Managing 3-wheelers in Asia: Cost-effective technology measures and financing options

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Clean Air Initiative for Asian Cities

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Outline

- Context and trends
- Strategies and policies in managing 2-3 wheelers
- Case Study: Available technologies and financing scheme for replacing 2-Stroke tricycles in Metro Manila

Growing number of 2-3 wheelers in Asia

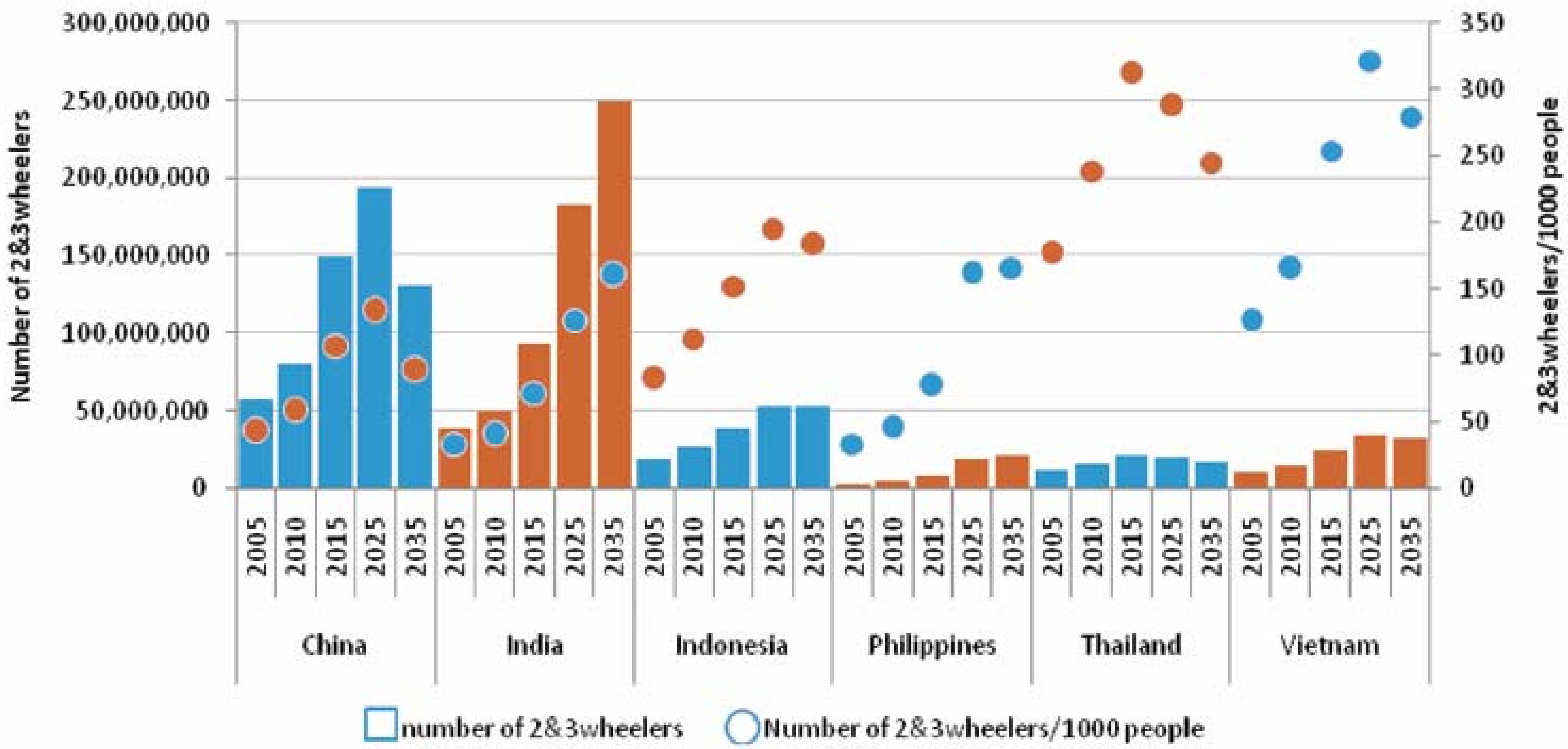
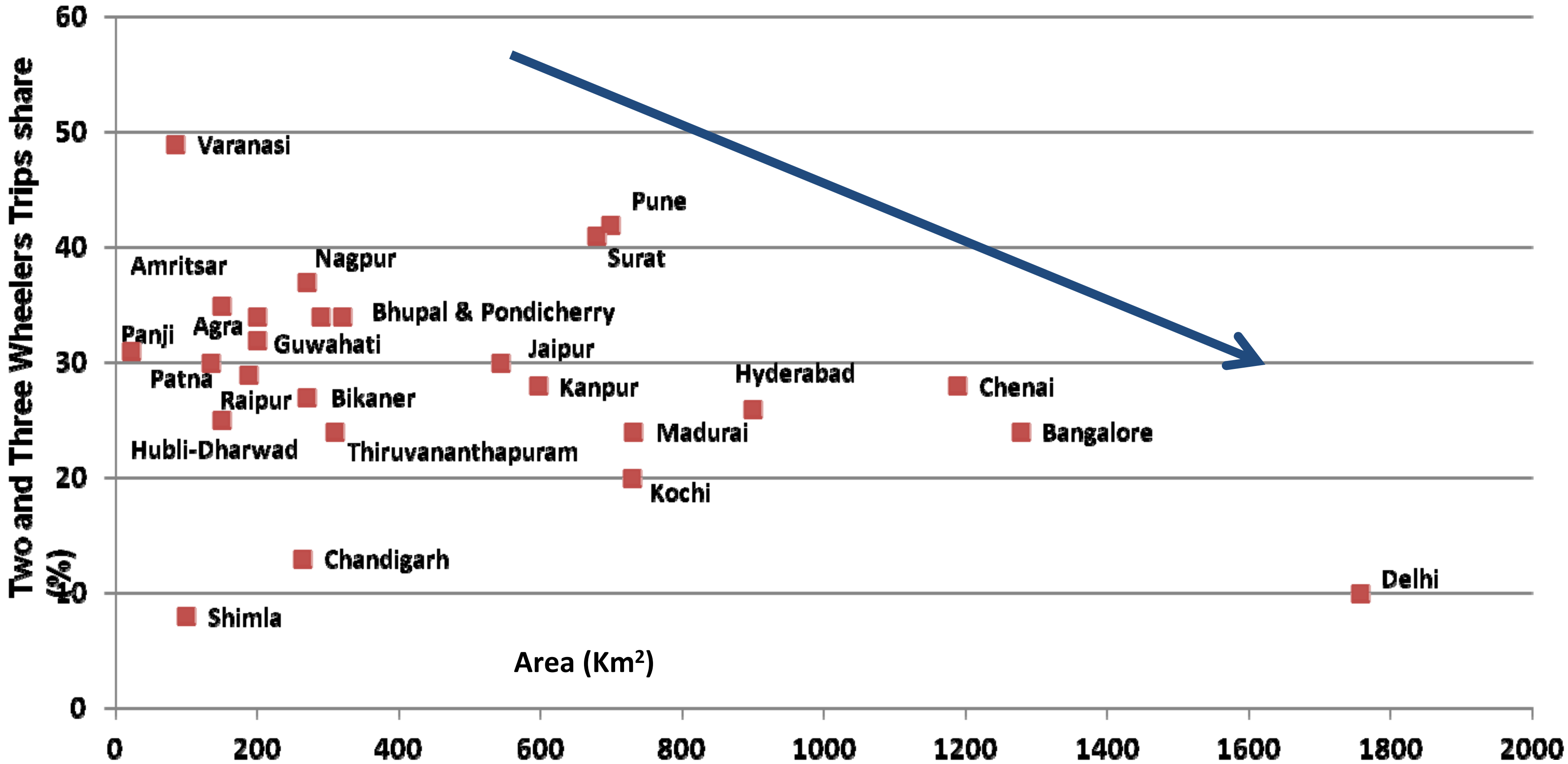


