CONGESTION PRICING: A CASE OF DELHI

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Minoti Rawat
Role of Government in controlling traffic in Delhi

To improve the quality of public transport, some measures taken by the Government are:

- Completion of second phase of Delhi.
- More than 3,500 low floor air-conditioned and non-air conditioned buses introduced by the Delhi Transport Corporation (DTC).
- Withdrawal of blue-line buses.
- Construction of new roads, foot bridges, flyovers and widening of existing road network (around 23 Flyovers were completed before commencement of CWG-2010).
- A Delhi Transport Infrastructure Development Corporation has been set up to manage Inter-State Bus Terminals in Delhi.
- Ring Road bypass and elevated corridors in some areas of Delhi like Barrapula drain have been provided with signal-free flow of traffic.
- Implementation of ITS in Transport

Source: Compiled from various sources- Rumani Saikia Phukan, 2012
DELHI CONGESTION: OVERVIEW

- Delhi **most polluted city in the world** – WHO (2014).

- The annual growth of vehicles in Delhi **increased** from 4.72 per cent in 1999-2000 to 6.89 per cent in 2014-15.

- As per the Delhi Economic Survey, vehicular pollution **rose by 135.59 percent** between 1999-2000 and 2011-12. In 2011-12 it **decreased marginally from 7.44 percent** in 2010-11 to **7.27 percent**.

- All these facts are despite of Delhi having **highest road density** of 2,103 km/100 sq.km.

- Recently introduced **Odd – even policy trial** for 15 days in January and second trial in April.

- Though, the city is **moving towards interesting opportunities** like odd-even but, for balancing long term it cannot depend on such regulatory ideas. Centre for Science and Environment Director General **Sunita Narain** during an event 'Our Right to Clean Air' said **“the curbs on vehicles can only be an emergency measure and not a permanent one”**.

- Thus, need to move to sustainable idea like **Congestion Pricing**

[Images: Increasing number of Private Motor vehicles, Pollution, Delays, Public Transport not able to cater Demand]
• RESEARCH QUESTION

Which factors can influence people to shift from private mode to public transport in Delhi (Connaught Place)?

• RESEARCH OBJECTIVES

To assess the role of Congestion Pricing in determining mode choice behavior
METHODOLOGY

Comprehensive search through Internet sources, cases where congestion charge is taken.

Analysis of existing conditions of the study area through analysing various reports.

Computation of marginal congestion cost for study area through Traffic volume, speed and VOT.

Orthogonal array used to form various scenarios.

Binary Logit Model and correlation used for analyzing survey results.

Mode Choice stated preference Survey.
The main intuition behind congestion charging is the internalization of negative externalities (time costs and delays) which are imposed to other road users by an additional driver entering the road.

The rational of this charge implies that the toll increases with congestion levels since the cost suffered by users is increasing with the quantity of vehicles \( (Q) \).

The difference between social and private marginal costs for each \( Q \) is exactly the optimal toll \( (P_s) \) needed to internalize congestion costs. Therefore the level of the optimal toll must vary with congestion levels and vehicle type (if different vehicles differently affect infrastructure costs). This concept is known as Pigouvian taxation and has remained the leading principle in transport economics on road traffic externalities regulation (Button and Verhoef, 1998).
“Externalities are goods that have an impact on welfare (positive or negative) that is not taken into account by the agent producing them.”

- (Friedman 1996)

Source: Dirk van Amelsfort, 2012
CONGESTION PRICING

It is described as a distance, area or cordon based road-user charging policy around congested city centres.
CONGESTION PRICING TECHNOLOGIES: Types of Electronic Toll Collection

1. Automatic Number Plate Recognition

2. Dedicated Short Range Communications

3. Vehicle Identification Number

4. Satellite Systems and Cellular networks

Source: Dirk van Amelsfort, 2012
BENEFITS OF CONGESTION PRICING

• **Time Savings**
  Reduce traffic levels and smooth traffic flow leading to shorter and more predictable journey times.

• **Wider Economic Benefits**
  Higher total number of people can reach the city within a given amount of time. It gives companies access to a bigger and more varied pool of labour.

