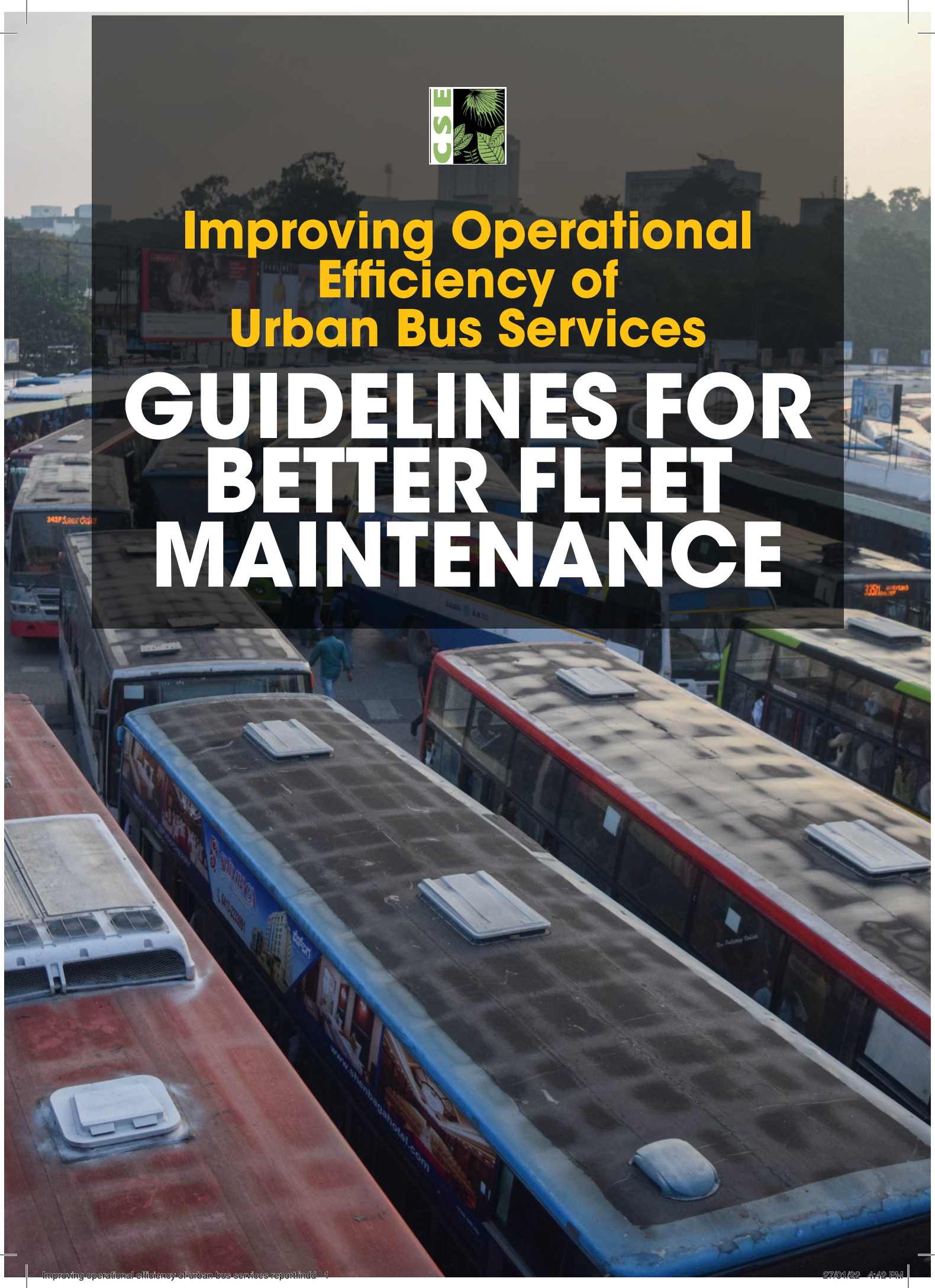

Improving Operational Efficiency of Urban Bus Services

GUIDELINES FOR BETTER FLEET MAINTENANCE

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Contents

List of figures

List of graphs

List of images

List of tables

WHY THIS MANUAL?

