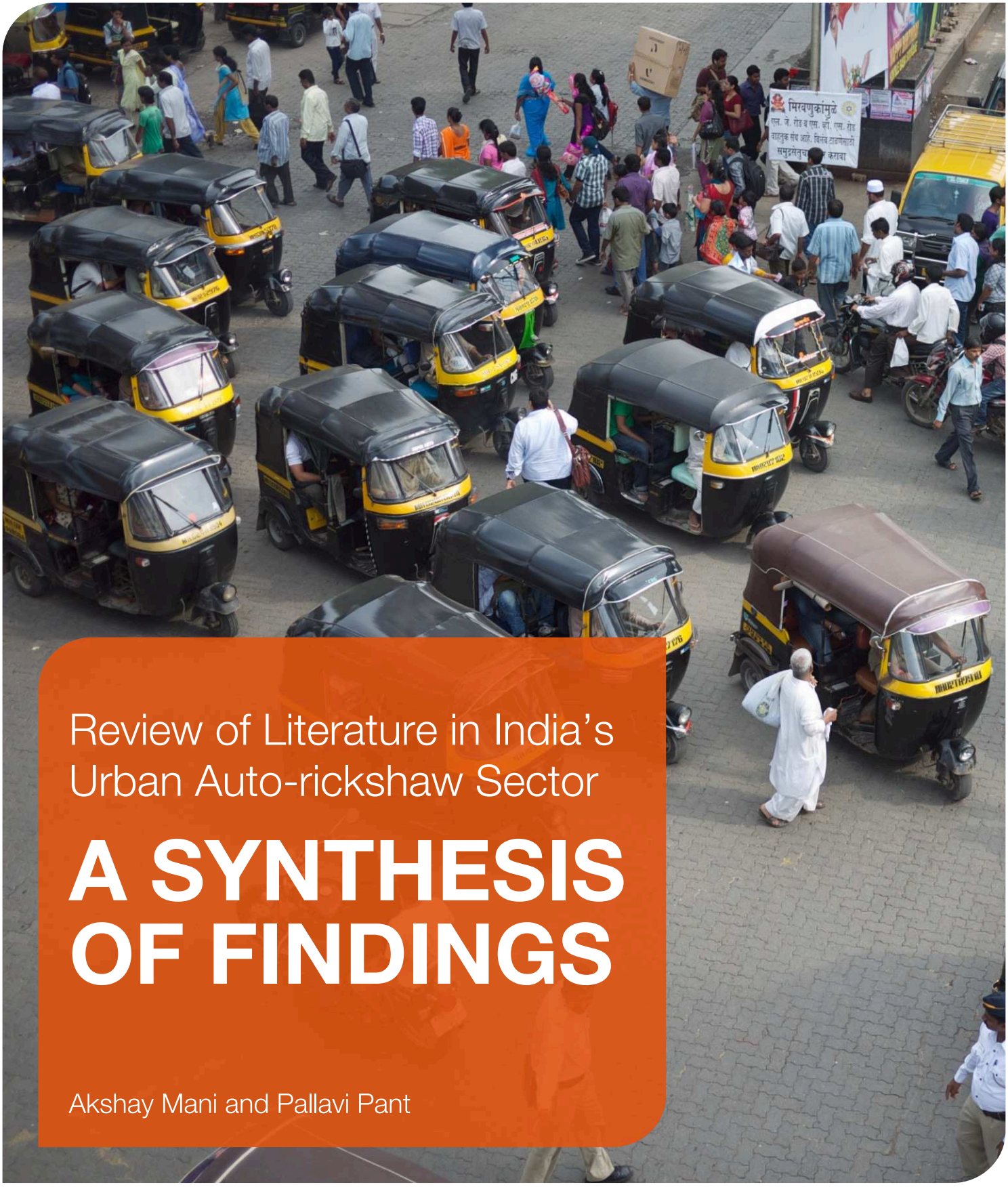

Review of Literature in India's Urban Auto-rickshaw Sector

A SYNTHESIS OF FINDINGS

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ABSTRACT

Objective of Study

India is experiencing rapid urbanization and unprecedented growth in private motor vehicles resulting in increased traffic congestion, air pollution, and road fatalities. The launch of the National Urban Transport Policy (NUTP) in 2006 laid the groundwork for an increased focus toward promoting sustainable transport modes - walking, cycling, and public transport – to address the negative externalities associated with urbanization and private motorization.

Amidst current trends in urban transport and the objectives stated in the NUTP there is a need for a specific focus on the auto-rickshaw sector. Auto-rickshaws are a ubiquitous part of urban transport in the majority of Indian cities, and as an intermediate public transport (IPT) mode they fill the gap between public and private modes of transport. A recent study conducted to assess the role of auto-rickshaws in promoting sustainable urban transport in cities specifically looked at auto-rickshaws as part of the Avoid-Shift-Improve (ASI) strategy to promote sustainable urban transport and provides recommendations on key reforms areas (Mani, Pai, and Aggarwal, 2012).

To ensure the success of targeted reform efforts it is important to gain a deep understanding of the various aspects of the auto rickshaw sector, including policies and regulations, market characteristics, operating characteristics, socio-economics, emissions, and safety. Numerous studies have been conducted in this regard and the objectives of this study are to provide a detailed review of the available literature, present the key findings in a systematic and structured manner, better understand the current state of the sector, identify key challenges, and highlight the gaps in current literature. The findings and recommendations of this study are also intended to inform future reform efforts to promote auto-rickshaws as key sustainable transport modes.

Other forms of IPT services such as cycle rickshaws, taxis, and informal public transport services such as share-auto-rickshaws and share-taxis exist in many Indian cities. However, they are beyond the scope of the current literature review. Additionally, the focus is on auto-rickshaws in urban areas, and hence, services in semi-urban and rural areas are outside the scope of this study.

Methodology

A wide range of sources have been considered in the literature review, including research and conference papers, reports, case studies, white papers, industry statistics and news articles. The review process focuses on the following key aspects (thematic areas) of the auto-rickshaw sector:

- Policy and Regulation: This covers current policies and regulations in the areas of permits, fares, emissions, and safety.
- Market Characteristics: This covers market size, vehicle production and sales trends, major manufacturers, engine technology, and fuel characteristics.
- Emissions Characteristics: This covers the major emissions-related challenges in the auto-rickshaw sector.
- Socio-economics and Operational Characteristics: This covers key socio-economic issues such as driver profile (age, family size, and educational qualifications), economics (costs and earnings), and the inter-relationships between them (such as how driver profile impacts economics). Additionally, this section covers the key operational characteristics of auto-rickshaw services such as average daily kilometers traveled, average number of trips, and empty kilometers traveled.
- Safety: This covers the key safety aspects of auto-rickshaws looking at both the safety impacts of auto-rickshaws on vulnerable road users (pedestrians and cyclists), and the safety of auto-rickshaw occupants (driver and passengers).

ABSTRACT

Key Findings and Recommendations

The key findings and recommendations from this study include the following:

Table A1: Key Findings and Recommendations

Aspects	Findings	Recommendations
Safety	• The key safety concern in the auto-rickshaw sector in cities is the risk of injuries and fatalities for auto-rickshaw occupants under increasingly mixed-traffic flow conditions.	• There is a need to pursue reforms in current motor vehicle safety regulations to either usher in improvements in current vehicle design features of auto-rickshaws or move to safer vehicle configurations in order to enhance the safety of occupants.
Emissions	• Particulate Matter (PM) emissions from two-stroke auto-rickshaws is one of the most critical environmental issues facing this sector.	• The emissions mitigation benefits of a range of possible options such as two-stroke direct fuel injection, four-stroke, alternative fuels such as CNG and LPG, and electric vehicles have been documented. • However, city specific solutions need to be implemented based on a comparative assessment of the above options in terms of life-cycle costs, environmental benefits, as well as supporting infrastructure such as fuel supply and recharging.
Policy and Regulation	• There is a lack of consistency and transparency in the use of scientific/analytical approaches in permit and fare policy frameworks across cities. • This is directly contributing to problems with driver economics and issues such as refusals and overcharging.	• Reforms in current permit and farepolicies based on scientific/analytical approaches need to be pursued in order to address current challenges faced by drivers and passengers.