• **Creation of an investment dividend**
  It represents an opportunity for cities to generate ring-fenced revenue for urban public transport.

• **Promotion of behavioural change**
  - It incentivise smarter transport and land-use choices.
  - It can encourage behaviour change, as fewer people will use cars and more will use less expensive travel modes, which are often more sustainable.

*Source: The NZ Transport Agency's BCA Strategic Options toolkit, 2014*
WORLD WIDE EXPERIENCES ON CONGESTION PRICING

Successful

• Singapore
• London
• Stockholm
• Norwegian Cities
## CASE STUDIES

<table>
<thead>
<tr>
<th>SINGAPORE</th>
<th>LONDON</th>
<th>STOCKHOLM</th>
<th>NORWEGIAN CITIES (OSLO, BERGEN AND TRONDHEIM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OBJECTIVE</strong></td>
<td>ALS - To control traffic congestion in (CBD) during peak hours. ERP – Charge vehicles as per use.</td>
<td>To reduce congestion, yield net revenues - payback initial costs.</td>
<td>To reduce congestion, increase accessibility and improve the environment</td>
</tr>
<tr>
<td><strong>RESULT</strong></td>
<td>31-44% drop in Traffic in restricted zone &amp; reduction in CO2 emission to 0.85%.</td>
<td>Reduced cars by around 20% and congestion by 30%. Revenue generated from an expected £130m (€190m) to around £90m (€131m) (2004).</td>
<td>Average journey times fell and the queuing times dropped by a third in the rush hours. 6% changed their transport mode and the number of cars in the park-and-ride facilities grew a 23% as well.</td>
</tr>
<tr>
<td><strong>LIMITATION/ADVANTAGE</strong></td>
<td>It was labour intensive &amp; not equitable to motorists and always a rush to enter the RZ just before or after the restricted hours. Charges are reduced when speeds exceed the optimal speed range</td>
<td>In London all vehicles pay the same charge. Around 40% of vehicles do not pay and numbers are still rising. Camera based ANPR system installed has been a failure. Too many number plates are misread and it is very expensive to run</td>
<td>Few routes were left free of charge as they had only one connection to the city centre. Thus, travel time and vehicle increased in these two routes</td>
</tr>
</tbody>
</table>

Source: Land Transport Authority, Singapore, GOH, Shou Xian, 2014
Source: Steve Kearns, Transport for London, 2014
Source: Jonas Eliasson, Centre for Transport Studies, 2014
Source: Computed from Singh & Sarkar
WORLD WIDE EXPERIENCES ON CONGESTION PRICING

Unsuccessful

- Hong Kong
- Edinburg
**CASE STUDIES**

### HONG KONG

**BACKGROUND**
First attempt to introduce an automatic system in 1980’s

An experiment including 2500 vehicles was initiated in 1983.

The idea was then a full scale implementation in 1985.

**OBSTACLES**
- The field trials took place during the early stages of a transfer of power from a British colonial government to popularly elected officials.

**TECHNOLOGY**
- The agreement that Hong Kong should be reunited with China, which led to a fear for an electronic monitoring system that was to be used for supervision.

**POLITICAL ACCEPTANCE**
- The technology at that time was undeveloped and thus with doubtful functionality.

**EQUITY: PEOPLE**
- People not perceive the benefits that the project would bring them.

### EDINBURG

**BACKGROUND**
The city of Edinburgh decided to carry out a referendum in February 2005.

**OBSTACLES**
- Edinburgh citizens rejected the project in a referendum – 74.4% of negative votes – and the council dropped the plan of charging road users.

**PEOPLE ACCEPTANCE**
- The public’s limited understanding of the scheme.

**EQUITY: PEOPLE & PLACE**
- Voters were unconvinced the scheme proposed would have achieved its dual objectives of reducing congestion and improving public transport.

