Use of Big Data to Evaluate and Improve Performance of Traffic Signal Systems in Resource-Constrained Countries

Evidence from Cebu City, Philippines

Yang Carl Lu, Holly Krambeck, and Liang Tang

Deployment of an adaptive area traffic control system is expensive; physical sensors require installation, calibration, and regular maintenance. Because of the high level of technical and financial resources required, area traffic control systems found in developing countries often are minimally functioning. In Cebu City, Philippines, for example, the Sydney Coordinated Adaptive Traffic System was installed before 2000, and fewer than 35% of detectors were still functioning as of January 2015. To address this challenge, a study was designed to determine whether taxi company GPS data are sufficient to evaluate and improve traffic signal timing plans in resource-constrained environments. If this work is successful, the number of physical sensors required to support those systems may be reduced and thereby substantially lower the costs of installation and maintenance. Taxi GPS data provided by a regional taxi-hailing app were used to design and implement methodologies for evaluating the performance of traffic signal timing plans and for deriving updated fixed-dynamic plans, which are fixed plans (with periods based on observable congestion patterns rather than only time of day) iterated regularly until optimization is reached. To date, three rounds of iterations have been conducted to ensure the stability of the proposed signal timings. Results of exploratory analysis indicate that the algorithm is capable of generating reasonable green time splits, but cycle length adjustment must be considered in the future.

Traffic congestion exacerbates pollution and greenhouse gas emissions and has a known, substantial negative impact on growth of urban gross domestic product. Without access to the sophisticated tools commonly used in advanced economies for monitoring real-time traffic conditions, collecting and analyzing historical travel time data, or optimizing signal timing plans, resource-constrained traffic management agencies are challenged to mitigate congestion.

To address this challenge, a World Bank team partnered with the government of Cebu City, Philippines, in 2011 to develop a web-based platform for collecting, visualizing, and analyzing traffic speed data derived from the smartphones of taxi drivers. This pilot project successfully achieved a proof of concept, and the platform, Cebu Traffic, won first prize in the 2013 Philippines National E-Governance Competition. Building on this success, the project team scaled up the initiative by developing open-source software and forming big data partnerships to substantially reduce the cost of traditional traffic data collection and analysis while simultaneously improving the quality. The resulting platform, Open Traffic, is the first scalable open-source program of its kind and may empower less advanced economies to leapfrog a stage in intelligent transportation system development (*1*). Krambeck et al. have reported on the Open Traffic methodology and preliminary results (*2*).

Y. C. Lu and H. Krambeck, World Bank, 1818 H Street, NW, Washington, DC 20433. L. Tang, University of Maryland, College Park, 1173 Glenn L. Martin Hall, College Park, MD 20742. Corresponding author: Y. C. Lu, ylu2@worldbank.org.

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STUDY OBJECTIVE

As a next step, the project team designed a study to determine whether GPS data from a taxi company are sufficient to evaluate and improve traffic signal timing plans in resource-constrained environments.

Deployment of an adaptive area traffic control system is expensive; physical sensors require installation, calibration, and regular maintenance. Because of low budgets and technical capacity in resource-constrained economies, area traffic control systems found throughout World Bank partner countries often are minimally functioning. In Cebu City, for example, the Sydney Coordinated Adaptive Traffic System (SCATS) was installed before 2000, and fewer than 35% of the detectors were in service as of January 2015. In Cebu, SCATS was set in a fixed-dynamic mode. As a result of detector failure, the system could select only from several predetermined phasing plans that included phase sequence and green time split. However, the system was able to adjust cycle length in response to input from functioning detectors.

To determine whether traffic signal timing could be improved in Cebu despite the low percentage of functioning detectors, the city granted the research team permission to develop and test new signal timing plans derived from taxi GPS data along the city's primary west–east arterial, National Bacalso Avenue.

The remainder of this paper proceeds with a literature review of GPS and mobile data applications in transportation. Next, the pilot area is introduced, followed by an overview of the methodology and the data used in the study. The team's traffic signal performance evaluation framework is presented, and the algorithm for systematic adjustment of signal timing is described. Then, field test results are summarized. Finally, conclusions and recommendations for future work are presented.

LITERATURE REVIEW

Since 2000, numerous studies have been conducted in advanced economies to explore innovative applications of GPS and mobile data to transportation. One pioneering example was the Mobile Century, conducted in 2008, which used GPS-enabled cell phones to monitor speed and travel time along California highways in real time (*3, 4*). In this pilot program, a virtual trip line (VTL) methodology was tested for triggering GPS data updates that ensured user privacy. A comparison with loop detector data proved the method's accuracy, even with a low penetration rate. This method subsequently was used in the World Bank's Open Traffic program and in the present study. More recently, the Texas A&M Transportation Institute and the state of Indiana produced a mobility report based on probe vehicle data (*5, 6*). Other studies have investigated the use of GPS data as an alternative source of household survey data (*7–9*), for evaluating the performance of public transit (*10*), and for developing an activity-based simulator (*11*).

GPS data have not been used as widely for signal control applications. Ban et al. proposed a delay pattern estimation method for signalized intersections under normal and oversaturation conditions that used the VTL concept (*12*). The model and algorithm were tested through both microsimulation and field experiments. Hunter et al. presented probe-vehicle-based comparisons between an optimized time-of-day control and SCATS on 15 intersections in Cobb County, Georgia (*13*). Performance metrics were speed, travel time, and delay. Results indicated that neither system dominates in performance for most parts of the network.

To the best of the authors' knowledge, most studies that have investigated the use of GPS data in signal control applications have focused on performance evaluation and none have focused on optimizing signal control solely on the basis of GPS data—or in resource-constrained countries. Therefore, in addition to evaluating performance, the present study explores the feasibility of improving signal timing with the support of taxi-generated GPS data.

