

**(Unintended) Transport Impacts
of an Energy-Environment Policy:
The Case of CNG Conversion of
Vehicles in Dhaka**

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TRB/2014

Transport Impacts



Ownership Impacts



Transport Impacts Summary
Vehicle ownership did not increase
Travel time increased
Congestion increased
Costs likely to increase substantially
Congestion costs

Travel Impacts



Background



Objectives

• Measure the impact of CNG conversion on vehicle ownership, travel time, and congestion costs

Air Quality Impacts



Air Quality Impacts Summary
Air quality improved in Dhaka
PM10 concentration decreased
PM2.5 concentration decreased
O3 concentration increased
CO concentration decreased

GHG Impacts



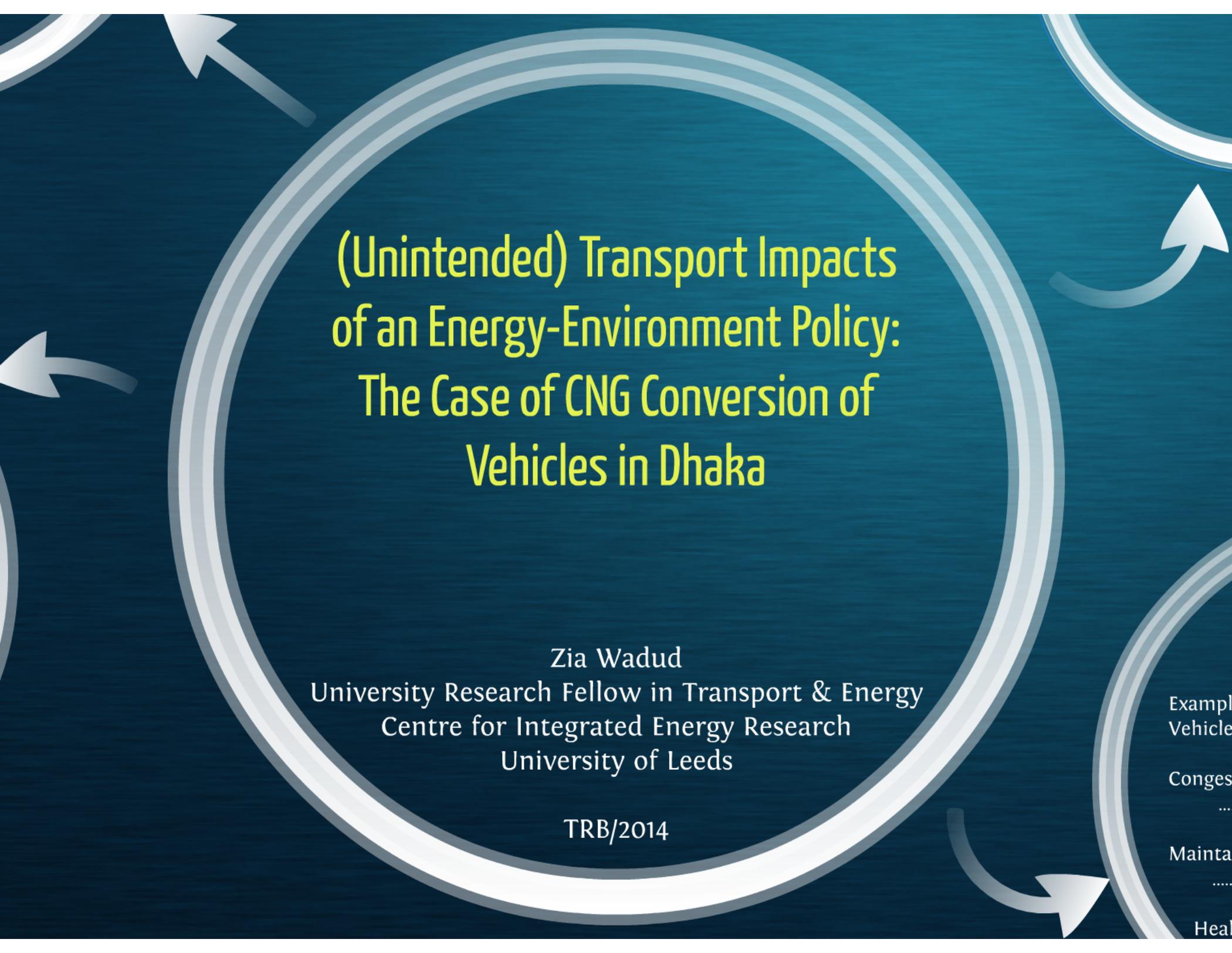
GHG Impacts Summary
Emissions in 2012 were 10% lower
Emissions in 2013 were 15% lower
Emissions in 2014 were 20% lower
Emissions in 2015 were 25% lower

Conclusions

Example of successful transition
Vehicle ownership did not increase
..... But vehicle travel did
Congestion costs nullify some benefits
..... But still only two-fifth of health benefits