It is now well understood that buses are the prime movers in Indian cities, that meet the bulk of the public transport demand. Every day, around 370 million commuters, use private and public bus services. This number is almost 16 times that of the number of passengers carried by Indian railways (i.e., 23 million passengers per day).[1] In addition to moving people, buses also provide livelihood to almost 40 million people and contribute about 8 per cent of the national Gross Domestic Product (GDP).[2] According to a 2016 Central Institute of Road Transport (CIRT) report, public transport agencies (PTAs), including state transport undertakings (STUs) and special purpose vehicles (SPVs), collectively own 151,288 buses, (this figure includes buses owned directly by them as well as those hired from the private sector).[3] It is important to note only 10 per cent of buses plying on India roads are public sector-owned.

Yet buses are victims of neglect. Over the past decades, Indian public bus transport agencies have experienced ridership losses that directly impact their earnings and make it hard to continue daily services needed to meet the growing travel demand. An internal assessment carried out by Centre for Science and Environment (CSE) shows that between 2013–18, Delhi has lost approximately 17 lakh in bus ridership, whereas Mumbai has lost around 12 lakh. One of the main reasons for this declining ridership is declining fleet sizes due to off-roading or scrapping of buses. During the same time frame of 2013–18, the overall bus fleet of Delhi has been reduced by 1,265 buses, and in Mumbai by 878 buses. The same if true for other cities as well.

It also demonstrates the crippling financial situation of most Indian PTAs that is preventing them from even maintaining their overall fleet strength, let alone augmenting the fleet. This is happening when cities need more buses due to natural growth and increased demand for mobility. The problem has become more acute during pandemic times. PTAs are struggling for survival. At present PTAs are not in a position to make substantial new investments to augment bus fleet. The physical distancing norms currently in place demand maximum utilization of existing buses. Fleet utilization rate of Indian PTAs have decreased even more over the past couple of years. As per a 2016 CIRT report, the overall fleet utilization of reporting PTAs has decreased from 92.3 per cent in 2007–08 to 88.7 per cent in 2016–17.[4] Thus, at present, officials of PTAs are under enormous pressure to improve the efficiency and maintenance of bus operations.

Additionally, conditions of buses in India are very poor as they are not well maintained. Any negligence in the maintenance activity makes buses dirty and unattractive to commuters. Studies have shown that a good maintenance regime can help improve fleet utilization rates, even with the aging fleets, e.g., Delhi Transport Corporation (DTC) and Chandigarh Transport Undertaking (CTU) both have been able to improve their respective fleet utilization rate to 97.45 per cent, which is much higher than national average, between 2014–15 to 2020–21.[5] A well maintained bus also looks clean and attractive. It helps in improving overall life of buses.

Inadequate bus infrastructure is always a big area of concern for India's bus industry. Only, a handful of Indian cities, e.g., big and old PTAs like Bangalore

Metropolitan Transport Corporation (BMTC) and Andhra Pradesh State Road Transport Corporation (APSRTC) have at least the necessary transit infrastructure to operate and maintain bus services on a daily basis. But new PTAs, like Capital Region Urban Transport (CRUT), Bhopal City Link Limited (BCLL) etc., still don't have many of the equipment required to carry out maintenance activities.

Indian PTAs are facing several challenges in maintaining fleets. They include unavailability of required numbers and types of equipment, use of old and dilapidated equipment, unavailability of required numbers and types of human resource etc. Additionally, data collection and storing techniques followed by PTAs are different from one another. Thus, any data gaps lead to poor assessments of fleet performance and make the maintenance work ineffective. In many cases, PTAs don't have any protocols to follow and things are pretty much happening on an ad hoc basis. For example, it has been observed in some states that in the absence of any formal maintenance protocol, different depots are following different time frames in managing and maintaining the buses. Sometimes, PTAs are also unaware of emerging new equipment and technologies and how to use them to improvise their current practices, due to this, it has been observed that even after acquiring new equipment, many PTAs are not able to get any benefit out of it.

