Operational and Maintenance Approach for

Improving Fuel Economy in City Bus Transport

Supplementary Guidance Note

SEPTEMBER 2016

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ESMAP
Energy Sector Management Assistance Program

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Acknowledgements

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ESMAP is a global multi-donor technical assistance trust fund administered by the World Bank. It provides analytical and advisory services to low and middle income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. For more information, please visit www.esmap.org.

This is a supplementary note to the Guidance for the Application of the ESMAP Operational and Maintenance Approach for Improving Fuel Economy (2011) and is based on on-ground piloting of the ESMAP approach in Indian cities.

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Table of Contents

Executive Summary

Rapid urbanization has created increased demand for more frequent public transport services. Many city public transport companies globally are under constant pressure to carry increasing passenger loads on their limited capacities. Fluctuating global and local fuel prices exert continuous pressure on operating costs more often than not rendering transport services unprofitable.

While government support to help city transport operators meet these challenges has not increased, local officials expect public transport companies to become more efficient and meet the growing general public transport needs.

Fuel is the single largest expenditure incurred by public transport companies. In bus transportation, fuel expenses could be 35-50 per cent of the total operating and maintenance costs for buses. In this scenario where additional funding is inadequate and fuel costs are high, improvements in fuel efficiency can help transport companies become more efficient and operationally sustainable.

Experiences from other Indian cities and also internationally suggest that energy efficiency can be vastly improved through targeted programmes focused on improving the driving skills of bus drivers and through comprehensive maintenance of buses. Such programs also result in improved road safety (safer drivers), increased service reliability (less breakdowns) and increased life of units, thereby leading to a reduction in maintenance costs and better air quality.

In 2011, the Energy Sector Management Assistance Program (ESMAP**)**, a global knowledge and technical assistance program administered by the World Bank, engaged in a study and published a guidance note[1] with recommendations on how city bus managers and their staff members could develop an action plan for improving fuel efficiency without significant capital investments. The paper researched different issues affecting fuel economy. However, in the absence of a carefully-controlled study, definitive conclusions could not be drawn though an action plan which focused on five key areas was recommended:

- Management commitment and ownership;
- Data collection and analysis;
- Maintenance directed at low fuel economy buses;
- Training directed at low-performing drivers; and
- Employee communication and rewards.

The report came to the following ‘tentative’ conclusion:

> *… The limited data suggests that the combination of driver training and organizational focus on fuel economy could provide fuel economy benefits in the 7 to 15 per cent range for organizations where fuel economy has not previously been a focus ….*

[1] Transit Bus Operational and Maintenance Practices to Maximize Fuel Economy (2011).

The report went on to draw a final 'tentative' conclusion:

> *… Overall, the testing showed that the recommended approach could be implemented without significant changes in operating structures, capital investment or upfront preparation. However, energy-efficient O&M practices must be carefully planned and must be appropriate to the size, resources, and 'culture' of each city bus company in order to be successful … (page 2).*

A series of 16 specific actions was developed in the key areas.[2] The recommended actions were field tested in three cities in southern India: Hyderabad, Vijayawada and Mysore. ESMAP funded another project in 2013 to test the practical application of the program's approach in four cities in India — Bhopal, Chandigarh, Jaipur and Mira Bhayandar, a distant suburb of Mumbai. These four cities are demonstration cities under the Global Environment Facility (GEF) grant funded Efficient & Sustainable City Bus Services Project being jointly supported by the Ministry of Urban Development and the World Bank.

This paper captures the on-ground implementation of this pilot project that worked with select city transport operators in the four cities. It highlights the demonstrated results and lessons learned on increasing efficiency and fuel economy of bus systems and reducing cities' energy consumption and pollution. The experiences gained from the pilot demonstrations of the ESMAP approach suggest:

- Improvement opportunities exist in all environments.
- A computerized and tailored analysis program such as Fuel Efficiency Analysis Tool (FEAT) and a local analyst skilled in database management and fuel efficiency analysis are required to implement the ESMAP approach.
- Driver training and bus maintenance schedules should be customized based on the capacity of a bus operator and the facilities available.
- The 'train-the-trainer' approach is an effective way of creating in-house, expert trainers.
- The driver checklist prepared for the pilot demonstrations can be useful in monitoring all drivers.
- The targeted bus maintenance protocols can only be effectively implemented and the results fully realized when there is adequate internal or external capacity to perform both Tier-1 and Tier-2 maintenance protocols.

Finally, the pilot demonstrations strongly show that the success and likely sustainability of such fuel efficiency programmes requires significant management commitment. Management support is needed to ensure that proper resources are provided to carry out fuel efficiency procedures on a regular and consistent basis. Management support is also needed to hold drivers and mechanics responsible and accountable for fuel efficiency.

Although the pilot demonstrations focused primarily on the technical aspects of the ESMAP guidance note, several managers said that they felt that monetary incentives were key to improving the performance of drivers who were not self-motivated to improve their performance. This suggests that the establishment of an employee rewards program (for example, monetary incentives and public recognition) could play a key role in motivating the drivers and

[2] A summary of the 16 actions is provided in Annex 1.

mechanics to make fuel efficiency a key focus of their work activities.

The following sections are detailed out in this note:

- **Initial Steps** to be observed around management commitment and resourcing when embarking on the ESMAP approach.
- **Targeting Methodology and Approach** for identifying the buses and drivers with lowest relative fuel economy and various data issues that must be considered.
- **Bus Maintenance Protocols** through a two-tier maintenance program and process for advancing from the first to the second tier.
- Critical topics for a **Driver Training Program** and the follow-up monitoring process of drivers.
- **Results and Lessons Learned** regarding start-up issues, the application of a technical analysis and protocols and management commitments from three rounds of applying the ESMAP approach.

1. Initial Steps: Management Commitment and Ownership

ESMAP recommended an action plan that focused on five principles that are a combination of technical and management actions (See Annex 1 for more details). To demonstrate the potential benefits of the ESMAP approach it was decided to limit the focus of the pilot demonstrations to three ESMAP technical actions:

- Data collection and analysis
- Maintenance of low fuel efficient buses
- Training of low-performing drivers

However, one of the key lessons learned from the pilots was the importance of management commitment. The pilots that were most successful were those with management commitment. Senior management must lead and oversee the entire ESMAP program to ensure alignment with existing staffing needs and for providing the necessary human physical resources for the program.

Therefore, it is important that the senior management's commitment is obtained before a city transport operator initiates the technical activities presented in this paper. It is recommended that this commitment involve the following:

- **Dedication of staff members for analysing fuel consumption data, performing bus maintenance protocols and conducting the driver training program.** One dedicated focal point person for managing and coordinating the fuel efficiency program is required. In addition, time must be dedicated for at least one mechanic and one maintenance helper (for conducting Tier-1 checks and managing Tier-2 checks), two driver trainers (for conducting regular classroom and practical driver training and follow-on monitoring) and a data analyst (for data compilation, analysis and validation for targeting). These resources are critical for the development of an in-house training unit and unless they are identified and dedicated at the start of the program, its sustainability and continuity are likely to be impacted.
- **Provision of sufficient physical facilities or outside services to perform the complete set of maintenance protocols.** This may require upgrading existing maintenance facilities and equipment or the use of third-party maintenance services.
- **Bus operating company should mainstream training as part of their overall operations.** The management, through the training unit, should develop a training calendar and ensure adherence to the agreed schedule for targeting poorly-performing buses and drivers and improving performance through the recommended bus maintenance protocols and driver program. The experience from the pilots suggests that these activities can be reasonably scheduled every two to three months.

2. Targeting Methodology and Approach

A four-pronged approach was implemented that encompassed:

- Analysing fuel consumption data for the most recent months to identify buses and drivers with lowest relative fuel economies.
- Applying a two-tier maintenance program for low fuel economy buses.
- Training identified drivers in fuel efficient driving techniques.
- Monitoring changes in fuel economy for the buses and drivers who participated in the program.

Technical Approach

An analysis of fuel consumption for the most recent month to identify the buses and drivers with the lowest relative fuel economies in the four demonstration cities entailed the following steps:

- **Data Validation -** Evaluating the validity of individual bus identification and fuelling records.
- **Technical Adjustments** - Addressing situations that require the grouping or splitting of fuel consumption data by bus routes before the data is analysed.
- **Targeting Approach -** Identifying the lowest performing buses and drivers after accounting for two major factors that affect fuel economy — route characteristics and bus type.
- **Fuel Efficiency Analysis Tool** – Conducting a targeting analysis using a Microsoft Access runtime program.

Data Validation

Data validation is important in any analysis program, particularly for those programmes which use data collected in daily operations. Data validation is a process to ensure that a program operates on correct and useful data. It uses validation rules that check for the ‘correctness’ of the data that form inputs for the analysis and reject data entries or records that do not pass the rules.

The targeting approach relies on bus fuelling data that is collected in daily operations. Each entry or record provides the following data items:

- Fuelling date
- Bus number
- Route number
- Driver number
- Daily operated km
- Fuel added in litres

Exhibit 1 provides an example of a log of daily fuelling data using these data items.

Many transport companies in India rely on manual records for maintaining daily fuel consumption data. When each bus is fuelled (typically at the end of the day), either the driver or a maintenance employee who is assigned the fuelling duty, records the data. In most companies, the data is recorded in paper form. In some systems, the data is entered into an electronic form.

A monthly analysis of about 3,000 data records related to fuel consumption for a depot housing 100 buses was conducted. All data available in paper format was transcribed into an electronic format. This

Exhibit 1: Example of Fuel Consumption Data

Input Date	Bus Number	Route Number	Driver			Daily Operated KM	Fuel Added (Liters)
			1	2	3		
1.2.2014	6017	1	216	206	299	262.0	96.8
1.2.2014	8551	1	158	303	182	262.7	85.4
1.2.2014	4787	2	154	129	152	260.5	78.9
1.2.2014	4775	3	213	122		210.7	73.1
1.2.2014	9046	4	150	101		264.0	89.7
1.2.2014	9223	4	381	182		275.8	97.8

data, however, needed to be validated since several errors could have occurred when the fuel consumption data was recorded, as well as when it was being transcribed, including:

- Different variations of a driver's name entered throughout the month
- Incorrect entries could have potentially been made
- Correct entries could have been incorrectly transcribed in the electronic format
- Data recorded even when the bus tank was not completely refuelled

The first issue related to **variations in a driver's name** can be minimized in general by issuing and recording driver employee codes (or numbers) instead of recording a driver's name. This avoids ambiguity and confusion related to common or similar first and last names.

The remaining three issues can be addressed using simple validation rules that are applied to fuel consumption data records (that is, one daily fuelling for a bus) before the data is analysed. Key validation rules should cover the following:

- **Missing or Incorrect Bus Numbers.** A bus number needs to be entered for each fuelling, which then needs to be compared to a vehicle inventory to ensure entry accuracy.
- **Missing Driver Numbers.** At least one driver number should be entered for each fuelling, which should then be compared to a master list of valid driver numbers. However, it may be difficult to maintain a current driver list at some companies because of the rapid turnover of drivers, especially newly recruited ones.
- **Unreasonable Fuel Consumption.** Fuel economy (kmpl) for each fuel consumption record can be calculated and compared to an expected performance range. A range of 1.0 kmpl (low) to 6.0 kmpl (high) was used in the demonstration. The range limit depends on the types of buses operated and local operating experiences with these buses.
- **Missing Bus Route Numbers.** At least one bus route number should be entered for each bus fuelling to be compared with a master list of valid bus route numbers.

Records that fail any validation rule can be reviewed and corrected. If the records cannot be corrected, they are excluded from the analysis. The goal is to correct all the failed records, but this may not be possible. If the failure rates exceed more than 1 per cent of the records, then the recording process should be reviewed to identify and correct systemic recording problems.

Technical Adjustments to Data

It is easier to analyse bus transport systems that operate under simplistic conditions such as:

- Only one driver assigned to a single bus on the same day;
- A single bus providing service only on one route on the same day; or
- If two buses provide service on a particular route they have the same bus type/seating configuration.

Unfortunately, many bus companies have developed bus and driver work assignments which while being efficient are complicated and do not meet these simple conditions. Two, sometimes three, drivers operate a single bus on the same day. A single bus might operate on more than one route in one day. Typically, one bus provides service on a single route only when the overall route distance is short and it has a low passenger load.

Hence, some technical adjustments to fuel consumption data that is analysed are required. These relate to fuel adjustments for routes split between multiple drivers, buses that ply multiple routes and routes that require more than one bus to cater to passenger loads with varying bus type configurations. Other adjustments must be made to the initial results of the analysis to develop composite scores for buses that operate services on more than one route and drivers who operate more than one bus during a month on the same route.

The most accurate method for addressing these complications is to refuel the bus each time a driver changes or a bus goes from one route to the other. This obviously is not practical in most operating environments. It is also not consistent with the common practice of refuelling buses when they return to their depots at the end of their day's work in preparation for pull-out the next morning.

