EVALUATING REAL-TIME PARKING INFORMATION: CASE STUDY OF AN ISOLATED UNIVERSITY CAMPUS

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ABSTRACT

While parking is an important issue in transportation engineering and planning, little research has examined the use of new parking information technologies on rural communities. The researchers have used Clemson University campus, in South Carolina, as a case study to determine the ability of roadside parking information systems for reducing delay, travel time and changing volumes. To examine these impacts, a traffic simulation model of the campus was built, calibrated, and validated. The model used a dynamic assignment approach to capture the rerouting of vehicles caused by parking availability information about several key parking lots. The researchers found that using roadside parking information systems, such as dynamic message signs, can reduce delay while not significantly impacting volumes, travel times, or speeds. These findings suggest that the delay reduction was caused by decreasing vehicle circulation time.
INTRODUCTION

Providing close parking on most university campuses is a significant challenge. While most faculty, staff, and students desire front-door parking spaces, trends are shifting towards pedestrian friendly core campuses (1; 2; 3; 4; 5; 6) and the need for new teaching and research buildings are usurping on-campus parking. As parking is gradually relocated to the periphery of college campuses, an opportunity arises for efficient routing of vehicles to available parking by using technology.

The use of intelligent transportation systems on university campuses is increasing. While planners and engineers for large urban campuses have been challenged with managing parking for years, some smaller and rural campuses are just beginning to encounter a limitation in feasible parking locations.

Clemson, South Carolina, a town with a population of approximately 12,500 residents (7), is home to Clemson University, providing education to approximately 17,500 students (8). The University’s athletic events, particularly football games, attract approximately 100,000 fans to this small-town environment, placing significant stresses on transportation systems and other facilities. Although these sporting events are infrequent (approximately 9 times a year), daily influxes of off-campus commuting students searching for parking spots cause a significant portion of traffic. These two factors combined, justified the investigation of real-time parking information system on Clemson University campus. The case study conducted for the Clemson University campus will be useful to other college campuses and rural communities around the country.

In support of a real-time parking information system, an intelligent transportation systems (ITS) architecture was developed (9), a system design has been recommended, and predicted benefits have been evaluated. This paper reports on the latter two.

RELATED PREVIOUS WORKS

Previous literature has reviewed motorist preference to real-time parking information systems, explored the options of displaying different messages, and has more recently began evaluating field tests of such systems. The early studies on real-time parking information investigated the preference of motorists to different types of information using stated and revealed preference surveys and tools (10; 11). Further work considered that different levels of detail need to be given at different distances to parking lots (12) and that different types of travelers will use different types of media (13). Other work on real-time parking information within a central business district investigated the timing of posted messages with respect to driver’s route change options using predictive algorithms. In particular, because parking information signs are commonly located some distance from the lot, the signs must display “Lot Full” prior to the lot actually reaching capacity, to minimize the formation of queues at the lot entrances (14; 15). More recently, Chen et al. proposed that instead of posting the same parking availability data on all VMS, that different information should be given to drivers from different approaches to disperse the traffic from all seeking the most desireable parking lots (16).
Another significant area of study includes case studies of real-time parking information systems. Burdette recommended a practical procedure for installing such a system at airports in 2001 (17) and the technology has been slowly gaining momentum since. A case study in St. Paul, Minnesota, evaluated the use of one of the first real-time parking information in the US during special events, finding that it reduced delay by 7.1 percent, travel time by 3.8 percent, and stopped delay by 8.3 percent. Other findings from this study indicated that after debugging the system it was reliable more than 96 percent of the time (18). Others have also examined parking for special events (19), some focusing on parking lot choice models (20) and others predicting 8 percent reduction in travel costs from optimal parking choice routing (21). These studies indicate that real-time parking information can significantly benefit motorists during special events.

Rephlo et al. investigated the use of real-time parking information at park-and-ride lots outside of Chicago and Washington, D.C. The methods included intercept transit rider surveys, transit employee surveys, transit ridership information, archived data, and parking lot in-and-out counts. The findings were inconclusive whether or not real-time parking information could reduce circulation within and between parking lots (22). On the contrary, others have simulated parking guidance systems for a parking garage, finding such systems can reduce parking circulation by over 16 percent (23). To solve these conflicting findings, further investigation is needed.