INTRODUCTION

India is experiencing rapid urbanization and motorization. While the urban population is growing at a rate of 3.16 percent per year, motor vehicles are growing at a rate of 9 percent (Sharma, Jain, and Singh, 2011). The increased demand for urban travel, along with unprecedented growth in private motor vehicles, is increasing the urban problems of congestion, air pollution, greenhouse gas (GHG) emissions, traffic fatalities and injuries, and lack of physical activity (MoUD, 2010). As a result, there has been an increasing focus on developing and promoting safe and environmentally friendly modes of transport.

Within the urban transport framework intermediate public transport (IPT) contributes to meeting daily mobility needs with 3 to 8 percent of the daily urban trips in Indian cities (Figure 1). Auto-rickshaws are the most common form of IPT in India (Mohan and Roy, 2003) and the use of auto-rickshaws is growing in other parts of the developing world as well. Indian manufacturers dominating the global market, and Indian auto-rickshaw exports grew from 66,795 units in Fiscal Year (FY) 2004-05 to 269,967 units in FY 2010-11.

Specifically, auto-rickshaws play an important role in promoting sustainable urban transport by providing the following types of IPT services in cities (Mani et al, 2012):

- Feeder services to public transport systems (buses and trains) for daily commute trips: Auto-rickshaws contribute to an integrated public transport system by providing first and last-mile connectivity to mass-transport modes such as buses and trains.

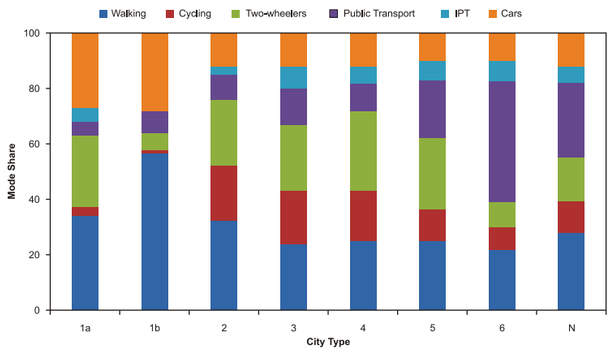
Nearly 75% of the global auto-rickshaw population is found in India

- Alternative mode to private motor vehicles for occasional and emergency trips: Auto-rickshaws, as a taxi mode providing efficient and reliable door-step pick-up services, can serve as an effective alternative to private motor vehicles for occasional trips, such as to the airport, and emergency trips.

This study presents a review of available literature in the urban auto-rickshaw sector in India. The objective of this review is to understand the current state of this sector, summarize the key issues, and highlight the gaps in current literature. Other forms of IPT services such as cycle rickshaws, taxis, and share-auto-rickshaw services exist in many Indian cities. However, they are beyond the scope of the current literature review. Also, auto-rickshaw services in semi-urban and rural areas are outside the scope of this study.

It is envisioned that the findings and recommendations of this study will inform future reform efforts undertaken to promote auto-rickshaws as a key sustainable transport mode.

Figure 1 : Mode Shares in Indian Cities, 2007



Source: MoUD (2008)
Note: City type (X-Axis) refers to cities categorized by population: 1a: <0.5 million with plain terrain; 1b: <0.5 million with hilly terrain; 2: 0.5 – 1 million; 3: 1-2 million; 4: 2-4 million; 5: 4-8 million; 6: > 8 million; N – refers to National

[1]Please note that this includes walk trips. If walk trips are excluded IPT modes will account for higher daily trip mode shares.
[2]Other common IPT modes in Indian cities include cycle rickshaws, taxis, share auto-rickshaws, share-taxis, tempos, and minibuses.

METHODOLOGY

As part of the literature review a wide range of sources have been reviewed including research and conference papers, reports, case studies, white papers, industry statistics and news articles. In order to streamline the literature review process the issues in the auto-rickshaw sector were categorized into several thematic groups as described in Table 1.

Table1: Thematic Sections of the Literature Review

Thematic area	Information included
Policy/Regulation	Permits Fares Emissions and safety
Market Characteristics	Market size Vehicle production and sales trends Key manufacturers Engine technology and fuel characteristics
Emissions Characteristics	Vehicle emissions characteristics
Socio-economics and Operations	Socio-economic profile of drivers/owners Operating characteristics
Safety*	Safety characteristics (pedestrian and occupant safety)

* Note: In addition to safety, comfort is an important issue for auto-rickshaw occupants. This area has not been covered in this literature review and should be looked into in future research efforts.

KEY LITERATURE SOURCES

There are a few studies that have analyzed the Indian auto-rickshaw sector comprehensively. iTrans (2009) presents the most comprehensive review of the sector and touches upon the various facets including modal splits, role of auto rickshaws in intermediate public transport, emissions and safety issues, and the socio-economic reality. Arora et al. (2010) presents an interesting analysis of the role of auto rickshaws as a mode of transport using three city-based case studies. The paper also deals with regulatory issues and presents a detailed analysis of the challenges and limitations related to the sector. In a similar vein, Luthra (2006) use Amritsar city as an example to present evidence on the role of auto rickshaws in IPT.

MoUD (2008) contains detailed information on modal splits, trip lengths, number of auto rickshaws in different cities across India, and the role of IPT and particularly auto rickshaws in the transport system for various cities. Shah and Iyer (2004) touch upon the regulatory regime, the role of auto rickshaws in a city's transport system, and their contribution to emissions, but the key emphasis is on technologies for emissions reduction, the use of alternate fuels, and vehicle maintenance.

Table 2 presents the key literature sources reviewed as part of the current research under each of the thematic areas discussed earlier.

Table 2: Key Literature Sources

Thematic Area	Literature Sources
Policy/regulation	Arora et al (2010); Ahmed (2008); CMVR (1989); Faruqi and Sud (2001); Garg et al (2010); Harding and Hussain (2010); ITDP (2009); iTrans (2009); Luthra (2006);Mohan and Roy (2003); MoUD (2006);Schaller (2007);Yakkundinath (2003)
Market characteristics	Garg et al (2010); Lukic et al (2008);Manufacturer websites; MoUD (2008); Mullick (2010); Reynolds et al (2009); Sapru (2005); Shah and Iyer (2004); UNEP (2011); USAID (2002)
Emissions characteristics	ARAI (2007); Garg et al (2010); Grieshop et al. (2012); ICCT (2009); iTrans (2009); Reynolds et al (2009); Reynolds et al (2011); Shah and Iyer (2004); UNEP (2011)
Socio-economics and Operations	Garg et al (2010); Harding and Hussain (2010); Mohan and Roy (2003); Rajkot CMP (2008); Reynolds et al (2011)
Safety	Mani et al (2012); Mohan et al (1997); Mohan and Roy (2003); Mukherjee et al (2007); NCRB (2010); Schmucker et al (2009); Shah and Iyer (2004)

KEY FINDINGS FROM THE LITERATURE REVIEW

The findings from the literature review are presented thematically in the following sections.

4.1 Policy and Regulation

At the national level, the Ministry of Road Transport & Highways (MORTH) is responsible for setting the regulatory standards of motor vehicles in India through the provisions of the Central Motor Vehicles Act 1988 (MVA) and the Central Motor Vehicles Rules 1989 (CMVR).

Using the provisions of these statutes the transport departments of the respective State governments directly regulate motor vehicles in cities. Regional Transport Offices (RTOs), the regional arms of the transport departments in cities, exercise regulatory powers over driver licenses, motor vehicle registration, permits, and motor vehicle compliance with safety and emissions standards. A detailed discussion of the regulatory structure for automobiles with a particular focus on two- and three-wheelers in India is presented in iTrans (2009).