Electronic monitoring of fuel consumption is another option for addressing these complications. However, these systems are generally not in use in any bus transport system in India. As such, ways and means for widespread application of electronic fuel consumption monitoring need to be explored before this option can be considered.

Technical adjustments to fuel consumption data were developed keeping in mind the operating environment in India. Many bus companies use manual approaches for recording fuel consumption data. However, many companies do not record the actual kilometres that individual buses operate on individual routes when a bus provides services on several routes in a single day. They also do not record the actual kilometres that individual drivers operate on individual routes when the drivers provide services on several routes in a single day.

Data Adjustment 1: Splitting Fuel Consumption Data Among Drivers

Many transport companies operate bus routes that have long service spans. The service on routes begins early in the morning (for example, 6 am) and ends late in the evening (10 pm). It is common to schedule this type of service using one bus and two drivers who work eight hour shifts each.

The bus is fuelled at the end of the day since it is not practical to refuel it each time a driver changes. The fuel record often shows the bus number, the route number, the names or employee identification numbers of the drivers, the kilometres operated and the litres of fuel consumed. In many cases, however, the company does not record actual kilometres operated by individual drivers on a daily basis.

The simple technical adjustment in this case is splitting the kilometres operated and the volume of fuel consumed equally among the drivers.

For example, Bus 45 is operated by Drivers 102 and 207 on Route 2. The bus travels 200 km and consumes 80 litres. This is split equally among the drivers to modify their individual records to reflect Driver 1 and Driver 2 both driving 100 km and consuming 40 litres of fuel each.

Technical adjustments are based on making equal apportionments (or groupings) of the fuel consumption data. While some error is introduced when making apportionments in this way, the overall targeting approach using such adjusted data will be able to objectively identify and rank the lowest performing buses and drivers.

Data Adjustment 2: Splitting Fuel Consumption Data Among Routes

Many transport companies schedule drivers to operate more than one bus route during the day using a single bus. This may be done because the routes have different starting and ending times or as an effort to reduce dead kilometres for routes with long distances and service spans.

The simple technical adjustment is splitting the kilometres operated and the litres of fuel consumed equally among the routes.

For example, Driver 104 operates Bus 45 on Routes 12 and 18. The bus travels 180 km and consumes 60 litres. This data is split equally between the two routes, with each having operated 90 km, consuming 30 litres each.

Data Adjustment 3: Route Grouping

A vast majority of transport companies operate bus routes with varying bus requirements. Most bus routes require at least two buses to meet passenger load demands, which also help maintain reasonable service frequencies on medium to long distance urban routes. At times some transport companies operate bus routes that require only one bus, especially when the routes are short and have low passenger loads.

Targeting low performing buses and drivers on such routes can present a problem if the same bus is assigned to the route every day. In this situation, the average fuel consumption will equal the fuel consumption of the single bus. There are no high or low performing buses on the route, just one bus.

A variation of this problem is when two types of buses are operated on a route, but there is only one bus operated of a single bus type. For example, a route may regularly use four 160-HP buses and one 130-HP bus.

The simple technical adjustment that is used to address this problem is grouping this route with one or more other routes to create a new 'combined route' for the purpose of targeting analyses. Routes which operate the same types of buses and have the same scheduled speeds are selected for this. The scheduled speed is calculated as the one-way route distance (for example, 17 km) divided by the scheduled time (for example, 60 minutes). This speed grouping approach is used because it is generally agreed that average speed is related to bus fuel economy. Typically, low-speed routes have lower fuel economy as compared to high-speed routes because the buses stop more frequently for passengers, traffic junctions and congested traffic.

An example of this grouping adjustment is shown in Exhibit 2. Three buses are operated on Route 1 while only one bus is operated on Route 3. Before grouping the routes, the average fuel economy cannot be calculated for Route 3 since it has only one bus. Fuel consumption data for Routes 1 and 3 is then grouped to create a combined Route 1/3. Route 1 was chosen because it has operating characteristics that are similar to Route 3: 1) it uses the same type of buses (Bus Type 1), and 2) it has a route speed (18.2 kmph) that is close to the route speed of Route 3 (18.9 kmph).

Exhibit 2: Example of Route Grouping

Bus	Route	Route Speed (kmph)	Bus Type	KM	Liters	(Step 1) Average kmpl	(Step 2) Route/ Bus Type Average (kmpl)	(Step 3) Relative Fuel Economy (kmpl)	Rank (1= Lowest)
Before Route Grouping (Separate Routes 1 and 3)									
56	1	18.2	1	4,435	1,341	3.31	3.45	-0.14	1
58	1	18.2	1	4,689	1,256	3.73	3.45	0.28	3
60	1	18.2	1	4,325	1,299	3.33	3.45	-0.12	2
Average	**1**	**18.2**	**1**	**13,449**	**3,896**	**3.45**			
61	3	18.9	1	4,897	1,404	3.49	Not Applicable		
After Route Grouping (Combined Route 1/3)									
56	1/3	18.2-18.9	1	4,435	1,341	3.31	3.46	-0.15	1
58	1/3	18.2-18.9	1	4,689	1,256	3.73	3.46	0.27	4
60	1/3	18.2-18.9	1	4,325	1,299	3.33	3.46	-0.13	2
61	1/3	18.2-18.9	1	4,897	1,404	3.49	3.46	0.03	3
Average	**1/3**	**18.2-18.9**	**1**	**18,346**	**5,300**	**3.46**			

Targeting Approach

The objective of the targeting approach is to identify buses and drivers with the lowest relative fuel economies. The central idea is that the fuel economy can be improved by focused maintenance of the targeted buses and by training targeted drivers.

The targeting approach considers two factors — route characteristics and bus type — both of which are well known to affect fuel economy. However, it is important that factors other than maintenance and driver training which may also affect fuel economy should also be considered. The fuel economy of different routes can vary based on a number of factors such as the number of stops per kilometre, the terrain (hilly or flat), passenger loads and traffic congestion. The fuel economy of different bus types can also vary based on bus size (length and seating capacity), engine horsepower, transmission type and use of air-conditioning.

The targeting approach uses an averaging method for comparing performance. The approach compares the performance of an individual bus or driver against the average performance on a specific route for a specific bus type. Buses and drivers are ranked based on their absolute differences in fuel economy (kmpl) from their route/bus type averages.

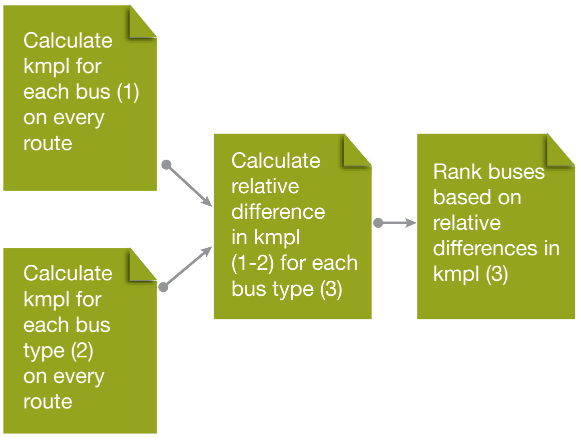
It is recognized that an individual bus or a driver is compared to an average that includes own fuel economy. Poor-performing buses and drivers will 'drag down' the averages and may mask how poorly the buses or drivers are performing. However, poor-performing buses and drivers will still be measured as below average, and these buses and drivers will eventually be selected since the targeting approach is performed monthly.

The approaches (and examples) for identifying buses and drivers are described in the next sub-sections.

Bus Targeting

Figure 1 gives the steps that are used for identifying buses with the lowest relative fuel economy as measured in kmpl.

Figure 1: Steps for identifying buses with the lowest relative fuel economy



An example of applying the bus targeting approach is shown in Exhibit 3. Nine buses are operated on Routes 12 and 14. Two different bus types operate on Route 12, while only one bus type operates on Route 14. In this example, Bus 108 is the lowest performing bus (rank =1) because its relative fuel economy of -0.27 kmpl is the lowest among the nine buses. Bus 108 is given this rank even though its absolute fuel economy (3.36 kmpl) is higher than that of Buses 101, 103, 105 and 106 because its potential for improvement — increasing 0.27 kmpl to become 'average' — is the largest among the buses.

Driver Targeting

Figure 2 gives the steps that are used for identifying drivers with the lowest relative fuel economy as measured in kmpl.

Figure 2: Steps Used for Identifying Drivers with the Lowest Fuel Economy

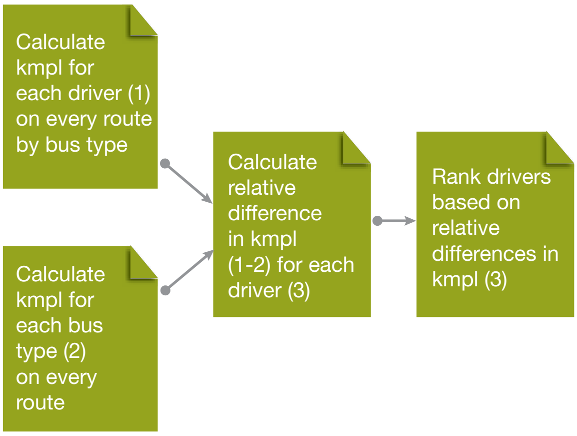


Exhibit 3: Example of Bus Targeting Calculation

Bus	Route	Bus Type	KM	Liters	(Step 1) Average kmpl	(Step 2) Route/ Bus Type Average (kmpl)	(Step 3) Relative Fuel Economy (kmpl)	Rank (1= Lowest)
101	12	1	4,435	1,341	3.31	3.45	-0.14	3
102	12	1	4,689	1,256	3.73	3.45	0.28	9
103	12	1	4,325	1,299	3.33	3.45	-0.12	4
Average	**12**	**1**	**13,449**	**3,896**	**3.45**			
104	12	2	4,897	1,404	3.49	3.22	0.26	8
105	12	2	4,478	1,501	2.98	3.22	-0.24	2
106	12	2	4,690	1,459	3.21	3.22	-0.01	5
Average	**12**	**2**	**14,065**	**4,364**	**3.22**			
107	14	1	4,890	1,267	3.86	3.62	0.24	7
108	14	1	4,550	1,356	3.36	3.62	-0.27	1
109	14	1	4,724	1,289	3.66	3.62	0.04	6
Average	**14**	**1**	**14,164**	**3,912**	**3.62**			

An example of applying the driver targeting approach is shown in Exhibit 4. This is based on the example shown in Exhibit 3 except that in this case the drivers are analysed. Nine buses are operating on Routes 12 and 14. Two different bus types are operating on Route 12, while only one bus type is operating on Route 14. In this example, Driver 583 is the lowest performing driver (rank =1) because his relative fuel economy of -0.38 kmpl is the lowest among the nine drivers. Driver 583 is given this rank even though his absolute fuel economy (3.07 kmpl) is higher than that of Driver 521 because his potential for improvement — increasing 0.38 kmpl to become 'average' — is larger than the potential improvement for Driver 521 (0.21 kmpl).

Adjustments to Analysis Results

In most service operations the same buses and same drivers do not operate the same routes every day. Due to bus breakdowns and driver absences some back-up buses and drivers may provide services on many routes during a month.

The differences in fuel economy are calculated for every driver and bus individually, and compared with the average fuel economy for the route and bus type. When a bus (or driver) provides services on several routes, the calculations are made for the same bus (driver) on several routes. For example, if Bus 12 operates on Routes 4 and 6, the analysis may determine that the relative fuel economy of Bus 12 is -0.12 kmpl on Route 4 and -0.24 kmpl on Route 6.

A weighted-averaging method is used to develop a composite score for relative fuel economy for buses and drivers that provide services on more than one route during a month. This method is described in the next two sections.

Exhibit 4 : Example of Driver Targeting Calculation

Driver	Route	Bus Type	KM	Liters	(Step 1) Average kmpl	(Step 2) Route/ Bus Type Average (kmpl)	(Step 3) Relative Fuel Economy (kmpl)	Rank (1= Lowest)
512	12	1	4,456	1,234	3.61	3.45	0.16	6
514	12	1	4,678	1,256	3.72	3.45	0.27	8
583	12	1	4,315	1,406	3.07	3.45	-0.38	1
Average	**12**	**1**	**13,449**	**3,896**	**3.45**			
511	12	2	4,987	1,432	3.48	3.22	0.26	7
521	12	2	4,489	1,489	3.01	3.22	-0.21	3
586	12	2	4,589	1,443	3.18	3.22	-0.04	4
Average	**12**	**2**	**14,065**	**4,364**	**3.22**			
506	14	1	4,980	1,276	3.90	3.62	0.28	9
567	14	1	4,540	1,245	3.65	3.62	0.03	5
569	14	1	4,644	1,391	3.34	3.62	-0.28	2
Average	**14**	**1**	**14,164**	**3,912**	**3.62**			

Analysis Adjustment 1: Weighted Bus Relative Fuel Economy

An individual bus may operate on more than one route during a month because, either:

- The bus is scheduled to operate on two or more routes on a single day; or
- The bus is a replacement (back-up) bus for a regularly-assigned bus that is in the depot for the day for repairs, preventive maintenance or routine inspection.

