IMPROVING BUS FUEL EFFICIENCY THROUGH FLEET MANAGEMENT AND MAINTENANCE PRACTICES

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SHAKTI
SUSTAINABLE ENERGY
FOUNDATION

CAMBRIDGE
SYSTEMATICS
CONSULTING & TECHNOLOGY PVT. LTD.

About Shakti Sustainable Energy Foundation:

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support energy efficiency and renewable energy.

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Table of Contents

Terms & Abbreviations

APSRTC	Andhra Pradesh State Road Transport Corporation
ASRTU	Association of State Road Transport Undertakings
BIS	Bureau of Indian Standards
Centro	Central New York Regional Transportation Authority
Client	Shakti Sustainable Energy Foundation
Consultant	Cambridge Systematics Consulting and Technology Pvt. Ltd.
CPCB	Central Pollution Control Board
ESMAP	Energy Sector Management Assistance Program
FEAT	Fuel Efficiency Analysis Tool
GEF	Global Environment Facility
GoI	Government of India
I&M	Inspection and Maintenance
KSRTC	Karnataka State Road Transport Corporation
MIS	Management Information Systems
O&M	Operations and Management
OEM	Original Equipment Manufacture
PM	Preventive Maintenance
PMI	Preventive Maintenance Inspection
Practice	Inspection and Maintenance (I&M) Practices
Project	Improving Bus Fuel Efficiency Through Fleet Management and Maintenance Practices
Shakti Foundation	Shakti Sustainable Energy Foundation
STUs	State road Transport Undertakings
SUTP	Sustainable Urban Transport Project
TCRP	Transit Cooperative Research Program
USA	United States of America
WMATA	Washington Metropolitan Area Transit Authority
WTA	Whatcom Transportation Authority

Chapter 1: Introduction

1.1 Background & Need

Transportation accounts for 23% of global energy consumptions (World Bank 2011). Given concerns about the environment and climate change, dwindling oil reserves, and energy security, sustainability and efficiency have become important considerations in the functioning of the transport sector.

Fuel costs constitute a major component of the total operating costs for bus-based public transport systems (World Bank 2011). Sound and good maintenance practices can significantly help to reduce Green House Gas emissions and lower fuel costs by improving fuel efficiency (World Bank 2011).

1.1.1 Scenario in India

The growth of the Indian economy has increased the demand for transport, including public transport, in India. This growth has led to an expansion of public transport services, and sale of buses, one of the primary means of public transport in the country, are estimated to grow from 0.11 million in 2012-13 to 0.21 million in 2024-25. Road transport currently accounts for 70% of the total diesel consumption in India, of which 77% is due to busses and trucks (Sharma 2014).

As demand for public transport continues to grow, it will become ever more important that fuel consumption of the bus fleet is minimized. One way to do this is by stimulating and supporting the adoption of good maintenance practices. Improvements in fuel efficiency can deliver large savings for operators of bus fleets. For example, a bus operator in Delhi, reports that almost 50% of their total operating cost is due to fuel expenses (Singh 2013). Thus any steps taken to improve the fuel efficiency of bus operations in India will help to reduce GHG emissions, lower operating costs, and reduce the need for expensive fuel imports.

1.2 Description

Shakti Sustainable Energy Foundation appointed Cambridge Systematics Consulting & Technology Private Limited as the consultant for carrying out this project- 'Improving Bus Fuel Efficiency through Fleet Management and Maintenance practices'. This project is intended to provide capacity building support to bus operators in India (particularly private sector bus operators), to improve their fuel efficiency performance through better Inspection and Maintenance (I&M) practices.

1.3 Report Layout

The first chapter introduces the project, and Chapter 2 presents the results of the literature review. Chapter 3 describes the theoretical framework developed. Chapter 4 caters to the existing I&M practices in India. Chapter 5 presents the developed framework and Chapter 6 the recommendations and conclusions.

Chapter 2: Literature Review

2.1 Existing Literature

The current project, as described above, intends to develop a tool that can be used by operators of city bus fleets, to improve their fuel efficiency performance, through better Inspection and Maintenance (I&M) practices.

Existing literature suggests that I&M practices affect the fuel efficiency of buses. The "*Best Operational and Maintenance Practices for City Bus Fleets to Maximize Fuel Economy*" guidance note by World Bank (2011) lists several examples of this. For instance, Ang and Deng (1990) find that in Singapore fuel economy improved by 3.2% on account of major maintenance regime. A UNEP (2009) study finds that in Jakarta maintenance practices resulted in a 5% reduction in fuel consumptions. The guidance note also suggests that Operations and Management (O&M) practices in Hyderabad are linked to improvements in bus fuel economy, as reported by APSRTC (2010), from 4.1 km/litre in 1981 to 5.2 km/litre in 2010-11. Again, this guidance note mentions that, improvements in fuel economy of 9% and considerable reductions in exhaust emissions were achieved in Bangkok, through scheduled maintenance of aging bus fleet.

2.1.1 Inspection & Maintenance (I&M) Practices

Inspection and Maintenance (I&M) practices or Preventive Maintenance (PM) practices or simply maintenance practices, as defined in the work of Schiavone and Transportation Research Board "Front Matter ." (2006), "*…are written instructions for carrying out specific job tasks such as preventive maintenance inspections (PMIs) and other bus- and facility- related repairs…*" (pp.3).

Again Weibull (Weibull.com (web-based resource portal in the field of reliability engineering) [Online]) defines the same as "*a schedule of planned maintenance aimed at the prevention of failures and breakdowns*". This definition continues to elaborate on the goal of preventive maintenance (PM)

practices – *"The primary goal of PM is to prevent the failure of equipment before it actually occurs."*

The "TCRP Synthesis 81 – Preventive Maintenance Intervals for Transit Buses" by TCRP (2010) mentions that I&M practices or Preventive Maintenance (PM) have three elements: 1) inspections; 2) repairs, campaigns, and replacements; and 3) overhauls/refurbish. Inspections, a common form of PM, have three functions: service line inspections, operator inspections, and PM Inspections (PMI).

The Synthesis also states that, once defects are identified they have to be repaired. Implementation of a defect classification system that identifies critical defects is one way to prioritize repairs. Defects identified during a PMI should be repaired either before the bus resumes revenue service, or at the next scheduled PMI. Allowing defects to accumulate causes the fleet to deteriorate over time. Campaigns, or retrofits are scheduled repairs that take place on an entire series of equipment or buses made in response to a common problem. In a perfect world the life cycle of key parts and components would be calculated from a database and replacements made at the optimal interval. In reality, the ability to estimate equipment life is a difficult task.

The Synthesis continues that, certain equipment is completely refurbished or overhauled on a periodic basis as a preventive measure. This occurs for larger, more expensive items such as entire bus overhauls, typically done at mid-life, and large components such as engines, transmissions, and axles. Overhauls are ideally done at the end of the life cycle to prevent more serious and costly problems. Overhauls also provide an opportunity to upgrade components to later technology.

2.1.2 Good Practices

Certain good practices associated with I&M are:

- Use of checklists, specific pass/fail criteria, and step-by-step instructions

enable I&M practices to be performed in a coherent manner, irrespective of labor background, and in accordance to regulatory and legal mandates.