Arora et al. (2010) present compelling evidence on the role of auto-rickshaws in Indian cities using case studies and point out the loopholes in the regulatory regime such as a lack of policy incentives for auto-rickshaws. They recommend a two-pronged approach for better regulation in this sector:

1. Greater cognizance of IPT services in Indian cities and its inclusion in urban transport policy framework together with support for development of physical infrastructure

2. Recognition of IPT service-providers as stakeholders in the public transport discussion and provision of benefit schemes and easy credit loans

4.1.1 National policy focus on auto-rickshaws

The National Urban Transport Policy (NUTP) was formulated by the Ministry of Urban Development (MoUD) in April 2006 as an overarching policy response to the growing concern with increasing urbanization and motorization and the ensuing challenges in accessibility, mobility, and escalating health and safety risks from excessive pollution and traffic accidents (MoUD, 2006). Its main objectives include:

- Incorporating urban transportation at the planning stage rather than existing as a subsequential need or a reactionary process
- Encouraging integrated land use and transport planning focussing on accessibility along with mobility
- Equitably allocating investments for people-based transportation rather than motor vehicles
- Improving networks between spaces for production, labour, and their corresponding markets

The NUTP framework regards para-transit modes such as auto-rickshaws as those that would not typically serve regular commute trips to work or school if good public transport were available. More specifically, it envisions their role as modes that would serve, "occasional trips such as trips to airports or rail stations with excessive baggage, or emergency trips that have to be undertaken immediately when it is not possible to wait for public transport". Based on the assessment that para-transit is not playing its intended role in cities, but instead competing with poor-quality public transport, the NUTP states that improving public transport is the key approach to restoring the intended role of auto-rickshaw and other para-transit modes in the urban transport system.

4.1.2 Permit and Fare Regulation

Permits

Permits for auto-rickshaws in cities are regulated by the Regional Transport Authorities (RTAs) established by the respective State governments. The RTO serves as the Secretary of the RTA and performs issuing and renewal of permits under the powers delegated by the RTAs.

Overall, the issue of permits has not received much coverage in the reviewed literature. However, information obtained anecdotally from RTOs of different cities, as well as several case studies (Faruqi and Sud, 2001; Yakkundinath, 2003),

There is a lack of a rational permit policy across cities, with some cities having closed permit systems while others having open permits

reveals the lack of a consistent permit policy across cities. While some cities have a closed permit policy with a cap on the number of auto-rickshaws plying on the road, such as Mumbai and Pune, other cities have adopted an open permit policy allowing entry of new auto-rickshaws, such as Surat and Rajkot. Further, it is observed that in cities with a closed permit policy there is no well-defined rational process for determining the cap on the number of auto-rickshaws.

There has been some city-specific research looking into the impact of permit policy on the economics of auto-rickshaw operations. For example, Delhi's cap on permits has led to a steep rise in the costs of owning/operating auto-rickshaws because of the increased cost of permits and overcharging/refusal of passengers due to an artificial constraining of supply in the face of ever-increasing demand (Harding and Hussain, 2010). Mohan and Roy (2003) have also touched upon the issue of permits in Delhi and discuss the typical costs associated with procuring a permit. They point to the role of private financiers and middlemen in leading to the increased cost of owning and operating an auto-rickshaw in Delhi. Garg et al. (2010) conducted a detailed assessment of the auto-rickshaw sector in Chennai and found that after the implementation of a fresh permit ban drivers had to pay as much as 70,000 to 1,00,000 Indian Rupees (INR) for permit that only costs about 375 INR. These studies point out the correlation between the type of permit policy adopted in a city (open or closed) and its impacts on the economics of auto-rickshaw operations (by impacting the permit costs).

While there is not much coverage in literature on the appropriate type of permit regulatory framework for the auto-rickshaw sector in Indian cities, research conducted by Schaller (2007) on taxi regulation for US and Canadian cities may have applications for permit regulation of auto-rickshaw services in Indian cities. Schaller's research looks at the need to focus on types of taxi markets when thinking about an appropriate regulatory framework for taxi services.

According to Schaller (2007) markets for taxi services can be categorized into:

- Dispatch (or dial-a-cab) market, where customers prearrange a taxi for pick-up through a taxi company using technology applications such as telephone, internet, or text messaging.
- Street hail and cab stand markets, referred to as 'walk-up' markets, where customers walk-up to get a taxi from the street and taxi stands respectively.

Schaller proposes a two-tier permit framework to serve both of these markets. One for fleet companies with entry qualifications such as requirements on fleet size, place of business, and ability to provide dispatch services to serve dispatch markets, and another for individuals or companies with entry controls, in the form of numerical caps on the number of permits which may be subject to periodic adjustments based on demand levels to serve walk-up markets. Adopting this framework will ensure that taxi services at high demand walk-up locations such as airports, railway stations, and other activity hubs can be provided without leading to an over-supply of taxi services while low-demand areas can be served effectively based on the availability of dispatch taxi services.

Given the applicability of similar market conditions for auto-rickshaw services in Indian cities there is a need to look into the feasibility of applying the above framework for regulation of the auto-rickshaw sector to ensure that both dispatch and walk-up markets are effectively served. This issue has not been covered in the available literature and is an important area of future research.

Fares

Auto-Rickshaw fares, like permits, are regulated by the Regional Transport Authorities (RTAs). Researchers have noted that government regulation of fares in the auto-rickshaw and taxi sectors is required in order to correct market imperfections. According to Schaller (2007), lack of information for consumers on appropriate pricing makes it important to stipulate standardized fares by the government. Further, fare deregulation could lead to charging of unrealistic fares especially in low-demand areas.

While the government is responsible for fare determination and revisions, research shows that there is a lack of a standardized procedure/policy at the regulatory level to implement revisions in auto-rickshaw fares in cities when taking into account changes in fuel prices and cost of living indices (iTrans, 2009). In Chennai, for example, the fares are not revised on a regular basis even though the prices of fuels have increased (Garg et al., 2010). Mohan and Roy (2003), assessing the situation in Delhi, report another aspect of fare policies related to the stipulation of fares based on improper estimation of true costs of ownership and operations of auto-rickshaws such as higher permit costs. These issues lead to larger challenges for drivers and passengers such as:

There is a lack of a standardized and transparent analytical framework for fare fixation and revision across cities

- Drivers either refusing passengers or not following the government stipulated fares. Overcharging was found as one of the most common grievances of the public against the auto-rickshaw drivers (Mohan and Roy, 2003; Garg et al., 2010; Harding and Hussain, 2010).
- Conflicts between the government and driver unions demanding fare increases which often manifest as strikes and associated service related problems for passengers.

Harding and Hussain (2010) have presented data from Delhi, highlighting the problems faced by auto-rickshaw drivers due to lack of fare revisions. According to the survey reported in Mohan and Roy (2003), the auto-rickshaw fare rates in Delhi were insufficient. It was also reported that if a reasonable meter-down fare is fixed drivers would be less averse to taking passengers for short-trips. The issue of haphazard fare selection is also discussed in iTrans (2009). A sensitivity analysis regarding the auto fares concluded that in order to increase the revenues of the operators it is better to do city-specific fare changes as opposed to a statewide increase (Ahmed, 2008). An assessment of the appropriate scientific or analytical methods for the estimation of fares for the auto-rickshaw and taxi sector has not received much coverage in the literature reviewed as part of this study.

4.1.3 Emissions Regulation

Emission Standards

Emission standards for motor vehicles, including auto-rickshaws, are stipulated by the Central Pollution Control Board (CPCB) under the Ministry of Environment & Forests (MoEF), Government of India. Based on the type of vehicle and fuel used, these standards are defined for criteria pollutants including Carbon Monoxide (CO), Hydrocarbons (HC), Nitrogen Oxides (NOx), and Particulate Matter (PM).

Emission norms for gasoline auto-rickshaws were first introduced in 1991 for CO and HC pollutants. These norms were progressively tightened in the subsequent years with the HC standard replaced by a combined HC and NOx (HC+NOx) standard. These progressive standards for gasoline auto-rickshaws are shown in Table 3.