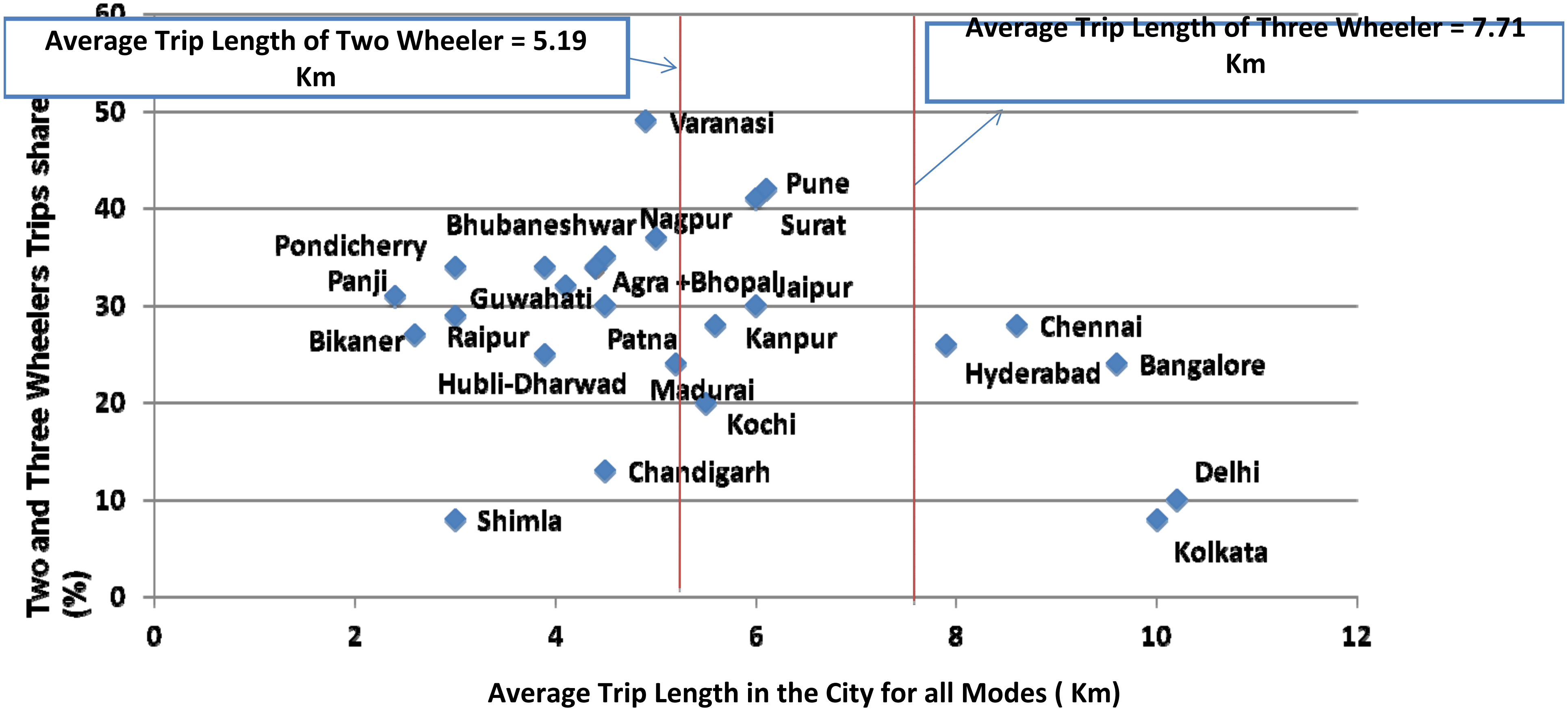
Figure 1. Two and three-wheelers in Asia
Source: CAI-Asia, ADB, Segment Y (2009)