A weighted-averaging method is used to develop a composite score for relative fuel economy for a bus that provides services on more than one route during a month. The individual, relative fuel economy scores for the bus on each route are weighted by the kilometres operated to calculate one composite value of relative fuel economy for the bus.

An example of calculating weighted bus relative fuel economy is shown in Exhibit 5. Bus 43 operated on Routes 12, 14 and 16 during the analysis month. The relative fuel economies were calculated for Bus 43 on Routes 12 (-0.27 kmpl), 14 (-0.14 kmpl) and 16 (-0.12 kmpl). The weighted-average relative fuel economy for Bus 43 was -0.18 kmpl. This result is used as the value to rank Bus 43 among the other buses operated by the transport company.

Exhibit 5: Example of Weighted Bus Relative Fuel Economy

Bus	Route	Bus Type	(1) Relative Fuel Economy (KMPL)	KM	(2) Percent of Total KM	(1) x (2) Weighted Relative Fuel Economy (KMPL)
43	12	1	-0.27	1,593	35.3%	-0.10
43	14	1	-0.14	1,627	36.0%	-0.05
43	16	1	-0.12	1,299	28.7%	-0.03
43	All	1	Totals	4,519	100.0%	-0.18

Analysis Adjustment 2: Weighted Driver Relative Fuel Economy

An individual driver may drive on more than one route or drive more than one type of bus during a month because:

- The driver is scheduled to operate on two or more routes on a single day;
- The driver operates a replacement bus that is a different type from the one that he normally operates; or
- The driver is a replacement (back-up) driver for a regularly-assigned driver who is absent for reasons such as sickness, family emergencies or paid leave.

A weighted-averaging method is used for developing a composite score for relative fuel economy for a driver who provides services on more than one route or operates more than one type of bus during a month. The individual, relative fuel economy score for the driver on each route is weighted by the kilometres operated to calculate one composite value of relative fuel economy for the driver.

An example of calculating weighted driver relative fuel economy is shown in Exhibit 6. Driver 213 drove four routes during the analysis month — Routes 21, 23 and 34 as part of his regular assignment and Route 26 on which he drove for three days as a substitute driver. The relative fuel economies were calculated for Driver 213 on Routes 21 (-0.27 kmpl), 23 (-0.14 kmpl), 26 (0.18 kmpl) and 34 (-0.12 kmpl). The weighted-average relative fuel economy for Driver 213 was -0.14 kmpl. This result is used as the value to rank Driver 213 among the other drivers in the transport company.

Exhibit 6: Example of Weighted Driver Relative Fuel Economy

Driver	Route	Bus Type	(1) Relative Fuel Economy (kmpl)	KM	(2) Percent of Total KM	(1) x (2) Weighted Relative Fuel Economy (kmpl)
213	21	1	-0.27	1,593	31.7%	-0.09
213	23	1	-0.14	1,567	31.2%	-0.04
213	26	2	0.18	569	11.3%	0.02
213	34	1	-0.12	1,299	25.8%	-0.03
213	All	1	Totals	5,028	100.0%	-0.14

Fuel Efficiency Analysis Tool (FEAT)

A simple, runtime Microsoft Access program, the ***Fuel Efficiency Analysis Tool (FEAT)***[3] was written to conduct the targeting analysis. The FEAT program was written to help managers in the four demonstration cities conduct the targeting methodology described in this chapter. The runtime versions allow users to run the FEAT program without purchasing or installing the Microsoft Access program on their computers.

Key Features of the FEAT Program

- Performs validation of monthly fuel consumption data and provides output reports of data records that fail the validation checks.
- Calculates and presents the buses ranked by their relative fuel efficiencies.
- Calculates and presents the drivers ranked by their relative fuel efficiencies.
- Calculates and presents the absolute fuel efficiencies of each bus.
- Calculates and presents the absolute fuel efficiencies of each driver.
- Presents the calculation results for each bus route.
- Calculates the changes in fuel efficiencies from one month to another for each bus.
- Calculates the changes in fuel efficiencies from one month to another for each driver.

The FEAT program requires some customization to perform the targeting analysis in a depot. An inventory of the buses operated is needed to validate fuel consumption data and, as necessary, to analyse consumption data by different bus types. A listing of bus routes operated is needed to validate fuel consumption data and, as necessary, to group or split the consumption data for analysis.

Ideally, the bus companies adopting the targeting methodology should make this analysis a standard component or reporting tool of their management information systems (MIS). The FEAT program can serve these companies as an interim program until this is done.

[3] The FEAT program was developed to support demonstrations in the four cities. The program provided reasonable results but has not been exhaustively tested for errors. The program can be obtained by contacting the World Bank office in New Delhi.

3. Bus Maintenance Protocols

The next step after ranking buses based on their relative fuel economies compared to route averages is selecting the worst performing ones and implementing a maintenance plan to improve their performance. This chapter presents the selection of low-performing buses and a description of the maintenance protocols that are included in the two-tier maintenance program.

Selection of Low-Performing Buses

Low-performing buses are selected from the buses in rank order of their relative fuel economies. The suggested ESMAP guideline[4] is that the lowest 10 per cent of the buses be selected monthly. A smaller percentage of buses (for example, 5 per cent) can be selected if the company's resources are limited.

The timing of maintenance protocols may also affect the selection of low-performing buses. The suggested approach is that a new group of low-performing buses be selected every month. However, since the implementation of the maintenance protocols could take almost an entire month, the group of buses selected at the beginning of month one should not be considered for selection until the beginning of the third month.

For example, Bus 106 is selected as one of the lowest-performing buses on January 1 based on an analysis of the December fuel consumption data. The maintenance protocols are applied to Bus 106 during January. A second analysis is performed on February 1 based on the analysis of fuel consumption for January. Bus 106 is not included in this analysis since it was undergoing the maintenance protocols during January. Bus 106 should again be analysed when the data for February is used. At the earliest this will be on March 1.

It is important to recognize that all under-performing buses will be selected eventually. The buses picked in January are the lowest 10 per cent performing buses. The buses picked in February are the next lowest 10 per cent performing buses. After the February selection, the lowest 20 per cent of the buses will have been selected to undergo the maintenance protocols. The performance of most of these buses will improve after the maintenance protocols are applied. Therefore, the buses that will be selected in March and April will predominately be the next lowest 20 per cent of the buses or buses that were generally ranked 21 per cent to 40 per cent in January and February.

The Two-Tier Maintenance Program

The objective of the two-tier maintenance program is to apply a systematic approach for improving the performance of buses with low relative fuel economies. The program involves going through a list of maintenance checks and making repairs or adjustments as necessary.

Many of the recommended checks are familiar because they are used in preventive

[4] Based on our experiences with various Indian bus companies and the resources that the companies could devote to implementing this program.

maintenance programmes commonly used by many bus transport companies. The two-tier program should not be considered as a substitute for normal preventive maintenance and inspection programmes. Instead, the program should be treated as a special 'campaign' program that focuses on improving the performance of targeted buses and as a supplement to on-going programmes.

Tier-1 Checks

Tier-1 checks and repairs (Exhibit 7) are applied to all the low-performing buses as per the recommendations of the vehicle manufacturer. The 19 items are simple checklists that can be performed at an operating depot and do not require a maintenance hoist or an inspection pit. More detailed guidance on performing Tier-1 checks is provided in Annex 2.

Generally, these checks can be performed by junior or mid-level mechanics. A team of one mechanic and a helper can perform Tier-1 checks for three buses during an eight-hour work shift.

Exhibit 7: Tier 1 Checklist and Repair Form

Name of the Depot: **Names of the Mechanic who attended:**		**Vehicle Number:** **Date:**		
Component	**Check/Attention**	**Observation/ Action Taken**	**Signature of Technician**	**Signature of Supervisor**
Tires/Wheels	1. Tire Inflation as per Inflation chart			
	2. Free Rolling of Wheels			
	3. Wheel Bearing Condition & Lubrication			
Brakes	4. Brake Pedal Free Play			
	5. Gap between Brake Liner and Drum/Disc			
	6. Caliper Boot & Wear Adjuster Cap			
	7. Brake Retraction after Pedal Release			
Driveshaft/ Axles	8. Lubrication of Driveshaft Joints & Bearings			
	9. Lubrication of Differential			
	10. Tightness of Driveline & Gearbox Mounting Bolts			
Accelerator/ Clutch Pedal	11. Condition of Clutch Pedal Linkages			
	12. Condition of Accelerator Linkages & Lubrication			
	13. Accelerator Return Spring Condition			
Engine	14. Air Cleaner Condition (Choke Indicator)			
	15. Exhaust Pipes/Muffler Blockage			
	15. Fault Codes Displayed from On-board Diagnostics			
	16. Visible Smoke Level on Snap Acceleration			
Air Conditioner	17. A/C Compressor Belt Tension			
	18. Refrigerent Pressure			
	19. Compressor Working Condition			

Tier-2 Checks

Tier-2 checks and repairs (Exhibit 8) are applied only to low-performing buses that do not show significant improvement (defined as greater than 3 per cent) after the Tier-1 checks are applied.

A two-step process is followed to determine if a low-performing bus has to undergo Tier-2 checks:

- If a bus fails some of the Tier-1 checks and repairs or adjustments are made, then the fuel economy of the bus (kmpl)

Exhibit 8: Tier 2 Checklist and Repair Form

Name of the Depot:		Vehicle Number:		
Names of the Mechanic who attended:		Date:		
Component	**Check/Attention**	**Observation/ Action Taken**	**Signature of Technician**	**Signature of Supervisor**
Wheels	1. Wheel Alignment			
	2. Tire Camber			
	3. Wheel Bearing Play			
Clutch	4. Condition of Clutch Facings			
	5. Condition of Pressure Plate & Flywheel Facing			
	6. Condition of Release Bearing & Linkages			
Fuel System Diesel/CNG	7. Leakage of Fuel from Fuel Tank/Fuel Lines			
	8. Leakage of Gas (with Smoke Detector)			
	9. Tightness of Tanks Mounting & Pipes Clamps			
Engine (Diesel)	10. Fuel Injection Pump Timing & Max Fuel Stop Setting			
	11. Fuel Injection Pump Working Condition			
	12. Condition of Injectors (Spray/Pressure Test)			
	13. Condition of Turbocharger			
	14. Tightness of Cylinder Head Bolts/Nuts & Cyl Head Condition			
	15. Engine Oil consumption/ Engine Blow-by Condition			
	16. Cylinders Compression Values (for High Oil Consumption)			
	17. Engine Overheating/Coolant Loss (Flush if Required)			
Engine (CNG)	10a. Air-Fuel Mixer Settings			
	11a. Gas Pressure Regulator Condition			
	12a. Ingnition Coil, Distributor, HT Cables & Spark Plugs			
	13. Condition of Turbocharger			
	14. Tightness of Cylinder Head Bolts/Nuts & Cyl Head Condition			
	15. Engine Oil consumption/ Engine Blow-by Condition			
	16. Cylinders Compression Values (for High Oil Consumption)			
	17. Engine Overheating/Coolant Loss (Flush if Required)			
Exhaust System	18. Condition of Muffler & Catalytic Converter			
	19. Exhaust Brake Butterfly Operation			

is tracked for two weeks. If there is less than a 3 per cent improvement in fuel economy as compared to the average for the previous month, then the bus proceeds for Tier-2 checks.

- If a bus passes all the Tier-1 checks, it then proceeds to Tier-2 checks. There is no need to monitor the fuel economy of the bus for two weeks because no repairs or adjustments are made.

Tier-2 checks are complex and require a maintenance hoist or inspection pit. Typically, these checks are performed at a central facility or an outside specialized facility. More detailed guidance on performing Tier-2 checks is provided in Annex 2.

These checks must be performed by expert senior mechanics. A team of one mechanic and a helper can generally perform Tier-2 checks for one bus during an eight-hour work shift.

Exhibit 9 provides an example of how this process was applied to three low-performing buses to which Tier-1 checks were applied. Bus 12 advanced to Tier-2 checks because no problems were found and it passed all Tier-1 checks. Buses 23 and 34 failed some of Tier-1 checks and repairs were made. Bus 23 advanced to Tier-2 checks because its average kmpl improved less than 3 per cent in the two weeks following the completion of Tier-1 repairs. Bus 34 did not advance to Tier-2 checks because its average kmpl improved more than 3 per cent in the two weeks following the completion of Tier-1 repairs.

It should be noted that the threshold value of a 3 per cent improvement is based on the judgment of experienced maintenance managers and average improvements found in prior applications of the ESMAP approach. Some companies may choose a different threshold value based on their own judgment and local circumstances.