PILOT AREA DESCRIPTION

The pilot study was conducted along National Bacalso Avenue, which is the main east–west corridor in Cebu City (population 922,611) (*14*). The study segment covered about 4.5 km between Tres de Abril Street and Juan Luna Avenue and carried approximately 50,000 vehicles per day. The western portion of the road was a median-divided urban arterial with three lanes in each direction, and the eastern portion was an undivided urban road with two lanes in each direction. In total, 12 signalized intersections were located in the study area (numbered from 34 to 45 in Figure 1). Intersection 43 currently is operated without signal control because of a previous incident and was not included in the study.

All signalized intersections included in this study are equipped with SCATS, which is capable of adjusting cycle length and green time splits in real time in response to detector input.

METHODOLOGY

When detectors are malfunctioning and cannot be immediately replaced, a common workaround is to switch from adaptive control to a fixed signal plan with preset green time splits. While using this workaround as a baseline, the team first sought to quantify the performance of the Bacalso signal timing plans with taxi GPS data. From these results, the team developed algorithms to generate a fixed timing plan solely based on GPS data that could achieve comparable performance to the existing plan. Next, the team began work on a fixed-dynamic method, whereby the fixed plan (with periods

FIGURE 1 Signalized intersections in study area (pilot intersections are numbered).

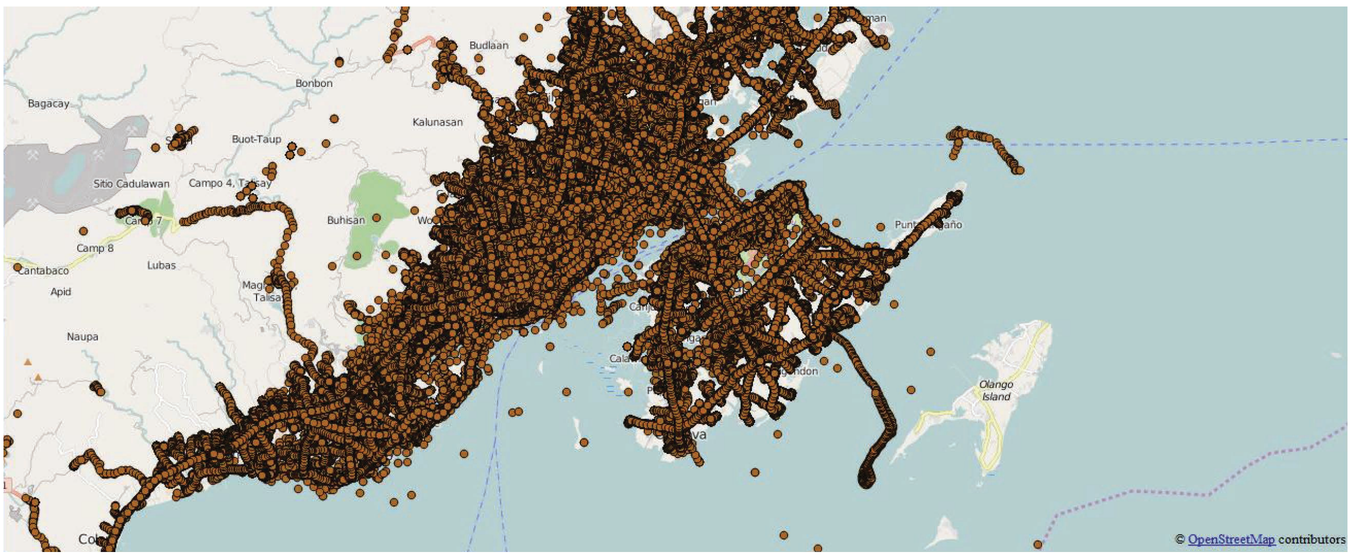
based on observable congestion patterns, as opposed to only time of day) is regularly iterated until optimization is reached. To date, the team has conducted three iterations of the above steps to ensure the stability of the proposed signal timings.

For data, the research team partnered with Grab (Transport App Company), a smartphone application for on-demand transport booking that generates taxi GPS data in countries the World Bank supports, which include Indonesia, the Philippines, and Vietnam. Through this partnership, the team was able to access a real-time stream of GPS data (updated about every 10 seconds) generated by more than 400,000 drivers registered on the Grab network in Southeast Asia and provided through Amazon Kinesis. To date, GPS points have been translated to travel times by linking latitude and longitude with geometric information provided by Open Street Map (OSM).

Maps of taxi data coverage in Cebu City and near one of the pilot intersections are presented in Figure 2. As a result of data inaccuracies or driver activities, some GPS points do not fall on roads; these data were excluded from analysis in the following process.

PERFORMANCE EVALUATION

Taxi GPS data were used to establish a comprehensive evaluation system for all intersections along the pilot corridor. Delay profiles and queue lengths were developed for every turning movement.