Maintain CNG price differential
..... Address congestion by other means

Health benefits may decrease in future
..... As vehicles get cleaner



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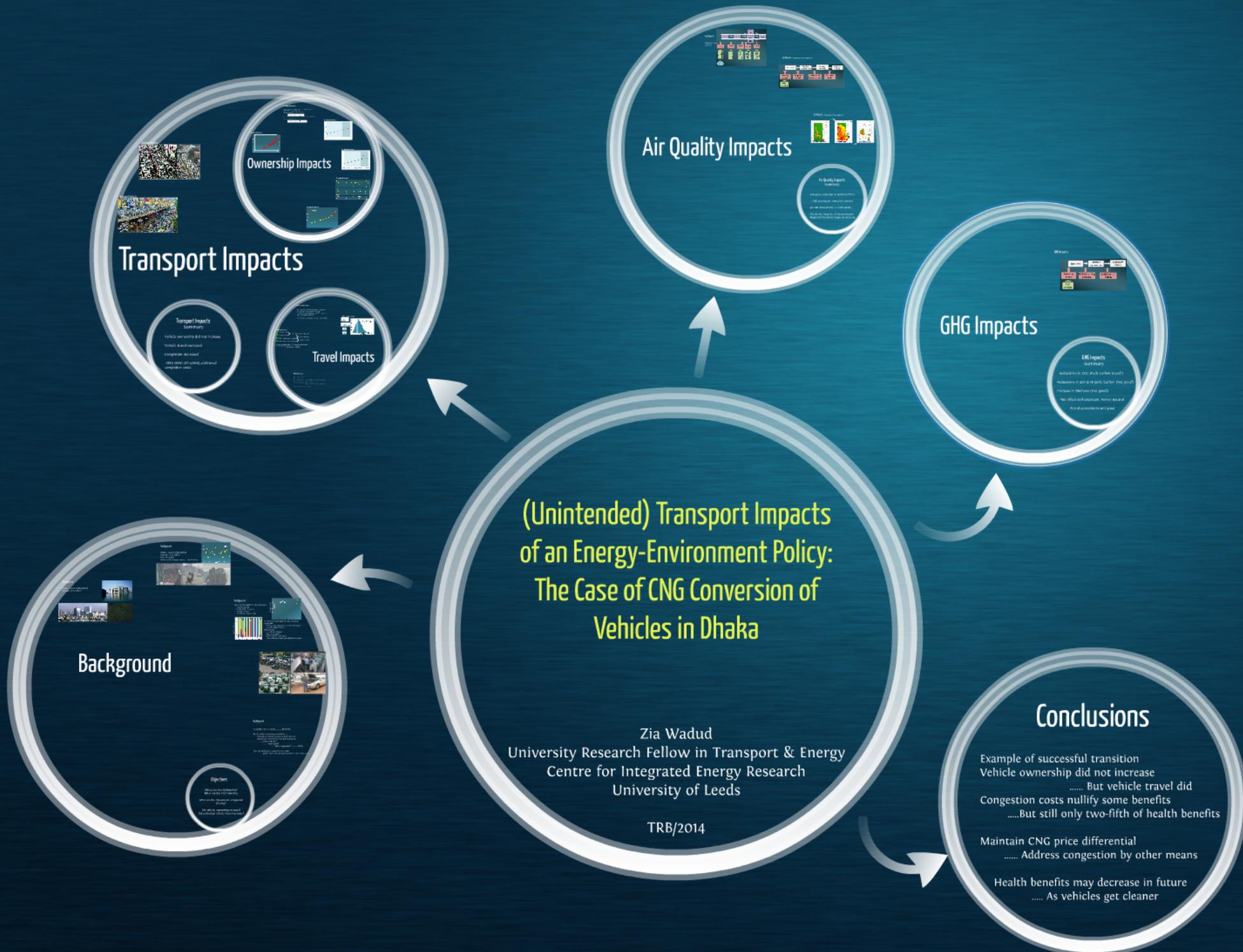
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Example
Vehicle

Conges
.....

Mainta
.....

Heal



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Background



Objectives

• Measure the impact of CNG conversion on vehicle ownership, travel time, congestion, and costs.

Air Quality Impacts



Air Quality Impacts Summary
• Significant reduction in particulate matter (PM10, PM2.5) and nitrogen dioxide (NO2) concentrations.
• Significant reduction in carbon monoxide (CO) concentrations.
• Significant reduction in sulfur dioxide (SO2) concentrations.

GHG Impacts



GHG Impacts Summary
• Reduction in total GHG emissions.
• Reduction in GHG emissions per vehicle.
• Reduction in GHG emissions per passenger-kilometer.

Conclusions

Example of successful transition
Vehicle ownership did not increase
..... But vehicle travel did
Congestion costs nullify some benefits
..... But still only two-fifth of health benefits

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..... Address congestion by other means

Health benefits may decrease in future
..... As vehicles get cleaner

Background

Background

Dhaka - capital of Bangladesh
 Megacity of 15 million
 Poor air quality
 Motor vehicle major source (- brick kilns)

Background

Dhaka - capital of Bangladesh
 Megacity of 15 million

Background

Four strongest benefits to CNG conversion

- Local air quality
- Global GHG emissions
- Energy security
- Foreign currency savings

Strong government push for CNG conversion supply side

- Remove monopoly of CNG conversion/supply
- Land for filling stations

Demand side

- Tax on cars reduced
- Safety campaigns
- Green vehicle conversion
- Price differential with petrol/diesel increased

Background

Background

Air quality improvements ----- BENEFITS

But in order to encourage transition ...

- Subsidies on petrol removed, diesel reduced
- CNG prices much lower than petrol & diesel
- More vehicles?
- More travel?
- More congestion? ----- COSTS

Stop the preferential treatment for CNG
 (diesel-CNG price parity discussed in the policy area)

Objectives

(What are the AQ benefits?
 What are the GHG benefits)

What are the impacts on congestion
 (if any)?

Did vehicle ownership increase?
 Did individual vehicle travel increase?



Background

Dhaka - capital of Bangladesh
Megacity of 15 million



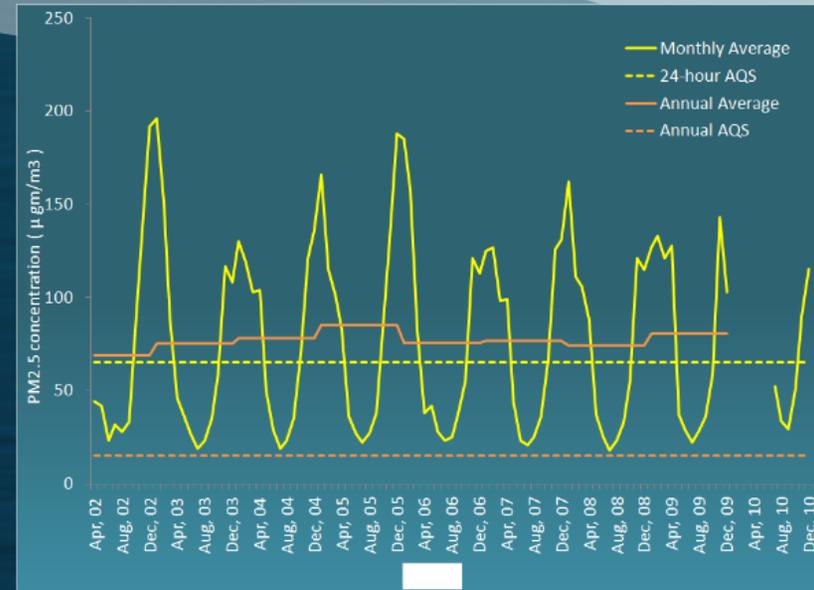
Background

Dhaka - capital of Bangladesh

Megacity of 15 million

Poor air quality

Motor vehicle major source (+ brick kilns)