Exhibit 9: Example of Advancing Tier 1 Buses to Tier 2 Checks

Bus	Average kmpl Previous Month	Passed All Tier 1 Checks?	2 Weeks After Tier 1 Checks Completed		Advance to Tier 2 Checks?	Reason
			Average kmpl	% Change Previous Month		
12	2.65	Yes	Not Applicable		Yes	Passed all Tier 1 checks
23	2.53	No	2.59	2.4%	Yes	Improvement < 3%
34	2.79	No	3.00	7.5%	No	Improvement > 3%

4. Bus Driver Training

A driver's performance is perhaps the largest factor impacting bus fuel economy. Significant improvements in fuel economy can be achieved through drivers employing more efficient driving techniques. Most bus companies have driver training programmes which focus primarily on safe driving and operating the buses in accordance with service schedules. The use of fuel-efficient driving techniques is included in these programmes, but often it is not emphasized even though some of these techniques are very supportive of safe driving. This chapter describes the driver training program that has been developed to improve the performance of drivers with low fuel economy.

Selection of Low-Performing Drivers

Low-performing drivers are selected from a listing of drivers in rank order of their relative fuel economies. The suggested ESMAP guideline[5] is that the lowest 5 per cent drivers be selected monthly. A smaller target percentage of drivers (5 per cent) than buses (10 per cent) are selected because bus companies often employ at least two drivers for every bus. A smaller percentage of drivers (for example, 3 per cent) can be selected if the company's resources are limited.

The timing of the driver training program may also affect the selection of low-performing buses. The suggested approach is that a new group of low-performing drivers be selected every month. Since implementation of the driver training program can take three to four weeks, the group of drivers selected at the beginning of month one should not be considered for selection until the beginning of the third month.

For example, Driver 56 is selected as one of the lowest-performing drivers on January 1 based on an analysis of December fuel consumption data. Driver 56 receives driver training during January. A second analysis is performed on February 1 based on the analysis of fuel consumption for January. Driver 56 is not included in this analysis since he received driver training during January. Driver 56 will again be analysed when the data for February is used. At the earliest, this will be on March 1.

It is important to recognize that all under-performing drivers will be selected eventually. The drivers picked in January are the lowest 5 per cent performing drivers. The drivers picked in February are the next lowest 5 per cent performing drivers. After the February selection, the lowest 10 per cent drivers will have been selected to undergo targeted training. The performance of most of these drivers will improve after they receive training. Therefore, the drivers who will be selected in March and April will predominately be the next lowest 10 per cent of drivers or drivers that were generally ranked 11 per cent to 20 per cent in January.

Driver Training Program

The training program consists of two components:

- One-day of classroom training

[5] This guideline is based on experiences with various Indian bus companies and the resources that the companies could devote to implementing this program.

- One-day of on-road training

Classroom Training

Classroom training is divided into two parts:

- motivation discussion on the important role played by drivers in fuel efficiency, and
- a presentation of technical driving techniques for improving bus fuel economy.

The classroom training usually takes about four hours depending on the level of driver participation in the training.

Motivation Training on the Important Role Played by Drivers

A significant amount of training time is devoted to driver motivation. Drivers have the maximum impact on bus fuel economy. They also happen to be the most autonomous employees in a company since they work independently and receive limited direct supervision. Therefore, significant improvements in bus fuel economy will occur only if the drivers are self-motivated.

The motivation is organized around six key messages:

i. **The purpose of the training is to provide driving tips, not driving instructions**. The motivation training begins by stating that the purpose of the training is to provide simple driving tips that will help the drivers save fuel. It is emphasized that the purpose of the training is not to teach drivers how to drive a bus.

ii. **Drivers have the ability to make impromptu decisions based on traffic and road conditions.** In this context the role of a driver is in a way similar to that of a judge in a court of law. A driver and a judge are both required to make appropriate assessments of a situation and decide on the best course of action. The basic differences are timing and scope of impact. A judge can take extra time to study the case and issue the final decision based on a careful review of the available evidence. The decision of the judge generally affects a small number of people. The driver must be more spontaneous and make his decision in a very short time (in seconds during emergencies). The driver must be vigilant at all times, have the ability to assess the traffic and road conditions and be prepared to take impromptu decisions. Any misjudgement by the driver will affect a large number of people travelling with him in the bus.

iii. **Being diligent helps a driver achieve what is important in life.** People choose to become drivers; they are not compelled. Therefore, each driver should be diligent in carrying out his duties and not complain about the circumstances. A driver should take responsibility for driving efficiently and achieving good mileage. This will result in savings for the bus company and help it remain profitable. If the bus company is profitable, it can pay drivers decent salaries. This, in turn, allows drivers to meet family needs, provide good education for their children and lead decent lives.

iv. **Reducing expenses is the best way for employees to help the bus company be profitable.** Reducing salaries and expenses is one way of helping a bus company remain profitable and possibly increase its profits. Whether salaries or expenses are reduced makes a huge difference to employees. Reducing salary expenses has an adverse impact on employees through reduced pay or staff retrenchment that involves job losses for drivers, conductors and other staff members. Reduction in other expenses such as fuel has a positive impact because no salaries are cut or jobs lost. In fact, this increase in profitability provides a bus company the opportunity to increase salaries or provide new salary incentives. Since fuel is the largest expense of a bus company and drivers are the primary users of fuel, drivers should be accountable and help a bus company reduce its fuel expenses.

v. **Targeting drivers and fuel consumption is the best way to reduce expenses.** If a bus company has to reduce expenditures to improve its income or profits, the most logical group of employees to target is drivers. Fuel is the largest expenditure item for most bus companies and drivers the major employees for managing this expenditure item. Focusing on better expense control by other employee groups in a bus company will help but will not yield the same level of cost savings or impact on company profitability.

vi. **The purpose of the training is to clear some misconceptions that all drivers have.** The motivation training ends by restating that the purpose of the training is to clear misconceptions that all drivers have. The saving of 2 litres of diesel a day is a practical and achievable target. This can be achieved only through some mindful driving that includes some important driving tips.

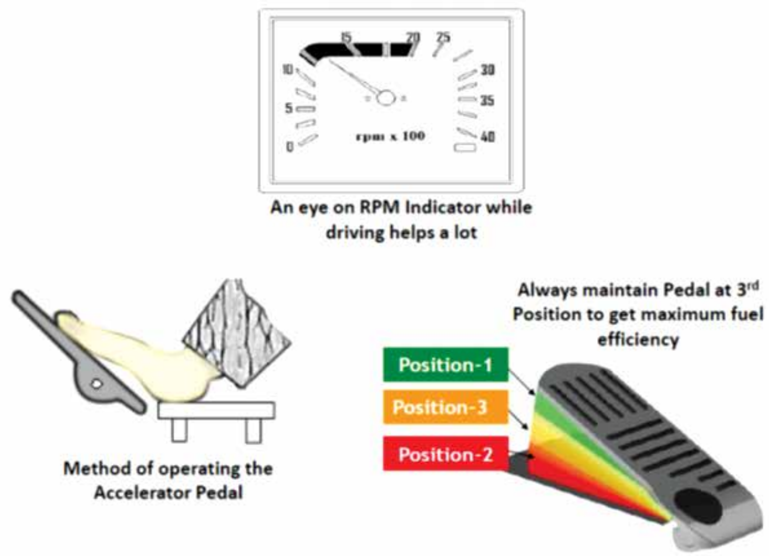
Becoming mindful drivers should not be construed as meaning that the drivers do not know how to drive. Instead, the only intent is to clear some misconceptions that all drivers have and to adopt some simple practices that will yield significant fuel savings.

Technical Driving Techniques for Improving Bus Fuel Economy

Fuel efficient driving techniques are discussed after the motivational training is completed. It is emphasized that all drivers can learn these techniques and apply them every day on their buses. Drivers must constantly remind themselves to use these techniques or they can slip into bad habits.

The training covers the following four key topics regarding fuel efficient driving techniques. The driver trainer refers to the figures in Exhibit 10 as part of the presentation.

Exhibit 10: Key Fuel Efficient Driving Techniques



i. **The Bus Starting Process.** Unnecessary fuel can be consumed during the starting process when the engine is cold. The driver can reduce the fuel consumed by:

- **Checking the air metres to see if they are correct before starting the ignition.** This eliminates the starting of a bus without proper air pressure.
- **Starting the bus in the idling condition without pressing the accelerator.** The driver consumes unnecessary fuel when he starts the bus by pressing the accelerator.
- **Keeping his foot on the foot rest near the accelerator.** Every bus should have a foot rest placed near the accelerator. This helps the driver eliminate the habit of resting his foot on the accelerator which pushes the accelerator down and consumes unnecessary fuel.

ii. **Shifting Gears.** Most buses in India use manual transmissions. Excessive fuel can be consumed through improper acceleration and shifting and poor matching of gears with bus speed.

Drivers can become more fuel efficient by shifting gears according to the following guidelines. These are general guidelines and should be modified to reflect the specific size and horsepower of the bus being driven:

- A driver should set the bus in motion using the first gear and without using the accelerator.

- A driver should use the second gear for driving up to a speed of 15 kmph and keep the accelerator at the ¼ accelerator position.
- A driver should use the third gear for driving up to a speed of 25 kmph and keep the accelerator at the ½ accelerator position.
- A driver should use the fourth gear for driving up to a speed of 35 kmph and keep the accelerator at the ¾ accelerator position.
- A driver should use the fifth gear for driving at top speed (45 to 50 kmph) and keep the accelerator in the full position.

Initially, a driver should follow these guidelines for shifting gears and selecting the proper gears. Monitoring the tachometer can help a driver. However, over time, a driver should learn to 'hear' how the engine is performing and keep the engine running smoothly by selecting the proper gear accelerator position.

Smooth shifting and selecting proper gears are very important in urban bus operations. Due to congestion and constant stopping and starting, bus drivers seldom operate in the top gear most of the time. Generally, drivers operate within the first three or four gears.

iii. **Use of Accelerator.** An accelerator position should be at a 45° angle when not in use. A driver can consume unnecessary fuel through an improper positioning of his foot. When the accelerator is not being pushed, the foot should rest on the foot pad and not on the accelerator. When the accelerator is being applied, a driver should use his toes to apply the pressure to the accelerator. This provides smoother acceleration. It also positions the foot to be in the proper resting position when the accelerator is not being used.

iv. **Driver Anticipation.** A good driver is always looking ahead in traffic to anticipate stops at traffic signals or bus stops and slowdowns due to traffic congestion. A driver should strive to smoothly accelerate and brake. He should avoid patterns of hard acceleration and braking often known as 'hurry-up-and-stop.'

A driver should make good use of bus coasting or momentum as a way of maintaining cruising speed, reducing fuel consumption and providing passengers with a comfortable ride. As a general rule, a driver should remove his foot from the accelerator about 100 metres before stoppage points such as bus stops or traffic signals and for slowing down at speed breakers and turnings.

It is emphasized throughout the discussion that these driving techniques have other benefits besides fuel efficiency. Using these techniques can promote greater bus safety because a driver is constantly anticipating how traffic and other vehicles will behave. Using the techniques also helps provide a more comfortable and smoother ride for passengers.

On-the-Road Training

The classroom training is followed by two to three hours of on-the-road training. A driver trainer takes the entire class of drivers on the road in an older bus on an actual bus route used by the bus company. The objective of

the training is to demonstrate fuel efficient driving techniques and to give each driver an opportunity to try the techniques in real world conditions.

The bus is driven on an actual bus route. Stops are made periodically to simulate picking up and dropping off passengers.

Before the bus is taken out for the training, it is fuelled or 'topped up' and the odometer reading is recorded. This is done because the fuel economy of the training trip will be calculated at the end of the training when the bus is refuelled and the ending odometer reading is taken.

The importance of parking the bus in a particular marked position at the fuelling station is also emphasized when fuelling the bus. Parking the bus in the same position at the fuelling station every time the fuel is topped ensures accuracy in the recording of the fuel consumed.

The first part of the training begins with a driver trainer demonstrating the proper techniques for bus starting, gear shifting and accelerating and stopping. The trainer uses an older bus to demonstrate that the techniques can apply to all types of buses.

After the driver trainer completes his demonstration, each driver is given the opportunity to demonstrate his application of fuel efficient driving techniques. Each driver is given five to ten minutes of driving time.

The driver trainer and the other drivers observe the performance of each driver. As appropriate, the driver trainer makes comments to the class and the driver about the positive aspects of his performance and suggestions for improvement.

After the training is complete, the bus is refuelled and its kmpl calculated for the training trip. Since all the drivers try to be fuel efficient on the training trip, the calculated kmpl is generally much higher than the average kmpl for the bus company's operations, sometimes greater than 50 per cent. The trainer emphasizes that the training kmpl results are achievable using good driving techniques.

Follow-Up Monitoring

It is important to reinforce the training that each driver receives. A driver trainer provides this reinforcement by monitoring each driver's performance in regular bus operations once a week for three weeks after a driver finishes his training.

The driver trainer uses a checklist (Exhibit 11) that covers key aspects of fuel efficient driving techniques. As appropriate, the driver trainer makes comments to a driver about the positive aspects of his performance and makes suggestions for improvement.