A few systems have been installed with no predicted measures of benefit. For example, a real-time parking information system was installed in Santa Monica, CA to reduce traffic congestion from shoppers without notice to the actual benefit-cost of such a system (24). More recently, a system is under construction in down-town Milwaukee, WI, to combat air pollution from vehicle emissions. Little is quantitatively reported about the proposed impact of this system (25).

Overall, previous studies have indicated significant interest in real-time parking information in the US and abroad. The benefits for such systems have been reported for use during special events (19; 20; 21); yet no conclusive quantitative evidence exists for using real-time parking information systems for rural areas or for permit-only surface parking lots on a more-permanent basis. To fill this gap in knowledge, the objective of this paper is to present quantitative findings of a real-time parking system evaluation on Clemson University campus in Clemson, SC.

**TRAFFIC SIMULATION MODELING**

To examine the impact of different transportation scenarios on and around campus, traffic simulation was chosen as a tool to collect data on the chosen measures of effectiveness. The proceeding sections discuss how the model was built, calibrated, validated, and how each scenario was hypothesized and run.

The researcher decided to select an off-the-shelf microscopic simulation suite with the capabilities to model the proposed traffic environment. Software was selected based on a thorough review of available traffic simulation software, focusing on abilities to model local and
arterial streets, actuated and coordinated signals, public transit vehicles, pedestrian, parking behaviors, three dimensional display, and the availability of an applications programming interface (API). The software VISSIM was chosen for its abilities to model pedestrians in more detail than other software.

6 **Model Building**

Traffic simulation software uses two key elements to build models, links and nodes. Links represent homogeneous pieces of roadway with the same number of lanes, the same rules such as no trucks in the left lane, and the same start and end place for all lanes. To delineate the start and end of each link a node is used as a junction point. Nodes can denote an intersection with two or more links, a lane drop or addition, or a rule change. If two links pass over each other without a node at their intersection, the software assumes that they pass over or under each other and do not interact. To model vehicular traffic accurately, the length of links and the spacing between intersections must be correct.

The researchers started building the model using scaled, high quality, aerial photographs from online sources such as Google and assembled them in drafting software (AutoCAD). This compilation of images was then saved as one image then imported and scaled in VISSIM. After the scale of the aerial photograph background was verified, the researchers began inserting the links, connectors, and nodes. The final network contained approximately 21,000 links or connectors, approximately 2,100 nodes, and 700 groups of parking spaces. Figure 1 shows the areal photographs used to scale the roadways (on left) and the created road network in VISSIM (on right).
Next parking lots were created to account for the significant number of parking spaces owned and operated by Clemson University Parking Services. VISSIM, while offering the ability to model individual parking spaces, requires large amounts of time for this level of detail. This researcher estimates that it would require approximately a half hour to create each individual space. Instead, the researcher used one parking lot for each set of adjoining spaces of the same restriction. For example if a lot had five faculty-staff spaces, then two visitor spaces, followed by five more faculty-staff spaces, it was modeled as three parking lots with five, two, and five spaces, respectively. Restrictions were placed on the link(s) entering each set of spaces to allow the correct class of vehicles. Drivers will enter each lot and proceed to the center before they park. As each row fills, drivers are rerouted to another row or lot, or one in the closest zone. Approximately 700 parking lots were modeled to account for all of the parking spaces on campus as well as the entrances and exits from the network. Figure 2 shows an example of how parking spaces were modeled in VISSIM.

![FIGURE 2 PARKING MODELED IN VISSIM](image)

To represent the volumes on each link, and the ability of traffic to select new routes, origin-destination (OD) matrices were developed. These OD matrices specified how many vehicles were traveling from each zone in the network and to which other zones they are heading to, during a given time frame. For example, one cell in the matrix might specify the number of vehicles traveling from zone 10 to zone 11 between 11am and noon. Figure 1 displays the distribution of zones through the simulated network. The benefit of using OD matrices over location-based volumes is during detours and rerouting, vehicles can choose new routes to their
zones, whereas the location-based method will show no change in traffic demand. The researcher used traffic data collected from Hi-Star traffic counters, traffic cameras, and manual counts, to create OD matrices for each hour of peak campus occupation between 10am and 2pm on weekdays. This timeframe was used because it represents the time when parking would be most difficult to find. Outside of this time period, motorists were assumed to take rather pre-set routes to campus due to the availability of parking.