### HONG KONG POLITICAL ACCEPTANCE

**TECHNOLOGY**

**POLITICAL ACCEPTANCE**

**EQUITY: PEOPLE**

**Source:** Report on the study of road traffic congestion (Hong Kong), 2014

**Source:** Daniel Albalate & Germà Bel, 2008
STUDY AREA: DELHI

- Population of about **16.3 million (2011)**
- Total number of vehicles **88.27 lakh**, with an increase of 6.4 per cent over previous year and in 2014-15 number of vehicles per thousand population is 487.
- **Contradiction** regarding the actual number of vehicles plying on Delhi’s road as the large number of vehicles registered in Delhi are plying in NCR areas and vis-à-vis the vehicles registered in NCR are plying in Delhi.

*The Municipal Corporation of Delhi (MCD) – 1,397.3 km², the New Delhi Municipal Council (NDMC) – 42.7 km² and the Delhi Cantonment Board (DCB) – 43 km².*
SURVEY LOCATION: CONNAUGHT PLACE

- 350 Stated Preference Surveys (350*4 = 1400)
- Only car users were surveyed
- The survey was conducted along eight arterial roads (especially the parking area)

Source: Google Earth
**CONGESTION PRICING: NEED**

<table>
<thead>
<tr>
<th>Roads</th>
<th>Capacity</th>
<th>2016 (PCU counts) Existing</th>
<th>2018 (PCU counts) BAU</th>
<th>2016 (v/c)</th>
<th>2018 (v/c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janpath</td>
<td>6000</td>
<td>5350</td>
<td>6126</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>K.G marg</td>
<td>4000</td>
<td>5543</td>
<td>6346</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Barakhamba Road</td>
<td>4000</td>
<td>6839</td>
<td>7830</td>
<td>1.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Vivekanand Road</td>
<td>4000</td>
<td>5723</td>
<td>6552</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Panchkuian Road</td>
<td>6000</td>
<td>4856</td>
<td>5560</td>
<td>0.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Baba kadhak Singh Marg</td>
<td>4000</td>
<td>7334</td>
<td>8396</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Sansad marg</td>
<td>4000</td>
<td>3815</td>
<td>4368</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Chelmsfoed Road</td>
<td>4000</td>
<td>3319</td>
<td>3800</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*PCU counts are for cars and for peak hours only*

- Volume by capacity ratio shows that **roads are saturated** during peak hours.
- Along Barakhamba Road and Baba Kadhak Singh Marg there is high number of offices, therefore comparatively they accounts for higher volumes.
- If the same conditions are projected for the coming two years, the volume by capacity ratio further crosses the acceptable levels. Therefore, **some measures are required which can lower down the traffic volumes.**

METHODOLOGY: COMPUTING MARGINAL CONGESTION COST

2009 data of Traffic Volume (PCU) on major roads (8 roads) at CP was escalated with 7% increase in traffic volume.

With the help of Microscopic Simulation Method Non-Linear, Speed was calculated.

VOT was calculated by applying WPI to VOT for primary route (2009) – 62.5 and multiplied by ratio of Per Capita Income of Delhi and India.

Marginal Congestion Cost was calculated by the obtained values.


Source: Calculating Transport Congestion And Scarcity Costs, Professor Chris Nash and Mr Tom, 1999 Sansom, (ITS)
METHODOLOGY: COMPUTING MARGINAL CONGESTION COST

Microscopic Simulation Method (Non-Linear)
(Speed Flow equations for Cars)

\[ y = 47.633 + (2268.931 - 0.407x)^{0.5} \] (for 4 lanes)
\[ y = 47.651 + (2270.637 - 0.294x)^{0.5} \] (for 6 lanes)

| y = Speed | Obtained from the above equation |
| x = PCU | Values obtained by escalating 2009 PCU counts |

Value of Time (VOT) (in Rs/hr)

Source: IRC sp 30 2009, 6.7, table- 6

Cars = VOT for primary route (2009) : 62.5

Source: http://www.eaindustry.nic.in/display_data.asp

| WPI (2014) | 182.01 |
| WPI (2009) | 127.86 |

Ratio of WPI = WPI(2014)/WPI(2009) : 1.42

Cars = VOT for primary route (2014) : 88.96

Per Capita Income Delhi 2013- 2014 (Constant Price) : 118411

Per Capita Income India 2013- 2014 (Constant Price) : 39904

Ratio of PCI = PCI(Delhi)/PCI(India) : 2.97

VOT Individual (Delhi 2014) : 264
METHODOLOGY: COMPUTING MARGINAL CONGESTION COST