- Listing the parts and special tools necessary for a particular PM activity, and issuing a parts-kit containing all the necessary parts and special tools.
- Assigning PMI activities to one group of technicians and repairs to another ensures the quality of the I&M practices. Alternately, Quality Assurance or Control checks may also be employed.
- Calculate the time required for and the costs of different PM activities helps significantly in determining the PM schedules, required budgets, and optimal staffing levels.
- Use of computer based software and Management Information Systems (MIS) for PMIs and for tracking repairs is also desirable.
- A 10% 'window' for performing PM activities, that is performing the activity before or after the scheduled time by a margin of 10%, may be acceptable, but delaying repairs excessively may result in deterioration in fleet.
- The original equipment manufacture (OEM) warranty must be taken into account while developing I&M practices, but after the expiry of the warranty any I&M practice so developed may require revisions. For instance, certain maintenance checks may be best done at shorter intervals on the relatively old bus whose warranty has expired.
- Customized I&M practices, developed and validated specifically for the concerned bus operator and updated regularly, involving both labor and management, produce better results compared to generic I&M practices.
- The I&M practices need to be developed not only considering the most competent technicians, but also the remaining technicians employed by the bus operator (Schiavone, Transportation Research Board " Front Matter ." 2006; TCRP 2010; World Bank 2011).

Here it must be noted that to develop the PM checklists, pass/fail criteria, and

instructions, simply documenting the agency's existing practices in written form is not sufficient. It is quite possible that the existing manner, in which the agency performs the task, falls short of best practices and even legal requirements. Mentioning the applicable regulations, however, is a good practice, and so is including body diagrams for bus body PMIs so that the position of the damage on the bus body can be marked. Further the PM instructions may be developed as a summary of the bus operators' training literature, or alternately can be detailed enough to cover all necessary information (Schiavone, Transportation Research Board " Front Matter ." 2006).

Another good practice, though not commonly implemented, is the specific identification and maintenance of busses with low fuel economy. Keeping record of the maintenance history of buses also adds to the quality of I&M practices. Disseminating information regarding fuel efficiency gains among the employees involved in I&M practices, and rewarding the better performing employees, also goes a long way in creating better I&M practices. So does involving the senior management, and possibly maintaining a senior executive concerned exclusively with fuel efficiency. Automating the collection and analysis of data, and introducing systems to monitor the data quality, also lead towards improvements in I&M practices. Maintaining a central facility for procedures that cannot be performed at depot level facilities, and upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization, is also advisable (World Bank 2011).

2.2 Features of Existing I&M Initiatives

I&M practices of certain bus operators exhibit good, or ideal features. Here, some specific examples of such ideal features are presented. Several such examples are available from the work of TCRP (2010). For instance, the Whatcom Transportation Authority (WTA), operating in the Washington State of the United States of America (USA), employs a Technician Certification Program to ensure that all technicians involved in their I&M practices follow the requirements and procedures set by the bus operator, and hence conduct I&M activities, especially those concerning safety, in a uniform manner. Again,

the Washington Metropolitan Area Transit Authority (WMATA), which operates in the national capital of USA, makes use of an innovative onboard monitoring system. When their busses return from revenue service, this system automatically, and wirelessly, downloads all data regarding defects and faults from the returning bus. Further, the Central New York Regional Transportation Authority (Centro), which provides bus services in the counties of Cayuga, Oneida, Onondaga, and Oswego, employs 19 distinct PM schedules to cater to the I&M needs of its 279 busses that are classified into 32 different categories.

The work of World Bank (2011) provides an example of ideal features of I&M practices from India. It notes that the use of posters, displaying data on bus fuel economy, by Andhra Pradesh State Transport Corporation (APSTC) were very effective in improving employee motivation, and hence bus fuel efficiency.

Chapter 3: Theoretical Framework

In this chapter the framework for preventive maintenance practices is developed from the theoretical insights explored in the second chapter.

3.1.1 Framework Conceptualization

The framework looks to provide a broad domain within which the concerned operators can develop and implement their PM regimes and fleet management database. This is essential since as revealed by literature customized I&M practices produce better results than generic I&M practices. Hence though the framework itself looks to be generic and usable by various bus operators, it does not attempt to lay down a similarly generic PM regime. Instead it allows for customized I&M practices to be developed by the concerned operators within the broad guiding principles of the framework. Figure 3.1 illustrates the conceptualization of the framework further.

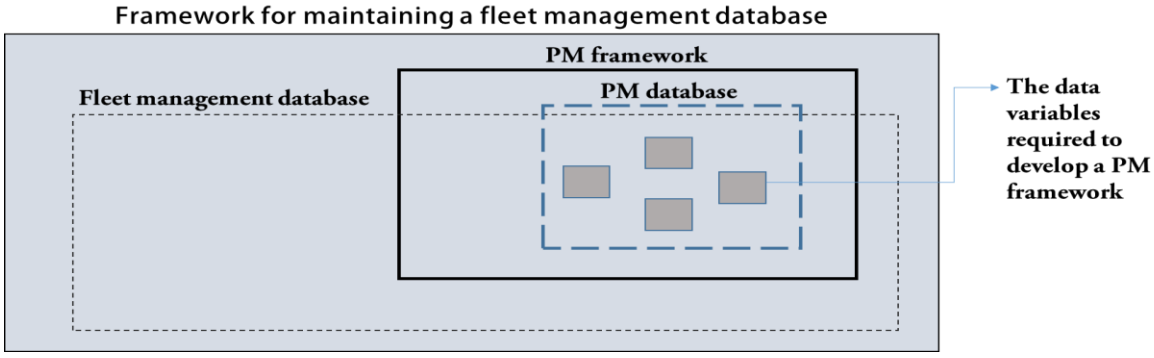

Figure 3.1: Framework Conceptualization.

3.1.2 Developed Theoretical Framework

The framework seeks to work through a set of guiding principles. These principles together attempt to bring out the good practices in I&M practices as highlighted in section 2.1.1, and are based on these same good practices.

Further the guiding principles are presented classified into clusters, each catering to a different prominent component or aspect of PM. The guiding principles are as follows:

Guiding Principles for Overall Development of the I&M Practices

- Customized I&M practices should be developed specifically catering to the concerned bus operator, and this process should involve participation from both management and labor.
- The I&M practices should be developed not only considering the most competent technicians, but also the remaining technicians employed by the bus operator.
- The OEM warranty should be taken into account while developing I&M practices, and different protocols may be prescribed for vehicles still within the warranty period and for those for which the warranty has expired.

Guiding Principles for I&M Personnel Efficiency and Efficacy

- Personnel involved in PM activities should be provided checklists, specific pass/fail criteria, and step-by-step instructions developed specifically for each activity.
- Sufficient time and efforts are needed to develop these, and these should not be simply a documentation of the existing practices of the operator.
- The instructions should be a summary of the training literature used by the operator and this detailed training literature should also be easily available in the workshop for reference.
- The parts and special tools required for a PM activity should also be listed along with the instructions and a parts-kit containing these should also be made available.
- It is also advisable to include bus body diagrams for bus body PMIs and to mention the applicable regulations for PM activities.

Guiding Principles for Quality Control

- To ensure quality the PMI activities and repair works should be assigned to different sets of technicians.
- Quality Control measures should also be incorporated.