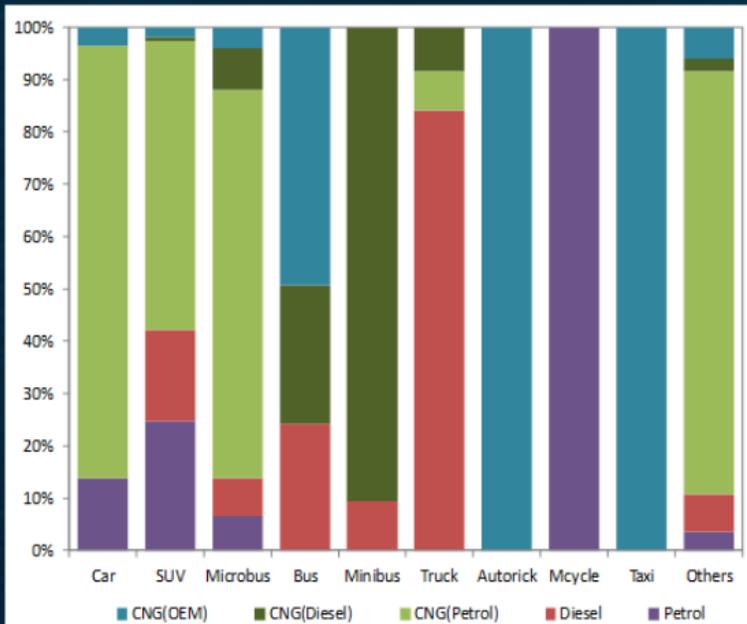


Background

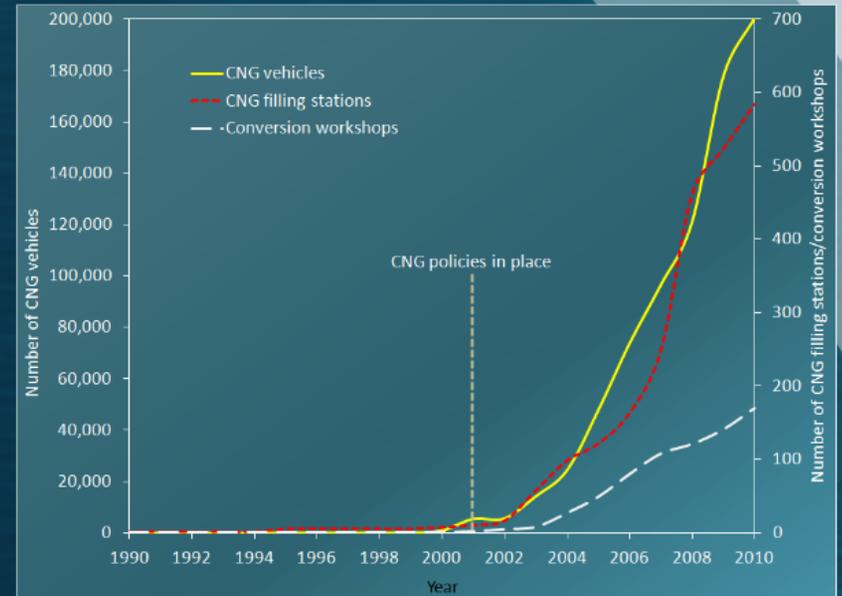
Four pronged benefits to CNG conversion

- Local air quality
- Global GHG emissions
- Energy security
- Foreign currency savings

NG Penetration



NG population



Strong government push for CNG conversion

Supply side:

- Remove monopoly of CNG conversion/supply
- Land for filling stations

Demand side:

- Tax on kits reduced
- Safety campaigns
- Govt. vehicles conversion
- Price differential with petrol/diesel increased

Background



Background

Air quality improvements =====> BENEFITS

But in order to encourage transition

Subsidies on petrol removed, diesel reduced
CNG prices much lower than petrol & diesel

..... More vehicles?

..... More travel?

..... More congestion? =====> COSTS

Stop the preferential treatment for CNG?

(diesel-CNG price parity discussed in the policy area)

Objectives

(What are the AQ benefits?
What are the GHG benefits)

What are the impacts on congestion
(if any)?

Did vehicle ownership increase?
Did individual vehicle travel increase?

Transport Impacts



Transport Impacts



Did ownership increase?

Intervention analysis on personal vehicles (car, SUV, Station wagon)
 Vehicle number ~ f(GDP, population)
 Dynamic autoregressive, distributed lag model
 Approach 1 (Model A)

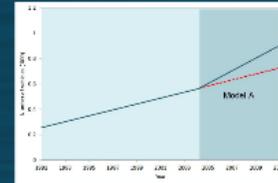
$$Y_t = \alpha + \sum_{i=1}^p \beta_i Y_{t-i} + \sum_{j=0}^q \gamma_j X_{t-j} + \epsilon_t$$

Run on a subsample till 2004, then predict till 2010, compare with real

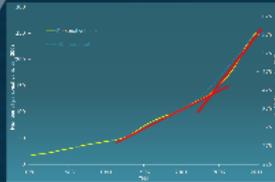
Approach 2 (Models B, C, D)

$$Y_t = \alpha + \sum_{i=1}^p \beta_i Y_{t-i} + \sum_{j=0}^q \gamma_j X_{t-j} + \delta D_t + \epsilon_t$$

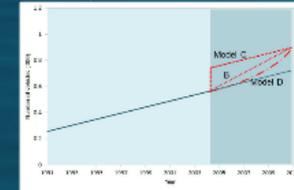
Did ownership increase?



Did ownership increase?



Did ownership increase?

