Reducing Pollutant Emissions and Fuel Consumption in Two-And Three-wheelers In India: A Technical Assessment

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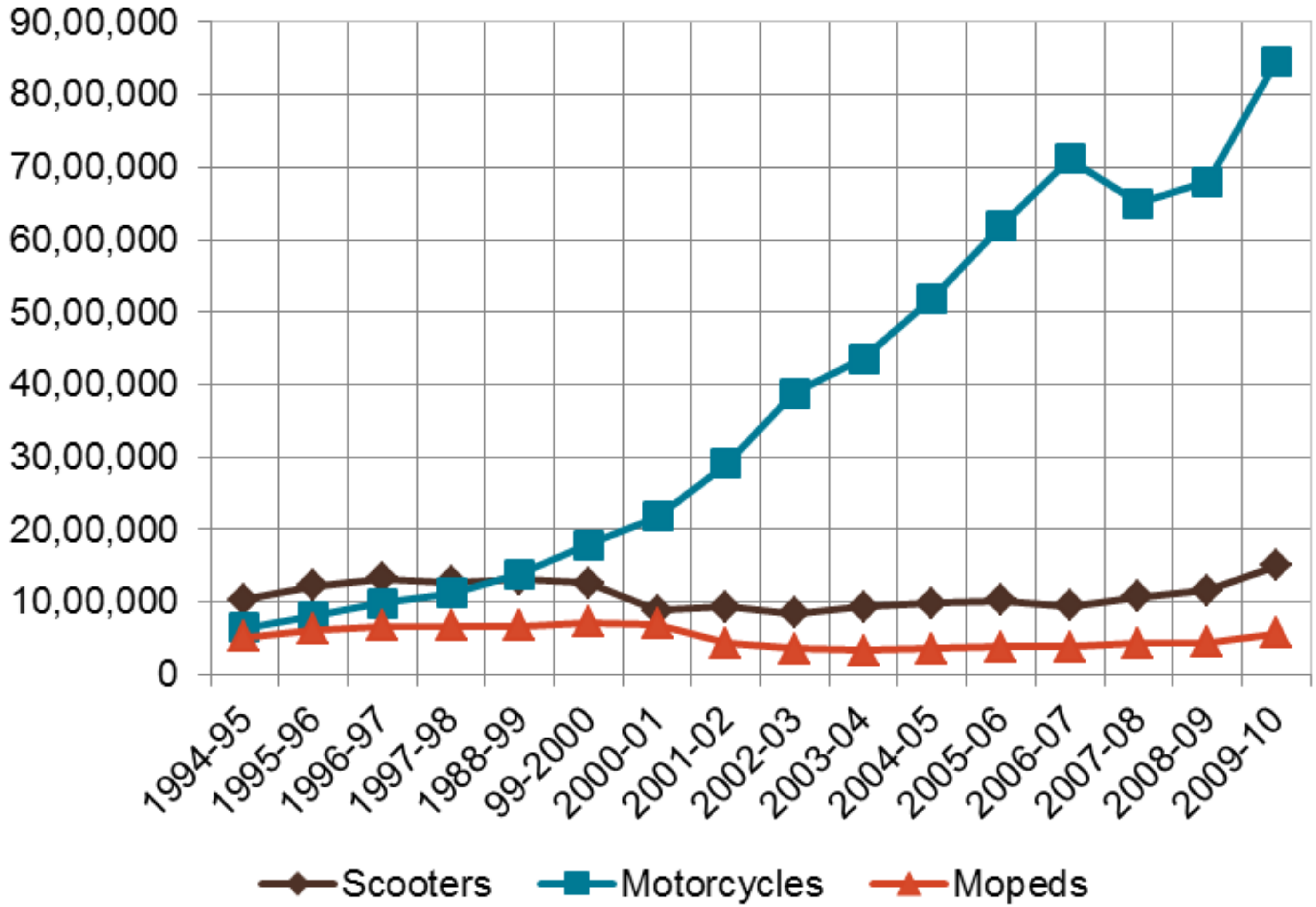
Importance of Two and Three-Wheelers in Indian Transportation

- Two-Wheeler sales growth at double digit rates in last decade – more than a million per month
  - Annual sales five times that of cars
- Three-wheelers play a crucial role as intermediate public transport
  - Annual sales surpassed over half a million
- Though vehicles meet stringent emission standards and are fuel efficient, their rapidly increasing numbers highlight the need to pay urgent attention to further reducing their emissions and fuel consumption

