimality, considering uncertain reservation requests and parking supply at future intervals. This approach is left to future investigation. In this paper, solving the above SO at each interval to achieve a myopic system optimum is proposed. This approach is simple to implement and computationally efficient.

PARKING RESERVATION WITH PRIVATE INFORMATION

Incentive to Lie

As previously mentioned, the parking cost is a combination of cruising and walking times. Figure 1 shows a scenario in which two vehicles (V1 and V2) reserve two spaces (S1 and S2), and D1 and D2 are their actual final destinations. In the figure, the number beside each link represents the cruising or walking time. To simplify, suppose the weights of the cruising time and walking time are both 1,
that is, \( e_{ij} = t_{ij} + w_{ij} \). The following table shows the parking costs of vehicles to the spaces:

<table>
<thead>
<tr>
<th>Driver</th>
<th>( S_1 )</th>
<th>( S_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_1 )</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>( V_2 )</td>
<td>27</td>
<td>62</td>
</tr>
</tbody>
</table>

Obviously, according to the definition of system optimum, the best assignment is \((V_1, S_2)\) and \((V_2, S_1)\), and the total cost is 57.

However, \( V_1 \) may misreport the destination to be assigned \( S_1 \), which leads to a lower parking cost for \( V_1 \). Figure 2 shows such a situation. Consequently, the parking costs change to those in the following table:

<table>
<thead>
<tr>
<th>Driver</th>
<th>( S_1 )</th>
<th>( S_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_1 )</td>
<td>12</td>
<td>55</td>
</tr>
<tr>
<td>( V_2 )</td>
<td>27</td>
<td>62</td>
</tr>
</tbody>
</table>

Thus, the system optimum assignment becomes \((V_1, S_1)\) and \((V_2, S_2)\) with a social cost of 74. However, in such a situation, the real social cost is 77, much larger than the situation in which both drivers report their destinations truthfully, that is, 57. Unfortunately, \( V_1 \) has an incentive not to do so.

Since the truthful parking costs are unknown to the parking reservation system, the system optimum reservation can be defined only as the one that minimizes the total reported parking social cost. Define \( \hat{e}_{ij} \) as the parking cost calculated according to the reported destination from the driver. Similar to SO, the system optimum based on the reported parking costs (SO-R) can be formulated as follows:

\[
\min \sum_{i,j} x_{ij} \hat{e}_{ij}
\]

subject to Equations 1–3

**Static Scheme Design**

To address potentially harmful misreporting, mechanism design techniques are applied to design a parking reservation scheme. Mechanism design is a subfield of economics that considers the problem of providing incentives to self-interested agents to provide truthful information and further achieve desired systemwide outcomes in the system (25). A mechanism design should be efficient, that is, the output can always achieve the desired system outcome; strategy proof, that is, drivers do not have an incentive to lie; and ex post individual rationality (IR), that is, participating in the mechanism is always no worse than not participating. Further, agents are supposed to have private information and assumed to be rational to maximize their utility. The parking reservation problem of interest in this paper does satisfy these assumptions: all drivers have their...
private information on their final destinations, and they attempt to minimize their individual parking cost.

Classical mechanism design is concerned with static, one-shot problems, in which all agents are assumed to make a one-time request and are patient enough to wait for the decision; examples include the first-price sealed auction, second-price sealed auction, and VCG mechanism (26). Among them, the VCG mechanism (27–29) is the most well-known mechanism for allocating multiple items and has been widely applied to areas such as network rate allocation (30), base station resource allocation (31), and Internet advertising (32). In this paper, the VCG mechanism is applied to design a static parking reservation system in which all drivers make reservations at the same time or are patient enough to wait for the final decision.

As per the VCG mechanism, each driver will be allocated a parking space and charged a parking fee. The fee is equal to the harm they cause to other drivers. Such a reservation scheme is supposed to provide incentive for drivers to report truthfully and to eventually achieve the desired outcome, that is, the minimal social cost.

Let \( P_i(X^*; e_i, \hat{e}) \) represent the actual or real parking cost for driver \( i \) when accepting the parking space assignment from the reservation system, where \( X^* \) denotes the solution to SO-R; \( e_i \) is a vector describing the real parking costs to all parking spaces for driver \( i \), that is, \( e_i = (e_{i1}, \ldots, e_{in}) \); and \( \hat{e} = (\ldots, \hat{e}_n, \ldots) \), representing all reported parking costs. The parking fee for driver \( i \), denoted as \( T_i(X^*; \hat{e}) \), is calculated below:

\[
T_i(X^*; \hat{e}) = \sum_{k \neq i} P_i(X^*; \hat{e}_k, \hat{e}) - \sum_k P_i(X^*; \hat{e}_k, \hat{e}_i)
\]  

where \( X^* \) denotes the solution to SO-R when driver \( i \) is excluded.