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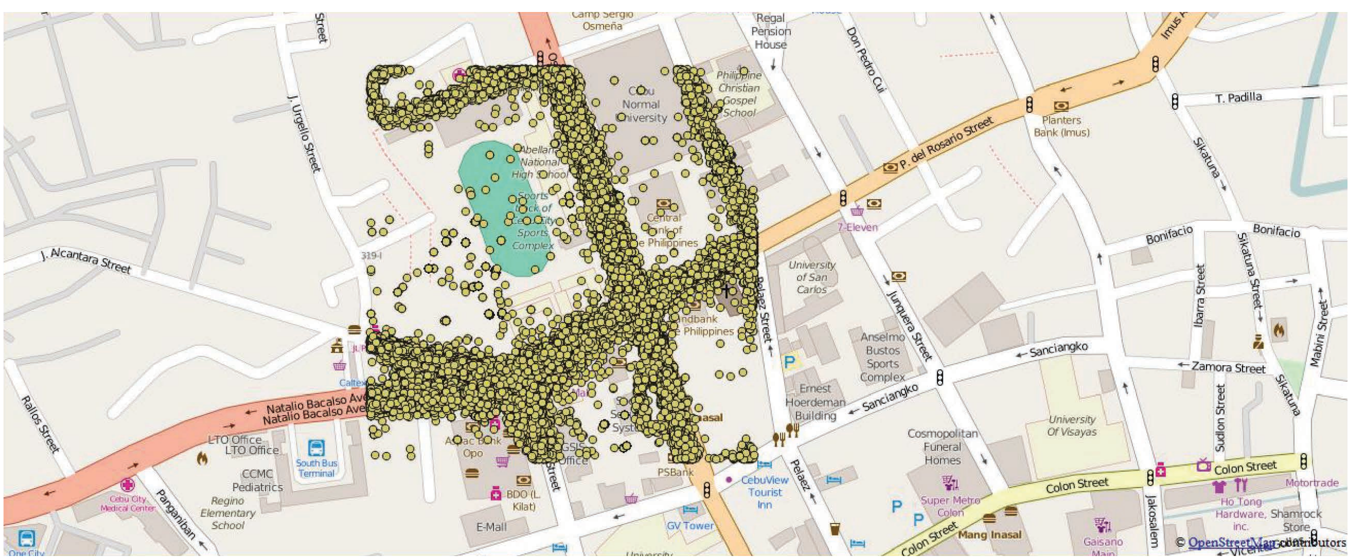

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FIGURE 2 Grab's GPS data coverage (*a*) in Cebu City (February to June 2015) and (*b*) near Intersection 30, National Bacalso Avenue at Osmena Boulevard.

Data Extraction

First, a reasonable data partition had to be performed to reduce the computational burden. The entire arrival, queuing, and departure process had to be recorded to allow computation of signal-related delay and queue. Therefore, for one specific intersection, the area that covered the target intersection and all adjacent intersections was extracted from the citywide GPS data set.

Given the latitude and longitude of the target intersection, the latitude and longitude of its adjacent intersections in the OSM were identified as the boundary points (*15*). If the nearest intersection were more than 1 mile away from the target intersection, then a point approximately 1 mile away along the road segment (defined as "way" in OSM) could be used instead. The latitude and longitude information of these identified boundary points then was used to create a polygon buffer to extract the data.

The data from the GPS stream used for this study were time stamp, vehicle ID, longitude, latitude, heading, and speed. For each targeted intersection, only the GPS data in the polygon buffer were used. After geographic extraction was completed, the weekend data were excluded because traffic patterns usually are different on these days.

Trip Construction

The effective trip was constructed to obtain the signal-induced delay. Three conditions were required to satisfy the effective trip criterion:

- The time interval between two consecutive points should be smaller than some threshold; otherwise, two separate trips may be combined as one, which usually results in an unreasonably long delay.
- The turning movement must have been completed. (To perform this check, it was assumed that four connecting links existed for the targeted intersection, and four regions were created to represent these links; the trip that started at one region and ended at one of other three passed the check. Because of inevitable inaccuracy, points near the intersection may have been assigned to the ending region, even if the turn had not been completed. Therefore, a small buffer was added at the ending region to ensure completeness of the turning movement and avoid underestimation of the delay.)
- The vehicle does not leave the road. This condition ensures that activities such as refueling are not included in the trip.

Given these requirements, the following steps were taken to create effective trips:

Step 1. Sort the GPS data records based on time, in ascending order.

Step 2. Separate data into multiple trips, based on the following criteria:

2.1. For point n with time $T(n)$ and the following point $n + 1$ with time $T(n + 1)$.

2.2. If $T(n + 1) - T(n) > 1$ minute, separate into two trips.

2.3. Keep only trips with more than two points so that relevant information can be computed from the trip.

Step 3. Based on the starting and ending points of each trip, determine the relative region with respect to the targeted intersection i. The steps to determine the region are

3.1. For each adjacent intersection A_{ij} ($j = 1{:}N$; $N = 4$ in most cases) that connects to the targeted intersection i identified in the section on data extraction, find the node M_{ij} that lies approximately in the middle between intersection A_{ij} and targeted intersection i (M_{ij} should be on the link that connects intersection A_{ij} and targeted intersection i);

3.2. Create a rectangular buffer R_{ij} from the latitude and longitude information of M_{ij}, adjacent intersection A_{ij}, and all points representing the geometric change between them. The rectangle buffer R_{ij} should be extended about 5 to 10 meters in each direction to cover all vehicles;

3.3. If the starting point or ending point is within rectangular buffer R_{ij}, label the starting point or ending point with number j; and

3.4. Delete trips if the corresponding starting point or ending point is not within any of the rectangular buffers or the starting point and ending point belong to the same region.

Step 4. For each trip, find the point that passes the intersection. The steps follow:

4.1. For the region j, which the first point of the trip belongs to, extend the boundary of rectangular buffer R_{ij} from M_{ij} to the targeted intersection i and denote it as R_{ijs}. Similarly, R_{ijs} should be extended about 5 to 10 meters in each direction;

4.2. Similarly, create a rectangular buffer R_{ije} for the region j, which the last point of the trip belongs to; and

4.3. Starting from the second point of the trip, if the point is within R_{ijs}, move to the next point; if not, determine whether the point is within R_{ije}; if the point is within R_{ije}, the time associated with this point is regarded as the time passing the intersection; if not, delete the trip.

Delay Computation

To estimate delay, the team preprocessed the OSM road base map by adding VTLs for each intersection approach. After the effective trip was constructed, the actual travel time from VTL 1 (VTL_1) to VTL 2 (VTL_2) through Intersection 0 could be obtained by computing the time difference between VTL_1 and VTL_2 (Figure 3).