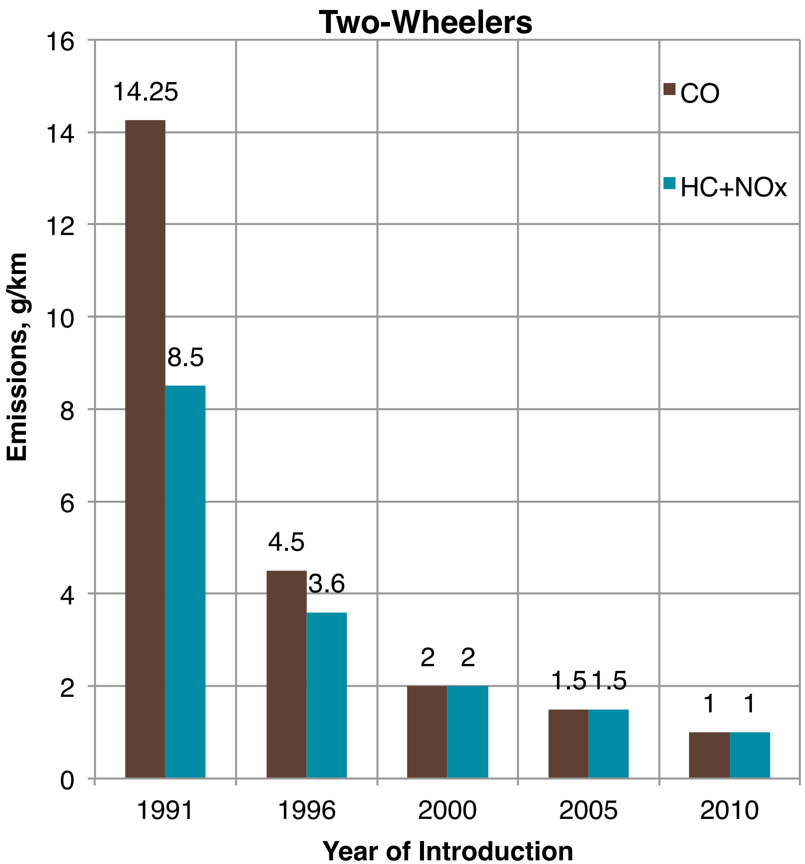
Two-Wheeler Sales Dominated by Four-Stroke Motorcycles

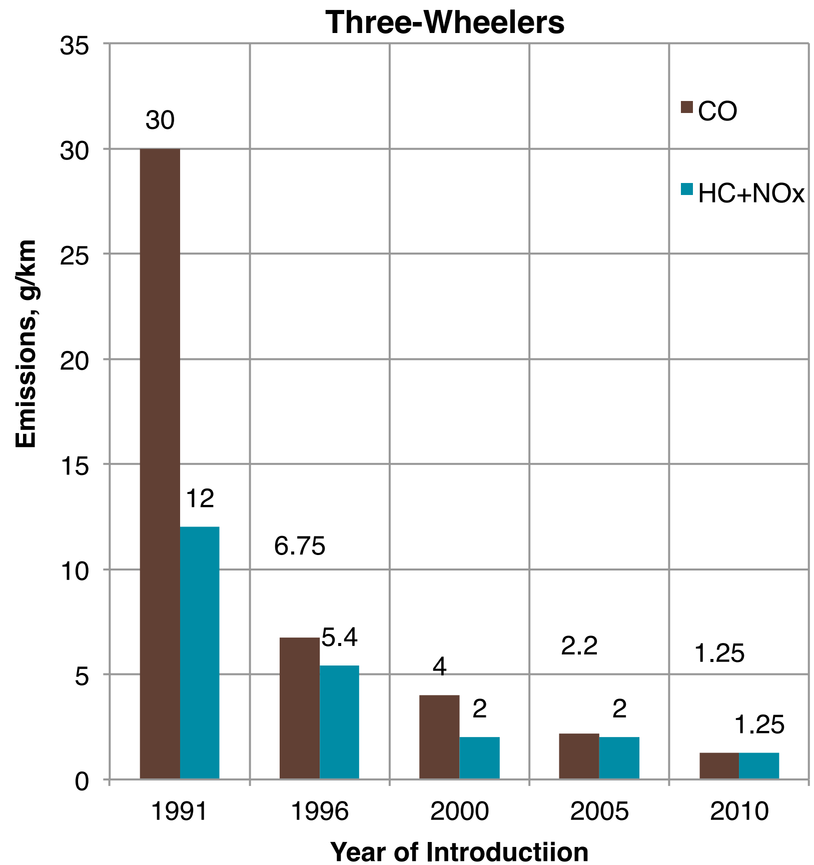


Webinar Contents

- ✓ Engine and after-treatment technologies used to meet BS III standards
- ✓ Proposals for a ten-year road map of progressively stricter emission standards – BS IV and BS V
- ✓ Known, Potential and Emerging technologies to reduce emissions.
- ✓ Recommendations for technical measures other than emission standards to reduce emissions
- ✓ Current fuel consumption profile and technological potential to achieve further reduction

