9th Urban Mobility India Conference & Expo 2016
Planning Mobility for City's Sustainability

CONGESTION PRICING: A CASE OF DELHI

Prof. H.M. Shivanand Swamy

Minoti Rawat

DELHI TRANSPORT: OVERVIEW

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.
- **BRT corridor** constructed in 2008 and scrapped in 2015.
- **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**

Increasing number of Private Motor vehicles

Pollution

Delays

Public Transport not able to cater Demand

Source: Compiled from various sources: Rumani Saikia Phukan,2012

- # RESEARCH QUESTION

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

- # RESEARCH OBJECTIVES

To asses 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.

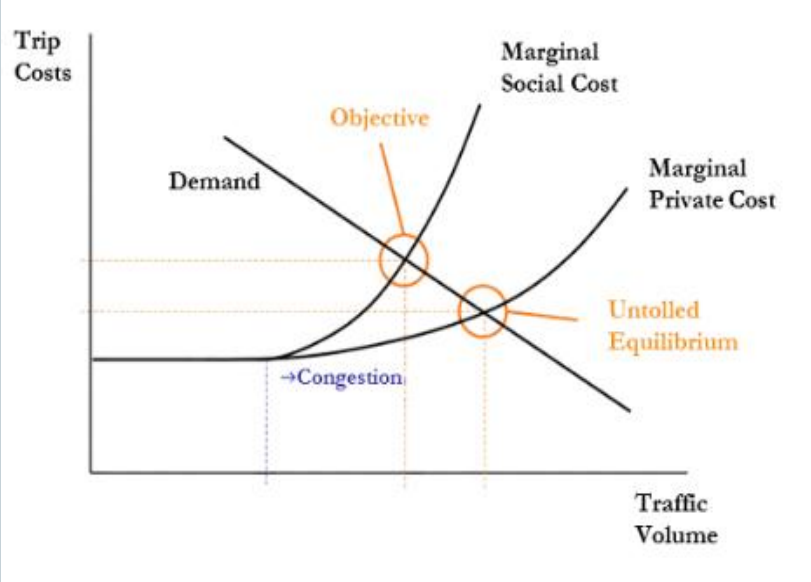
Computation of marginal congestion cost for study area through Traffic volume, speed and VOT