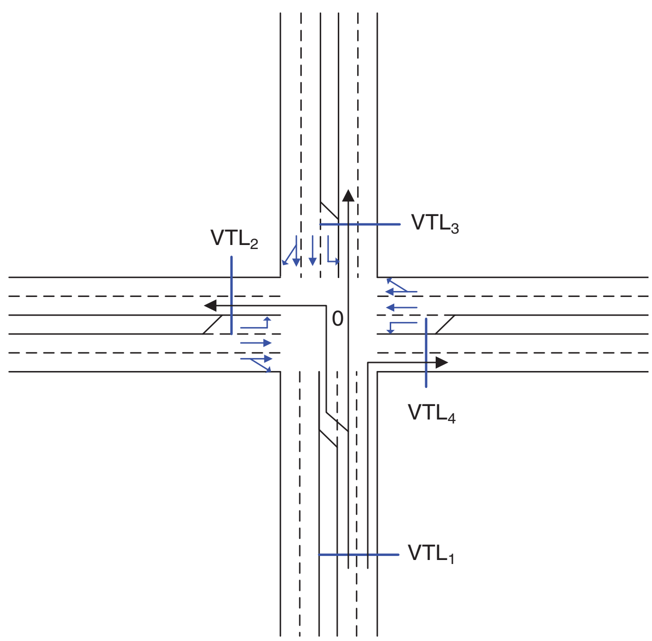
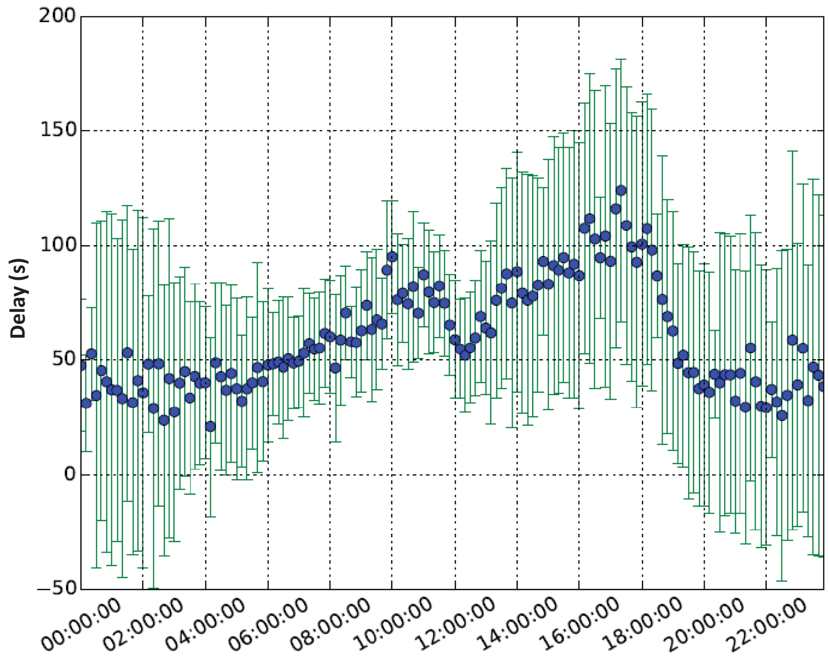


FIGURE 3 Example of delay computation and VTL concept.

Free-flow travel time was computed as the summed distance (VTL_1 to 0 + 0 to VTL_2) divided by the speed limit. The delay was the difference between actual travel time and free-flow travel time. However, because some developing countries may not have effective speed limits, the speed limit was estimated with GPS-derived speed estimates during the night, when traffic volume tends to be low. Results showed that a speed limit of 50 km/h (13.9 m/s) could be reasonable.

As an example, the evolution of delay for the eastbound left-turn (EBL) and eastbound through (EBT) movements on Intersection 30 is summarized in Figure 4. Blue dots represent the average value, and green bars mark the lower and upper bounds. When vehicles travel at extremely high speeds, the delay value is negative; therefore, these observations were excluded from the analysis. The delay of EBL movement increased at morning and afternoon peaks, while the delay associated with EBT movement was more flat.



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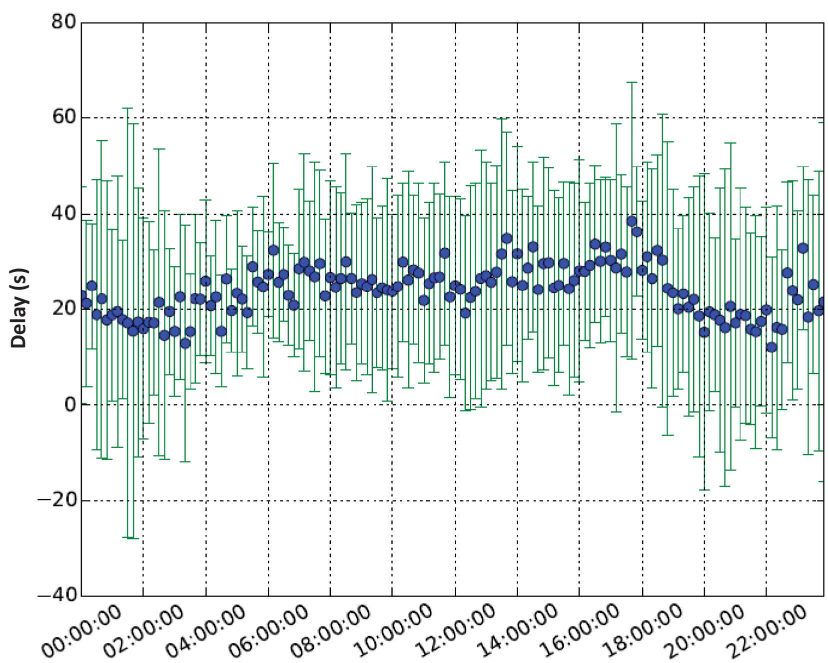

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FIGURE 4 Delay evolution at Intersection 30 for (*a*) EBL movement and (*b*) EBT movement.

Queue Estimation

Like delay, queue information is essential to the adjustment algorithm. For example, if the queue extends to the upstream intersection, the corresponding green time splits cannot be reduced further; otherwise, the risk of spillback is high. The process of queue index computation follows.

