Case Study –Congestion Charges in Singapore

Chapter 11 (p. 449-451) in Transportation Economics summarized the basic argument for congestion pricing under the assumption that capacity is fixed. From an economic standpoint, congestion pricing internalizes a congestion externality and the externality arises because an existing traveler on a congested road fails to take into account the time costs that her trip imposes upon all other travelers. Although this time cost is quite small for an individual, when summed over all travelers on the road, the externality can be quite large.

Congestion Externalities

Alternatively, if we discuss this in terms of cost curves, the presence of a congestion externality reflects the difference between the average variable cost and the marginal cost of producing trips (see Figure 11.2 and equations 11.2 and 11.3 in the text). Recognizing that the cost of a trip depends upon traffic flow, let the average variable and total variable cost of a trip be

$$avc(x) = \text{average variable cost for a given flow } x$$

$$= \Rightarrow tvc(x) = avc(x) \times x = \text{total variable trip cost cost for a given flow } x$$

$$= \Rightarrow mc(x) = avc(x) + x \frac{\Delta avc(x)}{\Delta x} = \text{marginal trip cost for traffic flow } x \quad (1)$$

Thus, the congestion externality is

$$x \frac{\Delta avc(x)}{\Delta x}.$$

In the Case Study for San Francisco (pp. 465-476), we saw how one would use information on traffic flow data, construction and land costs, and user time costs in order to estimate an optimal congestion charge. However, in reading this case study, one also sees that estimating an optimal congestion charge can be quite complicated. This raises an interesting question. Is it possible to obtain some ‘back-of-the-envelope’ estimate of the congestion externality and, therefore, the congestion price? The answer is a qualified yes.

First of all, what information do we need? From our discussion of tripmaking, we know that the average variable cost comprises two elements, the out-of-pocket expenses (gasoline, oil, etc.) and the time costs associated with the trip, which depends upon one’s value of time. Thus,

$$avc(x) = \text{out-of-pocket costs (x) + time costs}$$

$$= \text{out-of-pocket costs (x) + VOT (trip travel time (x))}$$
where VOT is the value that one places upon her time and trip travel time depends upon traffic flow \( x \). Recognizing that trip time is simply trip distance multiplied by the inverse of trip speed, we can write \( avc(x) \) as
\[
\begin{align*}
avc(x) &= \text{out-of-pocket costs}(x) + VOT(\text{trip distance})(\text{trip speed}(x))^{-1} \\
 &= VOT(\text{trip distance})(\text{trip speed}(x))^{-1} \\
&= \frac{\text{VOT}(\text{trip distance})(\text{trip speed}(x))^{-1}}{x}
\end{align*}
\] (2)
assuming that trip out-of-pocket expenses are negligible relative to time costs, which is typically the case for work trips during the peak period. Thus, for a given traffic flow \( x \), knowledge of trip distance, trip speed, and value of time provides an estimate of the average of variable trip cost. Calculating the average variable trip cost for two different flows, \( x_1 \) and \( x_2 \), yields an estimate of the impact that a change in flow has upon average variable costs.
\[
\Delta avc(x) = \frac{avc(x_2) - avc(x_1)}{x_2 - x_1}
\] (3)
And multiplying this change by the traffic flow prior to a congestion charge, \( x_{\text{pre}} \), yields our back-of-the-envelope estimate of the congestion externality,
\[
\frac{\Delta avc(x)}{\Delta x} x_{\text{pre}} = \frac{avc(x_2) - avc(x_1)}{x_2 - x_1} x_{\text{pre}}
\] (4)
Although relatively little data are need to estimate the congestion externality, the relevant trip travel data – average speed, trip distance, and traffic flow – are rarely collected. Interestingly, however, these data were collected in Singapore, a city-state and the first country to implement a congestion price scheme and make congestion pricing a permanent urban transport policy.
McCarthy and Tay (1993) analyzed these data to determine whether Singapore's congestion price was optimal.

The Singapore Experiment
Singapore's congestion price experiment started as a World Bank project in Singapore. The plan, implemented in on June 2, 1975 and called the Area License Scheme (ALS), required all passenger cars entering the congestion price zone during restricted hours to purchase a license for S$3 and display the license on the vehicle's windscreen. The 'congestion price zone' was approximately 725 hectares and included the downtown business and financial district as well as the commercial, hotel, and shopping districts in the heart of the city. The intent of the ALS was to reduce traffic by 25% - 30%, a reduction that would reflect a downtown traffic conditions that was essentially equivalent to those found in the off-peak period (Holland and Watson, 1978). Moreover, after Singapore implemented the licensing scheme, traffic reductions exceeded expectations and there is evidence (Menon et al., 1992) that the ALS has reduced peak-period traffic flow as much as 50%. As a demand management tool, the ALS appears to have been a resounding success.

There have been numerous modifications the Singapore initially implemented the ALS. According to the original scheme, the restricted hours were 7:30am – 10:30am, Monday through
Saturday (and exempting public holidays), car pools and cars with four passengers were exempt, as were taxis. In August 1975, the rate was raised to S$4 for private cars and taxis were included; and in January 1976, company cars were included with a license fee of S$8. In April 1977, the license fee for taxis was reduced to S$2 and in March 1980 the fee for cars was reduced to S$5. A major restructuring of the scheme occurred on June 1, 1989 which imposed license fees on all vehicles, including carpools and buses, other than ambulances, fire, police, and military vehicles. License fees on motorcycles, company registered car, and all other non-exempt vehicles was S$1, S$6, and S$3, respectively.