2-3 Wheeler Trip Share (e.g. in India)



Source: 2008. MOUD- Study on Traffic and Transportation Policies and Strategies in Urban Area. Analysis By CAI-Asia

Addressing short(er) trips (e.g. in India)



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Managing 2-3 Wheelers

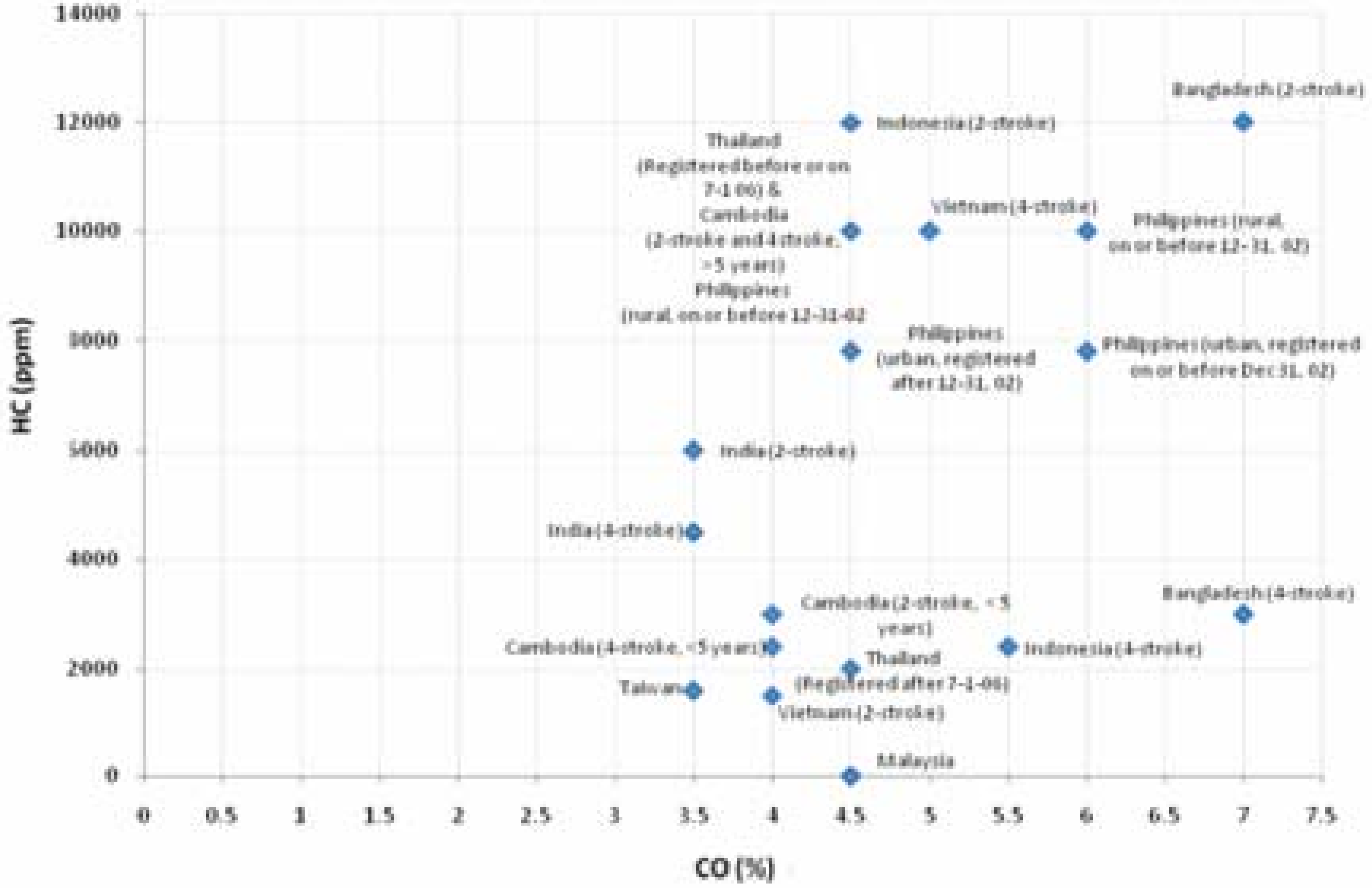
Elements	Examples
Urban Planning and Demand Management	• Institutionalizing 2-3 wheeler management plans • "Route measurement capacity" • 50-50 Traffic Scheme to limit the 3-wheeler operation daily • Separate lanes for motorcycles to address road accidents and congestion (Shanghai, China); Non-exclusive motorcycle lanes in Metro Manila • Banning of 2-&3-wheelers in major roads to avoid congestion and reduce accidents (most Asian cities have a similar policy)
Emissions Standards and Vehicle	• Institutionalizing emissions standards • Adoption of better technologies • Electric vehicles
Cleaner Fuels	• Lower sulfur fuels • Use of pre-mixed 2T oil
Inspection and Maintenance	• Periodic inspection and maintenance schemes