Step 1. For each trip, find the point when the vehicle joins the end of queue:

1.1. If the trip data do not contain speed information, compute the speed for each point (except the first point) by using the distance between the current and previous points divided by the time difference.

1.2. If the trip data do contain speed information, find the first point with speed less than 0.2 meters per second (m/s) between the trip starting point and the first point that passes the intersection; this point is considered as the queue starting point. If no point has a speed less than 0.2 m/s, then the queue length is set as zero.

Step 2. For each trip, compute the queue index:

2.1. Calculate the length from the queue starting point to the intersection, which is denoted as the queue length.

2.2. Divide the queue length by the segment length between the adjacent intersection and the targeted intersection to get the relative queue length as the index.

The queues for different approaches were quite different (Figure 5); therefore, the queue spillback risk was higher at some approaches. The queue length at the 95% level was more stable than the maximum value and therefore was used in later computations.

SIGNAL PLAN IMPROVEMENT

The method for adjusting the signal plans takes into consideration both efficiency and equity. The concept of equity derived from delays of all turning movements is defined in the next section. The algorithm tries to obtain a better equity performance by distributing the green time among different splits, and the queue and sample turning movements are treated as constraints and weighting factors during the adjustment process.

Accounting for Equity

The equity adopted in the algorithm is developed from the concept of signal failure, which means that the vehicles queued cannot pass the intersection in one signal cycle. If the intersection is operated under undersaturated conditions and the signal plans are well designed, then the signal does not fail because the overall volume does not reach operational capacity for the intersection. In contrast, a signal often fails under oversaturated conditions, which happens to be the case in Cebu City during peak hours. Even though signal failure was expected to be observed at the test site, the objective was to make the failure happen as infrequently as possible and to distribute the appearance evenly to different phases while accounting for the associated volume.

With the computed delay from GPS data and the current signal timing plan, the occurrence of signal failure can be estimated directly. If red phase time for movement i is assumed to be known and denoted as R_i, then the average delay during the red phase would be $R_i/2$ if all vehicles waited for one cycle at most. Because of the shockwave at the queue-formation and -departure process, actual obtained delay is expected to be longer. Therefore, a margin t_m is added to $R_i/2$ to represent the threshold of signal failure, and if the obtained average delay for the turning movement i is larger than $t_m + R_i/2$, then vehicles generally need to wait for more than one cycle to pass that intersection. Even though vehicles have to wait more than two cycles for some extremely congested intersections, the expected average delay should be larger than $t_m + R_i/2 + \mathrm{CL}$, where CL is cycle length.

With the computed dividing points and a large sample of delays (usually collected over 1 to 2 weeks), the cumulative distribution function (CDF) of delays can be created for all turning movements at each intersection, as presented in Figure 6 for three representative examples. In Figure 6*a*, most vehicles can pass the intersection in one cycle; this design is considered good. In Figure 6*b*, some vehicles must wait for more than one cycle, but all vehicles complete the passing within two cycles; this design is considered okay. In Figure 6*c*, the delay is extremely long and some vehicles wait for more than two cycles; this design is considered bad.

In the CDF profile, if the percentage of delay that falls into one of the three bins is exactly the same for different approaches (rare in reality), the intersection receives the highest equity score. A larger discrepancy suggests less equity. For example, as in Figure 6, delay in Bin 1 is almost 100% for EBT while delay in Bin 1 just reaches 60% for southbound through (SBT) movement.

Constraint and Weighting Factor

Queue length and volume also play important roles in signal plan adjustment. Queue length serves as a major constraint. As in the network context, a signal plan at one intersection is coupled with those of neighboring intersections. Therefore, a plan cannot be adjusted on the basis of only its own performance; its effect on adjacent intersections should be examined before changes are implemented. For example, if a green time split must be reduced because of the equity concern but the corresponding queue length is very close to the upstream intersection, the adjustment may be canceled because the split reduction very likely will result in queue spillback. However, if the algorithm suggests a split increase on the basis of an initial evaluation but the road segment downstream is fully occupied, the initial decision shall be reevaluated.

Traditionally, detected turning volume determines cycle length and green time splits. In this study, without the use of physical detectors, the only available volume information is the sample taxi count. Through some preliminary field evaluation, the team determined that the taxi count can represent the general trend of the total volume to derive weighting factors for adjusting signal plans based on equity (Y.C. Lu and H. Krambeck, unpublished report, July 31, 2016).

Because the highest equity does not always represent the most efficient solution and usually is not realistic, especially in urban networks, a sample count usually is included when the signal timing is adjusted. Three conditions are considered here to derive different treatments:

Condition 1. If the delay profile of movement associated with Phase A is worse than the one with Phase B and Phase A is associated with more volume, then green time splits should be distributed to Phase A with great confidence.

Condition 2. If the delay profile of movement in Phase A is worse than the one in Phase B while volumes for these two phases