Orthogonal array used to form various scenarios

Mode Choice stated preference Survey

Binary Logit Model and correlation used for analyzing survey results

CONCEPTUAL FRAMEWORK



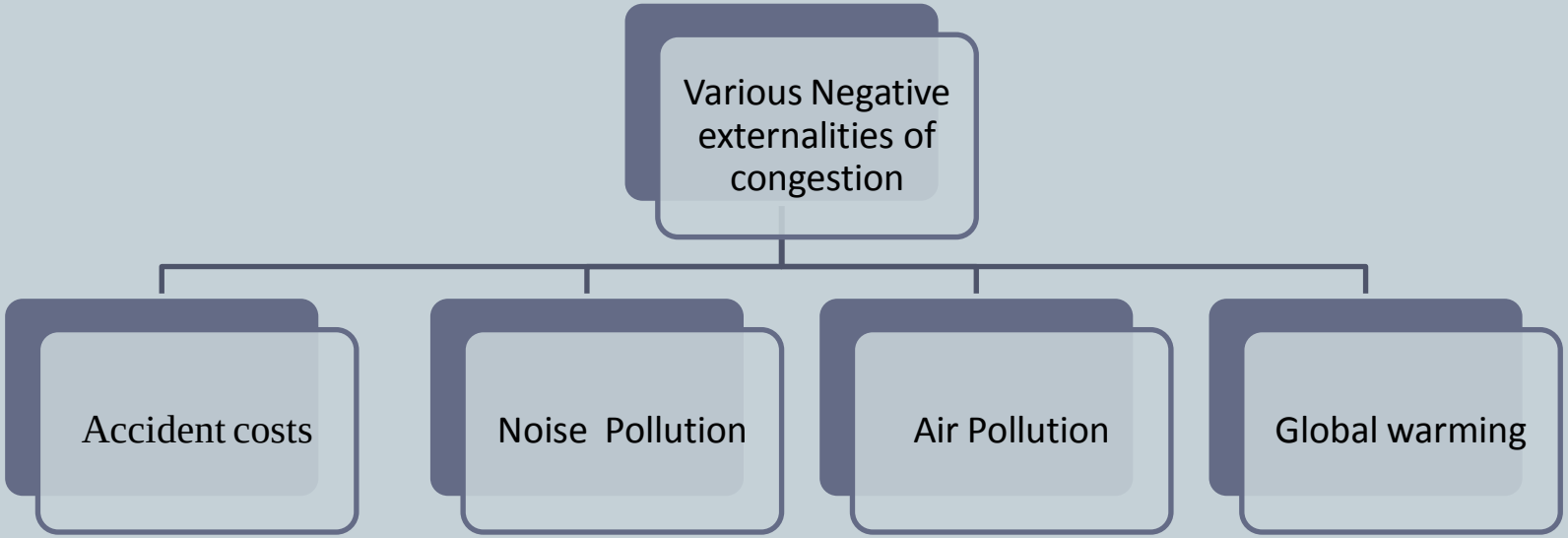
Source: Dirk van Amelsfort, 2012

- 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 (Ps) 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

- "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

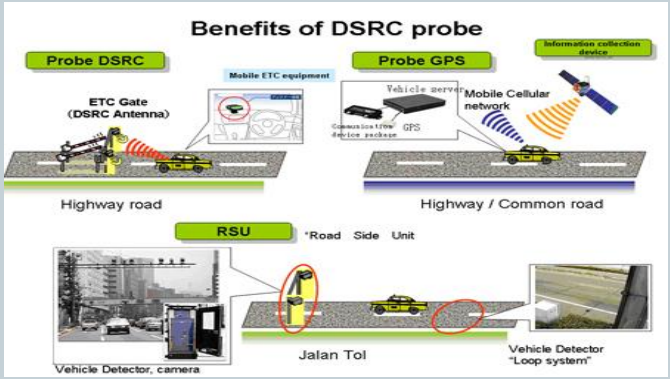
It is described as a distance, area or cordon based road-user charging policy around congested city centres.

Source: Dirk van Amelsfort, 2012

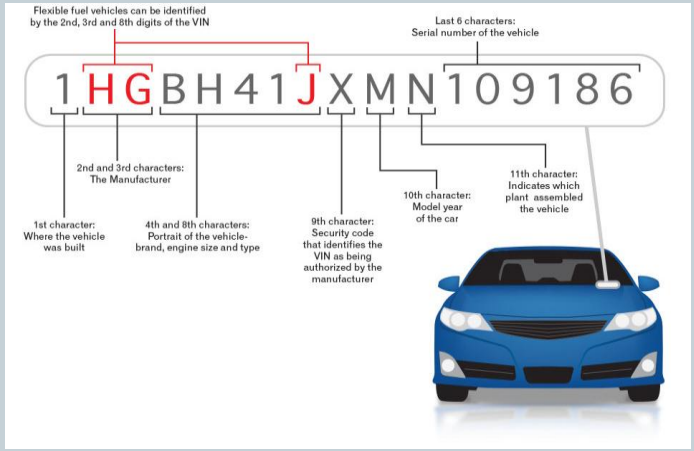
CONGESTION PRICING TECHNOLOGIES: Types of Electronic Toll Collection