Emissions Standards – Type Approval

	CO (g/km)	HC (g/km)	NOx (g/km)
Thailand (>150 cc)	2	0.3	0.15
Thailand (<150 cc, evap ? 2g/test)	2	0.8	0.15
Taiwan (>150 cc)	2	0.3	0.15
Taiwan (<150 cc)	2	0.8	0.15
Singapore (4-stroke)	13	3	0.3
Singapore (4 stroke)	13	3	0.3
Singapore (2-stroke)	8	4	0.1
Singapore (2 stroke)	8	4	0.1
Philippines (moped)	8	5	
Philippines (100 kg, 2-stroke)	32	12	
Philippines (>300 kg, 4-stroke)	35	8	
Philippines (<100 kg, 4-stroke)	17.5	4.2	
Philippines (<100 kg 2-stroke)	12.8	8	
Malaysia (4-stroke)	13	3	0.3
Malaysia (2-stroke)	8	4	0.1
Japan (4-stroke)	20	2.93	0.51
Japan (2-stroke)	14.4	5.26	0.14
China (<150 ml)	2	0.8	0.15
China (<150 ml)	2	0.3	0.15
India (2 and 3 wheelers)	1	1	

Source: ADB, 2002. Updated CAI-Asia 2010

Emissions Standards – In-Use



Source: ADB, 2002. Updated CAI-Asia 2010

Case Study: Metro Manila Tricycles

- "Primarily" serves as feeders in residential areas and provides as the main source of livelihood
- Substantial number of 2-Stroke tricycles, 10% >10 years old

- **Technology Options**

Vehicle Replacement Options

- Gasoline Carbureted Four Strokes
- LPG Carbureted Four Strokes
- Electric Trike
- Pedicab*

Retrofit Options

- Gasoline Direct Injection Retrofit
- LPG Direct Injection Retrofit
- Gasoline Four Stroke Repowering
- LPG Four Stroke Repowering

District	City	# TODAS	# tricycles	2 stroke
Capital District	Manila	-	5,000	
Eastern	QC	150	25,000	
	Marikina	56	3,519	25%
	Mandaluyo	49	3,833	
	Pasig	89	12,000	
	San Juan	11	526	55%
CAMANAVA	Caloocan	100	14,750	
	Malabon	50	4,600	
	Navotas	20	2,000	
	Valenzuela	41	7,000	
Southern	Makati	61	4,500	20%
	Pasay	-	3,000	
	Las Pinas	30	4,851	10%
	Muntinlupa	-	3,000	
	Taguig	54	4,300	
	Paranaque	50	4,787	
	Pateros	14	1,500	
	TOTALS	>775	**104,166**	
	Average	55	6,127	

