Accuracy Study of Parking Duration Data from Patrol Survey

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Patrol Survey

Patrol Survey

Average parking duration

http://davidmunro.blogspot.com
### Patrol Survey

**Introduction**

- **Model**
  - **Simulation**
  - **Conclusions**

**Patrol Survey**

- **e.g., interval δ=30 minutes**

**Source from "Urban road traffic surveys"**

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**Figure 4.3 Parking Patrol Survey form: Example**

<table>
<thead>
<tr>
<th>Registration Number</th>
<th>Time at Start of Route</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>09:30</td>
</tr>
<tr>
<td>1</td>
<td>V</td>
</tr>
<tr>
<td>2</td>
<td>P</td>
</tr>
<tr>
<td>3</td>
<td>P</td>
</tr>
<tr>
<td>4</td>
<td>P</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
</tr>
<tr>
<td>8</td>
<td>C</td>
</tr>
<tr>
<td>9</td>
<td>C</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
</tr>
<tr>
<td>11</td>
<td>C</td>
</tr>
</tbody>
</table>

**Notes**

- Heavy rain
- Rain stop

(Circled letters indicate double-parked vehicles)
Patrol Survey

Source from "Urban road traffic surveys"
Goals

• The necessity to make a tradeoff is unknown as the current accuracy is unknown.

• What did the tradeoff brought? In other words, how much did the accuracy increase by more investment?

• Is there another way to increase the accuracy besides a higher budget?

Find the current accuracy

Find the improvement of accuracy from a tradeoff

Find another method to improve the accuracy
Assumptions

- Imagine a simple parking scenario, a public parking area with enough supply and no restrictions of time and payment.

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</thead>
</table>

- Imagine a simple parking scenario, a public parking area with enough supply and no restrictions of time and payment.

\[ p \in \left[\frac{1}{C}, \frac{1}{C} \right] \]

\[ 0 \leq t_s \leq t_s^{\text{max}} \]

- Minimum time of stay
- Maximum time of stay
Accuracy Study of Parking Duration Data from Patrol Survey

Model

**Introduction**

**Model**

**Simulation**

**Conclusions**

\[
\delta \text{ observation interval}
\]

\[
\text{APD}
\]

**average parking duration**

\[
\beta \text{ the ratio of } t^\text{max}_s \text{ and } t^\text{min}_s
\]

\[
= \frac{b}{a}
\]

\[
\overline{T}_\text{real}
\]

**real APD**

\[
= \delta \cdot \frac{a + b}{2}
\]

\[
\overline{T}_\text{obs}
\]

**estimated APD**

\[
= \delta \cdot \sum_{i=1}^{\lfloor b \rfloor} i \cdot \left( \frac{p_i}{p^\text{obs}} \right)
\]

\[X = \frac{\overline{T}_\text{obs}}{\delta}\]

\[Y = \frac{\overline{T}_\text{real}}{\overline{T}_\text{obs}}\]

\[Y = \frac{1 + \beta}{2} \cdot \frac{1}{\beta - \sqrt{(\beta^2 - 1)(1 - \frac{1}{X})}} \cdot \frac{1}{X}\]
Model

While $\delta \in [t_{s}^{\text{min}}, t_{s}^{\text{max}}]$

- For a given $\beta$, the value of $X$ varies from 1 to $\frac{1+\beta}{2}$, a higher $X$ corresponds to a lower $\delta$.

- The average parking duration is always overestimated, the minimum value of the accuracy is $\frac{1}{2} + \frac{1}{2} \beta$.

- For a given survey intensity $X$, the accuracy is higher with a smaller $\beta$. Hence, one can find the lowest possible accuracy for a given range of $\beta$. 

\[ Y = \frac{1+\beta}{2} \cdot \frac{1}{\beta - \sqrt{(\beta^2-1)(1-\frac{1}{X})}} \cdot \frac{1}{X} \]
Numerical Example

• A basic range of $\beta$ could be obtained in a survey by approximating the longest and shortest parking duration.
• A patrol survey with interval $\delta=3$ hours, the data and results are analyzed.

Table 1     Survey results of the numerical example

<table>
<thead>
<tr>
<th>No.</th>
<th>$\delta$</th>
<th>No. of vehicles observed</th>
<th>Percentage/times</th>
<th>$T_{\text{obs}}$</th>
<th>$X$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$\delta_1 = 3$</td>
<td>271</td>
<td>38%</td>
<td>45%</td>
<td>17%</td>
</tr>
<tr>
<td>2</td>
<td>$\delta_2 = 6$</td>
<td>199</td>
<td>92%</td>
<td>8%</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>$\delta_3 = 9$</td>
<td>164</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

$t_s^{\text{max}} \leq 9$

$t_s^{\text{min}} < 3$

$t_s^{\text{max}} \in [6,12]$
**Numerical Example**

- We can assume a conservative value (i.e., 0.3 hours) as a minimum duration for vehicles based on real life experience. It means that, a person only parks the car when he/she needs to stay for more than 0.3 hours.

$$t_s^{\text{max}} \in [6, 9]$$
$$t_s^{\text{min}} \in [0.3, 3]$$
$$\beta \in [2, 30]$$