Progression of Two and Three-Wheeler Emission Standards





Prevailing Two and Three-Wheeler Emission Standards

2 or 4 Stroke SI or CI	2 or 3 Wheeler	Stage	Emission Standards, g/km CO	HC+NOx	PM	Drive Cycle	Durability km	DF
2&4	2	2010	1.00	1.00	-	IDC	30000	1.2
2&4 SI	3	2010	1.25	1.25	-	IDC	30000	1.2
2&4 CI	2&3	2010	0.50	0.50	0.05	IDC	30000	1.1

Note: Alternative Standards as per UNECE Global Technical Regulation (GTR2) notified for two-wheelers in June 2012 GTR2 specifies new classification of vehicles and a new drive cycle – World Motorcycle Test Cycle (WMTC)

GTR2 Emission Limits Notified as Alternative to 2010 Standards by India

Category	2 or 4 stroke SI or CI	2 or 3 Wheeler	Stage	Emission Standards (g/km)			Drive cycle	Durability
				CO	HC+NOx	PM		
Class 1+2.1	2&4(SI)	2	2011	1.87	1.08	none	WMTC	DF included
Class 2.2	2&4(SI)	2	2011	2.62	0.92	none	WMTC	DF included
Class 3.1	2&4(SI)	2	2011	2.62	0.55	none	WMTC	DF included
Class 3.2	2&4(SI)	2	2011	2.62	0.55	none	WMTC	DF included
Vehicle classification used by the Ministry of Road Transport and Highways in its Notification No GSR 103E dated 31st December 2010								
Class1	50<cc<150	Vmax < 50 km/h OR						
	cc >150	50<Vmax< 100 km/h						
Class 2.1	cc<150	100<Vmax < 115 OR						
	cc>150	Vmax < 115 km/h						
Class 2.2	any	115< Vmax < 130 km/h						
Class 3.1	any	130< Vmax < 140 km/h						
Class 3.2	any	Vmax > 140 km/h						

- Following India's Commitment to Transpose GTR2 into the Country's Regulations
- Draft notification in December 2010, final notification in June 2012

Technologies Used to Meet Current Emission Standards

Vehicle Category	Technologies Used
Two and Three-Wheelers, 2-Stroke SI	Most Models: Engine Optimization + Oxi Cat One 3-Wheeler Model with GDI introduced All except 6% of vehicles (mopeds) switched to 4-strokes
Two and Three-Wheelers, 4-Stroke SI	Most Models: Engine Optimization – some variable ignition timing), + Oxi Cat Some Models: Secondary Air Injection Some high end models: PFI with Oxi cat and/or TWC
Three Wheelers, 4-Stroke CI	Most models: Optimization of injection parameters and calibration for low emissions Majority of models: DI

Stringency of GTR2 Limits Adopted by India

- Three levels of stringency of emission limits provided in GTR2 to choose from to account for
  - Diverse traffic situation
  - Separated or combined limits for HC and NOx
  - Different reference fuels because of the market fuel situation
  - Environmental priorities energy/fuel conservation, or cost-benefit situation;
- Emission limits adopted in India are the least stringent and are based on a correlation with IDC results
- Emission Limits continue to combine HC and NOx

Three Alternative Emission Standards Recommended in GTR2

India Adopted Alternative 'A'

Alternative performance requirement A

	CO	CO	HC+NOx	HC+NOx	HC+NOx
Vehicle class	Class1 and Class 2.1	Class 2.2 and Class 3	Class1 and Class 2.1	Class 2.2	Class 3
Limit values, L_A in mg/km	1870	2620	1080	920	550

Alternative performance requirement B

	CO	HC	HC+NOx
Vehicle class	All	Class1 and Class 2	Class 3
Limit values, L_A in mg/km	12000	1000	800

Alternative performance requirement C

	CO	HC	HC	NOx	NOx
Vehicle class	All	Class1 and Class 2	Class 3	Class1 and Class 2	Class 3
Limit values, L_A in mg/km	2620	750	330	170	220

Approach for Developing Future Emission Standards on Lines of EU & GTR2, (1/2)

Take Indian notified GTR2 alternative limit values as base for current BS III

↓

Take proposed EU limit values for vehicles of EU classes in which Indian vehicle fall (almost all Indian two-wheelers fall into "EU Motorcycles classes: L3-e - A1, A2 and A3)

↓

Determine per cent of reduction of EU limit values from Euro 3 to Euro 4 (2015) and from Euro 4 to Euro 5 (2018) [NEXT CHART]

↓

Apply same per cent reduction to basic Indian GTR2 limit values (BSIII) for determining limit values for BS IV and BS V

Approach for Developing Future Emission Standards on Lines of EU & GTR2, (2/2)