Marginal Congestion Cost = \(-q(b/V^2)(dv/dq)\)

Where,

\(dv/dq\) - the slope of the speed/flow relationship, which varies with the type of road and volume of traffic

\(q\) - the volume of traffic (in PCUs)

\(v\) - the resulting speed, which varies with the type of road and volume of traffic

\(b\) - the value of time, which varies with the mix of journey purpose and income of the users

If we assume that traffic volume decreases 15% in 2018

<table>
<thead>
<tr>
<th>VOT (b)</th>
<th>264</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed 2016 (km/hr)</td>
<td>33</td>
</tr>
<tr>
<td>Speed 2018 (km/hr)</td>
<td>38</td>
</tr>
<tr>
<td>Traffic Volume 2016 (PCUs)</td>
<td>3009</td>
</tr>
<tr>
<td>Traffic Volume 2018 (PCUs)</td>
<td>2174</td>
</tr>
</tbody>
</table>

Therefore, Marginal congestion cost is 205
SCENARIOS: ORTHOGONAL ARRAY

The first step for an orthogonal array is to create the combinations of factor levels.

For the research finally three variables were selected for car commuters: Travel time, Congestion cost and Parking cost. For public transport two variable were selected travel time and travel cost (fare).

An orthogonal array, is used as it determines both the relative importance of each attribute as well as which levels of each attribute are most preferred.
### SCENARIOS : FRACTIONAL FACTORIAL ARRAY

<table>
<thead>
<tr>
<th>Card ID</th>
<th>Public Transport</th>
<th>Card A</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Travel Time Reduction</td>
<td>Travel Cost</td>
<td>Travel Time Reduction</td>
</tr>
<tr>
<td>1</td>
<td>Same</td>
<td>Same</td>
<td>-30%</td>
</tr>
<tr>
<td>2</td>
<td>Same</td>
<td>Same</td>
<td>-10%</td>
</tr>
<tr>
<td>3</td>
<td>-20%</td>
<td>+20%</td>
<td>-20%</td>
</tr>
<tr>
<td>4</td>
<td>-20%</td>
<td>+20%</td>
<td>-20%</td>
</tr>
</tbody>
</table>
## SCENARIOS: FRACTIONAL FACTORAL ARRAY

<table>
<thead>
<tr>
<th>Card ID</th>
<th>Travel Time Reduction</th>
<th>Travel Cost</th>
<th>Card B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Same</td>
<td>Same</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Same</td>
<td>Same</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-20%</td>
<td>+20%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-20%</td>
<td>+20%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Card ID</th>
<th>Travel Time Reduction</th>
<th>Travel Cost</th>
<th>Card B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Travel Time Reduction</th>
<th>Congestion cost</th>
<th>Parking Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20%</td>
<td>160</td>
<td>+30%</td>
</tr>
<tr>
<td>-30%</td>
<td>160</td>
<td>+20%</td>
</tr>
<tr>
<td>-30%</td>
<td>200</td>
<td>+30%</td>
</tr>
<tr>
<td>-30%</td>
<td>240</td>
<td>Existing Charge</td>
</tr>
</tbody>
</table>
BINARY CHOICE MODEL

- BINARY CHOICE MODEL IS ADOPTED: CHOICE BETWEEN CAR OR PUBLIC TRANSPORT

- Here the task is directly related to the estimation of utility levels; and not towards finding the strength of each variable which determines an individual’s choice of shifting to public transport. Thus, Binary Logit model is used for the research.

- Three main attributes were: Congestion Cost, Parking Cost and Travel time.