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

	SINGAPORE	LONDON	STOCKHOLM	NORWEGIAN CITIES (OSLO, BERGEN AND TRONDHEIM)
OBJECTIVE	ALS - To control traffic congestion in (CBD) during peak hours. ERP – Charge vehicles as per use.	To reduce congestion, yield net revenues - payback initial costs.	To reduce congestion, increase accessibility and improve the environment	Objective of generating revenue
SCHEME	Area Licensing Scheme (ALS), 1975 and Electronic Road pricing (1998)	The scheme covers the very heart of central London (21 square kilometres), the area is bounded by the Inner Ring Road. (implemented 2003)	Introduced in August 2007. A period trial - January 2006 until July 2006.	Road tolling schemes, introduced in Bergen (1989), Oslo (1990) and Trondheim (1991)
RESULT	31-44% drop in Traffic in restricted zone & reduction in CO_2 emission to 0.85%.	Reduced cars by around 20% and congestion by 30% . Revenue generated from an expected £130m (€190m) to around £90m (€131m) (2004).	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.	Traffic reduction of approx. 5-10% in all cities. Revenue generation annually – US$ 96m, US$ 9.6m & US$ 12.8m in Oslo, Bergen And Trondheim respectively.
LIMITATION/ ADVANTAGE	It was labour intensive & 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 *Source: Land Transport Authority, Singapore*, GOH, Shou Xian ,2014	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 Source: Steve Kearns, Transport for London, 2014	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 Source: Jonas Eliasson, Centre for Transport Studies, 2014	Working successfully on inner roads and fulfilling objective of generating revenue. 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

POLITICAL ACCEPTANCE

The field trials took place during **the early stages of a transfer of power from the British colonial administration 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 seen as a means of supervision.

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

EQUITY: PEOPLE

People **not perceive the equity problem** the project would **benefit them.**

EDINBURG

BACKGROUND

- The city of Edinburgh decided to carry out a referendum in **February 2005**.
- The scheme proposed was a two cordon congestion zones.
- **Revenues** were going to be devoted to improve **public transport**

OBSTACLES

PEOPLE ACCEPTANCE

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

The **public's limited under- standing** of the scheme.

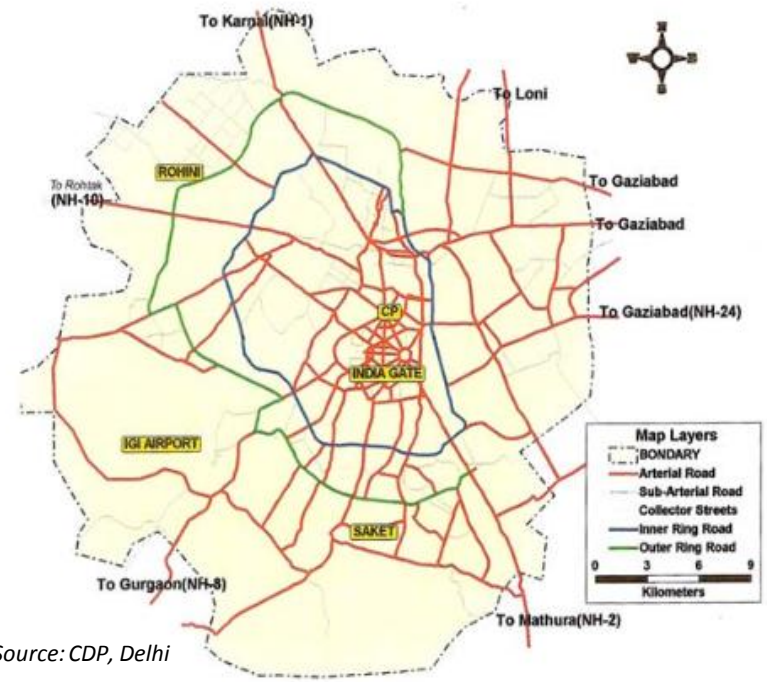
EQUITY: PEOPLE & PLACE

Voters were unconvinced scheme proposed would have achieved its dual objectives of reducing congestion and improving public transport.