<table>
<thead>
<tr>
<th>No.</th>
<th>$\delta$</th>
<th>$\bar{T}_{\text{obs}}$</th>
<th>$X$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\delta_1 = 3$</td>
<td>5.4</td>
<td>1.79</td>
</tr>
<tr>
<td>2</td>
<td>$\delta_2 = 6$</td>
<td>6.5</td>
<td>1.08</td>
</tr>
<tr>
<td>3</td>
<td>$\delta_3 = 9$</td>
<td>9</td>
<td>1</td>
</tr>
</tbody>
</table>

So $\beta \in [2.58, 30]$, then we can find both the lower and upper bounds for the accuracy of the survey as a function of $X$.

$$X \in \left[1, \frac{1 + \beta}{2}\right]$$

$X = 1.79$ when $\delta = 3$
### Results and correction

<table>
<thead>
<tr>
<th>Interval</th>
<th>( \delta )</th>
<th>3 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated APD</td>
<td>( \bar{T}_{obs} )</td>
<td>5.4 hours</td>
</tr>
<tr>
<td>Survey intensity</td>
<td>( X )</td>
<td>1.79</td>
</tr>
<tr>
<td>Accuracy of APD</td>
<td>( Y )</td>
<td>above 86%</td>
</tr>
<tr>
<td>Real APD</td>
<td>( \bar{T}_{real} )</td>
<td>[4.64, 5.4] hours</td>
</tr>
</tbody>
</table>

**Correction**

- **Goal:** making the relative error in a smaller range
- **Measure:** adjusting \( \bar{T}_{obs} \) to 5 hours

**Results:**

- Before correction:
  - \( 85\% \)
  - \( 86\% \)
- After correction:
  - \( 100\% \)
  - \( 100\% \pm 8\% \)

APD: average parking duration
Model

Note that the conclusions above only hold when $\delta \in [t_{s}^{\text{min}}, t_{s}^{\text{max}}]$. Fortunately, it is possible to verify this condition using the same survey data:

- When $X=1$, then $\delta \geq t_{s}^{\text{max}}$ and clearly the accuracy is low.
- When all the observed cars are observed at least twice, then $\delta \leq t_{s}^{\text{min}}$ and the survey intensity is simply higher than needed, survey cost could be reduced by extending the observation interval.
- When the percentage of cars being observed only once (i.e., $\frac{p_{1}}{p_{\text{obs}}}$) is very low, then $\delta \approx t_{s}^{\text{min}}$ and it’s possible to reduce the survey intensity without losing much accuracy.
Assumptions

Arrival time

500 vehicles arrive the parking area during a day following a continuous double peak distribution.

Parking duration

Gamma distribution is denoted by $G(k, \theta)$, the probability density function (PDF) is

$$f(x; k, \theta) = \frac{1}{\theta^k \Gamma(k)} x^{k-1} e^{-x/\theta}.$$
Findings from Simulations

• For each value of $k$ among $\{2, 3, 4, 5, 10, 15\}$, 3500 simulations have been ran with a changing value of $\theta$.

• The real average duration is typically overestimated.

• For a given $X$, the accuracy is very much influenced by $k$. (the “shape parameter” of gamma distribution)

• For a given $X$, a higher accuracy corresponds to a larger $k$.

• The absolute error of average accuracy is up to 30% in the simulation, but it becomes quite small (below 8%) for $X>1.5$. For instance, accuracy is $90\% \pm 8\%$.

Caused by natural variations
Conclusions

1. We have found that the most influential factor to the accuracy is the shape parameter of the parking duration distribution. Former survey experiences or results can be used to support fitting the distribution and estimating this value.

2. The coordination between survey costs and accuracy could be done by choosing a proper value of survey intensity. Higher survey intensity means a more expensive survey while it also gives better accuracy. Based on the model, we could find a proper value of survey intensity to guarantee that both are acceptable, or the minimum possible cost for a desired level of accuracy.

3. Through our study, it is proved that when survey intensity is below 1.5, the survey could be quite misleading, not only because a comparatively low accuracy, but also because the data recorded have with large natural variations.
Definitions

\[ \delta \text{ observation interval} \]

\[
a = \frac{t_s^{\text{min}}}{\delta}
\]

\[
b = \frac{t_s^{\text{max}}}{\delta}
\]

\[
M = \frac{C}{\delta}
\]

\[
\beta = \frac{t_s^{\text{max}}}{t_s^{\text{min}}} = \frac{b}{a}
\]

\[ p_i \text{ Probability of a vehicle being observed } i \text{ times} \]

\[
p^{\text{obs}} = \sum_{i=1}^{[b]} p_i
\]

\[
= \sum_{m=1}^{M} \left\{ \int_{(m-1)\delta}^{m\delta-t_s^{\text{min}}} f(t_a) \left[ \int_{t_s^{\text{min}}}^{t_s^{\text{max}}} f(t_s)dt_s \right] dt_a \right\}
\]

\[
+ \sum_{m=1}^{M} \left\{ \int_{m\delta-t_s^{\text{min}}}^{m\delta} f(t_a) \left[ \int_{t_s^{\text{min}}}^{t_s^{\text{max}}} f(t_s)dt_s \right] dt_a \right\}
\]