Exhibit 11: On Route Driver Performance Monitoring Checklist

Driver Name: ____________________	Driver ID No. ___________	Bus Number: ____________
	Route Number: _____________	Date: ____________________

kmpl of Driver during previous month (पिछले महीने के दौरान चालक की kmpl) ________

(for eg. Since monitoring will be done in January 2014, kmpl of driver to be put December 2013.
(उदाहरण के लिए: MONITORING जनवरी 2014 में करेंगे, तो चालक की दिसंबर 2013 की kmpl का उल्लेख करे)

Description	Week 1 Yes (हां) / No (नहीं)	Week 2 Yes (हां) / No (नहीं)	Week 2 Yes (हां) / No (नहीं)
BUS STARTING PROCESS			
1 Did the driver check BEFORE STARTING THE IGNITION whether the pressure in both the "AIR METERS" are correct? इग्निशन शुरू करने से पहले क्या चालक ने दोनों "एयर मीटर" में दबाव सही हैं या नहीं इसकी जांच की?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
2 Did the driver keep the FEET ON THE FOOT REST NEAR ACCELERATOR ? चालक ACCELERATOR के पास footrest पर पैर रखा था ?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
3 Did the driver start the bus in «IDLING» condition without pressing the accelerator ? चालक एक्सीलेटर दबाने के बिना IDLING CONDITION में बस शुरू कर दिया?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
Monitoring of GEAR AND ACCELERATOR usage:			
4 Did the driver set the bus in motion using FIRST GEAR WITHOUT ACCELERATOR ? क्या चालक ने बिना ACCELERATOR दबाये पहले गियर में बस को गति मे लेकर आया?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
5 Did the driver use SECOND GEAR for driving upto a speed of 20kmph and keep the ACCELERATOR at 1/4th position? क्या ड्राइवर ने 20kmph की रफ्तार तक ड्राइविंग के लिए दूसरे गियर का उपयोग किया और ¼ स्थिति पर ACCELERATOR रखा था ?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
6 Did the driver use THIRD GEAR for driving upto a speed of 30kmph and keep the ACCELERATOR at 1/2 position? क्या ड्राइवर ने 30kmph की रफ्तार तक ड्राइविंग के लिए तीसरे गियर का उपयोग किया और ½ स्थिति पर ACCELERATOR रखा था ?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)

Description	Week 1 Yes (हां) / No (नहीं)	Week 2 Yes (हां) / No (नहीं)	Week 2 Yes (हां) / No (नहीं)
7 Did the driver use FOURTH GEAR for driving upto a speed of 40kmph and keep the ACCELERATOR at 3/4 position? क्या ड्राइवर ने 40kmph की रफ्तार तक ड्राइविंग के लिए चौथे गियर का उपयोग किया और ¾ स्थिति पर ACCELERATOR रखा था ?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
8 Did the driver use FIFTH GEAR for driving at TOP SPEED and keep the ACCELERATOR in FULL position? क्या ड्राइवर ने TOP SPEED पर ड्राइविंग के लिए पांचवें गियर का उपयोग किया और ACCELERATOR को पूरा दबा रहा था?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
9 Depending upon road or traffic condition, did the driver use the POWERPOINT POSITION on the ACCELERATOR when driving at maximum speed? सड़क या यातायात की स्थिति पर निर्भर, क्या ड्राइवर ने अधिकतम गति से गाड़ी चला एक्सीलेटर पर पावरपोइंट स्थिति का उपयोग किया था?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
10 Did the driver use his / her TOES for PRESSING THE ACCELERATOR ? क्या ड्राइवर ने ACCELERATOR दबाने के लिए पैर की उंगलियों का उपयोग किया?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
11 Did the driver REMOVE THE FEET FROM THE ACCELERATOR 100 meters BEFORE the stoppage point such as bus stops, traffic signals etc. and for slowing down at speed breakers and turnings ? क्या ड्राइवर ने STOPPAGE POINT, जैसे बस स्टॉप, SIGNAL इत्यादी, से 100 मीटर पहले तथा गति- रोधक अथवा मोड़ पर बस की गति को धीमा करने के लिए ACCELERATOR से पैर हटाया ?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
12 Did the driver DRIVE WITHOUT PRESSURE AND WITH CONCENTRATION ? दबाव के बिना और एकाग्रता के साथ ड्राइवर ने ड्राइव किया था?	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)	Yes (हां) No (नहीं)
kmpl Achieved (kmpl हासिल की): ->			

Additional Comments of Trainer (ट्रेनर की अतिरिक्त टिप्पणियाँ):

Signature of Trainer : ______________________________ Signature of Driver: ______________________________

Name of the Trainer: ______________________________ Name of the Driver: ______________________________

Annex 1: Pilot Demonstration Details

Design

The objective of this project was to demonstrate and test the practical application of the ESMAP approach in four cities in India — Bhopal, Chandigarh, Jaipur and Mira Bhayandar.

After preliminary discussions with the transport managers in the four cities, it was determined that the ESMAP approach needed to be demonstrated first before the cities implemented all 16 action steps. This chapter describes the approach that was followed for the four demonstration cities. It then outlines the objectives of the demonstration.

Approach

The four cities were selected to demonstrate and test the application of the ESMAP approach that has been outlined in the previous three chapters. The ESMAP approach was applied at one depot in each city. Local staff in each city was trained to implement the approach.

The buses assigned to each depot varied from 50 buses in Mira Bhayandar to 210 buses in Jaipur (Exhibit 12). The smallest depot was in Mira Bhayandar with 50 assigned buses which represented the entire bus fleet in the city. There were multiple depots in the other three cities.

Exhibit 12: Buses Assigned to Demonstration Depots

City	Depot Name	Assigned Buses
Bhopal	City	149
Chandigarh	Depot 4	100
Jaipur	Sanganer	210
Mira Bhayandar	Flyover	50

The operating environments also varied in the cities (Exhibit 13). In three cities, there were dedicated maintenance facilities such as repair shop buildings, inspection pits and washing facilities. There were no dedicated maintenance facilities at Mira Bhayandar. Buses in this city were maintained out of doors under a flyover in very difficult circumstances.

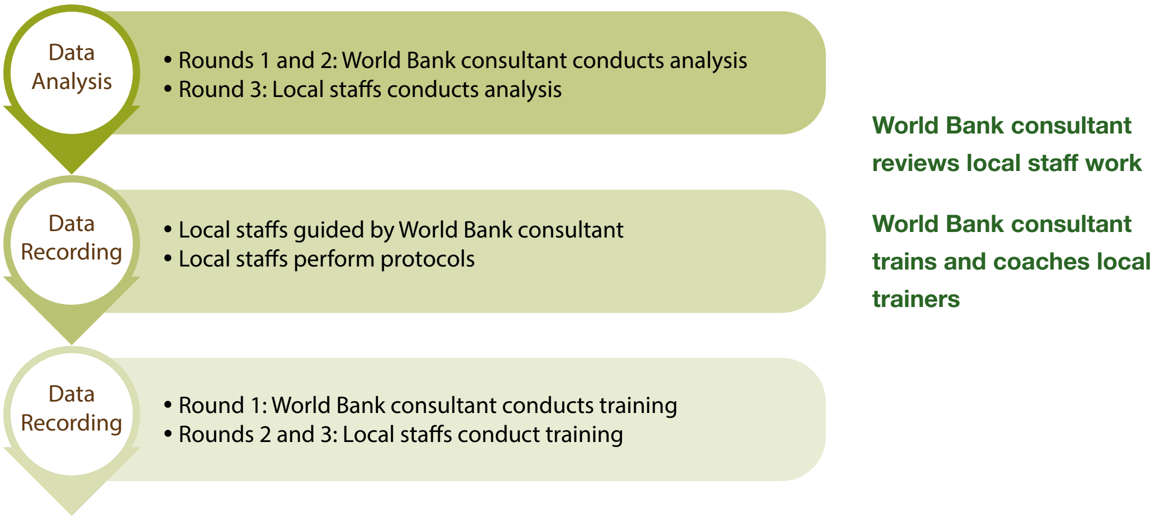
Exhibit 13: Key Operating Differences Among Four Cities

City	Depot Facilities?	Adequate Depot Capacity	Formal Fuel Efficiency Program?
Bhopal	Yes	Yes	Yes
Chandigarh	Yes	Yes	No
Jaipur	Yes	No	No
Mira Bhayandar	No	No	No

Depot 'adequacy' also varied in the four cities. Support facilities in Mira Bhayandar were clearly inadequate. Overcrowding was a severe problem in Jaipur where 201 buses were being maintained in a depot with design capacity for less than 100 buses. The depot in Jaipur was very old and in need of complete refurbishment. In contrast, adequate capacity was provided in Bhopal and Chandigarh. The Bhopal facility was operating at near capacity, but was well organized. The Chandigarh facility had acceptable space and facilities.

The last difference among the four cities was formal attention to fuel efficiency. The operators in three of the four cities did

Exhibit 14: Local Staff and World Bank Roles in Demonstrations



not have formal programmes that focused on improving fuel efficiency. The operator of the Bhopal depot had a formal fuel efficiency program that focused on driver performance. The program tracked and reported individual driver fuel efficiency. It provided financial rewards to drivers who performed above average and provided training to drivers who were significantly below average. The Bhopal management credits this program with improving fuel efficiency by over 10 per cent since it was initiated in 2011. The Bhopal operator did not have a comparable program that addressed bus maintenance.

Plan

The demonstration plan was to apply the ESMAP approach for three rounds. Every month (round) 5 per cent of the drivers and 10 per cent of the buses with the lowest relative fuel economies would be identified. The ESMAP driver training and maintenance protocols would then be applied to the identified drivers and buses.

The objective of the demonstrations was that the local managers would conduct a fuel economy analysis and apply driver training and maintenance protocols. As needed, technical support was to be provided by World Bank consultants.

After discussions with the managers in the four cities, an implementation plan was developed that phased in local fuel economy analyses and driver training. World Bank consultants would perform the fuel economy analysis in the first two rounds and hand over this responsibility to the local staff in the third round.

Similarly, World Bank consultants would conduct driver training in the first round. In the second round, the local staff would conduct the driver training under guidance and coaching of World Bank consultants. The local staff would conduct the driver training completely on its own in the third round. The roles of the local and World Bank consultants are summarized in Exhibit 14.

Objectives

There were four objectives for the pilot demonstrations which guided the conducting of the pilot and the development of technical material:

- Demonstrate a technical approach
- Develop and refine analysis techniques
- Document maintenance and training protocols
- Prepare an operations manual

Objective 1: Demonstrate a Technical Approach

The ESMAP recommended action plan focuses on five principles (Exhibit 15). These principles are a combination of technical and management actions.

To demonstrate the potential benefits of the ESMAP approach it was decided to limit the focus of the pilot demonstrations to three ESMAP technical actions:

- Data collection and analysis
- Maintenance of low fuel efficient buses
- Training of low-performing drivers

There would be no formal implementation of the two management action areas — management commitment and ownership and employee communication and rewards — in the pilot demonstration. These are actions 1-3 and 15-16 in Exhibit 15. It was felt that employee rewards and incentives and management bonuses could involve significant costs and the systems might be unwilling to implement these actions until fuel savings were shown.

It was expected that the full ESMAP program would be implemented after the technical benefits were shown.

Exhibit 15: Management and Technical ESMAP Principles

Princi-ples		Action		Management/ Technical
I.	Management Commitment and Ownership	1	Appoint a senior executive to be in charge of fleet fuel economy and tie some part of his/her bonus to meeting fuel economy goals.	Management
		2	Benchmark and set appropriate fuel economy goals by bus type for each year.	
		3	Communicate the fuel economy results achieved each year to both employees and the public.	
II.	Data Collection and Analysis	4	Automate data collection to the extent feasible and use analysis software to support maintenance.	Technical
		5	Set up data QA/QC procedures.	
		6	Analyze the data for separating the effects of driver, route and bus related effects on fuel economy.	
		7	Use data to refine periodic maintenance.	
III.	Maintenance of Low Fuel Efficient Buses	8A	Select 10 percent of the fleet showing the lowest fuel economy and conduct simple checks at depot.	Technical
		8B	Conduct detailed checks at central facility if bus passes step 8A.	
		8C	Compare pre-repair and post-repair fuel economy data on these buses to estimate program benefits.	
		9	Check repair quality on a random and periodic basis.	
		10	Obtain mechanic sign-off on repairs for traceability.	
		11	Require independent team audit of repairs across depots.	
		12	Retrain mechanics and update repair procedures periodically.	
IV.	Training of Low-Performing Drivers	13	Train drivers in fuel-efficient driving techniques and periodically retrain them.	Technical
		14	Select the 5 percent of drivers with the lowest fuel efficiency and conduct special additional training.	
V.	Employee Communi-cations and Rewards	15	Publicly display the fuel economy performance by driver and bus depot to employees.	Management
		16	Reward mechanics at the depot level and drivers individually for exceeding targets.	