Table 3: Emission Standards for Gasoline Auto-rickshaws in India, g/km

Year	CO	HC	HC + NOx
1991	12-30	8-12	-
1996	6.75	-	5.40
2000	4.00	-	2.00
2005 (Bharat Stage II)	2.25	-	2.00
2010.04 (Bharat Stage III)	1.25	-	1.25

Source: SIAM (2011a); iTrans (2009)

Auto-rickshaws in some cities run on diesel fuel. Table 4 shows the emission norms that have been stipulated for diesel auto-rickshaws in India. Since diesel fuel is a major source of PM emissions it is included in these standards - unlike the standards for gasoline vehicles which do not include PM.

Table 4: Emission Standards for Diesel Auto-rickshaws in India, g/km

Year	CO	HC + NOx	PM
1991	14.3	20	-
1996	5	2	-
2000	2.75	0.97	0.14
2005	1	0.85	0.10
2010	0.5	0.5	0.05

Source: iTrans (2009)

Alternative fuels such as Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) are increasingly being used in the auto-rickshaw sector due to their economic and environmental benefits. The emission standards for auto-rickshaws running on these fuels are stipulated for two categories: i) newly manufactured auto-rickshaws built to run on these fuels, and ii) in-use gasoline auto-rickshaws that are retrofitted with CNG or LPG kits.

For newly manufactured CNG or LPG auto-rickshaws the emission standards are essentially the same as the standards for gasoline auto-rickshaws (as shown in Table 3) except for the following modifications (SIAM, 2011a):

The current combined emission standard for Hydrocarbons (HC) and Nitrogen Oxides (NOx) is ineffective in addressing the high NOx emissions from four-stroke auto-rickshaws

- For CNG vehicles, hydrocarbon (HC) is replaced with non-methane hydrocarbon (NMHC), which is calculated as: NMHC = HC * (1-K/100), where K is the % methane content in natural gas.
- For LPG vehicles, hydrocarbon (HC) is replaced with reactive hydrocarbon (RHC), which is calculated as: RHC = 0.5 * HC

For auto-rickshaws retrofitted with CNG or LPG kits, the emission standards are the same as those for in-use gasoline auto-rickshaws except that, as discussed earlier and shown in Table 5, HC should be replaced with NMHC for CNG,and with RHC for LPG.

Table 5: Emission Standards for In-Use Gasoline/CNG/LPG Auto-rickshaws

Vehicle Type	CO, % vol	HC, ppm
Three-wheelers, (2/4-stroke),pre-2000	4.5	9,000
Three-wheelers, (2-stroke), post-2000	3.5	6,000
Three-wheelers, (4-stroke),post-2000	3.5	4,500

Source: iTrans (2009)

A review of current emission norms for auto-rickshaws provides the following insights:

- The emission norms are combined for HC and NOx and are not applied separately for these pollutants. This is particularly an issue when it comes to controlling NOx emissions from four-stroke auto-rickshaws which are able to meet the combined (HC + NOx) standard due to their lower HC emissions even though they have high NOx emissions.
- There are no emission norms for Particulate Matter (PM) emissions from gasoline auto-rickshaws. This is an important note for future consideration given the PM emissions problem from two-stroke gasoline auto-rickshaws (Shah and Iyer, 2004).
- There are no emission norms for greenhouse gas (GHG) emissions from auto-rickshaws. This is an important consideration given the increasing contribution of the transport sector to total CO_2 emissions in cities.

Compliance to Emission Standards

Compliance of motor vehicles to emission standards involves the following checks (iTrans, 2009):

- Compliance of newly manufactured vehicles to emission standards involves ensuring that manufacturers are complying with stipulated emission standards (as discussed in Tables 3 and 4) for newly manufactured vehicles.
- Compliance of in-use vehicles to corresponding emission standards involves roadside inspection of in-use motor vehicles, and issuing pollution under control (PUC) certificates indicating that emission standards are being met. All motor vehicles are required to carry valid PUC certificates, issued by state transport department authorized testing and certification centers, after a period of one year from the date of first registration and they are to be renewed every 6 months (CMVR, 1989).

iTrans (2009) highlights the following challenges with the current PUC system which need to be addressed to mitigate emissions from in-use motor vehicles, including auto-rickshaws.

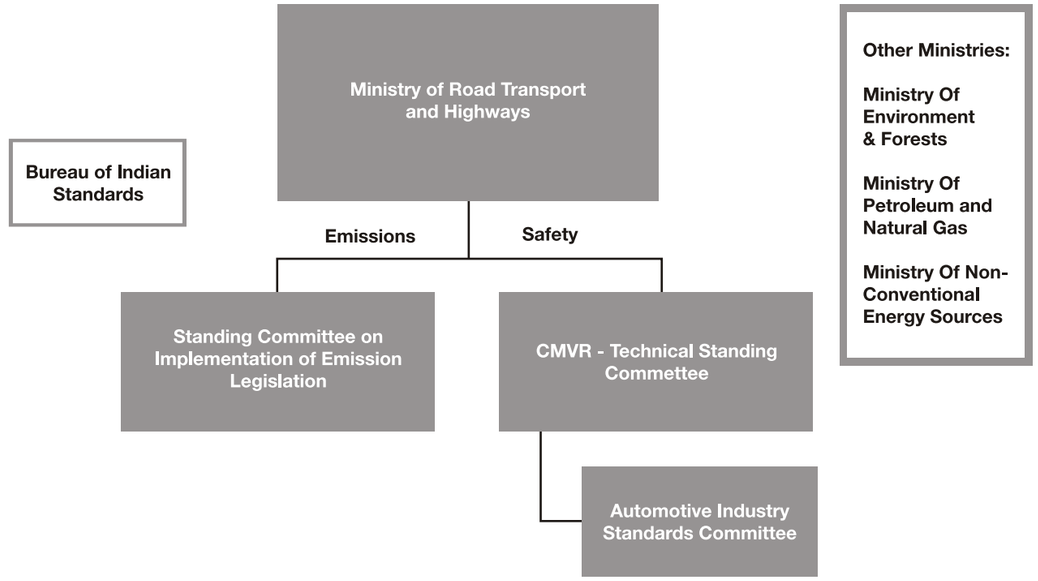
- Lack of government supervision of a large number of authorized privately-owned testing and certification centers in cities
- Lack of periodic calibration of testing equipment
- Lack of foolproof methods for issuing of PUC certificates
- Fraudulent practices undertaken by centers such as issuing of certificates without testing

4.1.4 Safety Regulation

Safety standards for motor vehicles, including auto-rickshaws, are stipulated by MORTH under the CMVRs. The CMVR – Technical Standing Committee (CMVR-TSC) is the committee instituted by MORTH to advise on issues related to motor vehicle safety regulations. Manufacturers are required to comply with these standards at the time of production, and in-use motor vehicle compliance to safety standards is ensured by RTOs in cities based on the provisions of the CMVRs. Issues regarding safety characteristics of auto-rickshaws are covered in Section 4.5.

Figure 2 shows the regulatory framework set up by MORTH for development and implementation of emissions and safety legislation for motor vehicles, including auto-rickshaws.

Figure 2: Regulatory Framework for Emissions and Safety Legislation



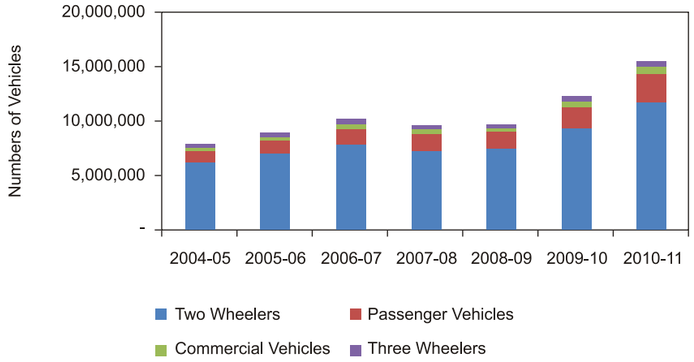
Source: SIAM (2011b)

4.2 Market Information

4.2.1 Market Size, Production and Sales Trends

Figure 3 shows the trends in the market size of auto-rickshaws compared to other motor vehicles. As seen in Figure 3, the auto rickshaw sector had a market share of 3.4 percent in 2010-11 among motor vehicles in India. Two-wheelers dominate the motor vehicle market with a 76 percent market share.