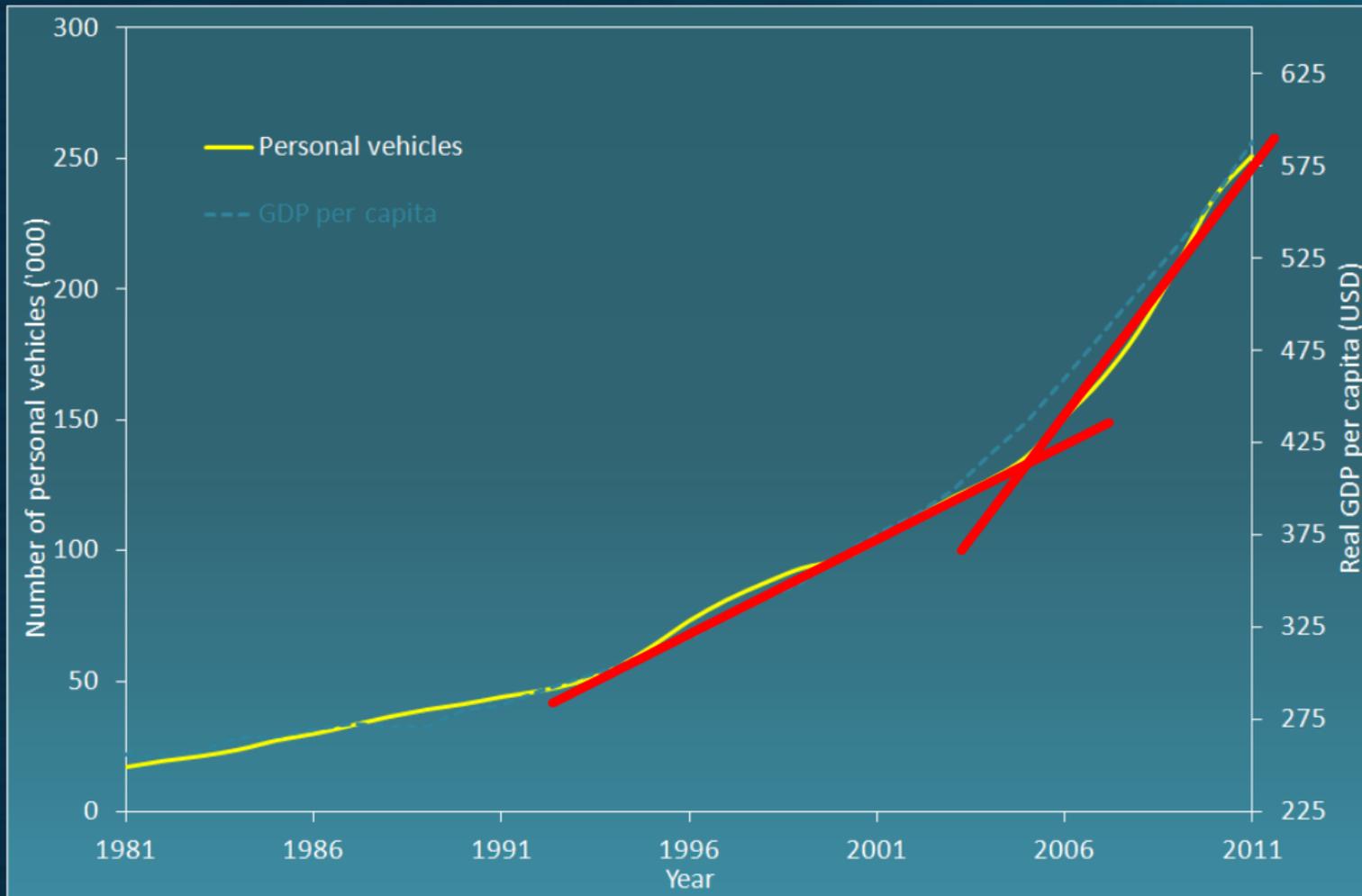


Ownership Impacts

Did ownership increase?

Parameter	A	B	C	D
Intercept	Intercept	$\alpha + \delta$	$\alpha + \delta$	$\alpha + \delta$
β_1	β_1	β_1	β_1	β_1
β_2	0	0	0	0
β_3	0	0	0	0
β_4	0	0	0	0
β_5	0	0	0	0
β_6	0	0	0	0
β_7	0	0	0	0
β_8	0	0	0	0
β_9	0	0	0	0
β_{10}	0	0	0	0
β_{11}	0	0	0	0
β_{12}	0	0	0	0
β_{13}	0	0	0	0
β_{14}	0	0	0	0
β_{15}	0	0	0	0
β_{16}	0	0	0	0
β_{17}	0	0	0	0
β_{18}	0	0	0	0
β_{19}	0	0	0	0
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β_{222}	0	0	0	0
β_{223}	0	0	0	0
β_{224}	0	0	0	0
β_{225}	0	0	0	0
β_{226}	0	0	0	0
β_{227}	0	0	0	0

Did ownership increase?



Did ownership increase?

Intervention analysis on personal vehicles (car, SUV, Station wagon)

Vehicle number = f(GDP, population)

Dynamic autoregressive, distributed lag model

Approach 1 (Model A):