Source: Cardenas, M. 2011. (Unpublished) Prepared for Clean Engines, Inc. (do not cite)

Gasoline Four Strokes

- Initial Cost : ~USD 1590.00 (P70,000.00)
- 10% to 40% better fuel economy
- Additional savings from avoided 2T oil use
- Higher maintenance cost
- 0.001 g/g_{fuel} PM emissions compared to 0.0147 g/g_{fuel} (2S)

	Carb 4S / Carb 2S Emission Factor and Fuel Use Ratio				
Reference	**FC**	**CO**	**HC**	**NOx**	**Drive Cycle**
Tzeng and Chen (1998)	0.86	0.81	0.24	5.11	TMDC
Tzeng and Chen (1998)	0.91	0.82	0.16	5.52	ECE
Priest et al (2000)	0.6	0.76	0.17	5.67	Steady State
Tsai et al (2005)	0.93	0.80	0.21	10.00	ECE
Tsai et al (2005)	0.88	0.70	0.22	10.40	KH
EPA (2005)	0.79	0.90		2.73	Off Road
Average	**0.83**	**0.80**	**0.20**	**6.57**	

Source: Biona, M., and CAI-Asia, 2011 (Unpublished)

LPG Four Strokes

- Initial Cost : USD 1590.00 – 1932.00 (P75,000.00 – P85,000.00)
- 15% to 20% better fuel economy relative to four strokes
- Lower fuel cost
- Additional savings from avoided 2T oil use
- Higher maintenance cost
- Preparations are on-going to offer this option to the market

	LPG Four Stroke / Carb 4S Emission Factor and Fuel Use Ratio					
Reference	**FC**	**CO**	**HC**	**NOx**	**PM**	**Drive Cycle**
Bui et al (2004)	0.8					Field Testing
Murillo et al (2005)	0.77	0.19	0.92			Marine Vehicle
Murillo et al (2005)	0.82	0.25	0.62	1.8		Marine Vehicle
EPA (2005)	0.84	0.26	0.44	1.41	0.84	Steady State
EPA (2005)	0.84	0.33	0.37	1.23	0.83	Steady State
Ristovski et al (2005)					0.57	Steady State
Average	**0.81**	**0.26**	**0.59**	**1.48**	**0.75**	

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

Electric Trikes

- Initial Cost: USD 4,091.00 – 5,227.00 (P180,000.00 – P230,000.00)
- Significant reduction in fuel cost
- Additional battery replacement cost
- Lower emissions impact
- Issues with performance in lower kWh models (1.5-3 kWh)

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

Gasoline DI Two Stroke Retrofit

- Initial Cost : USD 410.00 (P18,000.00)
- 30% to 40% better fuel economy
- Higher maintenance cost
- 50% lower PM emissions
- Some minor reliability issues encountered
- Limited only to Yamaha RS100 Model to date
- Distribution temporarily stopped

	GDI 2S/ Carb 2S Emission Factor and Fuel Use Ratio				
Reference	**FC**	**CO**	**HC**	**NOx**	**Drive Cycle**
Leigthon and Ahern (2003)	0.71	0.58	0.24		IDC
Archer and Bell (2001)	0.58	0.13	0.12	2.25	ECE
Archer and Bell (2001)	0.61	0.17	0.21	1.50	ECE
Bauer and Lorenz (2006)	0.68	0.28	0.12		IDC
Average	**0.65**	**0.29**	**0.17**	**1.88**	
Standard Deviation	**0.06**	**0.20**	**0.06**	**0.53**	

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

LPG DI Two Stroke Retrofit

- Initial Cost : USD 341.00 – 410.00 [P15,000.00 to P18,000.00 (estimated)]
- 17% reduction in fuel consumption compared to carbureted four strokes
- Limited data on emissions to date but expected to provide much lower emissions compared to carbureted four stroke
- In the later stage of development at Universiti Sains Malaysia (USM)

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

Gasoline Four Stroke Repowering

- Initial Cost : USD 500.00 – 568.00 (P22,000.00 – P25,000.00)
- 155 cc engine
- Same performance and emissions with carbureted four stroke tricycles
- Tested in Mandaluyong City with favorable results

LPG Four Stroke Repowering

- Initial Cost : USD 795.00 – 909.00 (P35,000.00 – P40,000.00)
- 175 cc engine
- Same performance and emissions with LPG four strokes
- Positive results of emissions and performance tests but tests on durability needed

Pedicabs

- Initial Cost : USD 227.00 – 340.00 (P10,000.00 – P15,000.00)
- No fuel cost
- No emissions
- Site and capability specific applications
- “Performance” perceived to be not at par with motorized tricycles

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

“TricyBoats”

- Initial Cost : Lower than four strokes
- Lower fuel cost
- No emissions and performance data available to date
- Emissions depends on the engines used but its safe to assume that its lower than two stroke tricycles
- Some are two stroke powered
- Regulations and Legality ???