Figure 3: Market Size Trends by Vehicle Type in India, FY 2004-05 to FY 2010-11

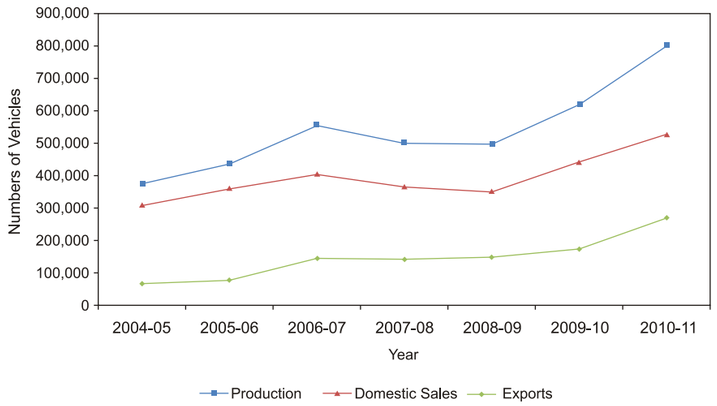


Source: SIAM (2011c)

City specific auto-rickshaw market size data is presented in MoUD (2008), which reports that cities in India have i) market density of auto-rickshaws between 2 and 11 vehicles per 1,000 population and ii) market size varying from 5,000 to 20,000 in small and medium sized cities (population less than 4 million) to more than 40,000 in large cities (population greater than 4 million). Cities with little or no public transport are found to have a higher proportion of auto-rickshaws (MoUD, 2008) - indicating the role auto-rickshaws play in substituting for public and private transport.

As shown in Figure 4, the auto-rickshaw industry is witnessing an increasing trend in terms of production and domestic sales in the past few years. A large part of this trend is driven by new vehicle sales in Tier II (population between 1 and 4 million) and III (population less than 1 million) cities.

Figure 4: Annual Auto-rickshaw Production and Sales Trends in India, FY 2004-05 to FY 2010-11



Source: SIAM (2011c)

4.2.2 Engine and Fuel Characteristics

Two-stroke auto-rickshaws dominate the market in many Indian cities, as drivers prefer their mechanical simplicity and ease of self-repair

Engine Technology

Auto-rickshaws in cities run on both two-stroke and four-stroke engines and typically run on small engines with engine size ranging from 150 to 175 cubic centimeters (cc). Reynolds et al (2009) report that two-stroke auto-rickshaws dominate the market in most Indian cities, due to their lighter weight and mechanical simplicity. They also present key engine specifications - engine displacement, power, torque, compression ratio, and curb weight – for Bajaj's two-stroke and four-stroke auto-rickshaws. Table 6 presents a comparison of the performance of two-stroke and four-stroke engines for a few key indicators. A detailed discussion of the emissions characteristics of two-stroke and four-stroke engines is presented in Section 4.3.

Table 6: Performance Comparison of Two-stroke and Four-stroke Auto-rickshaws

Indicator	Advantages of Two-stroke over Four-stroke Engines	Disadvantages of Two-stroke Engines over Four-stroke Engines
Capital Cost	Lower capital cost	
Power and Torque	Higher power and torque for the same engine size/weight	
Mechanics	Mechanical simplicity, which results in relative ease of maintenance	
Engine Size	Lighter and smaller size for the same power and torque	
Emissions	Lower NOx emissions	Higher PM, HC and CO_2 emissions
Fuel Economy		Lower fuel economy due to the "scavenging losses"
Noise		Louder noise

Source: Shah and Iyer (2004)

Fuels

Different combinations of fuel types are used across Indian cities including gasoline, and alternative fuels such as compressed natural gas (CNG), and liquefied petroleum gas (LPG). The focus on CNG and LPG has primarily been from the environmental benefits of these fuels compared to gasoline (Shah and Iyer, 2004). In some cities, such as Delhi, use of CNG on public transport vehicles, including auto-rickshaws, is mandatory. Other cities, such as Chennai, have stipulated the conversion of auto-rickshaws to run on LPG fuel (Garg et al, 2010).

Shah and Iyer (2004) note that the following issues need to be considered to assess the feasibility of an alternative fuel conversion program for the auto-rickshawsector:

- A comprehensive alternative fuel policy should be developed by the government based on involvement of different government and industry stakeholders. This policy framework should look at technical and financial (pricing) considerations for alternative fuels.
- An in-use testing program should be instituted to ensure that the alternative fuel conversion program for in-use

vehicles is properly implemented

- Adequate fuel supply infrastructure should be in place. There should be good fuel supply coverage throughout the city and fueling stations should be designed properly to avoid delays in fueling. Inadequate supply of LPG fuel in Chennai has been reported to be a major problem facing the auto-rickshaw sector as drivers end up spending a lot of time reaching the nearest fueling station and waiting in long queues for fuel (Iyer, 2012).

Other Technologies

In addition to looking at the feasibility of improved engine technology (two-stroke to four-stroke) and alternative fuels (such as CNG and LPG),research is currently underway to assess the feasibility of electric auto-rickshaws as a solution to address emissions from auto-rickshaws. Auto-rickshaws are considered to be apt for electrification due to the low speed and the relatively smaller kilometers (kms) travelled per day (Lukic et al, 2008). Kathmandu, Nepal, where around 650 electric tempos called Safa (large three-wheelers with a capacity of around 10 passengers) operate as public transport vehicles, presents a good case study of electric vehicle technology application in the auto-rickshaw sector (Shah and Iyer, 2004; UNEP, 2011).

As far as India is concerned, widespread use of electric auto-rickshaws has not happened yet. During 1999-2003, a public-private partnership (PPP) initiative called the India Zero Emissions Transportation Program (IZET) was launched by the United States Agency for International Development (USAID) with private participation from Bajaj Auto Ltd. and New Generation Motors (NGM) (USAID, 2002). The program's objective was to enable the designing, testing, and demonstration of electric auto-rickshaws in the Indian cities of Agra and Delhi. The larger aim of the program was the commercialization and widespread application of electric auto-rickshaws to achieve environmental benefits and reduce the health impacts from vehicular pollution. Though large scale commercialization has not been achieved, the program was successful in enabling the operation of electric three-wheelers (Eco-rick) at the Taj Mahal in Agra for elderly and physically challenged passengers (USAID, 2002).

Shah and Iyer (2004) and UNEP (2011) present a good analysis of the key factors affecting the viability of large scale commercialization of electric vehicles. According to them, the key impacting factors include:

- **Cost:** Cost of electric vehicles, primarily driven by the high battery cost, makes electric vehicles more expensive compared to gasoline-driven vehicles. Shah and Iyer (2004) report that battery costs could push electric auto-rickshaw prices to double the price of gasoline auto-rickshaws. Future improvements in battery types and technology will be important to bring costs of electric vehicles down and make them an economically viable option.

- **Recharging infrastructure:** The availability of adequate recharging infrastructure is essential to the large scale implementation of electric vehicles in a city.

- **Recharging time:** The time to recharge batteries could be a factor in making this a viable option. Shah and Iyer (2004) report battery recharging times from 6 to 10 hours; a barrier particularly for auto-rickshaws that operate on a shift basis. UNEP (2011) reports battery swapping as a possible solution to address this issue and cite the implementation of this concept as part of a pilot project in Tokyo's electric taxis.