Progressive per cent reduction of emission limit values in EU

Euro Level	Propulsion Class	Year	CO		THC		NOx		HC+NOx	
			g/km	(%) reduction *	g/km	(%) reduction	g/km	(%) reduction	g/km	(%) reduction
Euro 3	PI, V_{max} < 130 km/h	2006	2.62	0	0.75	0	0.17	0	0.92	0
Euro 4		2015	1.97	25	0.56	25	0.13	24	0.69	25
Euro 5		2018	1.14	42	0.38	32	0.07	46	0.45	35
Euro 3	PI, V_{max} ≥ 130 km/h	2006	2.62	0	0.33	0	0.22	0	0.55	0
Euro 4		2015	1.97	25	0.25	24	0.17	23	0.42	24
Euro 5		2018	1.14	42	0.17	32	0.09	47	0.26	38

Suggested Emission Limits Progression for Two and Three-Wheelers for Indian Road Map

Two Wheelers

Vehicle Class	Engine Capacity Range	Max speed ranges, km/h	CO, g/km			HC+NOx, g/km		
			2010 (BSIII) Existing	2015 (BS IV) Proposed	2020 (BSV) Proposed	2010 (BSIII) Existing	2015 (BS IV) Proposed	2020 (BSV) Proposed
Class 1	50 < cc <150	$V_{max} < 50$	1.87	1.40	0.84	1.08	0.81	0.53
	> 150 cc	$50 < V_{max} < 100$	1.87	1.40	0.84	1.08	0.81	0.53
Class 2.1	< 150 cc	$100 < V_{max} < 115$	1.87	1.40	0.84	1.08	0.81	0.53
	> 150 cc	$V_{max} < 115$	1.87	1.40	0.84	1.08	0.81	0.53
Class 2.2	any	$115 < V_{max} < 130$	2.62	1.97	1.18	0.92	0.69	0.45
Class 3.1	any	$130 < V_{max} < 140$	2.62	1.97	1.18	0.55	0.41	0.27
Class 3.2	any	$V_{max} > 140$	2.62	1.97	1.18	0.55	0.41	0.27

Three-Wheelers

Categ.	2 or 4Stroke	2 or 3 wheeler	Stage	Emission Standards, (g/km)			Drive cycle	Durability	
				CO	HC+NOx	PM		Test, km	DF
All	2&4 SI	3	2010	1.25	1.25		IDC	30000	1.2
	2&4 SI	3	2015	0.94	0.94		IDC	30000	1.2
	2&4 SI	3	2020	0.66	0.66		IDC	30000	1.2
	2&4 CI	2&3	2010	0.50	0.50	0.05	IDC	30000	1.1
	2&4 CI	2&3	2015	0.38	0.38	0.038	IDC	30000	1.1
	2&4 CI	2&3	2020	0.26	0.26	0.025	IDC	30000	1.1

"Known" and "Potential" Technologies to Meet Proposed 2015 and 2020 Two-Wheeler Standards

Year of Introduction	Emission Standard	2-stroke	4-stroke
2015 "KNOWN"	BS IV	*Most models: Improved Oxi cat *Some models: Air Assisted DI + improved Oxi cat *Some models: Electronic carburettor+Oxi cat	*Some models: Further Engine Optimization variable ignition timing + Improved Cat Con - Close Coupled Cat / Start-up Cat / Quick Warm-up Cat, Exhaust Insulation *Some models PFI *Some models: Electronic carburettor
2020 "POTENTIAL"	BS V	*Some models: Replace with improved 4-stroke engines *Some models: Air-Assisted DI + Oxi cat *Some models: Electronic carburettor +Oxi cat	*Most models: PFI + Oxi cat *Some models: Cat con with Closed Loop Some models: PFI +TWC *Some high end models: GDI

Cost Estimates of Technology Options by Various Researchers

System	Cost (US $)		
Source	Meszler	Winkler	Iyer
2-Stroke oxidation catalyst system	34	-	-
2-stroke oxidation catalyst with secondary pulse air-injection	46	-	-
2-stroke air assisted direct injection	42	45 – 51	-
2-stroke high pressure direct injection 2-stroke	-	60	-
2-stroke electronic carburettor	-	36 - 42	-
4-stroke secondary air systems	26	-	-
4-stroke secondary air and oxidation catalyst system	61	-	-
4-stroke three-way catalyst	39	-	-
4-stroke fuel injection without catalyst	111	-	85
4-stroke fuel injection with catalyst	166	-	-