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

Source: Daniel Albalate & Germà Bel, 2008

STUDY AREA: DELHI

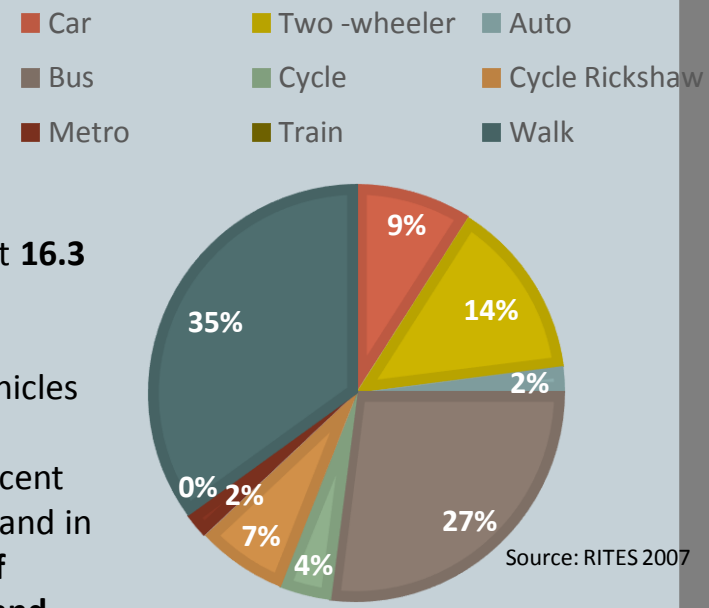


Source: CDP, Delhi

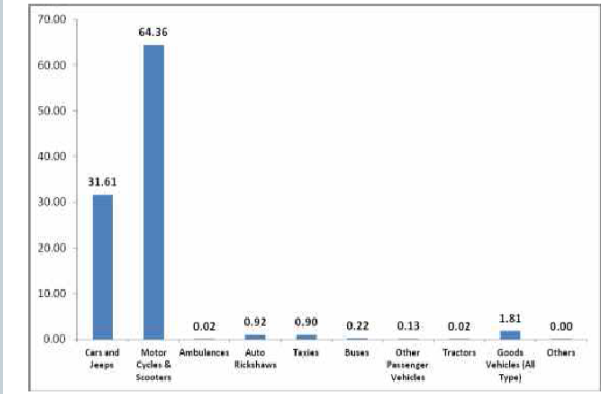
- The Municipal Corporation of Delhi (MCD) – 1,397.3 km^2 , the New Delhi Municipal Council (NDMC) – 42.7 km^2 and the Delhi Cantonment Board (DCB) – 43 km^2.

- 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- a-vis the vehicles registered in NCR are plying in Delhi.

MODE SHARE (INC. WALK TRIPS) (2007)



Source: RITES 2007



Percent of Vehicles population 2014-15
(source: Economic Survey Of Delhi, 2014-15)

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

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

*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**.

Source: computed data from Singh & Sarkar, **Journal of the IRC,** July – September 2009

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.

Source: Singh & Sarkar, **Journal of the IRC,** July – September 2009

A

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

Source: S. Velmurugan, Errampalli Madhu, K. Ravinder, K. Sitaramanjaneyulu & S. Gangopadhyay, **Journal of the IRC**, December 2010

B

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

Source: **IRC sp 30 2009**, 6.7, table- 6, Socio-Economic Profile of Delhi (2014-15)

C

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)**

D

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

Source: **S. Velmurugan, Errampalli Madhu, K. Ravinder, K. Sitaramanjaneyulu & S. Gangopadhyay,** Journal of the IRC, December 2010

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

VOT (b)	264
Speed 2016 (km/hr)	33
Speed 2018 (km/hr)	38
Traffic Volume 2016 (PCUs)	3009
Traffic Volume 2018 (PCUs)	2174

Therefore, Marginal congestion cost is 205

Source: CALCULATING TRANSPORT CONGESTION AND SCARCITY COSTS, Professor Chris Nash and Mr Tom, 1999 Sansom, (ITS) (UK model)