Define \( TC_i(X^*; e_i, \hat{e}) \) as the individual total cost, that is, the sum of the cruising time, walking time, and parking fee of driver \( i \). Mathematically, one has

\[
TC_i(X^*; e_i, \hat{e}) = P_i(X^*; \hat{e}_i, \hat{e}) + T_i(X^*; \hat{e})
\]

Because the real social cost obtained when all drivers report their destinations truthfully is less than the situation in which driver \( i \) reports untruthfully, one has

\[
P_i(X^*; \hat{e}_i, \hat{e}_i) + \sum_{k \neq i} P_i(X^*; e_k, \hat{e}_i) \geq \sum_k P_i(X^*; e_i, e_k)
\]

Further, considering another situation in which the real parking costs are \((e_i, \hat{e}_i)\) and all drivers except driver \( i \) report their truthful destinations, Equation 6 yields the following:

\[
P_i(X^*; e_i, \hat{e}) + \sum_{k \neq i} P_i(X^*; \hat{e}_k, \hat{e}) \geq P_i(X^*; e_i, \hat{e}_i) + \sum_{k \neq i} P_i(X^*; \hat{e}_k, e_i)
\]

Proposition 1. Suppose that under the VCG reservation scheme, driver \( i \) misreports his or her destination, that is, \( \hat{e}_i \neq e_i \). As a result, driver \( i \)’s individual total cost will be more than the cost would be if he or she reports the destination truthfully, regardless of what the other drivers report.

Proof:

\[
\begin{align*}
TC_i(X^*; e_i, \hat{e}) & = P_i(X^*; e_i, \hat{e}) + T_i(X^*; \hat{e}) \\
& \geq P_i(X^*; e_i, \hat{e}_i) + \sum_k P_i(X^*; \hat{e}_k, \hat{e}_i) - \sum_k P_i(X^*; \hat{e}_k, \hat{e}_i) \\
& = P_i(X^*; e_i, \hat{e}_i) + T_i(X^*; \hat{e}_i) \\
& = TC_i(X^*; e_i, \hat{e}_i)
\end{align*}
\]

where the first equality follows from Equations 4 and 5; the first inequality comes from Equation 7; and the second equality is from Equation 4. ■

To illustrate the above proposition, consider the parking reservation scenario in Figure 1, in which the system optimum assignment is \((V_1, S_2)\) and \((V_2, S_1)\). Take \( V_1 \) as an example. When \( V_1 \) is present, the total parking cost of the other driver, \( V_3 \), is 27; when \( V_1 \) drops out, the total parking cost is still 27 because the new system optimum assignment is \((V_2, S_1)\). According to the VCG mechanism, the parking fee charged to \( V_1 \) is \( T_1 = 27 - 27 = 0 \). Thus, the individual total cost of \( V_1 \) is \( TC_1 = 30 + 0 = 30 \). However, if \( V_1 \) misreports his or her destination as \( S_2 \) in Figure 2, the system optimum assignment becomes \((V_1, S_2)\) and \((V_2, S_2)\). Similarly, the parking fee charged for \( V_1 \) can be calculated as \( T_1 = 62 - 27 = 35 \), and therefore, the individual total cost becomes \( TC_1 = 12 + 35 = 47 \), much larger than before, that is, 30. Therefore, by charging a parking fee to \( V_1 \) according to the VCG mechanism, there is no incentive for the driver to misreport his or her destination. This is true for \( V_2 \) as well. Thus the reservation scheme yields the system optimum prescribed by SO.

Dynamic Scheme Design

Similar to the dynamic scheme with perfect information, a dynamic reservation scheme with private information is now designed; the scheme can be described as an online mechanism design problem. Online mechanism design is meant to provide a sequence of decisions over time rather than a decision at the end (25). For example, Friedman and Parkes considered the online VCG mechanism to design a pricing scheme of Wi-Fi at Starbucks to maximize the total profit (33). In their study, the agents have various valuations for the Wi-Fi service, and they arrive over time and can announce their arrivals only after they have arrived, that is, reservations are not allowed. Gershkov and Moldovanu discussed allocating a set of distinct durable goods to a set of buyers by applying the online mechanism design to maximize the welfare (34). Specifically, the buyers are assumed to be impatient and arrive sequentially according to a Poisson or renewal process, and further, their ranking of the goods is the same. Gerding et al. proposed a model-free (no assumption of future demand and supply of electricity) online mechanism design based on the greedy allocation algorithm for electric vehicle charging, to achieve a higher electricity allocation efficiency (35). Unfortunately, none of these online mechanism designs is applicable to the present parking reservation problem because of the characteristics of parking spaces. First, all parking spaces must be reserved before drivers arrive. Second, there is no generic ranking of parking spaces, as drivers’ parking space preferences depend on their...
current locations and final destinations. Third, unlike electricity, once a parking space is assigned to one driver, it cannot be assigned to another driver before the driver leaves the space.