Each matrix was developed using between 64 and 66 constraints and they contained 1,156 cells (34 zones x 34 zones). The researcher manually increased and/or decreased volumes until the OD total volume was within one percent and each route’s OD traffic volume was within 10 percent of the observed.

A separate OD matrix was developed for each class of vehicle based on campus parking restrictions and these matrices were input into VISSIM. These classes included faculty-staff, student commuter, student resident, facilities vehicle, handicapped vehicle, bus, trucks (heavy and light), and non-campus vehicle. Within each of these classes (except bus) there existed passenger vehicles (cars, SUVs, minivans), motorcycles, and light trucks. The proportions of these vehicles were determined by field observation and were organized by AASHTO vehicle type and the number parking permits sold during the 2007-2008 academic year.

Specifying the traffic control for all links and node is possibly the most time-consuming part of building a simulation model in a pedestrian-rich environment. In VISSIM, traffic control devises include routing decisions, speed changes, priority rules, stop signs, signals, and traffic detectors. The first type of simulated vehicle control inserted, routing decisions, only affect vehicles of a specific class. For example, faculty staff vehicle traveling to a particular zone will choose a different route than commuters. Speed changes specify the distribution of speeds that a
vehicle type will travel on a particular road segment. Because campus speed data was available, the 15th and 85th percentile speeds were specified where available and the speed limits were used as the 85th percentile speeds elsewhere. To define the right-of-way at intersections, priority rules were specified and conflict zones were identified to represent the complex interactions between vehicles and between vehicles and pedestrians. Lastly, the stop signs and traffic signals were input into the model.

Model Calibration and Validation

Calibration and validation are steps that verify the model represents the observed transportation network accurately. To ensure a realistic model an exhaustive procedure was developed based on the findings of other simulation studies. Calibration included the following three steps:

1. Check volumes using detectors on key radial routes and internal links as recommended by others (26; 27; 28), and adjust link costs to improve volume adherence to within one percent (total),
2. Verify signal operations,
3. Compare travel times along key routes (28) and adjust driver characteristics to match travel times within ten percent.

After calibrating the model by adjusting link costs or modifying the driver characteristic, validation was started. Since the model works stochastically, it is possible to do new runs to check if the range of results is valid. The validation included three steps:

1. Compare volumes again (26) to ensure it remains within one percent of observed. Figure 2 shows that the modeled volumes do not under or over estimate the observed volumes as the nodes are evenly-distributed on both sides of the 45° line.
FIGURE 4 Differences of Modeled and Observed Volumes

2. The second step conducted for validation compared the observed and modeled speeds along key links throughout the road network, as recommended by (29; 28). While the calibration step compared travel times, which includes control delay, comparing point measures of speed distributions can ensure the driver behavior is appropriate on a variety of link types. Statistical analysis revealed that the observed and simulated volumes were the same.

3. The final step taken to validate the simulation model included a graphical comparison of observed traffic videos and simulation animation by those intimately familiar with the traffic network (30), and is also known as face validation. During this step the researchers met with Clemson’s Director of Parking Services and reviewed the model’s 3D operation at several key intersections to ensure everything was operating normally.

After the completion of the calibration and validation steps, the model was assumed a fair representation of the transportation network on and around Clemson University campus.

Select and Identify Measures of Effectiveness

Selecting the appropriate metrics to evaluate a system is essential to accounting for the impacts of the selected transportation system changes. The researchers evaluated a thorough list of metrics and selected four based on input from project sponsors, including: travel times, delay, speed, and volume.

Real-time Parking Information

To evaluate the impact of a real-time parking information system on Clemson’s campus, the dynamic routing decision tool was used in the simulation software. This tool allows motorists to select another destination (based on their parking permissions) if their destination lot is full. The researchers simulated the implementation of three changeable message signs (CMS) along perimeter road based on input from a previous campus ITS Architecture stakeholder meeting and a subsequent system design. The signs were located on the east and westbound approaches to Cherry Road, and on the eastbound approach to Williamson Road as indicated by FIGURE 3. The boxes represent the CMS and the arrows represent the directions that the signs are facing towards, providing parking information to approaching motorists. Each sign was located based on the letter height of the sign, road speed limit, and driver sight distance. These details were available from a system design and were determined using shop drawings, vendor specifications, and standard transportation engineering design manuals such as the AASHTO Greenbook and the MUTCD (Manual of Uniform Traffic Control Devices).
FINDINGS