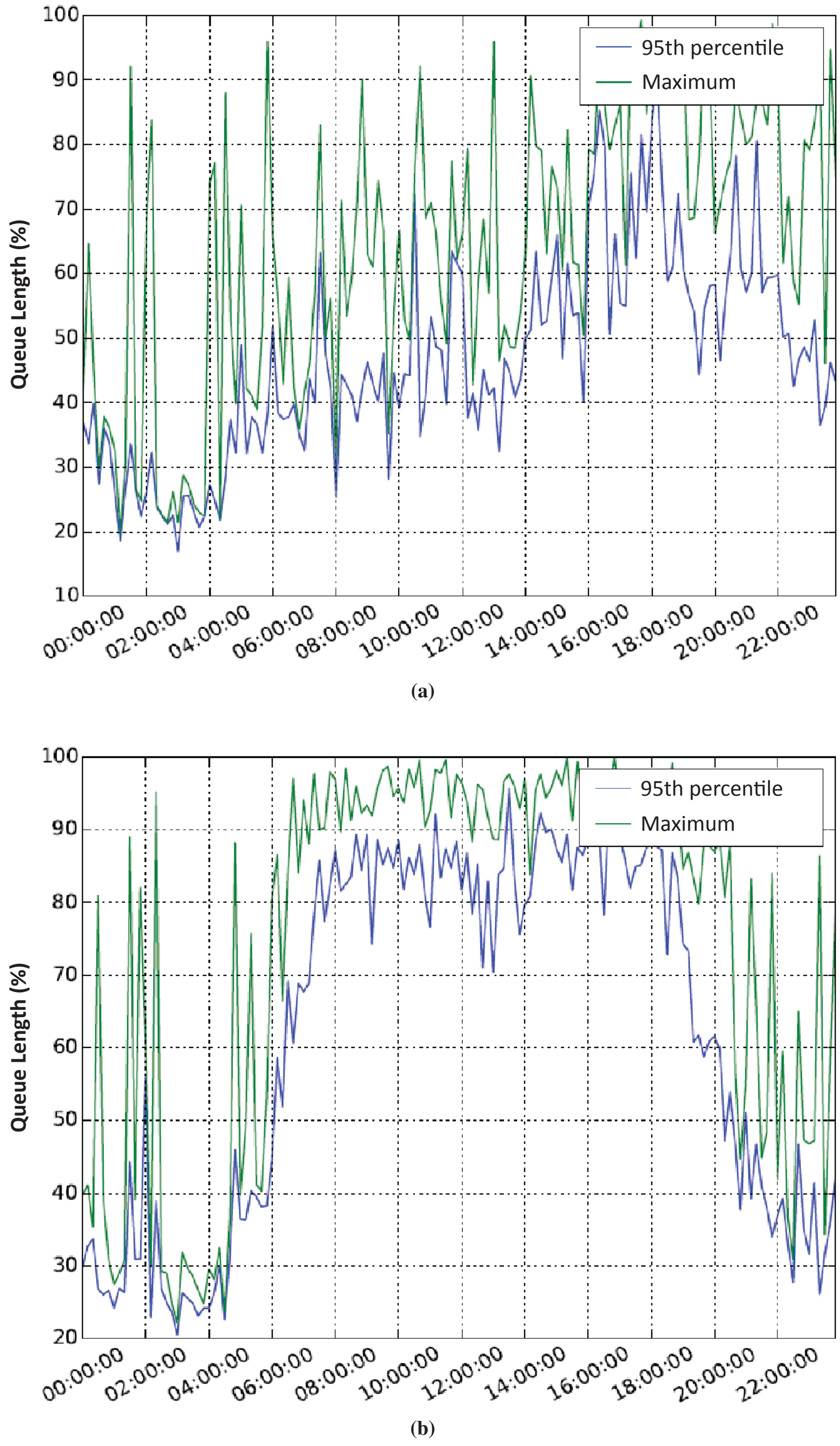

FIGURE 5 Queue profile at Intersection 30 for (*a*) westbound-through (WBT) movement and (*b*) EBL movement.