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

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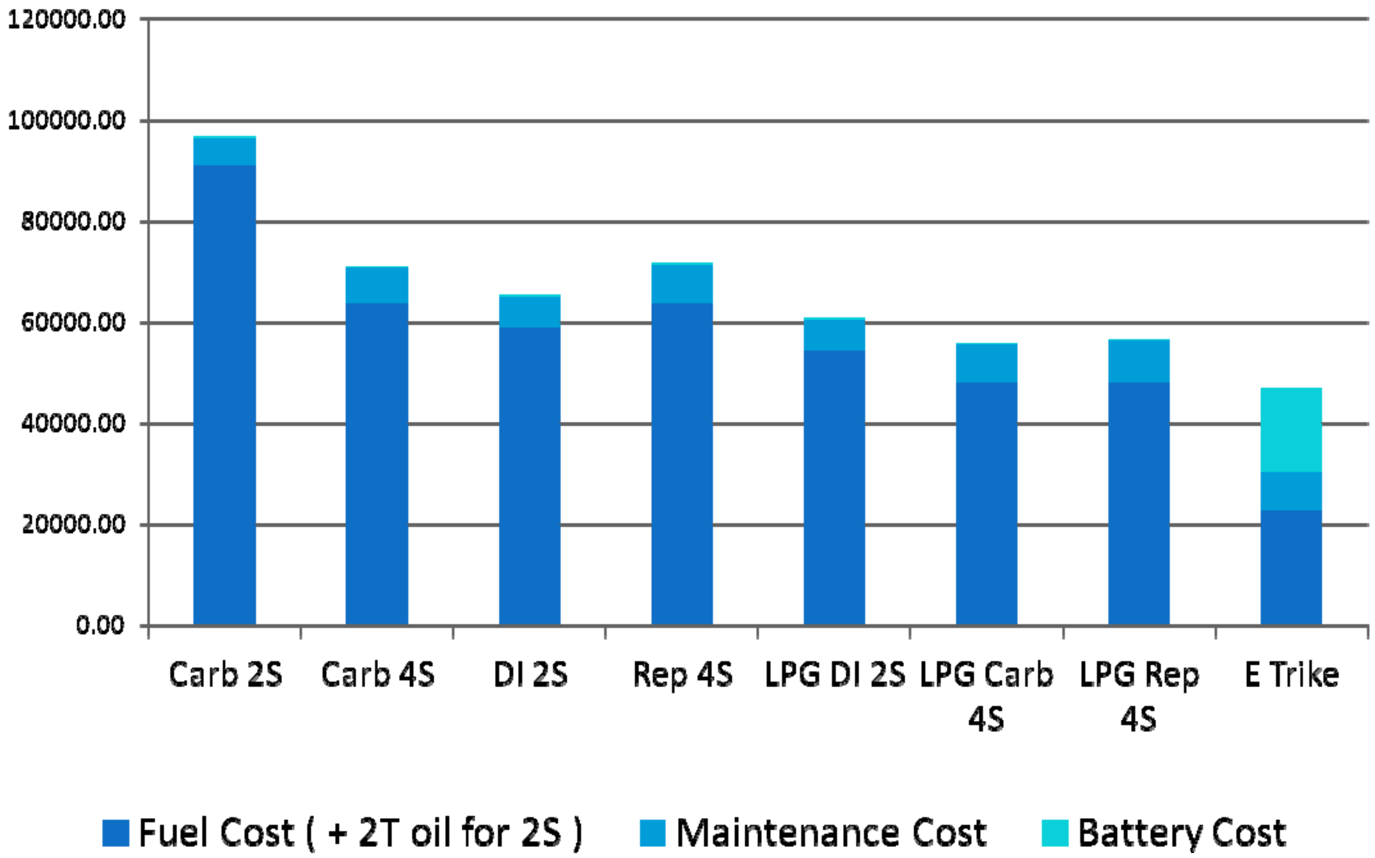
Financial Comparison

	Ref.	Replacement Technologies			Retrofit Technologies			
Parameter	Carb 2S	Carb 4S	LPG Carb 4S	E Trike	DI 2S	Rep 4S	LPG DI 2S	LPG Rep 4S
In US Dollar (USD)								
Initial Investment		1591	1932	4545	386	523	341	864
Annual Operational Cost								
Fuel Cost (+ 2T oil for 2S)		997	692	512	868	997	727	692
Maintenance Cost	121	159	172	173	140	175	138	189
Battery Cost	8	8	8	318	8	8	8	8
Annual Depreciation	57	80	97	193	95	109	91	143
Total Annual Costs	1662	1243	969	1196	1111	1289	963	1032
Annual Savings		419	693	466	551	373	699	630