There has also been some research and testing on the feasibility of hydrogen fuel for auto-rickshaws as a renewable and non-polluting source of fuel. In a cost-sharing project funded by USAID and the United States Department of Energy (DOE), Energy Conversion Devices Inc., in collaboration with Bajaj Auto Ltd., developed and demonstrated prototype hydrogen internal combustion engine (ICE) auto-rickshaws in India and the United States in 2004. The performance of these auto-rickshaws was found to be comparable with the original CNG-version of the vehicles (Sapru, 2005). Table 7 presents the key performance characteristics of hydrogen-fueled auto-rickshaws as observed from this project.

Table 7: Performance Characteristics of Hydrogen-fueled Auto-rickshaws

Indicator	Performance
Top speed	48 km/h
Driving range	130 kms
Fuel economy	7 grams/km
Reversible hydrogen storage capacity	1 kg
Refilling time	85% refilling in 15 minutes

Source: Sapru (2005)

The vehicle was displayed at a range of different venues, and although the project helped in creating awareness about hydrogen technology, it was observed that technical improvements would be required to ensure large scale viability of this technology for the auto-rickshaw sector, in particular in the areas of driving range enhancement and increased fuel economy (Sapru, 2005). The biggest barrier impacting the viability of hydrogen as a fuel for transport, and in particular, for auto-rickshaws, will be the storage and distribution infrastructure (that do not exist currently), which may significantly outweigh the costs of the vehicle and fuel (UNEP, 2011).

More recently, as part of a USD 1 million project co-funded by the United Nations Industrial Development Organization (UNIDO) International Centre for Hydrogen Energy Technologies (ICHET), a fleet of 15 hydrogen-fuelled auto-rickshaws, along with the requisite refueling infrastructure, were launched in Pragati Maidan in New Delhi in January 2012 (UNIDO, 2012). This project, referred to as DELHY-3W, aims to demonstrate the viability of hydrogen fuel technologies developed by partners in India for India's transport sector. Key partners in this project include Indian Institute of Technology Delhi (IIT Delhi), Mahindra & Mahindra, and Air Products USA. Though such initiatives are a positive step forward, their success will be ultimately determined by the ability to scale-up, and the issues discussed earlier, including storage and distribution of hydrogen fuel, would be important to address going forward.

4.2.3 Manufacturers

Table 8 presents the list of key passenger auto-rickshaw manufacturers in India, and their product characteristics.

Table 8: Passenger Auto-rickshaw Manufacturers in India

Manufacturer	Engine	Fuel	Market
Bajaj Auto Ltd.	Two-stroke (carburetor), Two-stroke Direct Injection (for gasoline), and four-stroke	Gasoline, CNG, LPG, Diesel	Urban
TVS Motors	Two-stroke (carburetor) and four-stroke	Gasoline, CNG and LPG	Urban
Mahindra & Mahindra	Four-stroke	Diesel	Urban, semi-urban, and rural
Piaggio Vehicles Pvt. Ltd.	Four-stroke	Gasoline, Diesel, CNG, LPG	Urban, semi-urban, and rural
Atul Auto	Four-stroke	Diesel, CNG, LPG	Urban, semi-urban and rural (mainly Gujarat and Rajasthan)

Sources: Bajaj Auto (2012); TVS Motors (2011); TVS Motors (2012); Mahindra & Mahindra (2012); Piaggio (2012); Atul (2012)

According to data available from 2009-10, Bajaj Auto was the largest passenger auto-rickshaw manufacturer in India with annual domestic sales of 166,882 vehicles, accounting for a market share of close to 48 percent (Bajaj Auto, 2010). However, it is reported that with increasing competition from other players such as TVS Motors in the urban market, and Piaggio (diesel vehicles) in semi-urban and rural areas, Bajaj Auto's leading position in the auto-rickshaw market will continue to be threatened by other players (Mullick, 2010; Iyer, 2012).

4.3 Emissions Characteristics

The key emissions issue in the auto-rickshaw sector in Indian cities is the emissions of particular matter of aerodynamic diameter of less than 10 microns (PM_{10}) from two-stroke auto-rickshaws. PM_{10} emissions are noted to be a major public health concern due to their impacts on morbidity and premature mortality (Shah and Iyer, 2004). ICCT (2009) report that auto-rickshaws contribute to between 6 and 24 percent of PM emissions from motor vehicles in five large cities in India, and these shares are significantly higher than their share of the total vehicle population. The primary reasons cited are the high proportion of high-emitting two-stroke engines, the use of inferior quality and excessive quantities of lubricating oil, and poor maintenance practices (ICCT, 2009). Additionally, long hours in congested traffic conditions further add to the emissions from auto-rickshaws (ibid.).

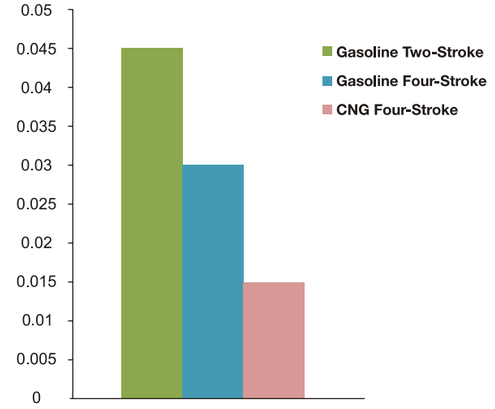
Shah and Iyer (2004) report that improvements in engine technology (moving from two-stroke to four-stroke engines) and the use of alternative fuels such as CNG and LPG can help address the emissions from two-stroke gasoline auto-rickshaws. They note that four-stroke gasoline engines have lower PM_{10}, HC and CO_2 emissions compared to two-stroke gasoline engines. Reynolds et al (2011), based on a study of CNG auto-rickshaws in Delhi, report that use of alternative fuels such as CNG as an emissions reduction strategy is most effective with four-stroke engines due to the inherent problems of scavenging losses and release of unburned lubricating oil in two-stroke engines. Further, a recent study estimated that the Indian Drive Cycle (IDC) underestimates PM emissions of auto-rickshaws by 16 percent and total hydrocarbon emissions by 49 percent (Grieshop et al., 2012). Figure 5 shows the PM emission factor comparisons between gasoline two-stroke, gasoline four-stroke and CNG four-stroke auto-rickshaws.

Particulate Matter (PM) emissions from two-stroke auto-rickshaws is one of the key environmental challenges facing this sector

Given that four-stroke engine is an established technology and already available and used in the market, a large scale shift from two-stroke to four-stroke gasoline engines presents the biggest opportunity to address emissions (PM_{10}, HC and CO_2) from the auto-rickshaw sector. However, the issue to consider with four-stroke engines is the higher NOx emissions compared to two-stroke engines (Shah and Iyer, 2004). Shah and Iyer (2004) report that four-stroke gasoline auto-rickshaws, although priced higher than two-stroke vehicles, have lower life-cycle costs due to their superior fuel efficiency/economy (10-20 percent improvement compared to two-stroke engines).

Figure 5 shows the comparison of PM emission factors of auto-rickshaws for different engine and fuel type combinations.

Figure 5: Comparison of PM Emission Factors (g/km) of Auto-rickshaws (post-2000 models)



Source: ARAI (2007)

As seen from Figure 5, the use of alternative fuels such as CNG on four-stroke auto-rickshaws can give additional PM_{10} emission reduction benefits compared to gasoline. However, the feasibility of using alternative fuels for auto-rickshaws as a PM_{10} emission reduction strategy should be assessed based on factors such as adequate availability of fuel, necessary fueling infrastructure, and life-cycle costs compared to gasoline (Shah and Iyer, 2004).

There is no clear consensus yet on whether LPG auto-rickshaws are feasible due to the relatively higher hydrocarbon content with comparable emissions for CO and NOx (iTrans, 2009). Apart from Garg et al. (2010), none of the studies have focused much on LPG auto-rickshaws.