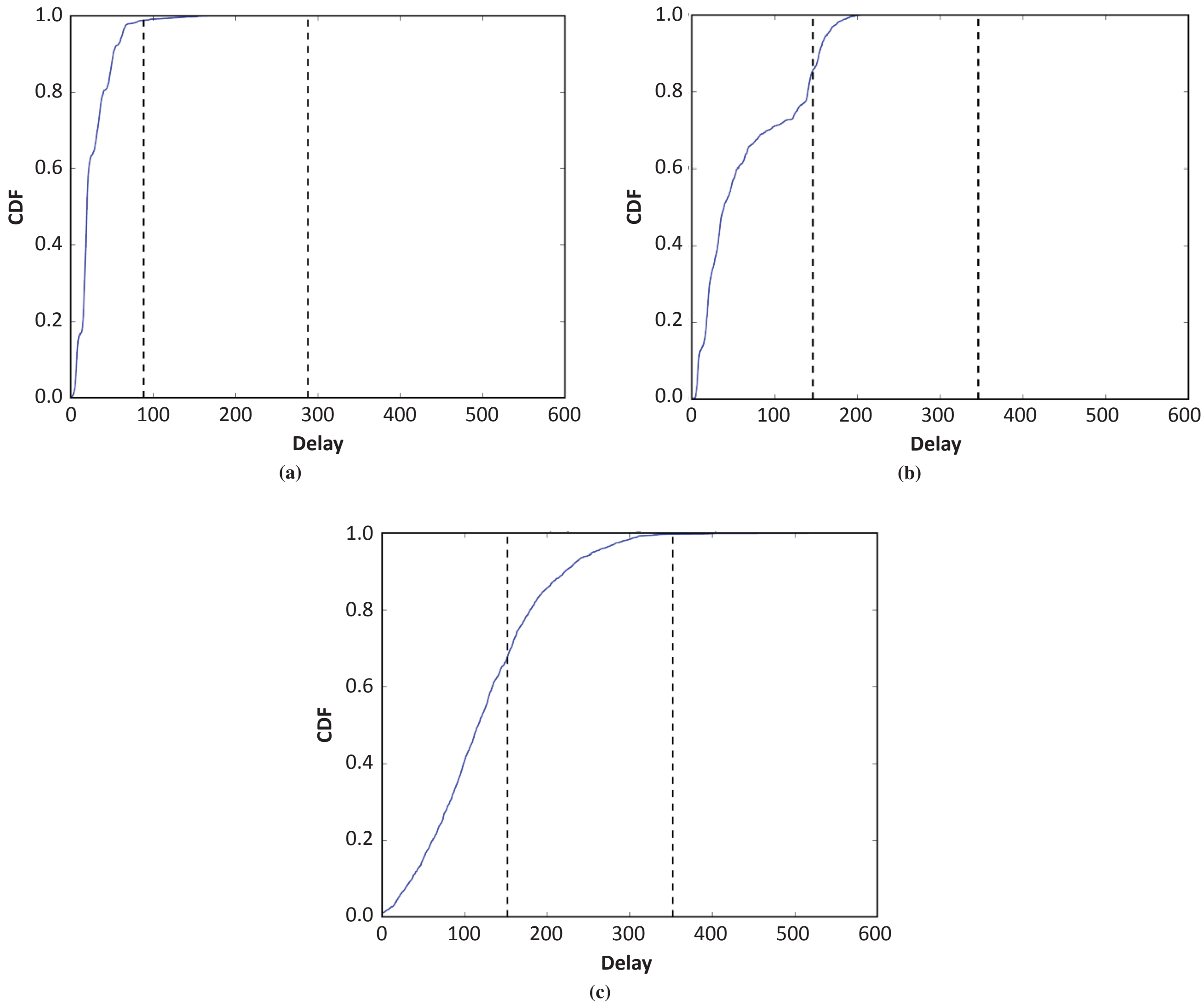

FIGURE 6 CDFs of morning delays at Intersection 30 (cycle length = 200 s): (*a*) EBT movement, good design; (*b*) EBL movement, okay design; and (*c*) SBT movement, bad design.

are comparable, then green time splits could be distributed to Phase A with some confidence.

Condition 3. The delay profile of movement in Phase A is worse than the one in Phase B, but Phase A is associated with less volume; under this condition, green time splits shall be distributed only to Phase A, with careful examination if the equity concern is severe.

Adjustment Algorithm

The algorithm for signal timing adjustment is intended to improve the equity of oversaturated intersections in the urban network while taking into account efficiency. The process follows.

Step 1. Generate the delay distribution for each movement.

Step 2. Identify the good and bad movement, if possible (as described in the section on accounting for equity), and move green time (e.g., 1%, 2%, and 3%) from the good to the bad movement:

2.1. Move 3% green time with Condition 1 (described in the previous section).

2.2. Move 2% with Condition 2.

2.3. Move 1% with Condition 3.

Step 3. If green time shall be increased for any approach of the targeted intersection, check the priority of its downstream intersection:

3.1. If the downstream intersection has lower priority, confirm the increase change.

3.2. Else if the downstream intersection has the same or higher priority,

3.2.1. If downstream queue (after adjustment) has spill-back, deny the change.

3.2.2. Else confirm the increase change.

Step 4. If green time shall be reduced for any approach of the targeted intersection, check the priority of its upstream intersection:

4.1. If the upstream intersection has lower priority, confirm the decrease change.

4.2. Else if the upstream intersection has the same or higher priority,

4.2.1. If current queue (after adjustment of the upstream intersection) has spillback, deny the change.

4.2.2. Else confirm the decrease change.

In Step 3, the downstream queue is considered to have caused spillback if (*a*) signal timing will not be changed at the downstream intersection, and the spillback exists; or (*b*) spillback does not currently exist, but the green time of corresponding downstream movement will be reduced to some extent. Similarly, in Step 4, the targeted intersection is considered to have caused spillback if (*a*) signal timing will not be changed at the upstream intersection, and the spillback exists; or (*b*) spillback does not currently exist, but the green time for the corresponding upstream movement will be increased to some extent. Notably, the adjustment always starts from the intersection with the highest priority.

Because of the lack of traffic volume data and limitations of the taxi-generated sample, one-time adjustment often was insufficient to reach the stable and acceptable performance expectation; several rounds of iterations usually were required. After 1 or 2 weeks of implementation, the signal performance was reevaluated and plans were adjusted again until opportunities for additional improvement were difficult to identify.

PILOT STUDY RESULTS

Pilot Field Test

The first field mission for signal work was completed in July 2015, and several issues were identified. The saturation flow rate in Cebu is low because of the characteristics of mixed traffic flow. The jeepney, a type of minibus common in Philippines, represented a large proportion of vehicles, and their frequent stops near intersections to pick up and drop off passengers negatively affected the departure efficiency. As a result, longer cycle lengths were needed to clear the waiting queue. At some intersections, large volumes of pedestrian crossings stopped car movements and used up the already insufficient green times. Pedestrian crossing bridges have been constructed near busy intersections but their usage rates are low. Finally, the team found that signal phases at some intersections were not optimized to manage flows.

After the initial trip, three rounds of field tests were conducted in 2016: February 22 to March 4, March 28 to April 8, and May 23 to June 3. The test objective was to study the feasibility of replacing the current system with the proposed fixed-dynamic system. The algorithm adopted to adjust the signal plans focused on the redistribution of green times to improve the equity while maintaining efficiency. In the first two adjustment rounds, only green times were adjusted. In the third adjustment round, cycle length was changed in an exploratory manner. Because adjusting cycle length for different hours increased the workload of local staff, only six of the 11 intersections were included, in two subsystems: System 42 (Intersections 34 and 33) and System 40 (Intersections 38, 30, 39, and 40). Law enforcement, pedestrian education, and workload phasing design all were beyond the scope of this study and limited the improvement obtained.

Analysis of Results

The green time splits were adjusted according to the algorithm described earlier, and the cycle length selected for both morning and afternoon peaks in the first two rounds was 200 seconds. In the third round, cycle length was increased by 5 to 10 seconds for the periods with higher volume. In the base scenario, cycle length was allowed to change in real time.

The delay profile for Intersection 34 is presented as an example in Table 1. Delays are categorized in three bins by cycle length (CL), and average delays are listed; values in boldface are those that reflect the greatest mobility improvements. Due to the lack of collaboration between the departments in charge of signal design and public works, the NBL movement, which was set to share two lanes in the signal system, was given only one lane in reality; therefore, the green time splits associated with that movement were insufficient to discharge the queue, and extremely long delays were observed in the base case. The performance evaluation system successfully detected this issue and allocated more green time to that approach. Although the delay with other approaches increased to some extent, equity and efficiency both improved overall.