Guiding Principles for Aromatization

- The time required for and the costs of different PM activities should be calculated.
- Computer based software and Management Information Systems (MIS) should be used for PMIs and for tracking repairs.
- A defect classification system should also be employed to prioritize repairs, and it should be ensured that defects identified are fixed before the vehicle resumes revenue service or at the next scheduled PMI to the extent possible.
- The maintenance history of each vehicle should also be maintained.
- The collection and analysis of data should be automatized to the extent

possible, and data quality monitoring systems should also be employed.
- The employment of a 10% window, however, can be acceptable.

Guiding Principles Regarding Human Resources

- Information regarding fuel efficiency gains should be disseminated among I&M personnel.
- The better performing I&M personnel should be appropriately rewarded.
- The senior management should be involved, and an executive should be assigned to exclusively look after fuel efficiency.

Other Guiding Principles

- Specific identification and maintenance of vehicles with low or poor fuel economy should be undertaken.
- A central facility for procedures that cannot be performed at depot level facilities should be maintained, especially by operators employing multiple depots in their operations. Alternately multiple smaller operators may jointly maintain such a central facility.
- Upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization is also advisable.

Within this framework, the identified data variables required to develop a preventive maintenance framework are accommodated and play a vital role as illustrated in Figure 3.1. These together constitute a dataset operating within the framework, and lead towards the standard template for maintaining a fleet management database that can be used for inspection and preventive maintenance practices and the Excel based spreadsheet model. Analysis from this spreadsheet model can provide interesting insights like identification of the poorly performing (low fuel economy) buses in the fleet of the bus operator, and the causes of poor fuel economy as will be demonstrated in the later part of this Report.

Further, the I&M practices need to account for applicable legal and regulatory requirements. These requirements may vary depending on jurisdictions, and the responsibility to understand and ensure compliance with all the applicable legal and regulatory requirements, lies with the bus operator.

Chapter 4: Existing I&M Practices in India

4.1 General Practices

In India, bus operators can broadly be classified into Public Bus Operators and Private Bus Operators. Where:

Public Bus Operators are of two types:

(1) State Road Transport Undertakings (STUs)

(2) Special Purpose Vehicles (SPVs) created under Jawaharlal Nehru National Urban Renewal Mission (JnNURM).

Private Bus Operators are also of two types:

(1) Organized Bus Operators

(2) Unorganized Bus Operators.

Later in this chapter each type of Bus Operators, their details and practices are discussed in brief. Figure 4.1 explains the structure of Bus Operators in India.

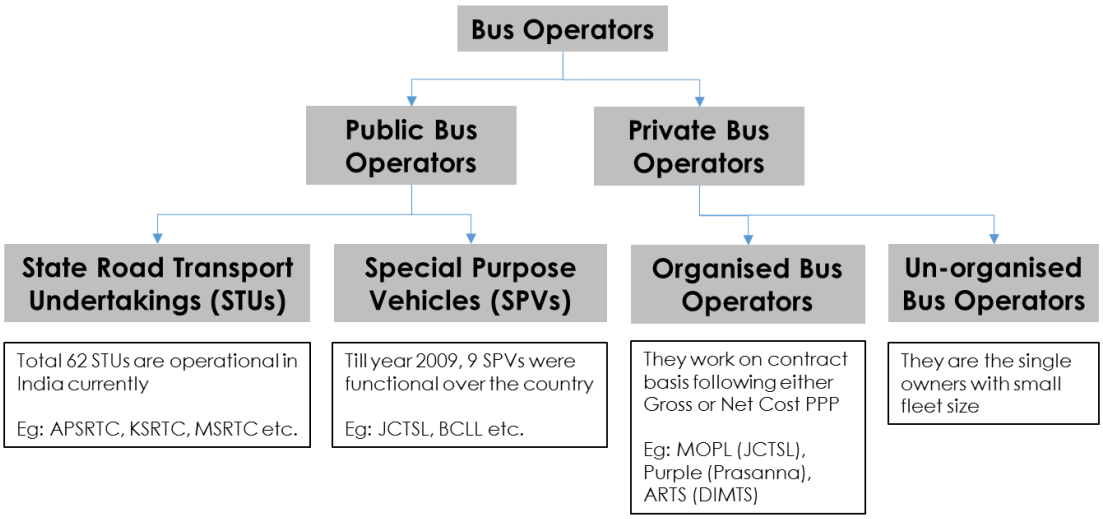

Figure 4.1: Structure of Bus Operators in India.

4.1.1 Public Bus Operators

4.1.1.1 State Transport Undertakings (STUs)

Bus based public transportation in terms of coverage and patronage is still dominated by the Public Bus Operators in India. 62 STUs under Public Bus Operators aggregately works 150,000 buses and serve 70 million travelers a day and give effective, monetary, reliable and efficient public transport facility in urban, sloping and provincial regions the nation over. (Source: www.asrtu.org)

"The STUs in the country are set up under the following four forms –

- *Departmental Undertaking directly under the State Governments*
- *Municipal Undertakings owned and controlled by the Municipal Corporations*
- *Companies formed under the Indian Companies Act 1956*
- *Road Transport Corporations formed under the RTC Act 1950"*

(pp.1-2, Source: ASTRU document – Revitalization of Passenger Road Transport Sector)

Most of the STUs are maintaining their buses with their built system but in recent practice it is also observed that few STUs are outsourcing the maintenance of buses to private contractors. Some STUs are outsourcing the complete maintenance work, while some outsource partial work on contract basis.

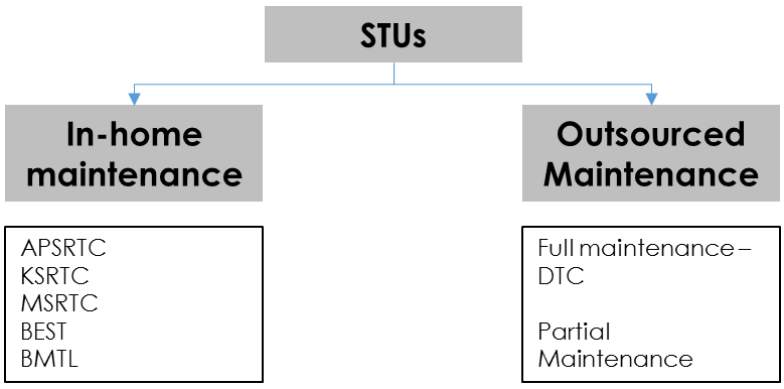

Figure 4.2: STU division on the basis of maintenance facility

Examples from both (in-house maintenance and outsourced maintenance) are discussed below in brief:

In-house maintenance:

Andhra Pradesh State Road Transport Corporation (APSRTC):

APSRTC has a total fleet of 12,152 buses (including RTC buses and Hired buses) as on 31st July 2015. Before the creation of Telangana state, APSRTC was the world's largest bus operator. The Corporation's transports facility is spread over 4.3 million kilometers which currently conveys 6.5 million individuals to their destinations .

It connects 14,123 villages to all the major town and cities in Andhra Pradesh and constitutes to 95% of the Road Transport in the state. The Corporation's buses also ply to important towns and cities in the neighboring States of Tamil Nadu, Karnataka and Odisha.