Notwithstanding the reported success of the ALS, it is important to recognize the economic implications of reducing traffic to a level that is comparable to off-peak conditions. Consider Figure 11.2 in the text. Given peak-period demand $D_p$, $T_1$ reflects an inefficiently high number of trips since marginal cost exceeds marginal benefit at this level. At the same time, a peak-period demand with $T_2$ trips reflects an inefficiently low number of trips since the marginal benefit is greater than marginal cost. $T^*$ is the optimal number of trips, where marginal benefit equals marginal cost. But notice that at $T^*$, the congestion price has not eliminated congestion, it has simply internalized the congestion externality so that we now have optimal level of congestion. Hence, an attempt to reduce peak-period congestion to a level, which equals off-peak conditions is generally inefficient and may result in much higher welfare losses than the inefficiently high level of traffic.

Calculating the Congestion Charge

In an analysis of traffic speeds and volumes in the restricted zone, the Singapore Public Works Department collected traffic flow data in February 1990. Along with these data, the Department also ran an important experiment. The Department defined two fixed circuits in the restricted zone, had someone drive these circuits in peak and off-peak periods between 76 and 105 times per day over a three day period, and collected travel time data for each of the trials. Table 1 summarizes the information collected along with other data needed to calculate the congestion externality.

There are three salient features about the road characteristics. First, the mean trip speed is higher on each circuit during the restricted period in comparison to the non-restricted period. This suggests that too many vehicles were being priced off the restricted zone roadways and onto the unrestricted zone roads. Second, and consistent with the first point, traffic flows during the restricted period were lower than during the non-restricted period. We would normally expect, even in the presence of congestion pricing, that vehicles/lane-hr would be higher during peak relative to off-peak periods. Third, the authors estimated pre-restriction traffic flow to be 750 vehicles/lane-hr, which is considerably greater than the post-ALS traffic flow during the peak-period.

In addition, the authors estimated that the 1990 average value of travel time, assuming Singapore’s six-day workweek, a wage rate equal to S$7.48, and that travel time is 50% of the wage rate, is S$3.74.
### Table 1
Congestion Externality for Two Typical Trips

<table>
<thead>
<tr>
<th>Road Characteristics</th>
<th>Circuit A</th>
<th>Circuit B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (kilometers)</td>
<td>7.17</td>
<td>6.66</td>
</tr>
<tr>
<td>Mean journey speed (km/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During restricted period</td>
<td>27.6</td>
<td>23.3</td>
</tr>
<tr>
<td>During non-restricted period</td>
<td>20.3</td>
<td>16.8</td>
</tr>
<tr>
<td>Mean Traffic Flow (vehicles/lane-hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During restricted period</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>During non-restricted period</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Pre-restriction Flow (vehicles/lane-hr)</td>
<td>750</td>
<td>750</td>
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</tbody>
</table>

Average variable cost (S$)
- 450 traffic flow: S$0.972, S$1.069
- 600 traffic flow: S$1.321, S$1.483

Time Cost
- Value of Time (S$/hour): S$3.74

Congestion Externality (S$)\(^a\)
- Circuit A: S$1.747
- Circuit B: S$2.068

Source: Adapted from McCarthy and Tay (1993), p. 98.  
\(^a\) The authors reported a S$1.70 congestion charge for Circuit A. This should have been S$1.74 as given in Table 1.

The last line of Table 1 reports the calculated congestion externality. For circuit A, these calculations are

\[
\Delta \text{avc}(x) \frac{\Delta x}{\Delta x} \approx \frac{\text{avc}(600) - \text{avc}(450)}{150} (750)
\]

\[
= \frac{.0023}{150} \times 750
\]

\[
= 1.747
\]

For Circuit B, these calculations yield an estimated externality equal to 2.068.

**Demand Management versus Economic Efficiency**

In the fifteen or so years since the road pricing experiment, Singapore has imposed a daily congestion charge on automobiles anywhere from S$3 to S$5. Based upon the congestion
externality reported in Table 1 and a license fee equal to S$3, the 1989 license fee was from 45.6% - 71.7% too high.

There are a number of comments on McCarthy and Tay’s (1993) analysis.

- the goal of urban transport policy should be to allocate resources as efficiently as possible rather than ‘manage’ demand. Highway demands are one side of the market and if urban transport policies do not consider the supply side, these policies will fail;

- the calculations presented here illustrate how, with relatively little information, one can get an idea of the order of magnitude of a congestion externality. However, it must also be remembered that congestion is not uniformly distributed but varies by time of day, vehicle, and location as well as by income (since one’s value of time depends upon income). An ideal congestion charge would take these other factors into account;

- in addition to vehicle congestion, there are also other types of external effects, including air pollution and vehicle crashes, which may justify a license fee that exceeds the congestion externality;

- one also sees the revenue potential of a congestion charge. As of 1989, Singapore levied a S$3 ‘congestion charge’ on private automobiles but imposed a S$6 charge on company registered vehicles. From an efficiency standpoint, a company registered vehicle and private vehicle entering the restricted zone at the same time will impose the same congestion externality on fellow travelers. There is no economic justification to discriminate between these vehicles. However, the objective may be revenue enhancement since the price elasticity of the demand for road space is likely to be smaller for company registered vehicles than for privately owned vehicles.
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<td></td>
</tr>
<tr>
<td>450 traffic flow</td>
<td>S$0.97</td>
<td></td>
</tr>
<tr>
<td>600 traffic flow</td>
<td>S$1.31</td>
<td></td>
</tr>
<tr>
<td>Average variable cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of Time (VOT)</td>
<td>S$3.74</td>
<td>S$3.74</td>
</tr>
<tr>
<td>Congestion Externality</td>
<td>S$1.70</td>
<td>S$2.06</td>
</tr>
</tbody>
</table>

Source: Adapted from McCarthy and Tay (1993), p. 98.