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

Operational Costs



Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

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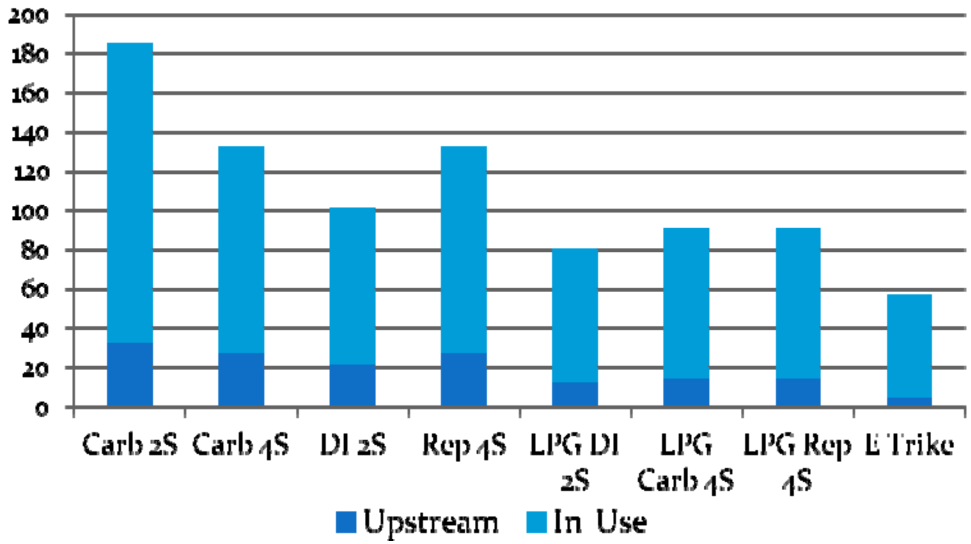
Payback Period

Parameter	Replacement Technologies			Retrofit Technologies			
	Carb 4S	LPG Carb 4S	E Trike	DI 2S	Rep 4S	LPG DI 2S	LPG Rep 4S
Initial Investment (Php)	70000	85000	230000	17000	23000	15000	38000
Daily Amortization	75.0	100.0	200	75.0	75.0	100.0	100.0
Daily Savings	76.5	121.5	148	93.3	74.4	107.0	119.3
Monthly Interest Rate	2%	2%	2%	2%	2%	2%	2%
Payment Period (in months)	55.5	47.2	87	8.9	12.5	5.7	16.0
Payment Period (in years)	4.6	3.9	7	0.7	1.0	0.5	1.3

Source: Biona, M.,and CAI-Asia, 2011 (Unpublished)