Objective 2: Refine Analysis Techniques

The 2011 ESMAP guidance note on *Transit Bus Operational and Maintenance Practices to Maximize Fuel Economy* has a very good overall approach but provides limited information on analysis techniques. As part of the preparation work for the pilot demonstrations, further work was identified and conducted in two analytical areas: data validation and targeting of low-performing buses and drivers.

This work is documented in detail in the chapter ***Targeting Methodology*** in this guidance note.

Objective 3: Document Maintenance and Training Protocols

The 2011 ESMAP guidance note on *Transit Bus Operational and Maintenance Practices to Maximize Fuel Economy* describes elements that comprise maintenance and driver training protocols but does not provide detailed instructions on how to conduct the protocols. These instructions are necessary for the local city staff members to conduct a fuel economy analysis and for applying the protocols.

Detailed instructions were prepared and are documented in the chapters ***Bus Maintenance Protocols*** and ***Bus Driver Training.***

Objective 4: Prepare Operations Manual

The 2011 ESMAP guidance note on *Transit Bus Operational and Maintenance Practices to Maximize Fuel Economy* is limited as it provides step-by-step procedures or is a 'how-to' manual. Hence, this current guidance note is written as a simple operations manual for local urban transport managers. It focuses on three ESMAP technical actions:

- Data collection and analysis
- Maintenance of low fuel efficient buses
- Training of low-performing drivers

In addition, a simple, runtime Access program ***Fuel Efficiency Analysis Tool (FEAT)*** was written to conduct the targeting analysis. The runtime version allows users to run the FEAT program without purchasing or installing the Microsoft Access program on their computers.

Annex 2: Pilot Demonstration Results and Lessons Learned

This Annex presents the results from three rounds of applying the ESMAP approach. It also discusses lessons learned regarding the application of a technical analysis and protocols.

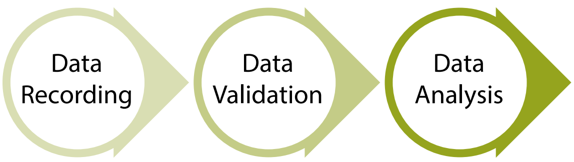
The Annex is divided into four sections:

- Data Collection and Management
- Driver Pilot
- Bus Maintenance Pilot
- Summary

Data Collection and Management

Results

Most transport companies in India rely on manual recording of daily fuel consumption data. When each bus is fuelled (typically at the end of the day), an employee who is assigned the fuelling duty records the fuelling data. In most companies, the data is recorded in a paper fuelling form. In some systems, the data is entered into an electronic form.



The daily recording of fuel consumption was an established practice at the four pilot cities. Internal control of fuel disbursement was a major reason for recording fuel consumption data in all the four cities.

The ESMAP targeting approach requires a monthly analysis of about 3,000 data records for a depot housing 100 buses. This approach requires a computer analysis of fuel consumption data. This means that a data entry clerk must transcribe the data from a paper fuelling form into an electronic format.

The electronic format for the fuel consumption data used in the FEAT program is an Excel spread sheet. Each row in the spread sheet is a fuel consumption record of filling a bus on a specific day. Each column is a data item such as date, bus number, driver number, daily operated kilometres and fuel added in litres. An example of the Excel spread sheet used for Bhopal is shown in Exhibit 16.

Initially this requirement was a problem for operators in Chandigarh, Jaipur and Mira Bhayandar because they were not familiar with the basic data entry requirements for a computerized analysis. Common errors included leaving blank rows in the spread sheet or not using the exact data labels for

Exhibit 16: Example of Bhopal Fuel Consumption Data Format

Input date	Bus Number	Rpoute Number	Driver 1	Driver 2	Driver 3	Daily Operated KM	Fuel Added Litres
01.03.2014	1082	Sr-2		CBB00709		88	23
01.03.2014	1083	SR-2		CBB00407		126	34
01.03.2014	1120	SR-2		CBB01342		130	32
01.03.2014	1329	SR-2		CBB01102		128	32

the data items (for example, using the word *date* instead of the *Input date* (Exhibit 16)).

In the beginning, often more than 20 per cent of the data records were found unusable. However, the World Bank consultants discussed these problems with the operators and the percentage of unusable records quickly declined to less than 2 per cent.

The operator in Bhopal did not have this data entry problem probably because he was using the data to track fuel economy by route and driver as part of his formal fuel efficiency program.

The validation (data-error checking) of the consumption data varied among the four cities. Initially the error checks in the FEAT program flagged about 20 per cent of the data records as being incomplete or questionable. By the end of the pilots, the data quality had improved in all the cities so that over 99 per cent of the data records passed the error checks.

The four cities were found to have limited or no analysis capabilities. The cities generally did not store the data in a format by which they could 'query' the data and perform special analyses.

As such it became important to identify the right person possessing the right talent and skill mix within the bus company who could manage a database and conduct the fuel efficiency analysis. The World Bank team worked with each bus operator to identify staff members with appropriate technical backgrounds and computer skills to perform the 'analyst' role during the course of the pilot demonstrations. The World Bank team trained these identified staff as 'analysts' to use the FEAT program.

The analysts quickly grasped and learned how to apply the FEAT program. By the third round, the analysts could conduct data validation and perform the targeting of poorly-performing drivers and buses independently and with no assistance from World Bank consultants.

The effort to identify and train local analysts highlighted the importance of the senior management's commitment. In two of the cities, the senior management empowered middle managers to address local analyst problems quickly.

However, in the remaining two cities instead of days it took several weeks to address the analyst issue. Only when the World Bank team in concert with the middle management met with the senior management to highlight the importance of the analyst was the issue resolved.

Lessons Learned

Bus operating company should consider moving towards automated recording of fuel data which, in addition to improving data accuracy, would also reduce the scope for fuel pilferage.

A major lesson learned was that the bus operators must have suitable staff to perform a fuel efficiency analysis required to implement the ESMAP approach. However, targeted training such as that provided by the World Bank team during the demonstrations is needed for analysts. When this is done carefully, the local analysts can acquire the skills to conduct data validation and targeting of poorly-performing drivers and buses independently.

The senior management's commitment is needed to support this effort. Middle managers need to be empowered to identify and train local fuel efficiency analysts and dedicate resources to this on-going effort.

Driver Pilot

Results

Three rounds of the driver pilot were conducted in the four cities in December 2013, February 2014 and March 2014.

Data was collected and analysed to assess the immediate impact of the training and follow-up monitoring of the targeted drivers.

This was done by comparing the fuel economy of each driver one month before and one month after the driver training was conducted. For example, in the first round in December 2013 the fuel economy of each driver in November (before month) was compared to the fuel economy in January 2014 (after month).

The results of the three rounds varied by round and city (Exhibit 17). The average improvement in kmpl was about 4 per cent. However, by city and month, the average improvements ranged from a low of -2 per cent to a high of 13 per cent. These results are lower than the previous ESMAP applications in which average improvements of 6 per cent to 8 per cent were observed.

The estimated daily fuel savings per driver also varied by round and city. The average daily savings across the four cities were more than 2 litres per day.

The maximum improvement by a driver in each city was also identified. The maximum improvements ranged from a low of 4 per cent to a high of 52 per cent. The results suggest the potential gains that can be achieved when a driver is properly motivated to improve and he receives good training and monitoring.

The results of the three rounds are suggestive of the potential of the ESMAP driver training protocols. However, the results varied by round and city.

There are several possible reasons why the average results varied by round and city. First, the management's attention in the past to encourage fuel efficient driving varied. Bhopal had an on-going program for encouraging drivers so less improvements were expected as compared to the other cities that had no programmes.

Second, the assignment of buses to drivers was not fixed during the pilots. It is possible that a driver's performance did improve after the training, but this improvement was not apparent because the driver operated different buses before and after the training and the 'after' bus was more poorly maintained than the 'before' bus.

Exhibit 17: Driver Training Pilot Results

	Month of Training	Drivers		% Change kmpl Month Before/After Training		Average Daily Liters Saved*
		Trained	Analyzed	Average	Maximum	
Round 1						
Bhopal	Dec 2013	10	9	3.1%	13.1%	1.0
Chandigarh	Dec 2013	15	13	10.2%	23.7%	7.3
Jaipur**	Dec 2013	13	2	-6.9%	0.2%	(2.6)
Mira Bhayandar	Dec 2013	9	4	-0.5%	4.0%	(0.2)
**Questionable November data						
Round 2						
Bhopal	Feb 2014	11	11	5.4%	16.4%	1.9
Chandigarh	Feb 2014	5	4	1.9%	9.0%	3.0
Jaipur	Feb 2014	31	26	5.6%	21.2%	2.6
Mira Bhayandar	Feb 2014	7	6	6.2%	14.6%	3.4
Round 3						
Bhopal	Mar 2014	8	7	-2.0%	5.4%	(1.0)
Chandigarh	Mar 2014	4	3	13.2%	29.0%	11.3
Jaipur	Mar 2014	21	18	4.2%	51.8%	0.5
Mira Bhayandar	Mar 2014	6	6	1.0%	24.0%	0.2

** Daily average based on 250 days per year*

Discussions were held about the varied results with the management in the four cities. The managers were generally enthusiastic about the targeted driver training approach. They offered the following reasons why they felt that the results did not match those achieved in the previous ESMAP applications and why their results varied from other cities:

- **Absence of Driver Incentives.** The focus of the pilots was on technical actions and did not include driver monetary incentives. Several managers mentioned that they felt that monetary incentives were key to improving the performance of drivers who were not self-motivated to improve their performance.
- **'Changing Behaviour Takes Time.'** The pilots were conducted over a period of several months. Some managers suggested that it may take more time to demonstrate to the drivers that the management was serious about improving fuel economy and it was in the best interests of the drivers to improve their performance.
- **Varied Follow-up Monitoring.** The purpose of the follow-up monitoring was to reinforce and, if necessary, correct the driving techniques provided in the training. It was recommended that the monitoring be conducted once a week for three weeks following the training. The local managers admitted that the frequency of this monitoring often departed from the recommendation.
- **'Learning Curve' for Local Trainers**. The managers felt that it took some time for local trainers used in the third round to become as proficient as the expert trainers provided by the World Bank who conducted the driver training in all the four cities in the first two rounds.

Local managers in the four cities were very positive about the pilot demonstrations and noted three features that they especially liked. The first was the 'train-the-trainer' approach. In the first two rounds, the local managers observed the World Bank expert trainers training their targeted drivers. The local managers conducted the third round of training on their own. The local managers felt that this was an effective way of creating in-house, expert trainers.

However, this process departed from the approach outlined in the demonstration plan. It was planned that the local trainers would conduct training in the second and third rounds. However, the trainers in all the four cities requested that they be permitted to observe the expert trainers for two rounds before assuming the training role.

The use of a technical analysis was the second feature cited by local managers. They felt that the use of a technical analysis reduced driver complaints. A common driver complaint was that his poor fuel economy reflected a bad bus or difficult route that he had been assigned and not his own driving performance. However, the analysis adjusted for different routes and bus types. Therefore, efforts were made to treat the drivers fairly and not to unfairly identify them for special training.

The provision of the driver checklist (Exhibit 11 in the chapter ***Bus Driver Training***) was the third feature cited by local managers. The checklist was prepared for use in the follow-up monitoring of trained drivers. The managers felt that the checklist was easy to use. They liked the requirement that a driver sign the checklist because it encouraged the driver to accept 'ownership' of the monitoring findings and recommendations.

Local managers in Jaipur felt that the use of the checklist promoted not only fuel efficiency but also safety and on-time driving. They started using the checklist to assist in the monitoring of all drivers.

Lessons Learned

The biggest lesson learned was that it was difficult to schedule and conduct targeted driver training every month at the beginning of the project. Time was needed for local managers to understand and accept two key elements of the ESMAP approach:

- There is value in providing targeted training to low-performing drivers.
- Follow-up monitoring and coaching are important to reinforce and, if necessary, correct the driving techniques provided in the targeted training.

Based on the pilot experience, it is suggested that initially targeted training be scheduled every two to three months. The training frequency can be adjusted based on the experience from the initial rounds.

Service demands can also limit driver availability for training. Managers may be reluctant to schedule drivers for training when there is a shortage of drivers.

It is suggested that local managers prepare and follow a training calendar. This reinforces the importance of targeted training and may encourage local managers to consider how service demands may affect training.

The preparation and commitment to a calendar may also focus attention on the question of how often targeted training is needed and how beneficial it is for a bus operator. The ESMAP approach targets 5 per cent of the drivers for training in each round. If a bus operator sees value in targeting 30 per cent of the drivers in one year, then this means scheduling the training six times in a year, or once every two months.

Another lesson was that the 'train-the-trainer' approach was an effective way of creating in-house, expert trainers.

However, all the four cities requested that their local trainers be given the opportunity to observe the expert trainers in action in the first two rounds as opposed to the planned involvement of the expert trainers in only the first round. This change should be considered in future 'train-the-trainer' efforts.