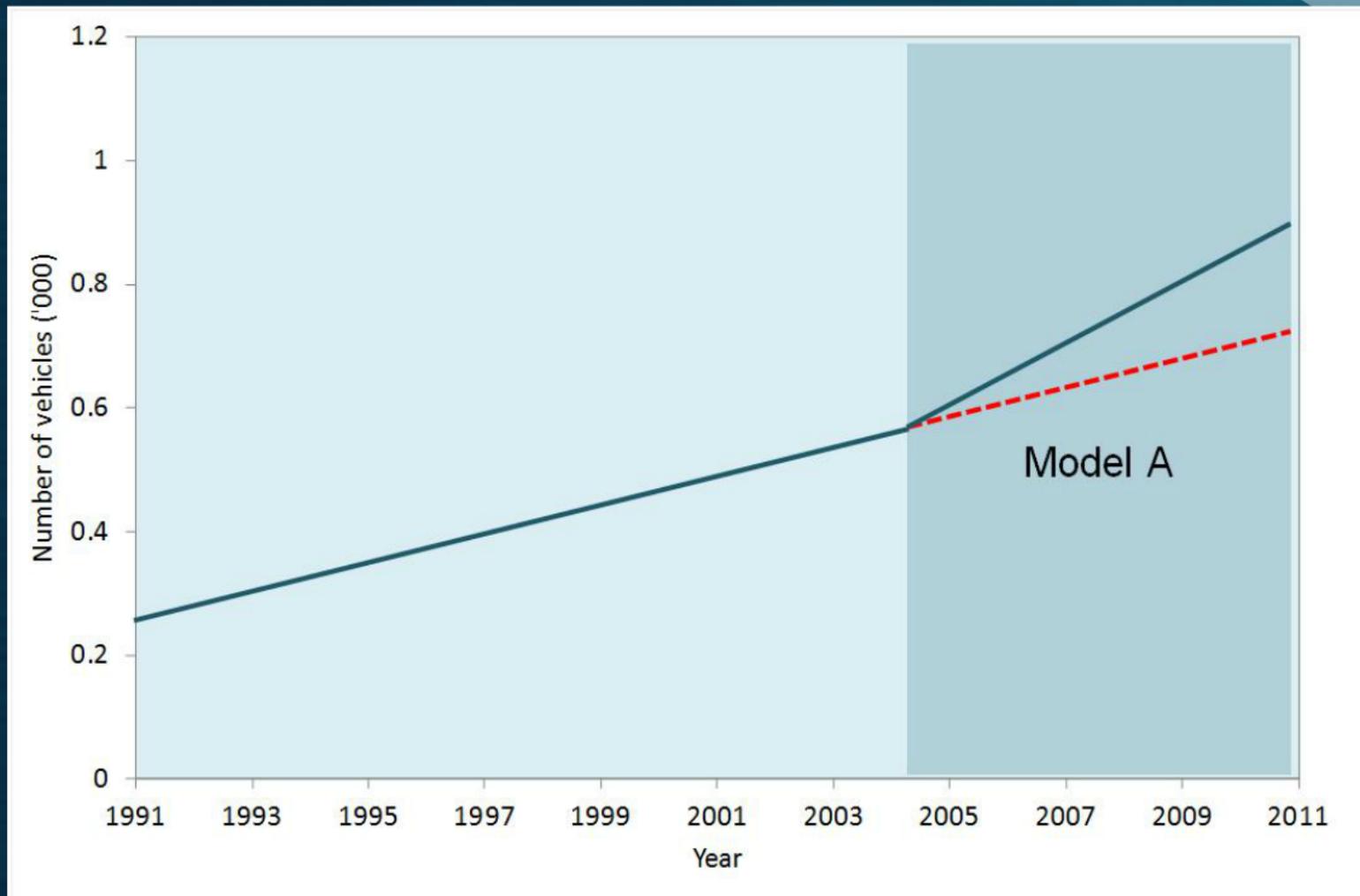
$$\ln V_t = \kappa + \sum_{i=1}^l \alpha_i \ln V_{t-i} + \sum_{j=0}^m \beta_j \ln GDP_{t-j} + \sum_{k=0}^n \gamma_k \ln P_{t-k} + \varepsilon_t$$

Run on a subsample till 2004, then **predict** till 2010, compare with real

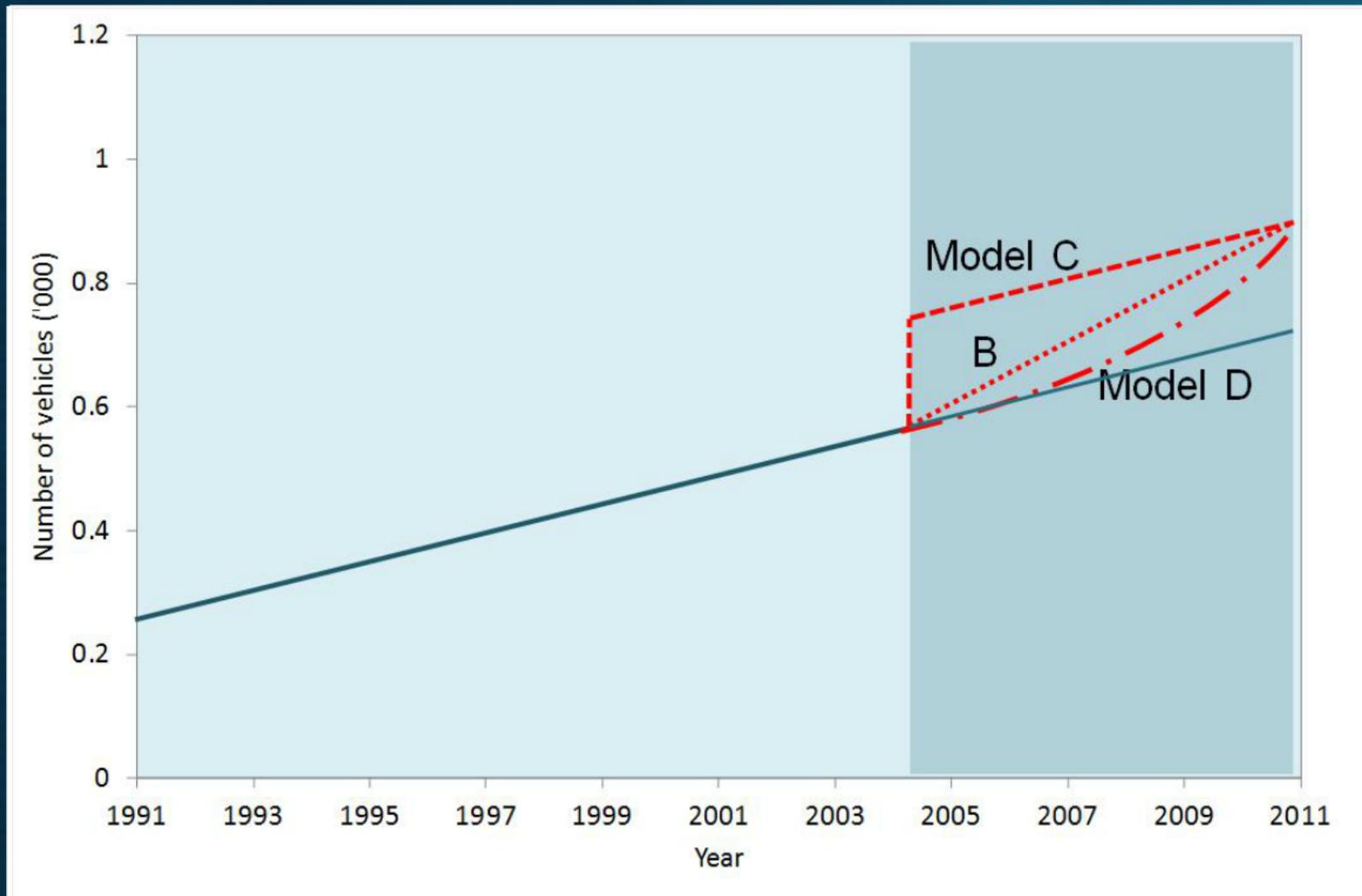
Approach 2 (Models B, C, D):