- Objective was to see which attribute influences people’s choice of mode.
**MODE CHOICE: ANALYSIS**

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
<th>95% C.I.for EXP(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Travel Time</strong></td>
<td></td>
<td></td>
<td>145.548</td>
<td>3</td>
<td>.000</td>
<td>86.407</td>
<td>21.905</td>
</tr>
<tr>
<td><strong>Travel time reduced (-10%)</strong></td>
<td>4.459</td>
<td>.700</td>
<td>40.556</td>
<td>1</td>
<td>.000</td>
<td>86.407</td>
<td>21.905</td>
</tr>
<tr>
<td><strong>Travel time reduced (-20%)</strong></td>
<td>1.103</td>
<td>.262</td>
<td>17.712</td>
<td>1</td>
<td>.000</td>
<td>3.012</td>
<td>1.802</td>
</tr>
<tr>
<td><strong>Congestion Cost (Rs 200)</strong></td>
<td>-.611</td>
<td>.272</td>
<td>5.067</td>
<td>1</td>
<td>.024</td>
<td>.543</td>
<td>.319</td>
</tr>
<tr>
<td><strong>Parking Cost</strong></td>
<td>.048</td>
<td>.007</td>
<td>48.128</td>
<td>1</td>
<td>.000</td>
<td>1.049</td>
<td>1.035</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>-4.854</td>
<td>.696</td>
<td>48.696</td>
<td>1</td>
<td>.000</td>
<td>.008</td>
<td></td>
</tr>
</tbody>
</table>

**Choice: Car/Public Transport**

- As there is an inverse relationship of travel time with choice of mode, it shows people are time sensitive.
- Congestion cost also shows inverse relationship with choice of mode, explaining respondents are cost sensitive too.
- But, parking cost doesn’t affect people’s choice for a particular mode.
From the above three scenario’s it can be interpreted, Congestion charge of Rs 240 would lead to maximum number of shift of mode from private cars to public transport.
### Mode Choice: Analysis

<table>
<thead>
<tr>
<th>Roads</th>
<th>Capacity</th>
<th>2016 (PCU counts) Existing</th>
<th>2018 (PCU counts) BAU</th>
<th>2016 (v/c)</th>
<th>2018 (v/c)</th>
<th>2016 (PCU counts) 26% shift to PT</th>
<th>2018 (PCU counts) 26% shift to PT</th>
<th>2016 (v/c)</th>
<th>2018 (v/c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janpath</td>
<td>6000</td>
<td>5350</td>
<td>6126</td>
<td>0.9</td>
<td>1</td>
<td>3959</td>
<td>4533</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>K.G marg</td>
<td>4000</td>
<td>5543</td>
<td>6346</td>
<td>1.4</td>
<td>1.6</td>
<td>4102</td>
<td>4696</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Barakhamba Road</td>
<td>4000</td>
<td>6839</td>
<td>7830</td>
<td>1.7</td>
<td>2</td>
<td>5061</td>
<td>5794</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Vivekanand Road</td>
<td>4000</td>
<td>5723</td>
<td>6552</td>
<td>1.4</td>
<td>1.6</td>
<td>4235</td>
<td>4848</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Panchkuian Road</td>
<td>6000</td>
<td>4856</td>
<td>5560</td>
<td>0.8</td>
<td>1.4</td>
<td>3593</td>
<td>4114</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Baba kadhak Singh Marg</td>
<td>4000</td>
<td>5734</td>
<td>8396</td>
<td>1.8</td>
<td>2.1</td>
<td>5427</td>
<td>6213</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Sansad marg</td>
<td>4000</td>
<td>3815</td>
<td>4368</td>
<td>1</td>
<td>1.1</td>
<td>2823</td>
<td>3232</td>
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<td>0.8</td>
</tr>
<tr>
<td>Chelmsfoed Road</td>
<td>4000</td>
<td>3319</td>
<td>3800</td>
<td>0.8</td>
<td>1</td>
<td>2456</td>
<td>2812</td>
<td>0.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>
CONCLUSION

• People are time sensitive as well as cost sensitive (Congestion cost).

• 13-26% respondent will shift to Public Transport if congestion pricing scheme is implemented in Connaught Place.

• Congestion pricing measure in isolation too cannot fulfil the future needs.

• Some non-pricing measures should be promoted like carpooling, vehicle quota system, free ride in public transport before peak hours etc.

• People right now doesn’t actually understand the idea of congestion pricing thus, when actually implemented the scenario would be different and more favorable.
THANK YOU

"Oh!... A COW WORSHIPPING NATION"