To design a dynamic reservation scheme with private information, the whole planning horizon is similarly divided into a finite number of short time intervals. At the end of each interval \( t \in \{1, 2, \ldots, T\} \), the reservation system will allocate spaces to the requests received within the interval and determine the corresponding parking fees. Similar to the perfect information case, applying the above VCG mechanism at each interval to achieve a myopic system optimum is proposed. Such a scheme is called an “iterative mechanism” in this study. Obviously, by using the iterative mechanism, no drivers have an incentive to misreport their parking costs at each interval. Further, as assumed previously, no new spaces will become available during the planning horizon. Thus the following proposition is put forth:

Proposition 2. For any driver, the earlier the reservation is made, the less individual total cost he or she will experience.

Proof. Suppose \( V_i \) makes a reservation at interval \( t \) and receives an allocated space \( S_q \). As a result, the individual total cost will be more than or equal to \( e_{i q} \) (it will be equal to \( e_{i q} \) if the parking fee charged \( V_i \) is 0.)

However, suppose that \( V_i \) makes a reservation at an earlier interval \( t' \), that is, \( t' < t \), and space \( j \) is assigned to \( V_i \). If \( S_j = S_{q'} \), since \( S_{q'} \) remains at interval \( t \), such an allocation will not affect the parking space assignment of the other drivers, thus \( T_i = 0 \). Consequently, his or her individual total cost \( T_i = e_{i q} + T_i = e_{i q} \). If \( S_j \neq S_{q'} \), to be assigned with \( S_{q'} \), \( V_i \) could misreport a destination and consequently \( T_i' = e_{i q} \). However, because of the strategy-proof property of the VCG mechanism, there is no incentive for \( V_i \) to do so, that is, \( T_i \leq T_i' = e_{i q} \). Therefore, the individual total cost of \( V_i \) when making a reservation at interval \( t' \) will be no larger than the cost when \( V_i \)'s reservation is made at interval \( t (t' < t) \).

The above proposition suggests that drivers will make their reservations as early as possible under the proposed iterative mechanism. For the proposed dynamic reservation scheme, if the interval is sufficiently long to be the planning horizon, it reduces to a static VCG mechanism; if the interval is short enough, it is essentially an FCFS scheme because at each interval there is at most one driver.

**NUMERICAL EXAMPLE**

To demonstrate the performance of the proposed reservation schemes, consider that 100 drivers travel to a downtown area and reserve parking via a reservation system that manages 100 parking spaces in the area. That is, \(|I| = |J| = 100\). One hundred different scenarios are randomly created by generating parking costs (sum of cruising and walking times) from \([1, 100]\) and determining the request sequences of all drivers from \([1, 2, \ldots, 100]\), both in a uniform manner. For each scenario, different durations of a time interval are considered, including \(1, 2, 5, 10, 20, 25, 50, \text{ and } 100\). Correspondingly, the number of intervals is \(100, 50, 20, 10, 5, 4, 2, \text{ and } 1\), respectively. The optimum assignment of each situation is obtained by solving \( SO \), and parking fees are calculated according to Equation 4. Table 2 presents the average social cost, revenue, and individual total cost for the problem with private information. The results are the same for the problem with the perfect information except that the parking fees will be 0.

<table>
<thead>
<tr>
<th>Intervals</th>
<th>Average Social Cost</th>
<th>Average Revenue</th>
<th>Individual Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>161.17</td>
<td>308.56</td>
<td>4.70</td>
</tr>
<tr>
<td>2</td>
<td>214.34</td>
<td>267.33</td>
<td>4.82</td>
</tr>
<tr>
<td>4</td>
<td>266.47</td>
<td>211.42</td>
<td>4.79</td>
</tr>
<tr>
<td>5</td>
<td>283.03</td>
<td>194.77</td>
<td>4.78</td>
</tr>
<tr>
<td>10</td>
<td>329.20</td>
<td>119.20</td>
<td>4.48</td>
</tr>
<tr>
<td>20</td>
<td>371.84</td>
<td>70.54</td>
<td>4.42</td>
</tr>
<tr>
<td>50</td>
<td>395.11</td>
<td>32.77</td>
<td>4.28</td>
</tr>
<tr>
<td>100 (FCFS)</td>
<td>424.47</td>
<td>0.00</td>
<td>4.24</td>
</tr>
</tbody>
</table>