From an emissions perspective, the use of electric vehicles in the auto-rickshaw sector may hold a tremendous potential to generate significant air quality benefits compared to petroleum-based vehicles due to the elimination of tailpipe emissions (UNEP, 2011). UNEP (2011) further states that electric vehicles may offer a truly carbon-neutral transport solution in cases where the electricity is generated from renewable sources. However, as discussed in Section 4.2, the future viability of electric vehicles for the auto-rickshaw sector remains to be seen based on an in-depth assessment of key factors such as economics, vehicle operating characteristics, recharging infrastructure, and power sources.

4.4 Socio-economic and Operational Characteristics

There has been some research that looks into the socio-economics of auto-rickshaw drivers. Mohan and Roy (2003) have studied auto-rickshaw driver characteristics in Delhi, including age and family size. They report that during the time of their study over 90 percent of the drivers surveyed were found to be below 50 years old and over 60 percent of drivers supported families of 5-8 persons, indicating auto-rickshaws were an important source of employment for working age men with dependents.

More recent studies, by Harding and Hussain (2010) in Delhi and Garg et al. (2010) in Chennai, have also found that most of the drivers interviewed belonged to the age group of 30-50. Harding and Hussain (2010) studied educational qualifications of drivers in Delhi and found that drivers had varying levels of educational qualifications ranging from illiterate to a few having 8th and 9th standard education. It was found that drivers with higher levels of education were typically migrants who could not secure a job befitting their educational qualifications in their home towns.

Auto-rickshaw services in most cities belong to the unorganized sector, where services are provided by individual drivers (owner-drivers or renter-drivers), and not organized fleet companies. Owner-drivers are those who own the vehicle and the permit while renter-drivers are those who rent the vehicle from the owner for either a single shift (10-12 hours) or for an entire day (24-hours) (Harding and Hussain, 2010). Typically, cities with closed permit systems have higher share of renter-drivers, due to the unavailability of new permits and escalation of permit costs, while cities with open permits have higher share of owner-drivers. For example, Garg et al (2010) report that highcost of credit in Chennai, due to closed permits, has skewed the auto-rickshaw sector towards rental driving with around 70 percent of the drivers being renter-drivers. Such trends have also been observed in Delhi where Harding and Hussain (2010) report that the government's permit and fuel conversion (to CNG) policies have led to an increasing number of renter-drivers in the city.

Auto-rickshaws in most cities belong to the unorganized sector, where services are provided by individual drivers and not by organized fleet companies

Garg et al (2010) report daily rental costs in Chennai of between Rs. 150-200, while rental costs in Delhi are as high as Rs 250-320 for a single 10-12 hour shift and Rs. 300-400 for a 24-hour period (Harding and Hussain, 2010). Daily income of auto-rickshaw drivers depends on daily operating characteristics in terms of fares charged, daily hours of operation, and corresponding daily loaded (passenger) kilometers traveled. In Chennai, Garg et al (2010) report that auto-rickshaw drivers typically earn around Rs 650 per day based on an average daily travel of around 100 kilometers. Accounting for rental, fuel, and maintenance costs, average daily savings amount to Rs. 150 or less. In Delhi it is reported that renter-drivers have total daily earnings of between Rs. 450-650 and have average daily savings of Rs. 120-230 for 10-12 hour work shift. In Delhi, approximately half the daily earnings, a significant share, of renter-drivers are accounted

for in paying rent (Harding and Hussain, 2010).Owner-drivers simply have higher life-cycle savings compared to renter-drivers as they don't have to incur the rental cost (Harding and Hussain, 2010).

These are important issues because driver profile (whether owner- or renter-driver) affects the economics (costs) and operations and has a bearing on the associated quality of service to passengers. For example:

- The presence of significant number of renter-drivers operating on shift-basis leads to poor-quality of service during shift-changing times as a result of refusals from drivers who have to drop-off the vehicle at designated shift-changing locations. Garg et al (2010) report the fuel-related problems, particularly with reference to LPG, shift changes have on auto-rickshaw driver economics.

- Fare hikes or lowering of operating costs, such as from use of alternative fuels, typically do not result in additional earnings for renter-drivers as they lead to rent hikes as well (Harding and Hussain, 2010; Garg et al, 2010). Thus, the burden of payment of daily rent affects quality of service in terms of refusals and overcharging.

Reynolds et al (2011) found that over 24-hour period auto-rickshaws in Delhi traveled between 90 and 210 kms accounting for an average of around 54,000 kms per year. In Chennai, auto-rickshaws are observed to travel around 100 kms on an average day. An important issue, both from an economics and environmental perspective, is the empty kms of auto-rickshaws which refer to the kms traveled without carrying any passengers. Lack of availability of adequate infrastructure (stands) is reported as one of the major issues contributing to empty trips of auto-rickshaws (Garg et al, 2010). Drivers having to go to designated shift-changing locations may also contribute to empty trips.

Table 9 shows the key operational characteristics of Rajkot's auto-rickshaw service based on data provided in the Comprehensive Mobility Plan (CMP). The results show that on an average more than 20 percent of daily trips of auto-rickshaws are empty trips.

Table 9: Key Operating Characteristics of Rajkot's Auto-rickshaw Service

Characteristics	
Maximum operating hours	18
Average operating hours	13
Average kms per day	89
Maximum distance travelled (kms)	200
Maximum trips per day	35
Average trips per day	16
Average trip length (kms)	5.4
Average passengers carried per day	51
Empty kms per day	19
Empty kms (%)	21%

Source: Rajkot CMP (2008)

4.5 Safety

While auto-rickshaws are perceived as more accident-prone than four wheelers (Shah and Iyer, 2004), it has been reported that auto-rickshaws cannot produce fatal accidents easily among vulnerable road users (pedestrians and bicyclists) due to their light weight and low speeds (Mani et al, 2012; Mohan and Roy, 2003). Corroborative evidence on this fact is presented by Mani et al (2012), who report that auto-rickshaws are relatively safer for pedestrians compared to cars and motorized two-wheelers based on an analysis of the contribution of motorized modes (auto-rickshaws, buses, cars, and motorized two-wheelers) to pedestrian fatalities in Mumbai and Bangalore (in terms of pedestrian fatality per 100,000 passenger kilometers travelled (PKT)).

Under growing mixed traffic flow conditions in cities, auto-rickshaw occupants face significant safety risk from multi-vehicle collisions due to the limited crash-worthiness of auto-rickshaws

There have been a limited number of studies related to safety of auto-rickshaw occupants (driver and passengers) and they can be divided into two major categories. The first category includes research that has been conducted using primary data on accidents and injury patterns. Schmucker et al. (2009) conducted a detailed analysis of the crash characteristics and injury patterns for auto rickshaws using Hyderabad as a case study. They concluded that there is a significant injury risk for auto-rickshaw occupants under multi-vehicle collisions due to the limited crashworthiness of auto-rickshaws. This risk is significantly higher for multi-vehicle collisions compared to single-vehicle collisions (collisions where no other vehicle is involved) or overturning. Their research shows that injury patterns of auto-rickshaw occupants in multi-vehicle collisions are similar to those of vulnerable road users involved in motor vehicle collisions.

The second category includes research using modeling tools. Mukherjee et al. (2007) presented results of modeling analyses for crash characteristics and concluded that a flip-over is highly unlikely in the case of an auto-rickshaw. Further, both the studies (Mukherjee et al, 2007 and Schmucker et al, 2009) point out small changes in design features could go a long way in improving the safety of auto-rickshaw occupants.

Schmucker et al (2009) report that vehicle design improvements such as seat belts and padding on stiff surfaces can play an important role in enhancing occupant safety under multi-vehicle collisions. Mani et al (2012) recommend reforms in current motor vehicle safety regulations should be a key focus area for automotive industry policy makers; either by introducing vehicle design improvements for auto-rickshaws or moving to safer vehicle configurations to enhance the safety of occupants.

SUMMARY OF KEY FINDINGS

Table 10 presents a summary of key findings from the review of available literature.