This installation was found to produce a total motorist benefit of approximately $135 each mid-day when parking is most difficult to find. Findings indicated that there was a significant reduction (with 95% confidence) in network delay, approximately 15 percent, from adding three real-time parking availability signs along perimeter road. FIGURE 4 displays the 95% confidence bounds of the simulated average network delay during current conditions and conditions after the use of real-time parking information signs. Because the confidence bounds do not overlap, the results indicate a significant change in delay. To quantify the time savings into dollars, the ITS deployment analysis system (IDAS) was referenced (31). Based on the IDAS default values, the in-vehicle value of time in 1995 dollar is 9.63($/hr) with three percent interest rate. To calculate the 2007 value, the following procedure was done:
Finally the total delay time was multiplied to in-vehicle cost to determine the saved money.

The average, highest and lowest amount of delay reduction, in hours, can be measured as follows:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Current Conditions</th>
<th>Real-time Parking Info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Delay (min)</td>
<td>3862</td>
<td>3271</td>
</tr>
<tr>
<td>High (min)</td>
<td>3917</td>
<td>3381</td>
</tr>
<tr>
<td>Low (min)</td>
<td>3686</td>
<td>3032</td>
</tr>
</tbody>
</table>

FIGURE 6 Confidence Bounds of Delay Findings, alpha=0.05

This reduction in network delay was converted into monetary units, finding a benefit of between $200 and $70 per midday for all motorists. Midday was used because it is when campus occupancy is highest and available parking is consequently most difficult to locate. Thus, adding the benefits for only weekday traffic during the school year could benefit Clemson motorists between $19,700 and $24,000 per year. Benefit of using such a system during special events and summer semesters will only increase the value. There was no significant change in
travel time or speeds due to implementing real-time parking information during midday (95 percent confidence).

It was assumed that there was no significant change in walking time or distances because the evaluated system was not influencing the availability of parking spaces. While the predicted reduction in delay is high, previous research has found that 15 percent of all downtown traffic can be searching for parking (15), and other studies have predicted similar findings for a smaller metropolitan area (18). Because a college campus’ core can be easily paralleled to a city’s downtown, the significant reduction in delay suggests that some vehicles take a significant amount of time to locate a acceptable parking spot. For example, a commuting student may start their search in the core of campus and eventually find available parking at the periphery.

The findings also indicated no significant change in travel times, volume, or speed along key routes on campus, as shown in FIGURE 5. Because neither of these factors changed significantly and because delay did decrease, findings suggest that parking search time is a significant factor in efficient parking operations. Specifically, because the traffic did not change (travel time, volume, or speed) on any routes providing mobility through and around campus, the delay the reduction in delay must have occurred within the parking lots. While previous research was unable to conclude that parking circulation is reduced by such a system (22), the findings herein show conclusive evidence that real-time parking information reduces vehicle circulation, and supports previous studies (15; 18).

(a)
FIGURE 7 Measures of effectiveness for real-time parking information model:
(a) Travel time, (b) Vehicle speeds, (c) Volumes
CONCLUSIONS

The simulation analysis of a real-time parking information system provided information on both the implementation and expected impacts of such a system on an isolated college campus. The simulation model helped evaluate the implementation of three locations, where variable message signs will be placed, along a key circumferential route, resulting in a 15-percent reduction in network delay. Because the volumes remained constant for the arterial and collector roads, the reduction in delay must have come from local campus roads and within parking lots. Thus, this research represents one of the first quantitative findings that real-time parking information reduces motor vehicle circulation.

If benefits are realized as predicted, a real-time parking information system could benefit Clemson commuters more than $20,000 per year if operated during only weekdays throughout the fall and spring semesters. The true benefits are likely greater if the system is effectively used during special events. Future work should evaluate the driver impact of different sign placements to determine best practices and investigate the potential benefits of operating this system during special events.
LIMITATIONS

The cost-benefit analysis was beyond the scope of this study; however, there are several sources for cost data that can be referenced and paired with the presented benefit data in future work (32). The authors acknowledge that different sign placement might impact the delay findings.

ACKNOWLEDGEMENT

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REFERENCES