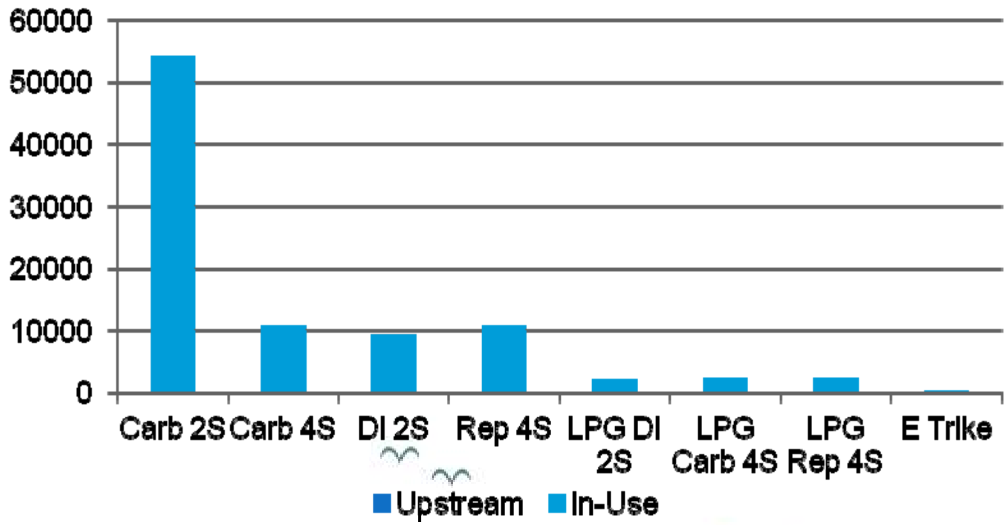
Environmental Comparison



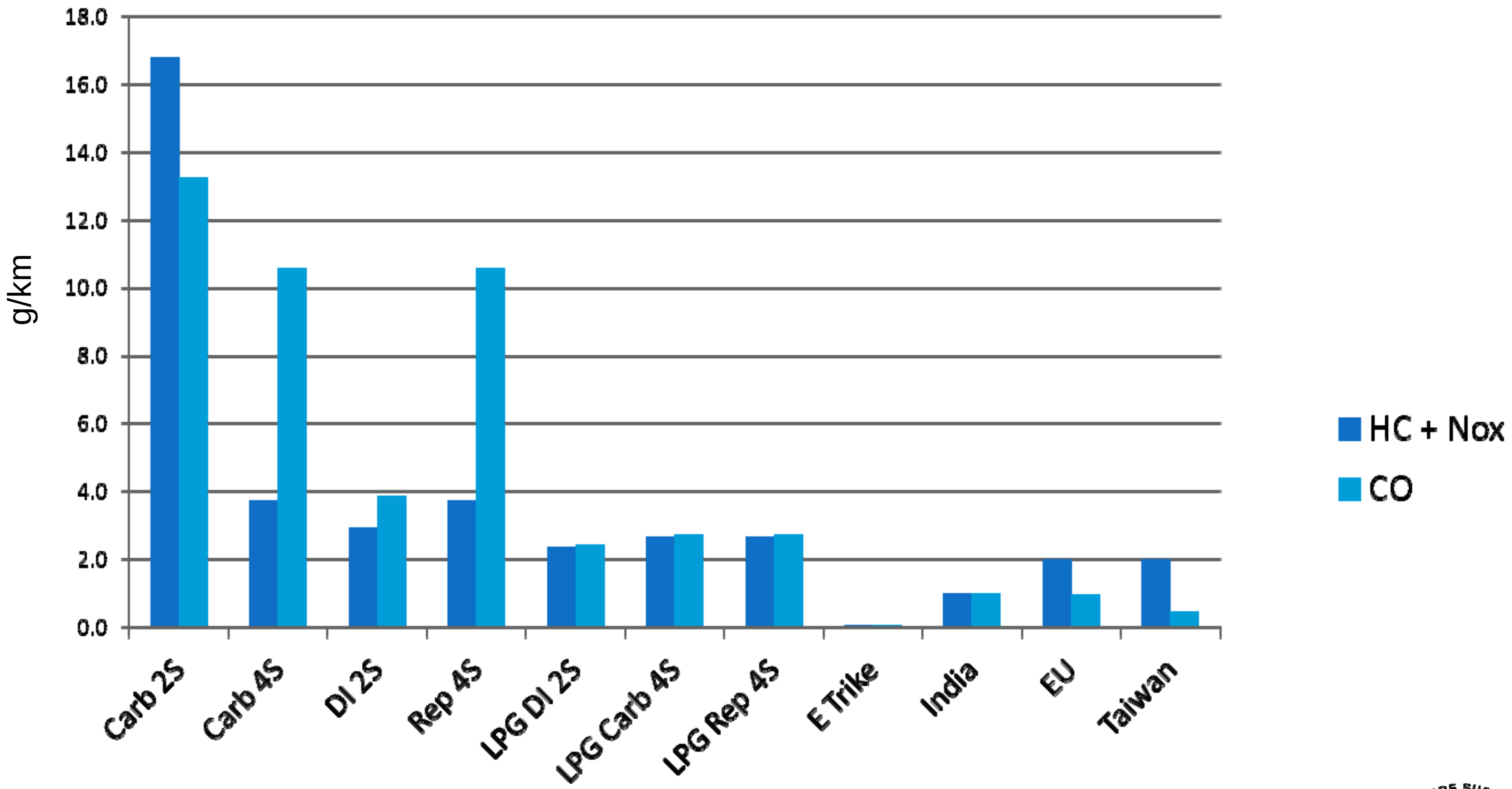
eq. kg CO_2

- Using fuel cycle analysis but limited to air emissions considering

HC and PM (m^3 air)



How they compare with other standards?



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Environmental Performance Analysis

- First and foremost, non-motorized pedicabs or improved pedicabs (electrically assisted) are the most environmentally sustainable
- Electric trikes prove the most reductions in reduction of emissions – e.g. HC, PM, NOx, CO_2 eq., and also liquid fossil fuel consumption
- The adoption of all the other technologies evaluated provides significant reduction relative to carburetted two stroke systems
- Gasoline and LPG 4-stroke and DI 2-stroke, but may however cause increases in NOx levels

Financial Viability Analysis

- Both the adoption of new gasoline and LPG carburetted 4-stroke options are viable should lending rates be limited to at most 2% per month – but the required equity funds in loan availment for these technologies could be an issue for some operators
- The capital cost and battery replacement cost of current models of electric tricycles in the country provides minimal net returns which may not be enough to justify their acquisition - equity funding is also a major issue
- The operational savings of all retrofit technologies are enough to justify their acquisition even at 3% per month lending rates - these options provide payback periods less than 1.5 years

Current initiatives in Metro Manila

- Mandaluyong and Pasig Tricycle Upgrading Program – Development of Revolving Microfinancing Scheme
  - PCA/CAI-Asia with initial 20 2-stroke replacement with 4-stroke with funds from Philippine Institute of Petroleum
  - Infusion of additional funds from City Mayor(s)
- ADB-Department of Energy Electric Tricycle Program
  - 20 electric lithuim-ion tricycles piloted in Mandaluyong
  - Goal of mainstreaming 20,000 electric tricycles in Philippine cities

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