As expected, when the number of time intervals increases, the social cost increases while the revenue decreases. Specifically, when the number of intervals is one, that is, static parking reservation, the scheme can achieve the system optimum, and the social cost is only 38% of that under the FCFS principle. However, in this situation, the revenue is also the largest, that is, 308.56, increasing the individual total cost of drivers to 4.70, as compared with 4.24 under the FCFS principle. In fact, the FCFS principle leads to the smallest individual cost because all the parking fees are 0. This reservation scheme manages to achieve system optimum, but has to charge quite a significant parking fee to ensure that all drivers report truthfully. The scheme performs well from a societal perspective, but individual drivers may have a different opinion.

**REVENUE REDISTRIBUTION**

It has been recognized in the literature that the VCG mechanism is not budget balanced (36). Myerson and Satterthwaite proved that it is impossible for an auction mechanism to be efficient, strategy proof, ex post IR, and exactly budget balanced simultaneously (37). In recent years, some attempted to achieve the budget balance by sacrificing either the strategy-proofness or efficiency (38, 39). Others proposed to redistribute the surplus to agents without affecting the properties of the VCG mechanism but approximately achieve the budget balance (36, 40–42). In this paper, redistributing the parking revenue is considered to reduce drivers’ individual travel costs. The rebate to each driver can be computed as the revenue collected by the reservation system without the driver divided by the total number of drivers (36). More specifically, the rebate to driver \( i \) is

\[
Z_i = \frac{\sum_{j \in N} T_j(X^*, \hat{c}_j)}{N}
\]

where \( Z_i \) is the rebate to driver \( i \) and \( N \) is the number of drivers.

The rebate depends only on the information provided by the other drivers regardless of driver \( i \). Therefore, the efficiency, strategy proofness, and ex post IR will not be affected. However, such a rebate scheme may run a deficit (43). Further, Proposition 2 may not hold as a result of the effect of rebates.

To demonstrate the revenue redistribution scheme, consider the example in the above section with a single time interval, that is, static reservation. Figure 3 shows the percentage of revenue redistributed to drivers. At least 43% of the revenue will be redistributed, and the
rebate percentage can reach more than 90% in some scenarios. On average, 76% of the revenue is redistributed. As a result, the average individual total cost of parking reduces to 2.34, which is much smaller than under the FCFS principle, that is, 4.24. Moreover, in all 100 random scenarios, there is no deficit for the reservation system.

To analyze the relationship between individual parking fees and rebates, they are plotted for one selected scenario in Figure 4. It is easy to see that individual rebates are relatively uniform, while individual parking fees vary drastically. This result demonstrates that the amount of an individual rebate does not relate to the amount of the individual parking fee. Consequently, a driver charged with a higher parking fee may receive a lower rebate or vice versa.

**CONCLUSIONS**

A smartphone-based parking reservation system to manage downtown curbside parking has been discussed, and reservation schemes to allocate parking spaces have been designed. First, the need for designing a reservation scheme to minimize the total parking cost was illustrated. Given that the parking cost is closely related to drivers’ private information, their final destinations, it was shown that drivers have an incentive to misreport the information. Consequently, the VCG mechanism was applied to determine parking fees to ensure that all drivers provide truthful information and parking spaces are allocated optimally. It was also verified that the iterative VCG mechanism could be used for dynamic parking reservation and a myopic system optimum could be achieved. In this reservation scheme, all drivers have an incentive to make their reservations as early as possible. A numerical example was provided to demonstrate the performance of the proposed schemes. As compared with the FCFS principle, the schemes can reduce the parking social cost by up to 38%. To deal with the large amount of parking revenue, which increases drivers’ individual costs, a revenue redistribution mechanism was examined. While achieving efficiency and strategyproofness, the mechanism rebates, on average, 76% of the revenue in the same numerical example, demonstrating its potential for making the proposed reservation system appealing to society and individual drivers.

Future research will relax the assumption of homogeneous parking duration and allow new parking spaces to become available in the planning horizon. Moreover, the revenue redistribution mechanism may be viewed by some as inequitable because drivers charged more may receive a lower rebate, and vice versa. More sophisticated forms of rebates can be investigated to address such an equity concern.
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REFERENCES


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