SCENARIOS: ORTHOGONAL ARRAY

Public Transport

Travel Time	Cost (fare)
Existing time	Existing Cost
-20%	+20%

Car

Travel Time	Congestion Cost	Parking Cost
-10%	160	Existing Parking Cost
-20%	200	+20%
-30%	240	+30%

- 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 FACTORAL ARRAY

Card A

Public Transport			Car		
Card ID	Travel Time Reduction	Travel Cost	Travel Time Reduction	Congestion cost	Parking Charge
1	Same	Same	-30%	240	Existing Charge

Public Transport			Car		
Card ID	Travel Time Reduction	Travel Cost	Travel Time Reduction	Congestion cost	Parking Charge
2	Same	Same	-10%	160	Existing Charge

Public Transport			Car		
Card ID	Travel Time Reduction	Travel Cost	Travel Time Reduction	Congestion cost	Parking Charge
3	-20%	+20%	-20%	160	+30%

Public Transport			Car		
Card ID	Travel Time Reduction	Travel Cost	Travel Time Reduction	Congestion cost	Parking Charge
4	-20%	+20%	-20%	200	Existing Charge

SCENARIOS : FRACTIONAL FACTORAL ARRAY

Card B

Public Transport

Card ID	Travel Time Reduction	Travel Cost
1	Same	Same

Card ID	Travel Time Reduction	Travel Cost
2	Same	Same

Card ID	Travel Time Reduction	Travel Cost
3	-20%	+20%

Card ID	Travel Time Reduction	Travel Cost
4	-20%	+20%

Car

Travel Time Reduction	Congestion cost	Parking Charge
-20%	160	+30%

Travel Time Reduction	Congestion cost	Parking Charge
-30%	160	+20%

Travel Time Reduction	Congestion cost	Parking Charge
-30%	200	+30%

Travel Time Reduction	Congestion cost	Parking Charge
-30%	240	Existing Charge

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

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Travel Time			145.548	3	.000			
Travel time reduced (-10%)	4.459	.700	40.556	1	.000	86.407	21.905	340.839
Travel time reduced (-20%)	1.103	.262	17.712	1	.000	3.012	1.802	5.034
Congestion Cost (Rs 200)	-.611	.272	5.067	1	.024	.543	.319	.924
Parking Cost	.048	.007	48.128	1	.000	1.049	1.035	1.063
Constant	-4.854	.696	48.696	1	.000	.008		

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.

MODE CHOICE: ANALYSIS

	Congestion Cost	Travel Time	Parking	Utility	Exponential	% shift to PT
Scenario 1	160	36	100	-0.746	0.474259803	13%
Scenario 2	200	36	100	-0.426	0.653116342	18%
Scenario 3	240	36	100	-0.106	0.899424648	23%

- 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

	Without Congestion Charge					With Congestion Charge			
Roads	**Capacity**	**2016 (PCU counts) Existing**	**2018 (PCU counts) BAU**	**2016 (v/c)**	**2018 (v/c)**	**2016 (PCU counts)26% shift to PT**	**2018 (PCU counts)26% shift to PT**	**2016 (v/c)**	**2018 (v/c)**
Janpath	6000	5350	6126	0.9	1	3959	4533	0.7	0.8
K.G marg	4000	5543	6346	1.4	1.6	4102	4696	1.0	1.2
Barakhamba Road	4000	6839	7830	1.7	2	5061	5794	1.3	1.4
Vivekanand Road	4000	5723	6552	1.4	1.6	4235	4848	1.1	1.2
Panchkuian Road	6000	4856	5560	0.8	1.4	3593	4114	0.6	0.7
Baba kadhak Singh Marg	4000	7334	8396	1.8	2.1	5427	6213	1.4	1.6
Sansad marg	4000	3815	4368	1	1.1	2823	3232	0.7	0.8
Chelmsfoed Road	4000	3319	3800	0.8	1	2456	2812	0.6	0.7

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

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