Dan Meszler "Air Emissions Issues Related to Two and Three-Wheeled Motor Vehicles - an Initial Assessment of Current Conditions and Options for Control - July 2007
Franz Winkler, Roland Kirchberger, Oliver Schoegl, Stephen Schmidt. "Strategies to Reduce Scavenge Losses of Small Capacity 2-Stroke Engines, Pressurized by the Common Market Costs", SAE Paper No. 2005-32-0098.
Iyer N. V., *A Technical Assessment of Emissions and Fuel Consumption Reduction Potential from Two and Three Wheelers in India. Prepared for: the International Council on Clean Transportation*, 2012: Washington DC

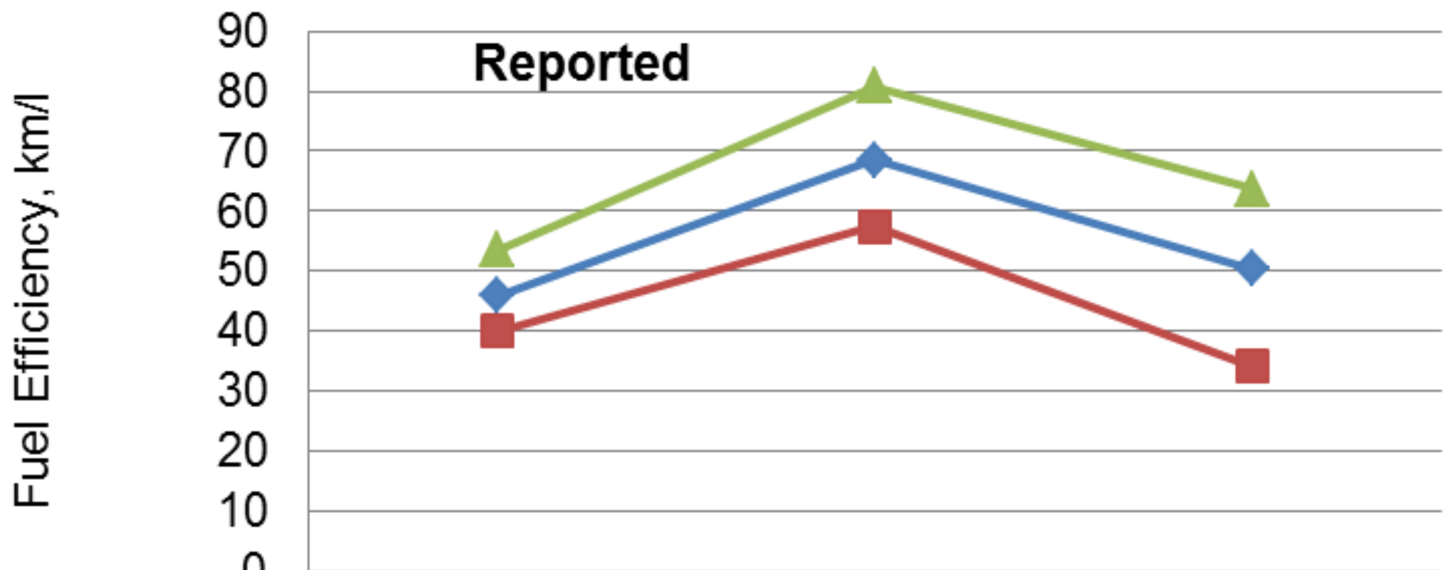
Potential Measures to Reduce Emissions from Diesel Three-Wheelers

- Change from Indirect Injection system (IDI) Direct Injection (DI) system
    - most diesel engines in India already use DI
- Most solutions used on larger engines may not be adoptable on small engines
    - Only change from DI to High Speed Direct Injection could be explored
- Need to explore solutions involving optimization of combustion, automatic ignition timing device, friction reduction through improved materials and better lubricating oils, improved air filters etc.

Technical Measures Other Than Mass Emission Standards

- ✓ Evaporative emission standards
  - ❖ Introduce as soon as possible and independently of next stage of mass emission standards – suggested 2g/test
- ✓ Improved durability requirements
  - ❖ Enhance from present 30,000 km to 50,000km and ensure demonstration of durability through actual testing
- ✓ Periodic vehicle inspection
  - ❖ Revamp existing system and introduce test like the ARAI loaded mode test method
- ✓ In-use conformity testing
  - ❖ Introduce initially as per Taiwan system, review after study
- ✓ On-board diagnostics (OBD)
  - ❖ initially for vehicles using electronic engine management

Fuel Efficiency Profile of Indian Two-Wheelers



	Scooter, 75-125cc	Motorcycle 75-125cc	Motorcycle 125-250
Average	46	68	50
Min	40	58	34
Max	54	81	64