The entire network is under the administrative control of 12 Regional Managers in 4 Zones. APSRTC under the present name was established on 11th January 1958 in pursuance of the Road Transport Corporations Act 1950. (Source: www.apsrtc.gov.in)

To achieve better fuel economy, APSRTC has devised their own system or program. . This program includes the review of existing system (age composition of current fleet, technologies adopted for bus maintenance, the existing emphasis on fuel economy and the characteristics of the routes in the city). It is a two tier maintenance system:

- **Tier-1:** Preventive Maintenance of Buses at Depots
- **Tier-2:** Major Repairs/Overhauls at Workshops

APSRTC uses modern and updated technologies to provide cleaning in minimum possible time with the help of automatic washing units installed at major bus stations. Also regular checks are carried out to maintain buses, to achieve zero breakdown, minimizing costs, ensure low emission and fuel efficiency.

The detailed analysis of their current fleet indicates considerable benefits can be achieved by the identification and repair of fuel inefficient older buses, repair of newer buses on regular intervals, identification of low fuel economy

drivers and re-train them. Some older buses are retired from service and at the same time APSRTC is also creating fleet of new buses in order to change the distribution of old and new buses. It can also be observed that APSRTC is upgrading its fleet from diesel buses to CNG buses and adopted a reward system for mechanics and drivers.

Observation: Some false practices were also detected, for example: the daily fluid top up levels are maintained in a log book but in actual they were not maintaining the database.

Maharashtra State Road Transport Corporation (MSRTC):

MSRTC is the second largest corporation in transport sector. Mechanical (ME) Department of MSRTC is responsible for production, operation and maintenance of fleet size as large as 16000. This department follows 3 tier systems for maintenance of buses. It includes:

- **Central Workshops (i.e. Pune, Aurangabad and Nagpur) -** The central workshops are responsible for purchase of new chassis and construction of new bus bodies, six monthly docking, RTO passing, assembly overhauling and accidental repair. Further, the Central Workshops are also equipped with repairs, calibration and reconditioning of engine and FI Pumps.
- **Divisional Workshops** - Divisional workshops looks after daily maintenance and running repairs of the buses
- **Depots** - Depot workshops also looks after daily maintenance and running repairs of the buses. The main jobs carried out are daily maintenance, decadal maintenance, engine oil change, by-monthly docking and running repairs. Also regular check of tyres and replacements are done by tyre rethreading plants.

According to Maharashtra State Board of Technical Education, Preventive Maintenance Schedule is done on regular intervals (Daily, Weekly and Monthly) which includes following checks:

Table 4.1: PM activities included in Maintenance Schedule

Daily	Weekly	Monthly
• Water level in radiator • Oil level in engine • Tyre Pressure • Electrical System • Braking System • Fuel level in the fuel tank	• Cleaning of vehicle • Lubrication of the vehicle • Tighten the nut and bolts • Battery electrolyte level • Clean Air filters • Brake and Clutch setting	• Engine oil change • Wheel Alignment • Change fuel filters • Engine tune up • Greasing of wheel bearing

Karnataka State Road Transport Corporation (KSRTC):

KSRTC manages a fleet of 8173 vehicles as on 30th September 2015. The Corporation has 15 divisions, 78 depots and operates from 146 bus stations. The entire fleet runs around 2.6 million kilometers per day, with 2.6 million passengers plying on this service. KSRTC also operates buses for connectivity with major town and cities of neighboring states such as Maharashtra, Andhra Pradesh, Tamil Nadu, Goa and Kerala. To increase operational efficiency KSRTC is sub-divided into 4 separate Corporations :

- North West Karnataka Road Transport Corporation (NWKRTC)
- North East Karnataka Road Transport Corporation (NEKRTC)
- Karnataka State Road Transport Corporation-Bangalore (KSRTC-Bangalore)
- Bangalore Metropolitan Transport Corporation (BMTC)

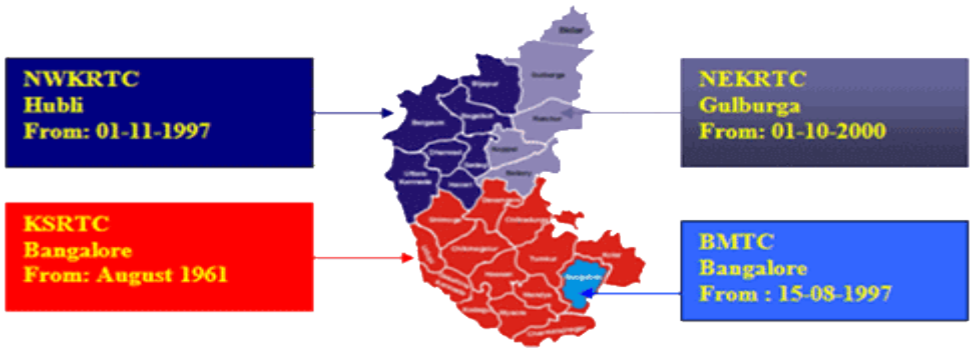

Figure 4.3: Sub-divisions of KSTRC

KSRTC follows a very rigid and efficient organizational structure for their fleet management and maintenance. It can be explained taking example of one

of the corporations out of four. The figure below explains the structure at corporation and division level.

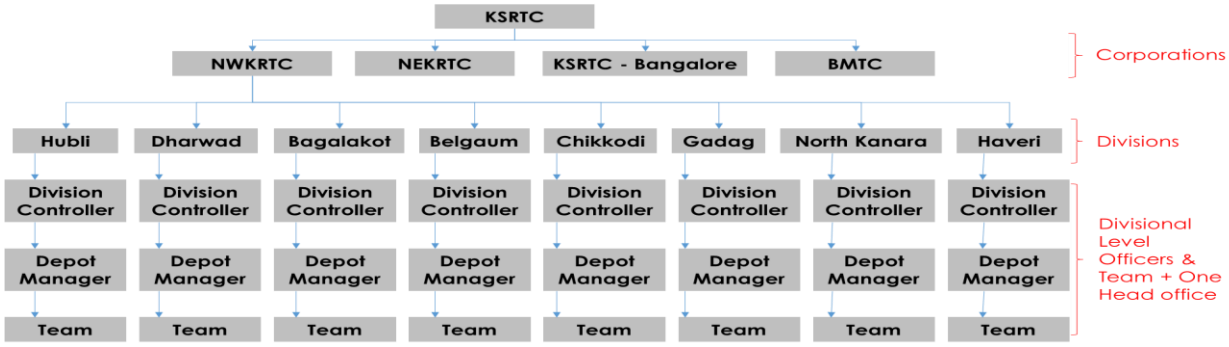

Figure 4.4: Structure of KSRTC

It is noteworthy that there is a central mechanical officer at the corporation level, then each division has their own divisional mechanical officer and each depot has its own team of technicians for maintenance of buses. In addition to division-depots they have head office in each division which moniters the smooth functioning of all the depots under that division.

Each depot looks after the daily checks, monthly checks and a monthly sheet is maintained monitoring the fuel efficency of each bus and fuel efficiency achieved by each driver. This process is termed as **'Good Fuel Efficiency & Assessment'**. If lower fuel efficiency is observed in any bus then they try to identify the reason for lower fuel efficiency by continous monitering of bus, routes and drivers. Once they identify the reason for the above said, then an attemt is made to rectify the reasons by shuffling the drivers, routes or minor mechanical corrections in the buses. This is one of the best practices observed in Indian context. They have Fuel Management System (FMS) to carry out the good fuel efficiency & assessment.

Observation: But there is an issue with the whole process. To calculate the fuel efficiency of the buses they follow only memo (i.e. route kilometers) instead of actual readings. This may misguide the whole assessment. Therefore, actual reading from odometer or digital meter should be used for proper assessment of fuel efficiency. Also, maintenance is done on the basis of the calculation of total kilometers based on memo which should be done on actual readings.