The overall weighted intersection delays are summarized in Figure 7 for morning peak (7 to 11 a.m.) and afternoon peak (3 to 7 p.m.), respectively. In the morning peak, mobility improved 9.9%, 14.8%, 6.1%, 8.3%, 15.9%, and 13.6% for each intersection. However, in the afternoon peak, delay increased by 16%, 15.6%, −3.3%, −3.8%, 26.2%, and 1.5% for each intersection.

The advantage of the GPS-based methodology for adjusting green time splits was clearly proven; the methodology improved performance in the morning peak, when suitable cycle lengths were selected.

TABLE 1 Delay Profile Comparison for Intersection 34

		Base				Iteration 3			
Period	Direction	< 1 CL (%)	< 2 CL (%)	> 2 CL (%)	Avg. Delay	< 1 CL (%)	< 2 CL (%)	> 2 CL (%)	Avg. Delay
a.m.	EBT	79.78	19.97	0.26	70.27	33.42	66.58	0.00	82.92
	WBT	97.92	2.08	0.00	61.28	75.00	25.00	0.00	41.07
	SBL	96.47	3.53	0.00	62.11	67.69	32.31	0.00	62.97
	NBL	19.64	44.64	**35.71**	**310.06**	29.41	64.71	**5.88**	**145.33**
p.m.	EBT	91.37	8.24	0.39	54.76	44.94	54.81	0.25	69.61
	WBT	92.83	7.17	0.00	31.55	74.51	25.49	0.00	38.29
	SBL	98.05	1.95	0.00	63.84	76.56	23.44	0.00	52.57
	NBL	25.22	54.78	**20.00**	**268.85**	20.00	80.00	**0.00**	**135.72**

NOTE: SBL = southbound left turn; NBL = northbound left turn.

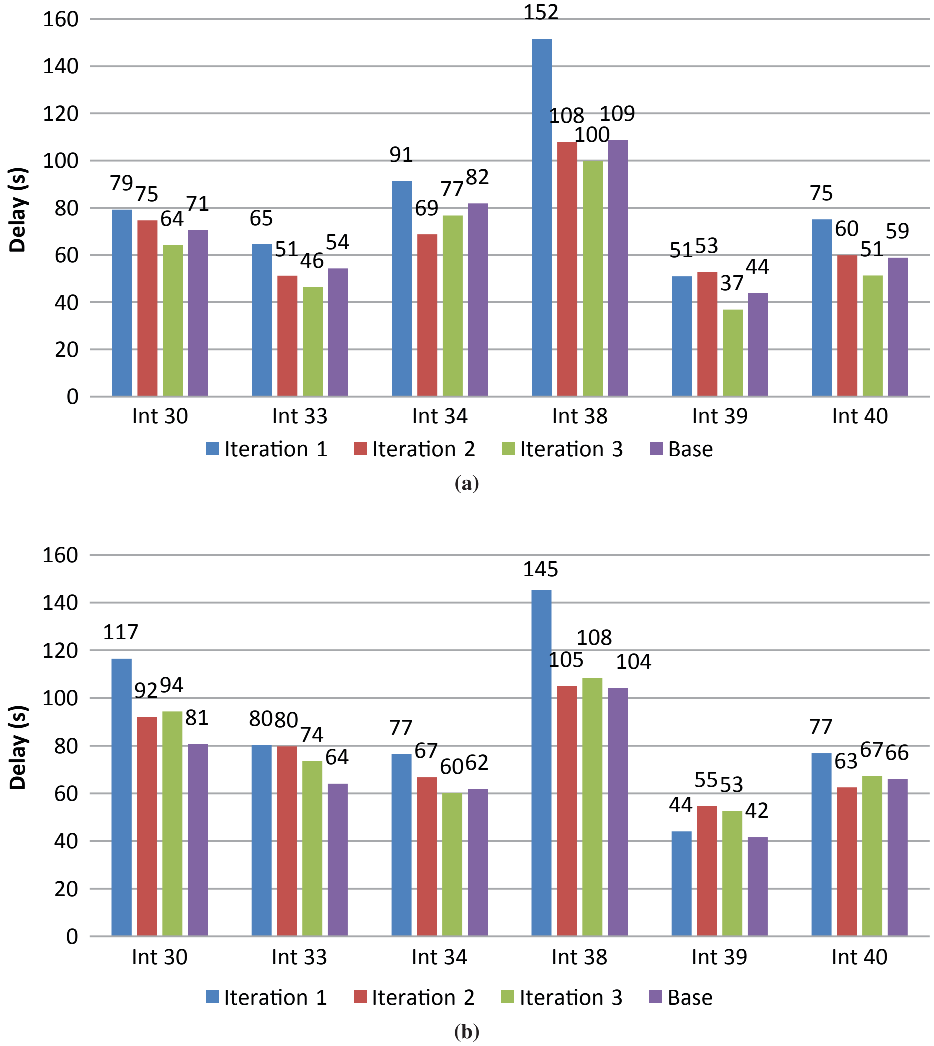

FIGURE 7 For different signal plans, delays during (*a*) morning peak (7 to 11 a.m.) and (*b*) afternoon peak (3 to 7 p.m.) (Int = intersection).

The team also observed that the cycle length for the afternoon peak was not well designed and the benefit of split adjustment was diminished. A more systematic way to adjust the cycle length based on the GPS data must be developed further.

CONCLUSIONS AND FUTURE WORK

Taxi GPS data were converted successfully into intersection performance metrics such as delay and queue length. To improve system equity and efficiency, the team developed and proposed a signal plan adjustment methodology based on the evaluation system. Pilot field tests along National Bacalso Avenue in Cebu City proved the capability of the methodology in allocating green time splits.

Moving forward, additional work must identify optimal cycle length. After the algorithm is finalized, the next steps would be to obtain more flexibility in setting up the cycle length on the basis of revealed delay patterns to develop a more robust performance index, which can remove the effect of incidents, and to extend the application from the corridor level to the network level.

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