An unexpected lesson was that the driver checklist prepared for the pilot demonstrations can be useful for monitoring all drivers.

Bus Maintenance Pilots

Results

The bus maintenance pilots were planned and conducted in Bhopal, Jaipur and Mira Bhayandar. Chandigarh did not participate in the maintenance pilots because the bus fleet at the only depot suitable for the demonstration was scheduled to be replaced during the time of the demonstration. Chandigarh did not wish to spend additional money on extra buses that would soon be replaced.

Mira Bhayandar could only participate in the first round because it had difficulty implementing the protocols within the prevailing conditions in terms of space/facility available for bus maintenance. Jaipur had similar problems implementing Tier-2 checks because of the overcrowded conditions at its depot.

Three rounds of the bus maintenance pilot in the three cities were conducted in November/December 2013, February/March 2014 and April/May 2014.

Each round can potentially take a full month to conduct if some buses have been advanced to Tier-2 maintenance protocols. This is the reason that the pilots in most rounds and cities extended over portions of two calendar months.

Data was collected and analysed to assess the immediate impact of applying the maintenance protocols. This was done by comparing the fuel economy of each bus one month before and one month after the maintenance. For example, in the first round, which occurred in November/December 2013, the fuel economy of each bus in October (before month) was compared to the fuel economy of the bus in January 2014 (after month).

Exhibit 18: Bus Maintenance Pilot Results

	Month(s) of Maintenance	Tier Applied		Number of Buses	% Change kmpl Month Before/After Tier (1/2)		Average Daily Liters Saved*
		1	2		Average	Maximum	
Round 1							
Bhopal	Nov/Dec 2013	X	X	13	11.4%	22.6%	0.6
Jaipur	Nov/Dec 2013	X		18	12.0%	31.0%	3.5
Mira Bhayandar	Nov/Dec 2013	X		4	30.4%	43.3%	19.1
Round 2							
Bhopal	Feb/Mar 2014	X	X	15	2.8%	30.8%	1.0
Jaipur	Feb/Mar 2014	X	X	21	6.1%	20.8%	0.7
Round 3							
Bhopal	Apr/May 2014	X	X	15	-2.3%	9.8%	-4.4
Jaipur	Apr 2014	X		19	-2.8%	22.4%	-1.6

** Daily average based on 300 days per year*

The results of the three rounds varied by round and city (Exhibit 18). The initial strong improvement in kmpl in the first round (11 per cent to 30 per cent) declined significantly in the next two rounds.

The estimated daily fuel savings per bus also varied by round and city. The average saving was almost 3 litres per day.

The maximum improvement by a bus in each city was also identified. The maximum improvements ranged from a low of 9 per cent to a high of 43 per cent. The results suggest the potential gains that can be achieved when focused maintenance protocols are carefully applied to low-performing buses.

The results were as expected when the targeted maintenance moved its focus from the lowest to better performing buses. For example, in Bhopal average performance improvement for the lowest 10 per cent performing buses was 11.4 per cent in Round 1. The average improvement for the next lowest 10 per cent performing buses targeted in Round 2 declined to 2.8 per cent.

It is also likely that the performance improvements would have been greater in Jaipur and Mira Bhayandar if Tier-2 checks had also been done. Jaipur and Mira Bhayandar did not have the internal capacity to conduct the more intensive Tier-2 checks. They also did not opt to expend financial resources to have Tier-2 checks performed externally by third party maintenance services.

Therefore, the pilots conducted in Jaipur and Mira Bhayandar were probably not good technical tests of the full value of applying the maintenance protocols.

There are several possible reasons why the average results varied by round and city. First, are the differences in maintenance facilities and programmes. Bhopal had good maintenance facilities and structured maintenance programmes while both facilities and programmes were in poor condition in Jaipur and Mira Bhayandar. Therefore, less improvement was expected in Bhopal than in Jaipur and Mira Bhayandar.

Second, the assignment of buses to drivers was not fixed during the pilots. It is possible that the performance of a bus did improve after the maintenance protocols were applied, but this improvement was not apparent because the bus was operated by different drivers before and after the training and the ‘after’ driver was less efficient driver than the ‘before’ driver.

Lessons Learned

A major lesson learned was that it is very difficult to schedule and conduct targeted bus maintenance every month. The implementation of the protocols can take a full month if some buses have been advanced to Tier-2 maintenance protocols.

When starting a targeted maintenance approach, time is needed to familiarize local staff with the approach. Local managers need to become comfortable with the idea that the ESMAP maintenance approach is not a replacement for, but an enhancement of, their existing maintenance program.

Based on the pilot experience, it is suggested that initially targeted maintenance be scheduled every three months. The targeted maintenance frequency can be adjusted later to every two months based on the experience from the initial rounds.

The other lesson learned was that physical maintenance capabilities and senior management commitment are important. Jaipur and Mira Bhayandar did not perform complete protocols because their physical maintenance facilities were not sufficient to support on-going maintenance.

An alternative was to have Tier-2 checks performed externally by a third party maintenance service. However, there was no senior management commitment to incur these extra costs when the bus operators were straining to meet on-going maintenance needs.

Therefore, it is suggested that the results of the ESMAP maintenance protocols can only be fully realized when there is adequate internal capacity or access to outside maintenance services to perform both Tier-1 and Tier-2 maintenance protocols.

Summary

The experiences gained from the pilot demonstrations of the ESMAP approach suggest:

- Improvement opportunities exist in all environments.
- A computerized and tailored analysis program such as FEAT and a local analyst skilled in database management and fuel efficiency analysis are required to implement the ESMAP approach.
- Driver training and bus maintenance schedules should be customized based on the capacity of a bus operator and the facilities available.
- The ‘train-the-trainer’ approach is an effective way of creating in-house, expert trainers.
- The driver checklist prepared for the pilot demonstrations can be useful in monitoring all drivers.
- The targeted bus maintenance protocols can only be effectively implemented and the results fully realized when there is adequate internal or external capacity to perform both Tier-1 and Tier-2 maintenance protocols.

Finally, the pilot demonstrations strongly show that the success and likely sustainability of such fuel efficiency programmes requires significant management commitment. Management support is needed to ensure that proper resources are provided to carry out fuel efficiency procedures on a regular and consistent basis. Management support is also needed to hold drivers and mechanics responsible and accountable for fuel efficiency.

Although the pilot demonstrations focused primarily on the technical aspects of the ESMAP guidance note, several managers said that they felt that monetary incentives were key to improving the performance of drivers who were not self-motivated to improve their performance. This suggests that the establishment of an employee rewards program (for example, monetary incentives and public recognition) could play a key role in motivating the drivers and mechanics to make fuel efficiency a key focus of their work activities.

Annex 3: 16-Point ESMAP Action Plan

Summary of Actions for Instituting Transit Bus Maintenance Practices for Fuel Economy

Princi-ples		Action	
I.	Management Commitment and Ownership	1	Appoint a senior executive to be in charge of fleet fuel economy and tie some part of his/her bonus to meeting fuel economy goals.
		2	Benchmark and set appropriate fuel economy goals by bus type for each year.
		3	Communicate the fuel economy results achieved each year to both employees and the public.
II.	Data Collection and Analysis	4	Automate data collection to the extent feasible and use analysis software to support maintenance.
		5	Set up data QA/QC procedures.
		6	Analyze the data for separating the effects of driver, route and bus related effects on fuel economy.
		7	Use data to refine periodic maintenance.
III.	Maintenance of Low Fuel Efficient Buses	8A	Select 10 percent of the fleet showing the lowest fuel economy and conduct simple checks at depot.
		8B	Conduct detailed checks at central facility if bus passes step 8A.
		8C	Compare pre-repair and post-repair fuel economy data on these buses to estimate program benefits.
		9	Check repair quality on a random and periodic basis.
		10	Obtain mechanic sign-off on repairs for traceability.
		11	Require independent team audit of repairs across depots.
		12	Retrain mechanics and update repair procedures periodically.
IV.	Training of Low-Performing Drivers	13	Train drivers in fuel-efficient driving techniques and periodically retrain them.
		14	Select the 5 percent of drivers with the lowest fuel efficiency and conduct special additional training.
V.	Employee Communications and Rewards	15	Publicly display the fuel economy performance by driver and bus depot to employees.
		16	Reward mechanics at the depot level and drivers individually for exceeding targets.

Source: Guidance Note: Best Operational and Maintenance Practices for City Bus Fleets to Maximize Fuel Economy (2011), page 12.

Annex 4: Tiered Maintenance Program[6]

KEY POINTS OF THE MAINTENANCE APPROACH IN FUEL ECONOMY IMPROVEMENT

Two-Tier Maintenance Approach

The two-tier maintenance approach should be adopted for the attention of a target group of vehicles.

In the Tier-1 Maintenance Program, the identified vehicles are subject to some 16 minor checks/repairs which can be easily performed by junior level mechanics. A team of one junior mechanic and a helper should perform Tier-1 maintenance for three vehicles during an eight-hour duty spell.

Manpower Requirement: The total man-hours required for Tier-1 checks/maintenance on 10 vehicles would be 53.40 hours, that is, 8/3=2.67, 2.67 x 2 (mechanic + helper) =5.34 hours per vehicle.

If a targeted vehicle needs attention as per Tier-1, it needs to be attended to and the daily and weekly fuel performance of individual vehicles has to be monitored.

In case a vehicle passes all checks in Tier-1, then there is a need to take up the vehicle for **Tier-2 Maintenance** either in the depot or the workshop and its performance has to be monitored as above**.**

In the Tier-2 maintenance program a more specific category of works should be performed by expert mechanics by detaining the vehicle for the day. A team of one mechanic and a helper should complete Tier-2 maintenance in duty spells of eight hours.

Manpower Requirement: As such, the man-hours required for Tier-2 are 16 per bus (one mechanic plus one helper). For 10 vehicles, the man-hours would be 80 hours.

Tier-1 Maintenance Program

Tyres/Wheels

Figure 3: Checking the Air Pressure

Tyre inflation: When not properly inflated, tyres flex more under load. This produces heat and increases rolling resistance, which wastes fuel. Bus tyres inflated 10 pounds per square inch (psi) below recommended air pressure levels can reduce the fuel economy between 0.5 and 1 per cent.

Check the tyre inflation for all tyres including the spare tyre preferably using an automatic tyre inflator in a cold condition and inflate to correct level. The tyre pressure should meet the specified values as prescribed by the tyre/vehicle manufacturer. A comprehensive chart (Exhibit 19) should be displayed conspicuously. The correctness of the gauges used for inflation check should be ascertained periodically with the help of a master pressure gauge. Proper dust caps should be fitted to the tyre valves to avoid air loss due to gradual leakage owing to dust particles trapped in the valve seal area.

[6] Developed as part of ESMAP support for the demonstrations in four Indian cities in 2013.

Exhibit 19: Tyre Inflation Chart

Vehicle Type	Tyre Designation	Cross ply Nylon		Steel Radial	
		Front	Rear	Front	Rear
Long Wheelbase	9.00-20, 14PR	5.95 kg/cm^2 85 psi	5.30 kg/cm^2 75 psi	8.10 kg/cm^2 115 psi	7.00 kg/cm^2 100 psi
Small Wheelbase	9.00-20, 14PR	4.90 kg/cm^2 70 psi	4.90 kg/cm^2 70 psi	7.40 kg/cm^2 100 psi	7.40 kg/cm^2 100 psi
12 mtr Bus FE	10.00R20, 16PR			8.45 kg/cm^2 120 psi	7.40 kg/cm^2 105 psi
12 mtr Bus RE	10.00R20, 16PR			8.45 kg/cm^2 120 psi	7.75 kg/cm^2 110 psi
12 mtr Bus RE	295/80 R 22.5			8.10 kg/cm^2 115 psi	8.45 kg/cm^2 120 psi
CNG FE	10.00R20, 16PR			8.10 kg/cm^2 115 psi	5.65 kg/cm^2 80 psi

Free Rolling of Wheels: Ensure free rotation of tyres without any drag or resistance. This can be done by jacking the wheel and rotating the wheel with hand. The wheel should rotate freely and come to a standstill after some time and turn back partially instead of halting abruptly.

If there is any abnormal noise from the wheel bearings, the vehicle should be taken for thorough inspection of wheel bearings and condition of grease. Wheel grab may also occur because of sticky brakes.

Brakes

Check the brake pedal free play and ensure that recommended free play is maintained in the foot brake lever so that brakes are always in completely released condition when the foot is not rested on the pedal.

Jack up the wheels, rotate and apply brakes. Check for free rotation of all wheels when the brakes are in released condition. Check the gap between the brake liner and the drum with feeler gauge and ensure that 0.5 to 1 mm clearance is always maintained between the brake drum and the liner.