Outsourced Maintenance:

Delhi Transport Corporation (DTC):

DTC has current fleet strength of 4,705, including 3,125 low floor buses and remaining standard floor buses (Source: DTC Statistic Book).

DTC has outsourced the maintenance of 3,125 Low Floor Buses (1,875 Non-AC and 1,250 AC) to Tata Motors and Ashok Leyland. Contractor shall guarantee minimum average fuel efficiency in terms of kms operated per Kg of CNG fuel consumed (KMPKG) of the buses supplied against instant tender for the Warranty Period and beyond Warranty Period of buses (hereinafter referred to as 'Fuel Efficiency Norms') as per the following:

Observation: DTC is only considering mechanical fitness as a reason for lower fuel efficiency and the fact cannot be ignored that sometimes route characteristics and bus drivers can also be responsible for lower fuel efficiency.

Table 4.2: Fuel efficiency norms prescribed by DTC

Sl. No.	Description	Non-AC	AC
1	During Warranty Period	2.6	2.35
2	After Warranty Period upto 8 years operation	2.47 (2.6-5%)	2.23 (2.35 -5%)
3	More than 8 years to 7.5 lakhs Kms. or 12 years of operation whichever is later	2.42 (2.6-7%)	2.19 (2.6-7%)

4.1.1.2 Special Purpose Vehicles (SPVs)

After the launch of flagship GOI Scheme under JnNURM, it is observed that among the 49 mission cities (initial phase) having buses as a mode of public transport, 15 were part of the overall interstate operations and only 12 cities had gone ahead and set up a city specific Special Purpose Vehicle (SPV) for managing the operations.

Of the 49 JNNURM mission cities which established bus based public transport systems, 15 cities were part of the overall interstate operations and only 12 cities established a city specific Special Purpose Vehicle (SPV), working under the umbrella of local bodies/ municipal corporations.

Only 9 mission cities had gone ahead with the Public Private Partnership (PPP) model with an objective of harnessing the efficiencies of private sector operators. The list of SPVs is as follow:

1. Raipur
2. Bengaluru
3. Bhopal
4. Indore
5. Jabalpur
6. Ujjain
7. Amritsar
8. Ludhiana
9. Jaipur

4.1.2 Private Bus Operators

The role of the private bus operators is to complement the services of the STUs. Basically they occupy the space vacated by the public operators. They sometimes create a wide network of operations and opportunity for organized and unorganized sectors.

Private bus operators are of two categories:

- Organized large scale players which work with the Government on contract basis or on net/gross cost models
- Unorganized small fleet operators. It is very difficult to capture the unorganized fleet operator practices, due to scale of their operations and un-willingness or non-availability of correct information. Also they do not follow any good maintenance practices owning to small fleet size and lack of depot infrastructure.

The case studies from organized private bus operators are presented below:

Antony Road Transport Solutions Pvt. Ltd. (ARTS)-Rajghat Depot, Delhi:

ARTS works under the umbrella of DIMTS and operate buses for Cluster-7 in Delhi. They function out of the Rajghat Depot, Delhi. They have fleet strength of 116 buses and operate buses on 7 routes.

ARTS conducts routine maintenance works along with the use of Management Information System (MIS) for identification of buses performing low on fuel efficiency and the cause for the low fuel efficiency (driver/bus/route).

Prasanna Purple Mobility Solutions Pvt. Ltd. (PPMSL), Pune:

PPMSL operates a fleet of 567 buses. They work on net cost model hence it becomes important for them to cut the expenses in every possible way. Fuel contributes to 45-50% of their expenses which is a huge part, hence it become very important for them to keep check on fuel efficiency so as to reduce overall cost of operations. Therefore they follow a very strict mechanism to monitor the fuel efficiency on daily basis.

Service line inspections, Bus PMIs and safety related inspections are conducted on daily basis. PM repair activities are conducted on interval of 10 days. They periodically (monthly) update PM procedures to ensure buses stay in best fit.

4.2 Questionnaire Survey Compilations[1]

4.2.1 DIMTS Cluster Bus Operations – ARTS, Rajghat Depot-2

ARTS operating from the Rajghat Depot number two in Delhi has 116 buses in its fleet. These buses run on CNG and their annual distance travelled is about 70,000 km to 80,000 km.

Here Service Line Inspections are carried out every 10 days or 2000 km (weekly check-up). Bus PMIs are conducted during docking, and safety related PMIs as per safety checking error found. Four types of PM repair activities are also conducted, and a PM overhaul/refurbish activity called Motor Vehicle Inspection (MVI) is conducted every 2 years for a new bus and then on a yearly basis after that.

Interval windows are used in deciding if PM activities are carried-out on time. OEM warranties do bear influence in deciding PM intervals, and the PM intervals are changed after the expiry of manufacturer warranty. PM

[1] As revealed by the concerned agencies through the questionnaire survey.

procedures are updated or reviewed every 2 to 3 months, and PM activities have been introduced due to unique operating conditions. PM activities have also been introduced due to unique environmental conditions; as a result of information from road call reports, driver reports, service line inspections and the like; and due to the agency's fleet composition.

Check lists are used to guide PM activities and technicians are provided with written instructions for PM activities. Again for the PM activities, specific pass/fail criteria are followed and the technicians are informed of the applicable regulations for the particular activity. Computerized checking is used to ensure that the PM activities are carried out on time, and the time required for different PM activities have also been calculated.

A record is kept of the maintenance histories of the vehicles, and the number of spare busses required for the overall PM activities has been calculated to be 5% of the fleet. Parts-kits are issued for PM activities, and low fuel economy buses are subjected to targeted PM activities.

PM personnel receive incentives/awards of 10% on lesser breakdown achievements, and safety related in-house communication/promotion measures are used in support of PM activities as well.

4.2.2 DIMTS Cluster Bus Operations – ABG, Sunehri Pulla Depot

This facility caters to 211 buses that run on CNG. Here Service Line Inspections are conducted daily, and Bus PMIs and safety related inspections are conducted weekly. PM repair activities conducted here include docking, engine related activities (every 10,000 km), CNG filter related activities (every 40,000 km), differential/oil/major tune-ups related activities (every 80,000 km), and the like. PM overhaul/refurbish activity - Motor Vehicle Inspection (MVI) is conducted every 2 years for a new bus and then on a yearly basis after that, as per Government of Delhi regulations.

OEM warranties bear influence on deciding PM intervals, and provisions exist for changing the intervals after expiry of the OEM warranty. PM procedures are

reviewed or updated when there is an appropriate reason or need to do so, and PM activities have been introduced due to unique environmental conditions.

Checklists are used to guide PM activities, and the technicians are provided written instruction for PM activities. Specific pass/fail criteria are also followed for the PM activities and computerized tracking is employed to ensure PM activities are carried-out on time. The time required for different PM activities has also been calculated.

The policy on repairing defects revealed by PM inspections remains subject to the availability of technicians, parts, and the like. Records of the maintenance histories of vehicles are maintained, and the combined cost of labour and parts has also been calculated.

Quality Control is carried-out, for instance through manual check by superintendent and separate servicing. Targeted PM activities for low fuel economy buses are also undertaken, and incentives or awards are provided to best performing PM personnel in the form of cash bonus. In-house communication/promotion measures, for instance posters, are also utilized.