Table 10: Key Findings from Literature Review

Thematic Area	Key Findings
Policy/Regulation	**Permits** • Permits for auto-rickshaw services are regulated by Regional Transport Authorities (RTAs). • There is a lack of consistency and transparency in permit policies across cities with some cities having closed permit systems while others having open permits. • There is a need for further research on the appropriate type of permit policy framework for the auto-rickshaw sector. Research conducted in the US on taxi permit policies based on segmentation of taxi markets (dispatch, hail and stand markets) may have important applications for the auto-rickshaw sector in Indian cities. **Fares** • Fares for auto-rickshaw services are regulated by the Regional Transport Authorities (RTAs). • Though there is a case for government regulation of fares, there is a lack of a standardized analytical framework for fare determination, implementation, and revision for the auto-rickshaw sector that takes into account fuel prices and cost-of-living indices. • This leads to significant challenges, such as refusals and overcharging by drivers, and conflicts between driver unions and regulatory authorities. • There is a need for further research on best practices on fare regulation in the auto-rickshaw and taxi sector and opportunities for reforms in current fare policies based on these experiences. **Emissions** • Emission standards for motor-vehicles, including auto-rickshaws, are stipulated by the 'Standing Committee on Implementation of Emission Legislation' under the Ministry of Road Transport and Highways (MORTH) • The combined emission standard for hydrocarbon (HC) and nitrogen oxides (NOx) is ineffective in addressing the problem of NOx emissions from four-stroke auto-rickshaws. • There are no emission norms for PM emissions from gasoline auto-rickshaws. This is an issue because of the high PM emissions from two-stroke gasoline auto-rickshaws. • There are no emission norms for GHG emissions from auto-rickshaws. This is again a challenge because of the growing contribution of the transport sector to GHG emissions. • Compliance to emission standards comprises of i) manufacturer compliance at time of production; and ii) compliance of in-use motor vehicles through the PUC program. There is a critical need for reforms in the current PUC programs of States to ensure better emissions compliance of in-use motor vehicles.

Thematic Area	Key Findings
	Safety • Safety standards for motor vehicles, including auto-rickshaws, are stipulated by the Ministry of Road Transport and Highways (MORTH), under the Central Motor Vehicle Rules (CMVRs). • The CMVR- Technical Standing Committee (TSC) is instituted for motor vehicle safety regulations. • Enforcement of safety standards comprises of i) manufacturer compliance at time of production and ii) compliance of in-use motor vehicles which is ensured by the RTOs
Market Characteristics	**Market Size** • Domestic production and sales trends indicate that the auto-rickshaw sector is continuing to grow in India. • Auto-rickshaws run on small engines with engine size ranging from 150 to 175 cc. **Engine and Fuel** • Two-stroke auto-rickshaws dominate the market in a number of Indian cities owing to the mechanical simplicity and lighter weight preferred by drivers • Two-stroke auto-rickshaws have lower capital cost, higher power, and mechanical simplicity over four-stroke auto-rickshaws. However, their disadvantage lies in high levels of PM (with harmful health impacts), HC, CO_2 emissions, and lower fuel economy. • Across Indian cities, different types of fuels are used on auto-rickshaws including gasoline and alternative fuels such as CNG or LPG (for their environmental benefits). • There is a need for a comprehensive fuel policy framework for auto-rickshaws that looks at pricing as well as feasibility of alternative fuels (such as fuel supply infrastructure and in-use testing program that ensures successful conversion). • The feasibility of electric vehicles for the auto-rickshaw sector is getting attention due to their environmental benefits (zero tailpipe emissions)compared to gasoline or alternative fuel-driven vehicles. • Key factors impacting viability of electric vehicles include: i) capital cost of vehicles, ii) availability of recharging infrastructure; and iii) recharging time. **Manufacturers** • Major manufacturers in the passenger auto-rickshaw market include- Bajaj Auto, TVS Motors, Mahindra & Mahindra, Piaggio, and Atul Auto. • Bajaj Auto holds the highest market share, but is facing stiff competition from other players due to their growing focus in not only urban, but semi-urban and rural segments.
Emissions	• PM emissions from two-stroke auto-rickshaws is key. The noted public health impacts of PM including morbidity and premature mortality. • Improvements in engine technology (two-stroke to four-stroke auto-rickshaws) and use of alternative fuels present significant opportunities to address PM emissions problem. • However, large scale conversion to four-stroke auto-rickshaws should address the NOx emissions problem from these vehicles.

Thematic Area	Key Findings
	• Alternatively, direct fuel injection technology for two-stroke engines may hold significant promise as a solution to address the environmental and fuel efficiency problems with conventional two-stroke engines and needs to be researched further. • Electric vehicles may hold tremendous long term potential as an emissions mitigating solution, but their feasibility depends on many factors like costs and recharging infrastructure.

Socio-economics and operations	**Driver Profile**
	• Studies from a few cities indicate that a large share of auto-rickshaw drivers belong to the 30 to 50 age group.
	• Auto-rickshaws in most cities belong to the unorganized sector where services are provided by individual drivers (who may be owner-drivers or renter drivers) and not by organized fleet companies
	• Cities with a closed permit policy are observed to have higher share of renter-drivers.
	• Driver profile (owner- or renter-driver) has an impact on quality of service.
	  • Higher share of renter-drivers results in higher cases of shift-changing, and poor quality of service (such as refusals) during shift-changing times
	  • High rental costs (upto 50% of daily revenues) lead to higher cases of refusals and overcharging by drivers
	Economics and Operations
	• Reported data indicate daily earnings of drivers of up to Rs. 650 and average daily travel of upto 100 kilometers.
	• Typical daily operating costs include fuel and maintenance. Renter drivers incur additional cost of daily vehicle rent.
	• Empty trips/kilometers traveled is one of the key operational issues which affects operating costs and leads to additional emissions. Reported data for Rajkot indicates empty kilometers of more than 20% of daily kilometers traveled.

Safety	• Auto-rickshaws are reported to be safer for pedestrians and bicyclists compared to other motor vehicles (such as cars) due to their light-weight and low speeds. • National level accident statistics indicate that auto-rickshaws are associated with less than 7% of total accidents compared to more than 20% for cars and 22% for motorized two-wheelers. • The issue of concern is the safety risk of auto-rickshaw occupants (driver and passengers). • Research shows that auto-rickshaw occupants face significant injury risk under multi-vehicle collisions due to the limited crash worthiness of auto-rickshaws. • It is reported that in order to improve the safety of occupants on urban roadways regulatory reforms in current motor vehicle safety regulations should be pursued to either bring vehicle design improvements to auto-rickshaws or move to safer vehicles.

CONCLUSIONS AND WAY FORWARD

The auto-rickshaw sector is going to continue to be an important component of the overall urban transport system in Indian cities (Mani et al, 2012). As cities in India grow and expand auto-rickshaws, as part of an integrated public transport system, will continue to play the crucial supportive role in meeting growing urban transport needs. It is imperative that a robust policy framework is soon brought into effect that recognizes the role of the auto-rickshaw sector in sustainable urban transport and puts in place the requisite measures in order to create the right environment to promote reforms in the sector. In that context, further research into appropriate frameworks for permit and fare regulation will require urgent attention as it has been documented that changes in permit and fare policies can have lasting impacts on economics and quality of service.

Another important aspect is the issue of emissions from the auto-rickshaws - particularly two-stroke engines that constitute a large share of the vehicle fleet in several Indian cities. In the current context of increased attention to urban air pollution and GHGs emissions it will be important to assess the feasibility of implementing emissions mitigation solutions for auto-rickshaws. This will entail assessing the range of different emissions mitigation options (two-stroke direct fuel injection engines, four-stroke engines, electric vehicles, and alternative fuels such as CNG and LPG) and identifying city specific solutions that are feasible both in terms of life cycle economics and environmental benefits.

Lastly, vehicle design issues for auto-rickshaws need to be addressed due to the growing cases of multi-vehicle collisions of auto-rickshaws under mixed traffic flow conditions in Indian cities and the safety risks they pose for auto-rickshaw occupants (driver and passengers).

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