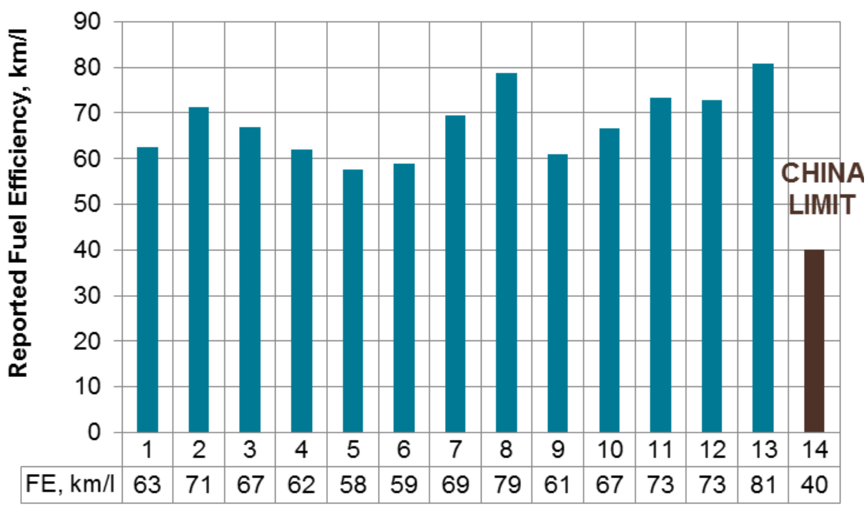
Based on fuel efficiency values reported in Bike India Magazine

Fuel Efficiency Standards in China

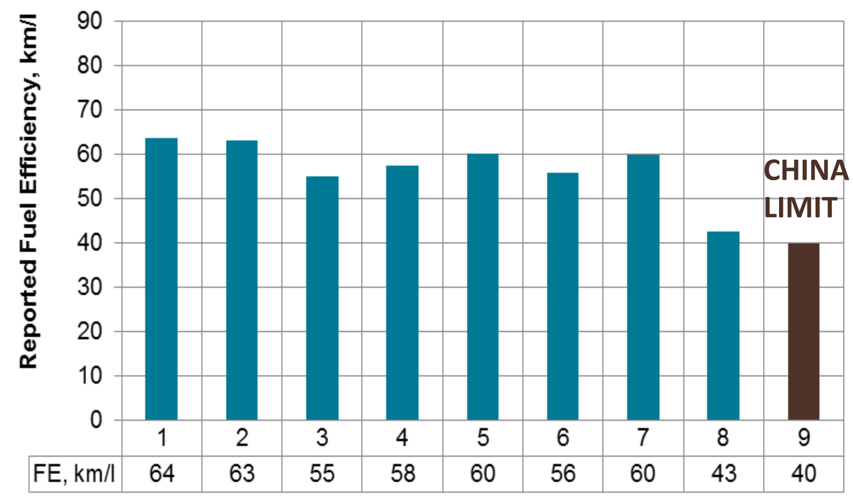
Engine size, cc	China 2-Wheeler	China 3-Wheeler	Taiwan 2-Wheeler
≤50 (mopeds)	2.0	2.3	2.3
≥ 50 - 100	2.3	3.3	2.7
≥100 – 125	2.5	3.8	2.8
≥125 – 150	2.5	3.8	2.8
≥150 – 250	2.9	4.3	4.0
≥250 – 400	3.4	5.1	4.0
≥400 – 650	5.2	7.8	5.5
≥650 – 1000	6.3	9.0	6.3
≥1000 – 1250	7.2	9.0	6.9
≥1250	8.0	9.0	6.9

All fuel efficiency values in litres/100km

Reported Fuel Efficiency of Indian Motorcycles and Comparison with Chinese Standards



Motorcycles 100 – 125 cc



Motorcycles 125-150 cc

Reported fuel efficiency is based on values from Bike India magazine

Fuel Consumption Reduction Achievable from Various Technologies – 1/2

Source/Reference	Engine Type	Fuel Efficiency Improvement (%)	Nature of Estimate
Air Assisted Fuel Injection Used in 2-Stroke Engines			
***(Bauer 2011),* Envirofit Retrofit Kit**	Bajaj Auto 3-wheeler	36	Preliminary results of actual measurements
(Archer 2001)	50cc engine	50	Test Results
(Leighton 2003)	Various Indian vehicles	33 - 40	IDC prediction
(Govindarajan 2005)	Not specified	25 - 30	General estimate
Gasoline Direct Injection Used in 4-Stroke Engines			
(Leighton 2003)	GDI Technology	13 - 16	IDC prediction
(Govindarajan 2005)	GDI Technology	20	General estimate