$$\ln V_t = \kappa + \sum_{i=1}^l \alpha_i \ln V_{t-i} + \sum_{j=0}^m \beta_j \ln GDP_{t-j} + \sum_{k=0}^n \gamma_k \ln P_{t-k} + \text{Dummy} + \varepsilon_t$$

Did ownership increase?



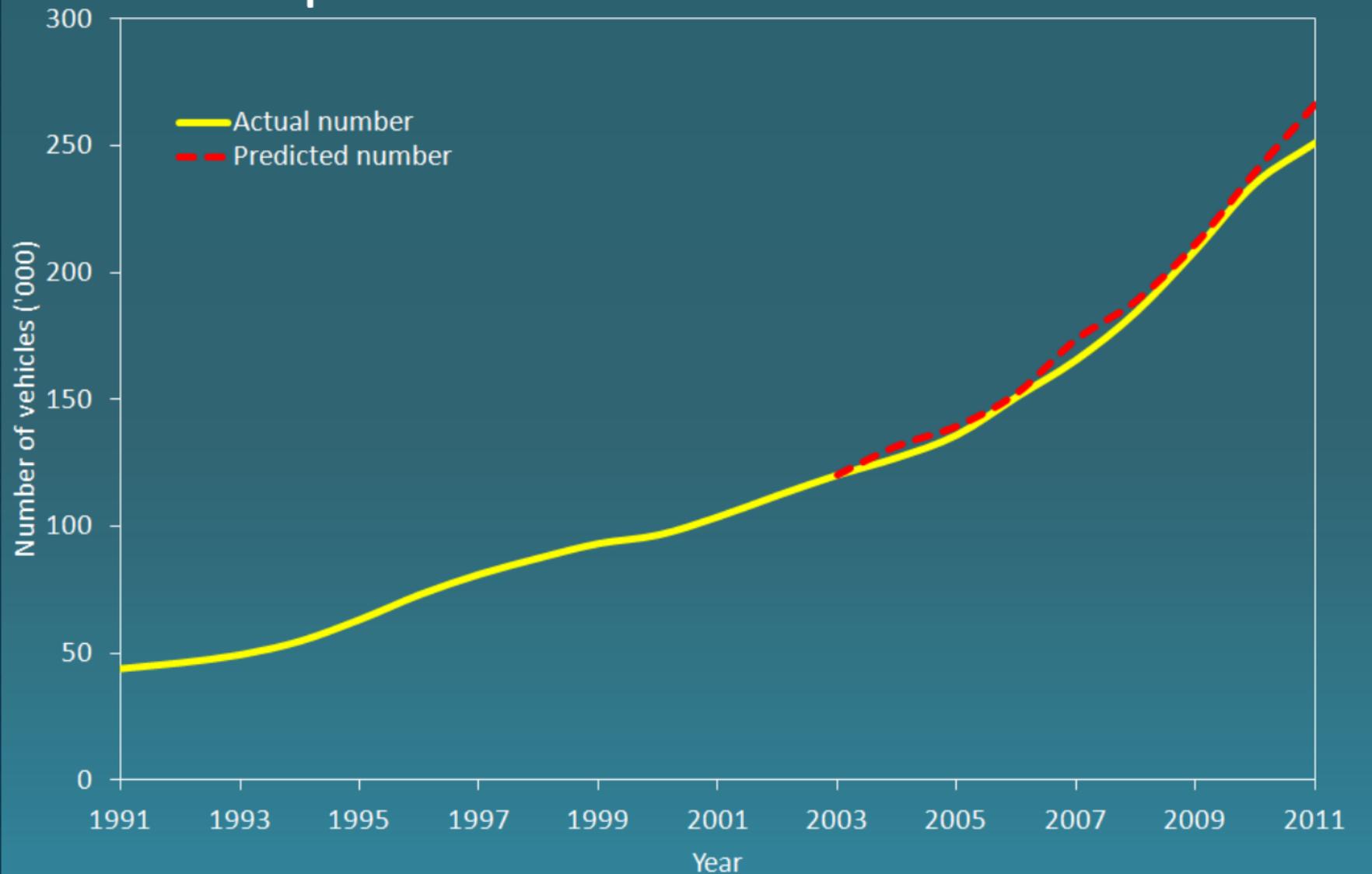
Did ownership increase?



Did ownership increase?

Parameter	A	B	C	D
Dummy	None	$D_g=0$ if $t<2004$ $=t-2004$, else	$D_s=0$ if $t<2004$ $=1$, else	$D_{int}=D_s \times \ln GDP$
l	2	2	2	2
m, n	0	0	0	0
$\ln V_{t-1}$	1.475***	1.497***	1.434***	1.435***
$\ln V_{t-2}$	-0.795***	-0.799***	-0.790***	-0.793***
$\ln GDP$	0.369**	0.307**	0.388***	0.393***
$\ln P$	0.386**	0.376***	0.437***	0.437***
$D_g/D_s/D_{int}$	-	-0.002	-0.027	-0.005
constant	-4.734**	-4.416***	-5.268***	-5.286***
N	21	29	29	29

Did ownership increase?

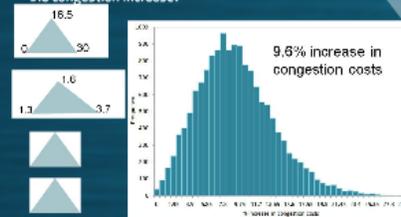


Did congestion increase?