4.2.3 Purple (Prasanna) – Prasanna Purple Mobility Solutions Pvt. Ltd., Pune

Prasanna Purple Mobility Solutions Pvt. Ltd. operates a fleet of 567 buses. Out of 567, 292 are diesel operated and 275 are CNG operated buses. Service line inspections, Bus PMIs and safety related inspections are conducted on daily basis. PM repair activities are conducted on interval of 10 days (basic overall checkup – air / coolant / clutch / breaks / greasing / tire pressure / electricals / sensors), after 36,000 km (hub greasing, spark plugs etc.) and major checkups after 18,000 km (engine works, filters etc.).

PM overhaul/ refurbish activity is conducted at the interval of 72,000 km. Different buses have different intervals for PM activities on the basis of manufacturer. Interval windows are used in deciding if PM activities are

carried-out on time. PM activities are carried after following interval brackets: 3000 km, 9000 km, 18000 km, 36000 km and 72000 km.

OEM warranties bear influence on deciding PM intervals because warranty laps if prescribed PM schedule from manufacturer is not followed. They periodically (monthly) update PM procedures to ensure buses stay in best fit. Due to environmental conditions in particular seasons few additions are made in PM activities such as wiper setting, AC setting etc.

Checklists are used to guide PM activities, and the technicians are provided written instruction for PM activities and computerized checking is used to ensure that the PM activities are carried out on time. A record is kept of the maintenance histories of the vehicles, and the number of spare busses required for the overall PM activities has been calculated to be 10% of the fleet.

The combined cost of labour and parts has also been calculated and it depends on model of vehicle and work done in each PM activity. The policy on repairing defects revealed indicates that safety issues are not compromised but other (non-safety related) repairs may be delayed. Parts-kits are issued for PM activities, and low fuel economy buses are subjected to targeted PM activities by tracing buses on daily basis.

4.2.4 Jaipur Bus: Mateshwari Operations Pvt. Ltd. – Vidhyadharnagar B-Depot, Jaipur

Mateshwari Operations Pvt. Ltd. operating from Vidhyadharnagar B-Depot of R.S.R.T.C. has 115 buses in its fleet. These buses run on Diesel and their annual distance travelled varies from 80,000 km to 84,000 km.

Here Service Line Inspection are carried out on daily basis. Bus PM Inspections are conducted weekly. PM activities are defined on the basis of total distance travelled by the bus. First PM check is carried out at 10,000 km and it includes wheel set check. Second PM repair check is scheduled at or after 20,000 km and it includes front and rear wheel check, air pressure and suspension works. Then next check is scheduled on and after 40,000 km and it includes engine,

front and rear wheel, gear, clutch and AC works. Finally after 80,000 km there is a need to change engine oil, coolant, steering oil along with other repair activities. In addition to that regular greasing is done to ensure smooth functioning of the buses. This schedule is subjected to change on the basis of recommendation from experts from Tata and Ashok Leyland. Also, immediate actions are taken on the reported defects from drivers. Furthermore, there is a safety related PM inspection which is carried out on annual basis to check the fitness of the buses. PM overhaul/refurbish activity is conducted after 4-5 lakh kilometers.

Except for oil change period every bus has same interval for PM activities. OEM warranties bears influence on PM intervals, and manufacturers set pre-defined intervals for PM. This pre-defined intervals may vary on the basis of field observations made by the mechanics and drivers. Due to unique environmental conditions there may be changes in PM activities so as to ensure smooth functioning of AC's due to high temperature.

Checklists are used to guide PM activities, and technicians are provided written instructions for PM activities. Specific pass/fail criteria are not followed on this depot but they do follow door checks to ensure if the bus is healthy for field or not. Computerized and oral tracking is employed to ensure PM activities are carried out on time.

Strict policy of 'fixing all defects immediately' is adopted, and to ensure the safety of the passengers is their prime motive. In case, if spare parts are not available and if defect are not related to safety then only it can be delayed otherwise the above mentioned policy is strictly followed. Records of the maintenance histories of vehicles are maintained and within a month they are upgrading their system to calculate the cost (labor and parts combined) for various PM activities.

Parts-kits are issued for PM activities for some parts. Targeted PM activities are followed immediately for low fuel economy buses and PM personnel receive incentives/awards on lesser breakdown achievements.

On the basis of observations, the depot officials have provided the following suggestions:

- It would be essential to phase out the old buses as their spare parts are not easily available in market, and
- OEM are not interested to make it available in market as they have stopped manufacturing the older models.

4.2.5 Jaipur Bus – Sanganer Depot, Jaipur

This depot is considered as a case study despite the fact that there is no private involvement as a reference case as it plans to initiate PPP model on the lines of Vidhyadharnagar B-Depot (Jaipur) in the future.

This facility caters to 309 buses that run on Diesel. Out of fleet of 309, 281 are low-floor buses, 20 mini-buses (non-AC) and 8 AC mini buses. Annual distance travelled varies from 87000 km to 91000 km. Here Service Line Inspections are conducted daily, and Bus PMIs and safety related inspections are conducted weekly. PM activities include docking, wheel grease and lining work, coolant & gear oil etc. (every 20,000 km), wheel alignment, oil filter change, clutch plates and deep cleaning activities (every 40,000 km), oil, coolant, filter and major tune-ups related activities (every 80,000 km). PM overhaul/ refurbish activity – Motor Vehicle Inspection (MVI) or RTO fitness Inspection is conducted on yearly basis as per RTO Jaipur regulations.

For PM activities an interval window of 1000 km is used on due maintenance. OEM warranties bear influence on deciding PM intervals, but no changes are made post OEM warranty expiry. Checklists are used to guide PM activities and written instructions for technicians are pasted on notice board, along with the timely verbal communications.

Specific pass/fail criteria are also followed for the PM activities. Both computerized and manual formal tracking are employed to keep the record of PM activities and keep check on due maintenance. Fixing all defects immediately is their primary objective.

A record is kept of the maintenance histories of the vehicles, and the number of spare buses required for the overall PM activities has been calculated to be 5% of the fleet and as per OEM recommendations. Cost of PM activities are not calculated differently but is calculated on the basis of the parts used and actuals.

A special supervisor is given responsibility of Quality Control/Assurance for all the PM activities. Targeted PM activities for low fuel economy buses are also undertaken, and increments and certificates are awarded to best performing PM personnel and drivers for achieving lower breakdown rates.

Table 4.4 summarizes the PM Practices of different bus operators explored.

Table 4.4: Summary of PM Practices.