Fuel Consumption Reduction Achievable from Various Technologies – 2/2

Source/Reference	Engine Type	Fuel Efficiency Improvement (%)	Nature of Estimate
Port Fuel Injection Used in 4-Stroke Engines			
Hero Honda Glamour FI *(Bike India 2011)*	125 cc engine	11	Actual road conditions
TVS Apache RTR FI *(Bike India 2011)*	160cc engine	10	Actual road conditions
HMSI Stunner CBF Fi *(Bike India 2011)*	125cc engine	9.2	Actual road conditions
Honda (Claim)	All Models	6	Actual driving conditions
(Archer 2001)	150-200 cc engines	20	IDC tests
Honda Programmed FI	All Models	7	Steady speed
	All Models	10	Fuel economy test cycle
(Leighton 2003)	Various Indian vehicles	3 – 8.5	IDC prediction
(Ahern 2011)	Indian low bmep lean engines	2 - 4	General estimate
(Pundir 2011)	Not specified	4 - 10	General estimate

Setting up Fuel Efficiency Standards

- Indian four-stroke powered two-wheelers are among the most fuel efficient
- Gains from use of new technologies likely to be limited
- Industry has already started voluntary declaration of fuel efficiency of two-wheelers
- Fuel efficiency norms for four-wheelers already finalized by the government
- Formulation of Fuel efficiency norms for two and three-wheelers expected to be taken up after a few years

Summary & Conclusions

Need to draw up a ten-year road map for 2 and 3-wheelers consisting of

- Progression of mass emission standards on the lines of EU progression from Euro 4/5/6. Suitable technological solutions seem to be available
- Introducing evaporative emission limit of 2g/test
- Other technical measures such as enhancing durability limit to 50,000km, improving periodic vehicle inspection methods such as adopting a loaded mode test, introducing in-use vehicle compliance and on-board diagnostics
- Introducing standards to achieve fuel efficiencies even better than the already superior levels by world standards

Proposed Actions and Time Lines

S No	Regulation	Description	Year of Introduction	
			2015	2020
1	Mass Emission	BS IV, using GTR cycle and limits	√	
2	Mass Emission	BS V, using GTR cycle and limits		√
3	Evaporative Emission	2g/test using SHED	√ *	
4	Durability	Increase to 50,000km	√	
5	PUC Inspection	Adopt ARAI loaded mode test	√	
6	In-use conformity testing	System as per Taiwan	√	
		After study of feasibility and effectiveness		√
7	On Board Diagnostics (OBD)	For vehicles using electronically controlled fuel management	√	
8	Fuel Efficiency Standards	Proposals to be worked out	√	

* Implementation at Earliest Possible without Waiting for Next Stage of Emission Standards

Thank You

Appendix

Some Low Cost Technology Solutions

Company/ Organization	**Main Features**
'Synerject Systems Integration'	Recommend (a) minimizing the functionality of the components to meet small engine requirement only. (b) redesign of key system specific components (e.g.,ECU and fuel pump) to reduce cost and complexity.
Yamaha Motor Company	Highly accurate methods developed to measure intake air mass, detection of acceleration, etc., without using a throttle position sensor, cam timing sensor, and barometric sensor. An injector in-tank fuel pump module developed to achieve compactness. Fuel pump, fuel pressure regulator, fuel filter, and fuel level gauge integrated into one compact form.
Scion-Sprays Ltd, UK	Novel engine management system called the Pulse Count Injection (PCI) system, which is designed specifically for low cost small engines.
Dell'Orto	Electronic Carburettor Compact, highly integrated contactless throttle position sensor, closed coupled unheated oxygen sensor feedback, small and fast electro-valve and the battery-less, low-cost ECU".
ARAI	Electronic Carburettor: Uses a solenoid valve in the air bleed circuit of the carburettor to control the fuel flow and the air-fuel ratio. An electronic control unit controlled the functioning of the valve

"Emerging" Technologies to Meet Proposed 2020 Two-Wheeler Standards

- <u>For Two-Stroke Engines</u>
- Graz University of Technology (GUT) – The Low Pressure Direct Injection System
- Honda R&D Company – Stratified Charge Auto-Ignition
- Institut Francais du Petrole (IFP) – Controlled Auto-Ignition
- <u>For 4-Stroke Engines:</u>
- Yamaha Stratified Charge Combustion with EGR