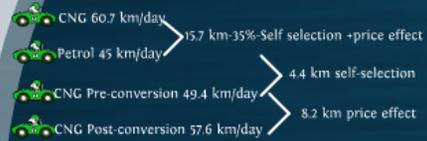
VKT-congestion; speed-flow-density - city specific
No such relationship available in Dhaka
Elasticity of congestion/delay w.r.t. VKT: 0.3 to 6.2
Deakin and Harvey (1997): 1.6

7.4% increase in congestion costs due to price-effect

Did congestion increase?



Did travel increase?



Pre-conversion large sample = f(pre-conversion small sample)
Price effect 8.6 km/day; self-selection 7.1 km/day
4.7% increase in total VKT

Travel Impacts

Did travel increase?

Questionnaire survey

On-road CNG vehicles travel 35% more than on-road petrol vehicles

Difference due to price effect + self selection
(some similarity with diesel in Europe?)

Price effect matters for this analysis

Did travel increase?

Questionnaire survey

On-road CNG vehicles travel 35% more than on-road petrol vehicles

Difference due to price effect + self selection
(some similarity with diesel in Europe?)

Price effect matters for this analysis

Did travel increase?



CNG 60.7 km/day



Petrol 45 km/day



CNG Pre-conversion 49.4 km/day



CNG Post-conversion 57.6 km/day

15.7 km-35%-Self selection +price effect

4.4 km self-selection

8.2 km price effect

Pre-conversion large sample = f(pre-conversion small sample)

Price effect 8.6 km/day; self-selection 7.1 km/day

4.7% increase in total VKT

Did congestion increase?

VKT-congestion; speed-flow-density – city specific

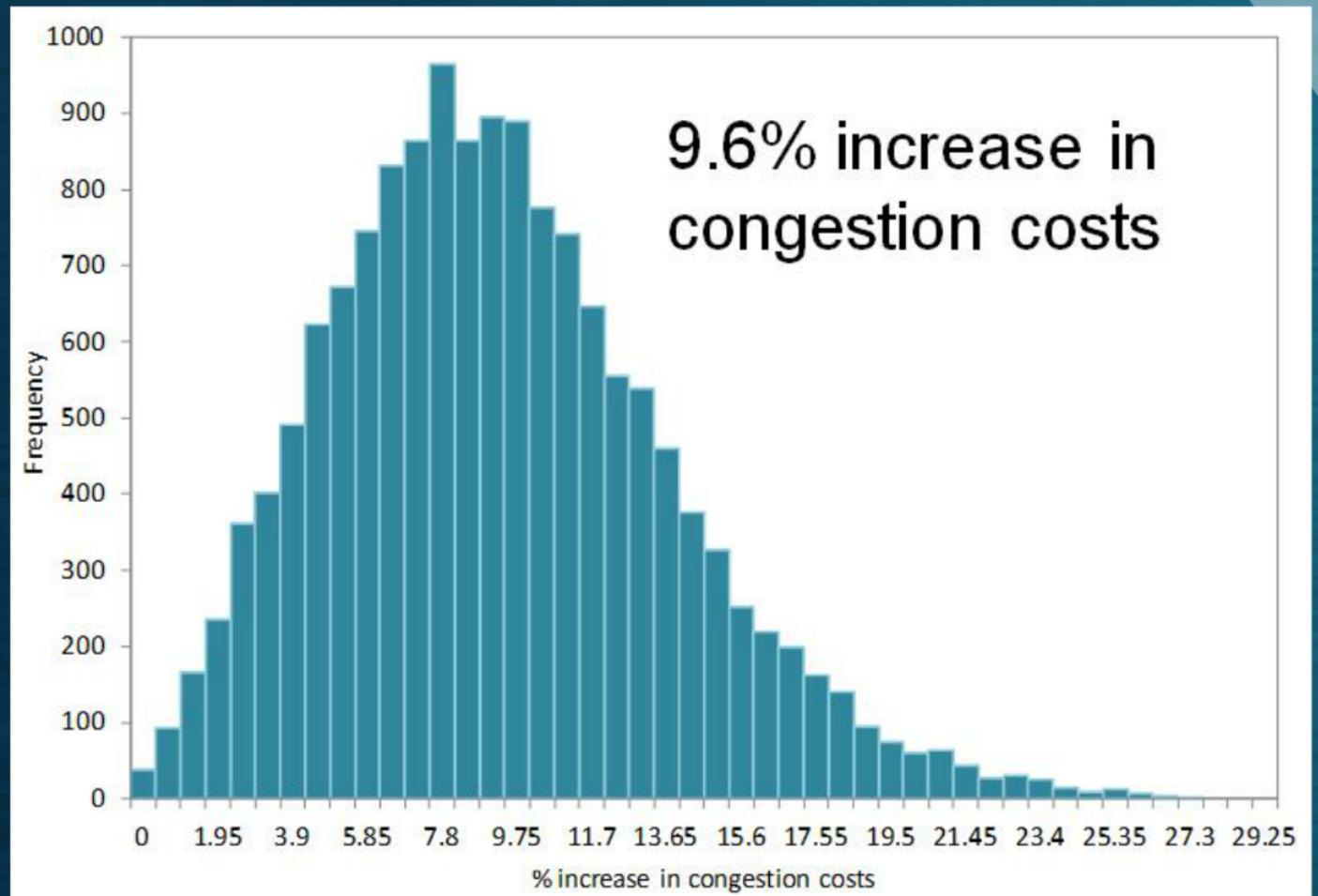
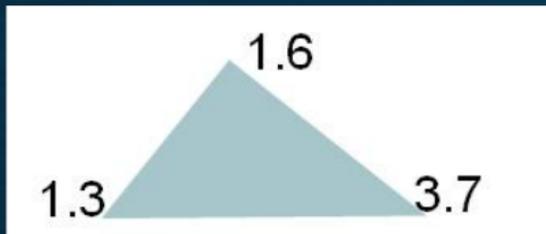
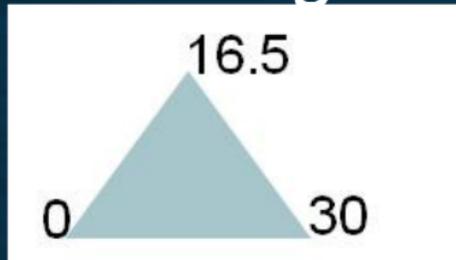
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Elasticity of congestion/delay w.r.t. VKT: 0.3 to 6.2

Deakin and Harvey (1997): 1.6

7.4% increase in congestion costs due to price-effect

Did congestion increase?