Name of the Bus Operators / PM Practices	ARTS, Rajghat Depot	ABG, Sunehri Pulla Depot	Purple (Prasanna)	Vidhyadhar Nagar Depot	Sanganer Depot
Service Line Inspections	every 10 days or 2000 km	daily	every 10 days	daily	daily
Bus PMIs	during docking	weekly		weekly	weekly
Safety related PMIs	as per safety checking error found	weekly			weekly
Retrofit/Refurbishing	yearly (new bus after 2 years)	yearly (new bus after 2 years)	every 72,000 km	every 4-5 lakh km	yearly
Engine related activities		every 10,000 km	every 18,000 km	every 40,000 km	
Fuel system related activities		every 40,000 km			
Differential/oil/major tune-ups related activities		every 80,000 km	every 18,000 km	every 80,000 km	every 80,000 km

PM Practices \ Name of the Bus Operators	ARTS, Rajghat Depot	ABG, Sunehri Pulla Depot	Purple (Prasanna)	Vidhyadhar Nagar Depot	Sanganer Depot
The OEM warranty taken into account while developing I&M practices, and different protocols prescribed for vehicles still within the warranty period and for those for which the warranty has expired.	✓	✓	✓	✓	✓
Personnel involved in PM activities are provided checklists, specific pass/fail criteria, and step-by-step instructions developed specifically for each activity.	✓	✓	✓	✓	✓
Sufficient time and efforts to develop PM practices, and these are not simply a documentation of the existing practices of the operator.					✓
The parts and special tools required for a PM activity are listed along with the instructions and a parts-kit containing are also made available.	✓		✓	✓	
Quality Control measures are incorporated.	✓	✓		✓	✓
The time required for different PM activities are calculated and the costs of different PM activities are calculated.	✓	✓	✓		✓
Computer based software and Management Information Systems (MIS) are used for PMIs and for tracking repairs.	✓	✓	✓	✓	✓
The maintenance history of each vehicle are maintained.	✓	✓	✓	✓	✓
The 10% window is employed.			✓	✓	×
The better performing I&M personnel are appropriately rewarded.	✓	✓		✓	✓
Specific identification and maintenance of vehicles with low or poor fuel economy is undertaken.	✓	✓	✓	✓	✓

Legend	
Conclusive evidence that this depot follows particular practice.	✓
Conclusive evidence that this depot dosen't follow particular practice.	×

Note: The blank boxes above indicates no conclusive evidences.

4.3 Conclusions

In this chapter the existing general PM practices in India have been presented along with specific mentions of the PM practices followed at select depots, compiled through questionnaire surveys.

The positive points of the existing practices along with their gaps with the developed theoretical framework are highlighted in the following chapter in attempts to incorporate and address them in the tool being developed.

Chapter 5: The Developed Framework

5.1 Problems & Gaps in Existing Practices

Existing I&M practices in India show considerable variety and the alignment of the agencies explored through the questionnaire survey with the theoretical framework is illustrated in Table 5.1.

Table 5.1: Alignment of the agencies explored through the questionnaire survey with the theoretical framework.

Guiding Principles \ Name of the Bus Operators	ARTS, Rajghat Depot	ABG, Sunehri Pulla Depot	Purple (Prasanna)	Vidhyadhar Nagar Depot	Sanganer Depot
Overall Development of the I&M Practices					
Customized I&M practices should be developed specifically catering to the concerned bus operator, and this process should involve participation from both management and labor					
The I&M practices should be developed not only considering the most competent technicians, but also the remaining technicians employed by the bus operator					
The OEM warranty should be taken into account while developing I&M practices, and different protocols may be prescribed for vehicles still within the warranty period and for those for which the warranty has expired.	✓	✓	✓	✓	✓
I&M Personnel Efficiency and Efficacy					
Personnel involved in PM activities should be provided checklists,	✓	✓	✓	✓	✓
specific pass/fail criteria,	✓	✓		×	✓
and step-by-step instructions developed specifically for each activity.			✓		
Sufficient time and efforts are needed to develop these, and these should not be simply a documentation of the existing practices of the operator.					✓
The instructions should be a summary of the training literature used by the operator and this detailed training literature should also be easily available in the workshop for reference.					
The parts and special tools required for a PM activity should also be listed along with the instructions and a parts-kit containing these should also be made available.	✓		✓	✓	
It is also advisable to include bus body diagrams for bus body PMIs and to mention the applicable regulations for PM activities.					
Quality Control					
To ensure quality the PMI activities and repair works should be assigned to different sets of technicians.					
Quality Control measures should also be incorporated.	✓	✓		✓	✓

Guiding Principles \ Name of the Bus Operators	ARTS, Rajghat Depot	ABG, Sunehri Pulla Depot	Purple (Prasanna)	Vidhyadhar Nagar Depot	Sanganer Depot
Atomatization					
The time required for different PM activities should be calculated and the costs of different PM activities should be calculated.	✓	✓	✓		✓
Computer based software and Management Information Systems (MIS) should be used for PMIs and for tracking repairs.	✓	✓	✓	✓	✓
A defect classification system should also be employed to priorities repairs, and it should be ensured that defects identified are fixed before the vehicle resumes revenue service or at the next scheduled PMI to the extent possible.					
The maintenance history of each vehicle should also be maintained.	✓	✓	✓	✓	✓
The collection and analysis of data should be automatized to the extent possible, and data quality monitoring systems should also be employed.					
The employment of a 10% window, however, can be acceptable.			✓	✓	×
Human Resources					
Information regarding fuel efficiency gains should be disseminated among I&M personnel.					
The better performing I&M personnel should be appropriately rewarded.	✓	✓		✓	✓
The senior management should be involved, and an executive should be assigned to exclusively look after fuel efficiency.					
Others					
Specific identification and maintenance of vehicles with low or poor fuel economy should be undertaken.	✓	✓	✓	✓	✓
A central facility for procedures that cannot be performed at depot level facilities should be maintained, especially by operators employing multiple depots in their operations. Alternately multiple smaller operators may jointly maintain such a central facility.					
Upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization is also advisable.					

Legend	
Conclusive evidence that this depot follows particular practice.	✓
Conclusive evidence that this depot dosen't follow particular practice.	×

Note: The blank boxes above indicates no conclusive evidences.

From Table 5.1 it is observed that OEM warranties do hold influence on deciding PM intervals. Use of checklists and specific pass/fail criteria in regard to PM activities are also common. Technicians are usually provided with written instructions for PM activities, and computerized tracking is employed to ensure timely conduction of the PM activities. Records of the maintenance histories of

the vehicles are also maintained. In all the depots targeted PM activities are conducted for low fuel efficiency buses.

However, certain aspects like customized PM practices specific to the bus operators, PM practices accounting for technicians other than the most competent personnel, providing instructions to technicians that are a summary of the training literature, assigning PM inspections and repairs to different set of technicians, adopting defect classification systems, automatized data collection and monitoring systems, dissemination specific information regarding fuel efficiency among technicians, involving the senior management in fuel efficiency related aspects, use of centralized facilities, and upholding fuel efficiency as a performance parameter as important as fleet utilization are rarely covered. These are where the gaps between the existing practices in India and the developed theoretical framework are identified to be.

5.2 Mitigation Strategy

Having established the gaps between the existing practices in India and the developed theoretical framework in the previous section the strategy to mitigate them emerges clearly and automatically: Among the guiding principles developed, the ones that find rare implementation in the existing practices need to be prioritized. Accordingly the priority matrix for this purpose is created and the developed framework finds expression through this priority matrix of the guiding principles.

5.3 The Framework

The framework is illustrated here in this section through Table 5.2 along with the current prioritization as emanating from the identified gaps between the existing practices in India and the developed theoretical framework.

The argument for the prioritization is as follows: If the guiding principle is in practice in some form at four or all five depots examined (see Table 5.1) then it is classified as High priority. If in two or three depots examined then as

Moderate priority and if in only one or none of the depots examined, then it is classified as Low priority.

Table 5.2: The framework along with the required prioritization.