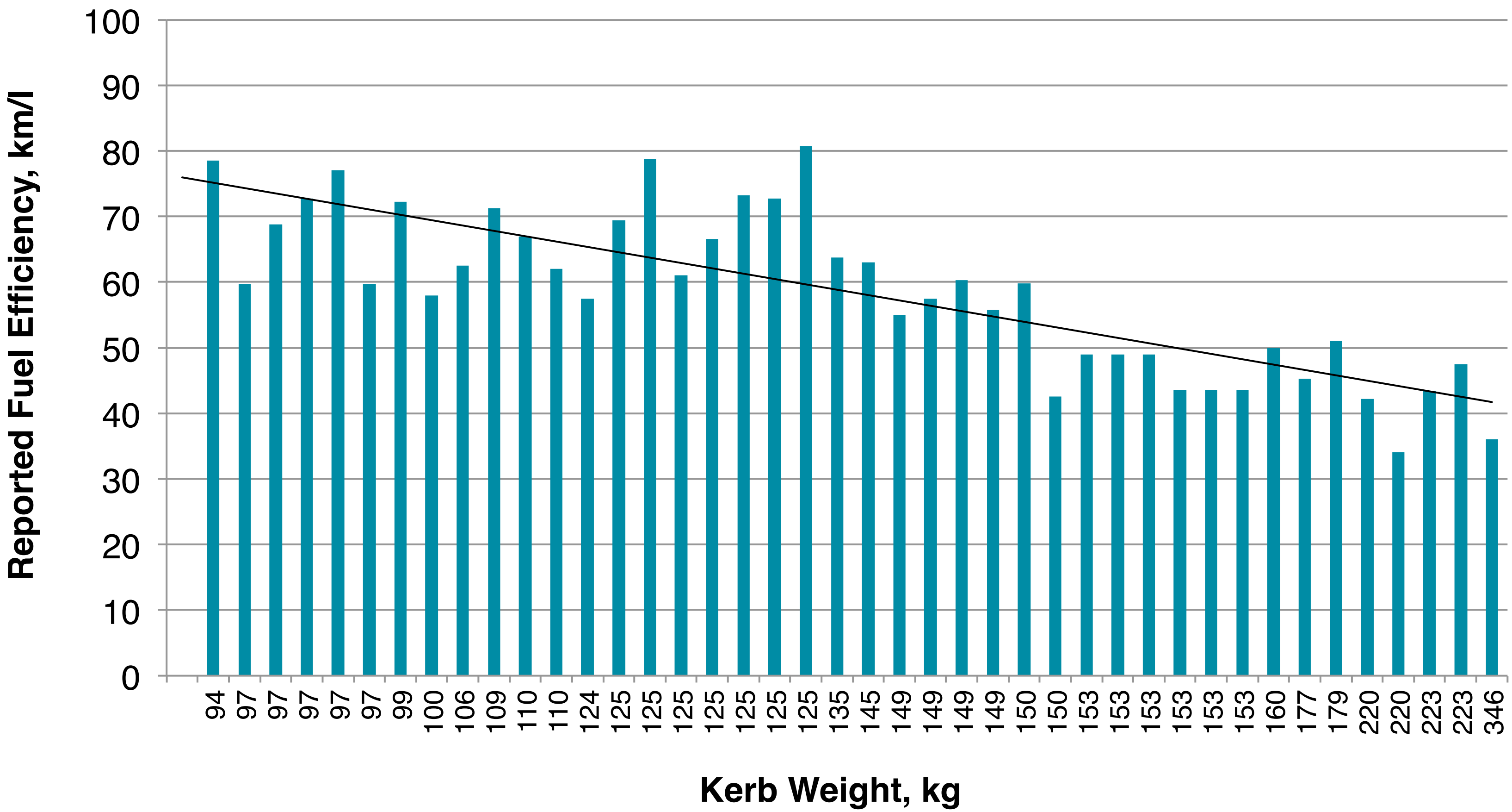
Some Vehicle Models Using Fuel Injection Technology Already Introduced

Company/Model Name	**Main features**
Bajaj Auto Auto-rickshaw using 2-stroke GDI technology	of 44km/l in addition to a reduction of 50 per cent in CO, and a 25 per cent reduction in hydrocarbon and oxides of nitrogen
Honda Motorcycle & Scooter India's 'CBR250R'	Single cylinder 249cc DOHC engine with PGM-FI fuel injection, 4-valves and liquid cooling
TVS Motor Company 's 'Apache RTR 160'	150cc four-stroke fuel injected version with fuel efficiency of 55km/l compared to 50km/l of the carburetted version (Bike India report)
Honda Motorcycle and Scooters India's 'CBF Stunner'.	125cc engine, fuel efficiency 66.6km/l compared 60km/l of the carburetted version (Bike India report)
Hero Honda's 'Glamour'	125cc four-stroke engine, fuel efficiency 80.75 km/l compared to 72.74 km/l of carburetted version

Inferences from Analysis of Fuel Efficiency Profile

- Motorcycles in the 75-125 cc capacity range are the most fuel-efficient followed by scooters with engines in the same capacity range. The fuel efficiency of motorcycles of 125-250 cc capacity range is somewhat better than that of the scooters of the same capacity range
- Fuel efficiency shows a progressively decreasing trend with increasing engine displacement.
- Fuel efficiency shows a progressively decreasing trend with increasing kerb weight in case of motorcycles. No such trend is seen in case of scooters.

Relation Between Kerb Weight and Fuel Efficiency of Motorcycles



* Based on fuel efficiency values reported in Bike India magazine