Transport Impacts Summary

Vehicle ownership did not increase

Vehicle travel increased

Congestion increased

-USD 160M (80-420M) additional
congestion costs

Air Quality Impacts Summary

0.01 g/m³ reduction in ambient PM_{2.5}

~ 1,965 premature mortality avoided

@ USD 200,000 VSL ==> USD 400M

VSL & non-linearity of Concentration-Response functions major uncertainty

GHG Impacts Summary

Reductions in CO₂, Black Carbon (Good!)

Reductions in SO₂ & Organic Carbon (Not good!)

Increase in Methane (Not good!)

Net effect still uncertain, minor/ neutral

Petrol conversions not good

Conclusions

Example of successful transition

Vehicle ownership did not increase

..... But vehicle travel did

Congestion costs nullify some benefits

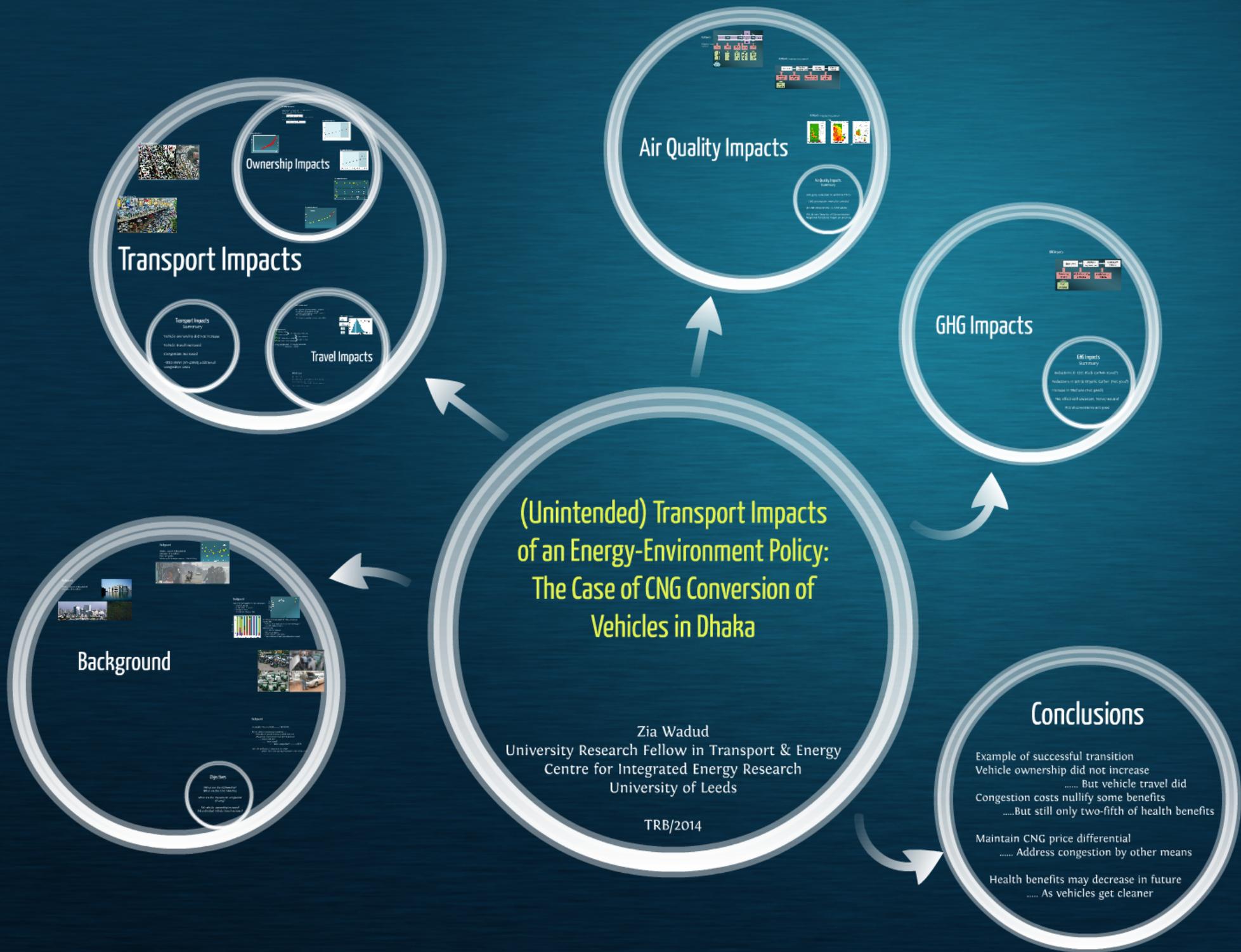
.....But still only two-fifth of health benefits

Maintain CNG price differential

..... Address congestion by other means

Health benefits may decrease in future

..... As vehicles get cleaner



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TRB/2014

Transport Impacts



Ownership Impacts



Transport Impacts Summary
 Vehicle ownership did not increase
 Reduced in peak hours
 Congestion reduced
 Less delay in public transportation

Travel Impacts



Background



Objectives

• To assess the impact of CNG conversion on vehicle ownership, travel time, and congestion in Dhaka.

Air Quality Impacts



Air Quality Impacts Summary
 Air quality improved in Dhaka
 PM10, PM2.5, SO2, NO2, CO, O3
 Reduction in PM10, PM2.5, SO2, NO2, CO, O3

GHG Impacts



GHG Impacts Summary
 Reduction in GHG emissions
 Reduction in CO2, CH4, N2O, HFC, PFC, SF6
 Reduction in CO2e (kg per km)

Conclusions

Example of successful transition
 Vehicle ownership did not increase
 But vehicle travel did
 Congestion costs nullify some benefits
But still only two-fifth of health benefits

Maintain CNG price differential
 Address congestion by other means

Health benefits may decrease in future
 As vehicles get cleaner