Guiding Principles	Current Prioritization
Overall Development of the I&M Practices	
Customized I&M practices should be developed specifically catering to the concerned bus operator, and this process should involve participation from both management and labour	**Low**
The I&M practices should be developed not only considering the most competent technicians, but also the remaining technicians employed by the bus operator	**Low**
The OEM warranty should be taken into account while developing I&M practices, and different protocols may be prescribed for vehicles still within the warranty period and for those for which the warranty has expired.	**High**
I&M Personnel Efficiency and Efficacy	
Personnel involved in PM activities should be provided checklists, specific pass/fail criteria, and step-by-step instructions developed specifically for each activity.	**High**
Sufficient time and efforts are needed to develop these, and these should not be simply a documentation of the existing practices of the operator.	**Low**
The instructions should be a summary of the training literature used by the operator and this detailed training literature should also be easily available in the workshop for reference.	**Low**
The parts and special tools required for a PM activity should also be listed along with the instructions and a parts-kit containing these should also be made available.	**Moderate**
It is also advisable to include bus body diagrams for bus body PMIs and to mention the applicable regulations for PM activities.	**Low**
Quality Control	
To ensure quality the PMI activities and repair works should be assigned to different sets of technicians.	**Low**
Quality Control measures should also be incorporated.	**High**
Atomatization	
The time required for different PM activities should be calculated and the costs of different PM activities should be calculated.	**High**
Computer based software and Management Information Systems (MIS) should be used for PMIs and for tracking repairs.	**High**
A defect classification system should also be employed to priorities repairs, and it should be ensured that defects identified are fixed before the vehicle resumes revenue service or at the next scheduled PMI to the extent possible.	**Low**
The maintenance history of each vehicle should also be maintained.	**High**
The collection and analysis of data should be automatized to the extent possible, and data quality monitoring systems should also be employed.	**Low**
The employment of a 10% window, however, can be acceptable.	**Moderate**
Human Resources	
Information regarding fuel efficiency gains should be disseminated among I&M personnel.	**Low**
The better performing I&M personnel should be appropriately rewarded.	**High**
The senior management should be involved, and an executive should be assigned to exclusively look after fuel efficiency.	**Low**
Others	
Specific identification and maintenance of vehicles with low or poor fuel economy should be undertaken.	**High**
A central facility for procedures that cannot be performed at depot level facilities should be maintained, especially by operators employing multiple depots in their operations. Alternately multiple smaller operators may jointly maintain such a central facility.	**Low**
Upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization is also advisable.	**Low**

Further, the I&M practices need to account for applicable legal and regulatory requirements. These requirements may vary depending on jurisdictions, and the responsibility to understand and ensure compliance with all the applicable legal and regulatory requirements, lies with the bus operator.

Figure 5.1: The Developed Framework

Clip-art sources:
http://www.integrant.com/; http://www.ormazabal.com/;
https://www.iconfinder.com/; http://www.callcriteria.com/;
http://www.247jobline.co.uk/; http://librecat.org/

Chapter 6: Recommendations & Conclusions

6.1 Ensuring Compliance

Once the operator has set-up its preventive maintenance procedures using the framework described in this report, it is essential to ensure compliance with the set-up procedures. Hence, the framework is designed to address this holistically and in an ongoing process, intrinsically. If all the elements of the framework are incorporated in the set-up procedures compliance need not be an issue. For instance, some of the guiding principles especially contributing towards ensuring compliance are as follows:

- The I&M practices should be developed not only considering the most competent technicians, but also the remaining technicians.
- To ensure quality the PMI activities and repair works should be assigned to different sets of technicians.
- Quality Control measures should also be incorporated.
- Computer based software and Management Information Systems (MIS) should be used for PMIs and for tracking repairs.
- A defect classification system should also be employed to prioritize repairs, and it should be ensured that defects identified are fixed before the vehicle resumes revenue service or at the next scheduled PMI to the extent possible.
- The maintenance history of each vehicle should also be maintained.
- The collection and analysis of data should be automatized to the extent possible, and data quality monitoring systems should also be employed.
- The employment of a 10% window, however, can be acceptable.
- Information regarding fuel efficiency gains should be disseminated among I&M personnel.
- The better performing I&M personnel should be appropriately rewarded.
- The senior management should be involved, and an executive should be assigned to exclusively look after fuel efficiency.

- Upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization is also advisable.

6.2 Improving Fuel Economy Performance

An attempt has been made to identify the various causes for poor fuel economy. According to the causes identified a major way to ensure good fuel economy performance is to ensure the proper preventive maintenance of the fuel systems of the vehicles. It has been revealed that even small number of breakdowns in the fuel system of the vehicles go a long way in reducing the overall fuel economy performance of vehicles. Hence it is recommended that preventive maintenance of the fuel system of the vehicles be conducted in an air-tight manner, without even the slightest compromise. The developed framework looks to account for this, and some of the guiding principles highlighting this aspect are as follows:

- A defect classification system should also be employed to priorities repairs, and it should be ensured that defects identified are fixed before the vehicle resumes revenue service or at the next scheduled PMI to the extent possible.
- The maintenance history of each vehicle should also be maintained.
- I&M personnel should be informed regarding fuel efficiency gains.
- The senior management should be involved, and an executive should be assigned to exclusively look after fuel efficiency.
- Specific identification and maintenance of vehicles with low or poor fuel economy should be undertaken.
- Upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization is also advisable.

Here it is encouraging to see that some of the measures like specific identification and maintenance of vehicles with low or poor fuel economy is being undertaken with increased priority in India. This is also reflected in the fact that for this reason this principle comes out to be of lower priority in our developed framework since it is already in active implementation in the existing practices in India. However, the other recommended measures, for

instance upholding fuel efficiency as an indicator of performance in a manner similar to fleet utilization also need to be implemented with similar priority to achieve further improvements in fuel efficiency performance. These are not currently reflected in the existing practices and hence come out to be of higher priority in the developed framework.

Apart from this higher attention to preventive maintenance of tire related and mechanical aspects of the vehicles can also be expected to contribute to better fuel efficiency performance.

6.3 Conclusions & Discussions

This report reflects the importance of preventive maintenance practices in improving fuel efficiency.

A lot has been said and done in improving the driver's contributions to fuel efficiency. But a large contribution can also be made to fuel efficiency performance through proper preventive maintenance practices. And this is the aspect that now needs to be the focus of attention since this has received lesser attention in the past as compared to the driver element. This fact was also highlighted through anecdotal evidence detected during the informal interactions with the personnel involved with bus operations, when visits were made to the bus operators to collect data. To compile and study such anecdotal evidence in an attempt to understand how to bring about similar improvements with the preventive maintenance technicians as has happened with the bus drivers in the past few years can itself be a research worth conducting.

The importance of modelling approaches in improving fuel efficiency cannot be stressed enough. In a domain looking to maximize efficiency, modelling techniques and approaches hold the key. However in the Indian context the modelling domain seems to be a bit underappreciated. Be it due to institutional inertia or because of lack of qualified personnel to implement such measures or due to lack of availability and maintenance of data to implement the

modelling procedures. Here an interesting topic of further research can be a pan-India study of availability of data for modelling purposes.

Further there is a lot that the government can do at this juncture to popularize modelling approaches in an attempt to improve fuel efficiency and more. It will go a long way if certain basic modelling techniques, like the simple regression analysis, are made the basic standard of bus operations. This will enable not only higher fuel efficiency performance but also the provision of a higher level of service to the passengers.

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