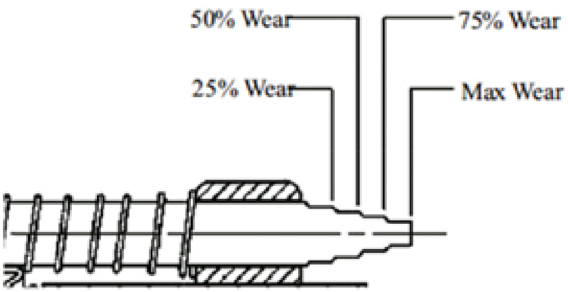
Check the condition of the brake calliper boot and wear adjuster cap. If the wear adjuster indicates excess wear of brake pads replace the brake pads.

Brake pads should be replaced when the lining thickness has worn to 3 mm.

Where a visual pad wear indicator is incorporated into the brake it provides a quick and simple method of assessing the remaining pad life.

In a new pad condition the end of the indicator stem will extend past the edge of the housing casting. As the pads wear the length of the indicator past the edge of the casting will reduce. The indicator is incremented with each increment equating to a level of pad wear.

Jack up the wheels, rotate and apply brakes. Check for quick retraction of brakes on releasing the brake pedal. Check for uneven wear in brake drums/discs, cam shaft



bushes and slack adjusters. Also check the condition of the brake valve or relay/quick release valves for any defects that may cause delayed retraction of brakes.

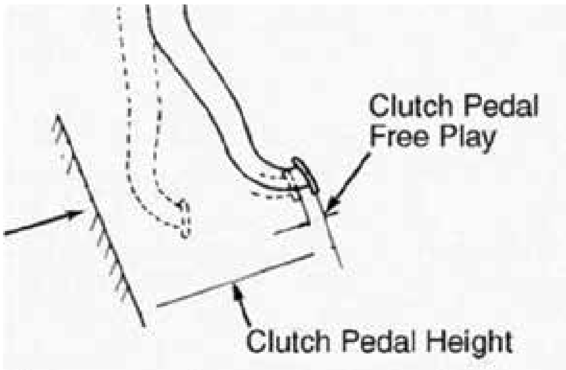
Driveshaft/Axles

Check the condition of the bearings and universal joints in drive shafts and lubricate all greasing points.

Check the tightness of the driveline and transmission mounting bolts and tighten if required.

Clutch Pedal

Check the clutch pedal free play and ensure that correct free play as prescribed by the vehicle manufacturer is always maintained. Carry out adjustments to the clutch linkages to obtain recommended play.



Accelerator Pedal Linkage

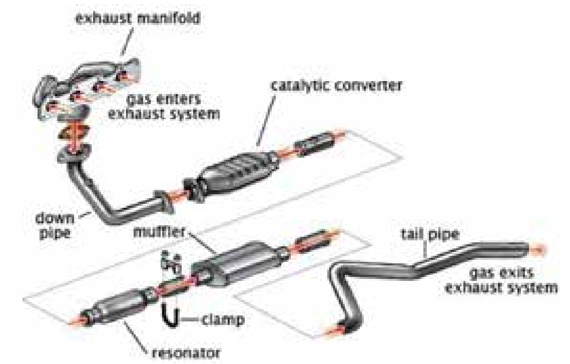
Check the condition of accelerator linkages for worn out ball joints, sagged return springs and loose fasteners. Rectify the defects and maintain recommended free play at the accelerator pedal.

Engine Air Cleaner

Check the condition of the air filter with the help of the choke indicator and replace the filters if required.

Engine Exhaust

Check the exhaust pipes and muffler for blockage and attend to it if necessary.



Onboard Diagnostics

Check the fault codes displayed on the dashboard and take corrective action as per the troubleshooting guide.

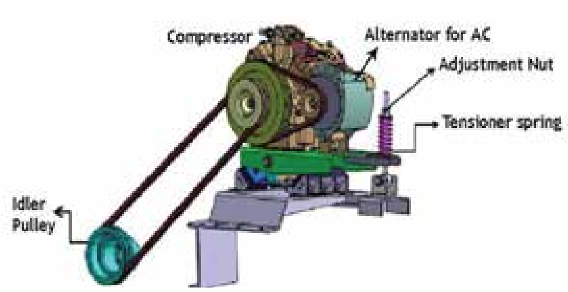
Exhaust Smoke

Check the smoke level visually on snap acceleration. If the smoke indicates any visual signs of improper combustion take up the vehicle for thorough attention in Tier-2 maintenance.

Air-Conditioner

Check the condition of the compressor drive belts and adjust if necessary.

Check the sight-glass and observe the refrigerant level. Check for refrigerant leakage if any and take up the vehicle for repairs and re-filling of refrigerant. Check the condition of the electromagnetic clutch and noise levels from the compressor, attend if necessary. Ensure proper alignment of drive belts and check the condition of idler pulley bearings and belt tensioner mounting.



Tier-2 Maintenance Program

Wheels

Check wheel alignment either using a computer wheel alignment system or a manual toe-in/toe-out checking gauge. Always maintain a toe-in of 0-3 mm or as prescribed by the vehicle manufacturer. Adjust the wheel alignment accordingly.

Check tyre camber and ensure the values as prescribed by the vehicle manufacturer.

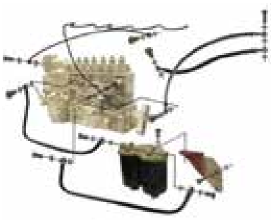
Clutch

Check the clutch wear condition through wear indicator or through visual inspection. Replace the clutch disc, pressure plate and flywheel if the wear is beyond the prescribed limits.

Check clutch withdrawal bearings and linkages for free movement. The worn out/ defective withdrawal bearings and linkages should be replaced. Parallelism in clutch withdrawal levers should be ensured while fixing the clutch pressure plate.

Fuel System

Check the diesel fuel tank and fuel lines for leakage and arrest leakages. Use gas detector (sniffer sensor) to check leakage of CNG and replace the defective parts.

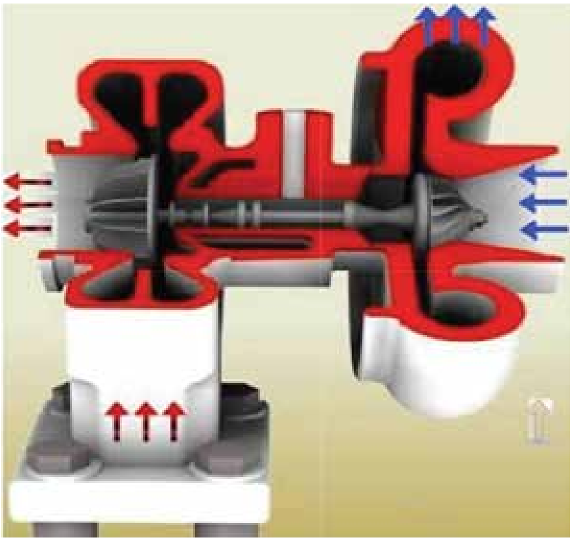


Engine Diesel

Check the fuel injection pump timing. Adjust the plunger lift if necessary as recommended by the vehicle manufacturer. Replace the fuel injection pump duly re-calibrating the pump/governor settings.

Remove the fuel injectors, carry out pressure, spray pattern and dribbling test on injector tester and replace the injectors if necessary.

Check the free rotation of the turbocharger shaft and its axial/radial play. Replace the turbocharger assembly if necessary. Ensure proper lubrication of the turbocharger bearings.



Check the engine blow-by and carry out engine compression test if necessary. Take up engine for piston rings and engine valve replacement or carry out engine re-build if required.

Check the tightness of the cylinder head bolts/nuts and ensure that the bolts/nuts are tightened to recommended torque.

Check the valve lash and adjust to correct setting as per the manufacturer's specifications.

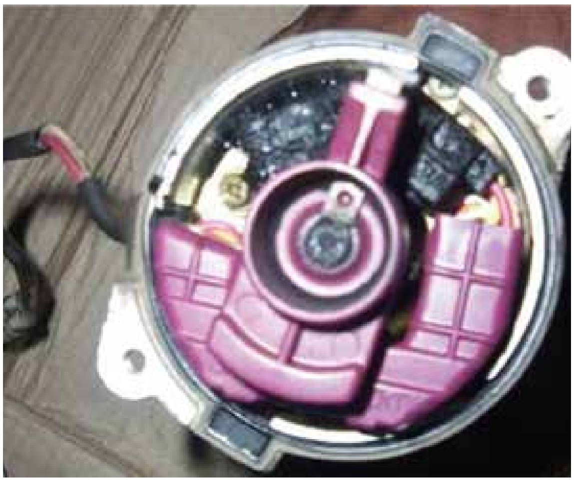
Check the engine cooling system for coolant loss/overheating. Replace the perished/ damaged coolant hoses. Check the coolant fan belt and adjust the belt tension if necessary.

Engine CNG

Check air fuel-mixer settings and ensure correct mixture settings as per the manufacturer's recommendations.

Check gas pressure regulators and overhaul if necessary.

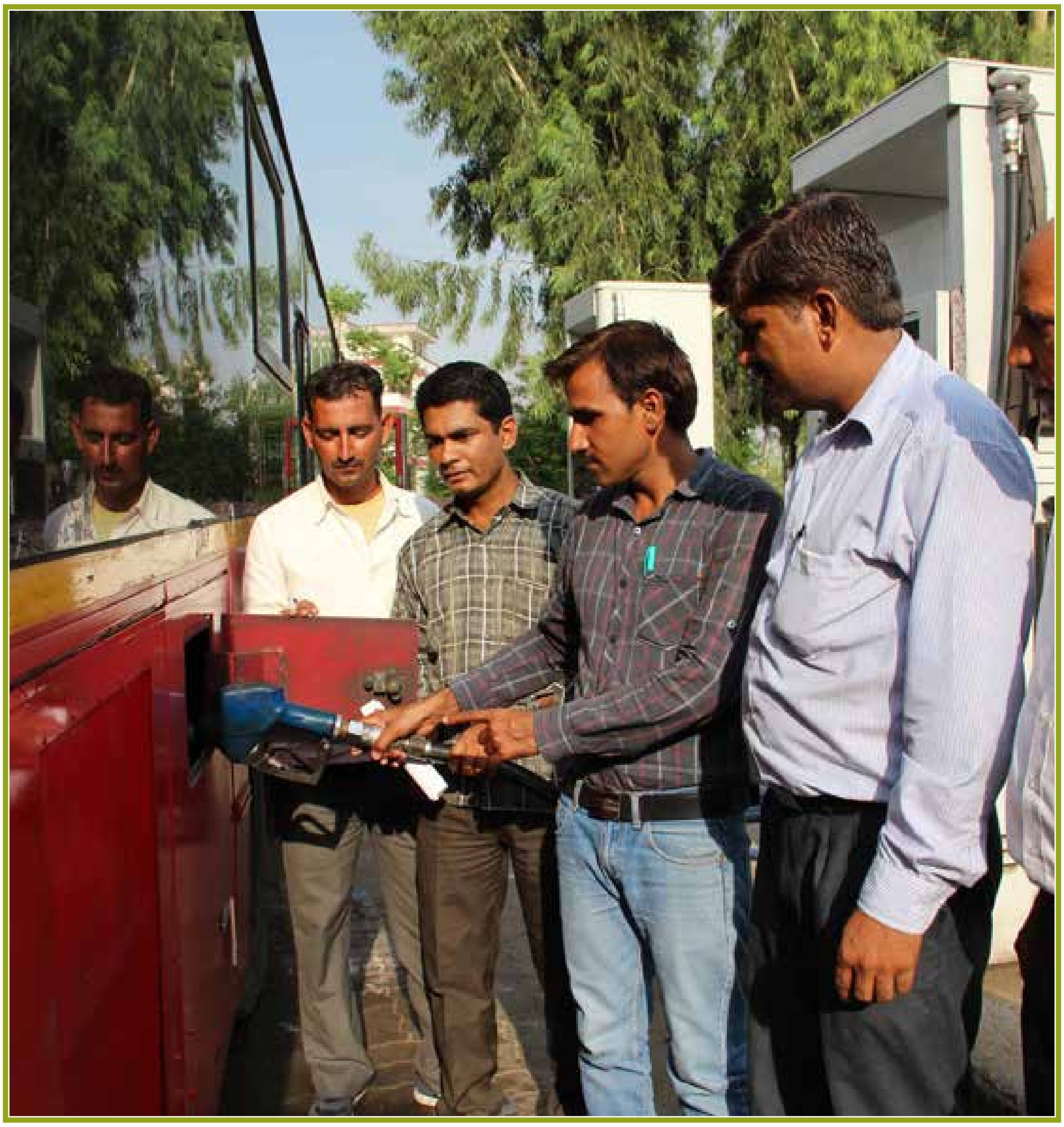
Check the ignition system with due attention to ignition coil, distributor, HT cables and spark plugs. Check and adjust the distributor timing as prescribed by the vehicle manufacturer.



Remove the spark plugs and check them using the spark plug tester, replace the defective spark plugs.

Exhaust System

Inspect the functioning of the engine exhaust brake and replace the butterfly valve if found sticky or defective. Check the exhaust brake actuator and attend if necessary.



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