Thus, depot-based management and fleet maintenance have strong bearing on the operational performance of the fleet, ridership and fare revenue. As PTAs have begun to focus on post-pandemic recovery, the Union ministry of housing and urban affairs has begun the process of introducing 20,000 new buses under the current Union budget, Department of Heavy Industry is implementing the electric bus programme and it has become necessary to guide grassroots action in cities. Bus fleet operation and augmentation require strong institutional preparedness and systems for proper bus maintenance, scheduling, and depot-based management of bus operational parameters.

CLEAN AIR AND LOW CARBON BENEFITS OF DEPOT BASED BUS MANAGEMENT AND MAINTENANCE

While a lot has been said about the importance of improving bus services and operations to effect substantial modal shift to public transport and accordingly several service-level benchmarks have been designed to inform the bus augmentation process, there is very little clarity on how such efforts need to translate at the level of depot management and related infrastructure. Depots are the nerve centres for translating the specifications related to proper operational planning, maintenance and improving economic efficiency of the operations on ground. Still, bus depots are the most neglected part of the bus system and are treated as a basic garage to park buses for rudimentary maintenance and scheduling of operations.

The key parameters of bus operations that nearly all PTAs are required to track include passenger numbers, load factor, fleet utilization, occupancy, headway, fuel efficiency and fuel consumption, fare collection, profits and losses among others. But they are not linked with the larger ecosystem planning to improve overall performance and to provide intended benefits of clean and low carbon mobility. There is enormous potential to intervene at the level of the depot to improve each of these parameters within the larger ecosystem planning.

There is also limited clarity about the linkage between these performance parameters and bus maintenance practices in the depots and how its neglect

can reduce bus ridership, revenue and also increase fuel consumption and fuel costs, labour costs and overall economic inefficiency and emissions. It is also not well understood how bus depot management is linked with the larger agenda of reducing carbon and pollution footprint of bus operations. Depot level infrastructure for maintenance and operational planning has to improve and should be consistent with the improvement in bus technology and IT applications for bus tracking and passenger information system.

Both routine and advanced aspects of bus maintenance in depots have enormous implications for resource savings and operational efficiency. For instance, if the fuel efficiency in terms of kilometre per litre is not tracked bus-wise and route-wise, it can lead to enormous fuel wastage. There is a big role of preventive maintenance and drivers training in controlling fuel inefficiency. Standard maintenance practices including fuel leakage, smoky exhaust, chocked up filters, etc. and regular observations of air pressure drop, brake pressure leakage, wheel temperature, tyre pressure, clutch slippage among others can substantially improve fuel efficiency.

For instance, adopting better bus operation and management practices that focus on allocating buses to fixed drivers on fixed routes, route-wise fixing of fuel consumption, communicating fuel economy data to the drivers and operators, and rewards for eco-driving can contribute substantially towards fuel savings that can cumulatively translate into reducing carbon footprints. It has been observed across depots that buses on the same route can consume different amount of fuel and the variation can be substantial due to faulty buses or defective driving.

Similarly, lack of preventive maintenance and inefficient depot management can cause more component defects and breakdowns. Often replacements of spare parts can be expensive. Also inadequate planning for spare parts at economical costs can reduce bus services and the number of scheduled trips, thereby leading to lower fleet utilization, reduced ridership and economic losses. Lack of spare parts management can also lock in enormous capital. Moreover, maintenance and repair requirements can increase the maintenance cost and also the downtime of vehicles. Proper maintenance can minimize breakdown of buses. It evident that almost 70 per cent of bus maintenance-related issues can be resolved by following a strict preventive maintenance regime.

While bus numbers are expected to increase to meet the growing demand for travel in cities, more and more depot spaces will be created for serviceability and operations of buses. But designing of these depots need to consider the full range of maintenance practices and operations to meet the requirements of the existing fleet as well as the future fleet. It is also necessary to consider the advancement in maintenance systems and technologies that help to improve the overall efficiency and identification of technical glitches on time to reduce the time and labour costs of maintenance that otherwise has a bearing on the overall economic efficiency of bus operations.

It may be noted that depots are constructed to last for at least 40 to 50 years. Therefore, designing a depot keeping in view the infrastructure requirements to meet the needs of ever-changing bus technologies is important. It should account for future requirements. For instance, most cities have constructed inspection pits according to the older design of high floor standard buses. But bus designs and technologies are changing rapidly. Moreover, several depots have already witnessed transition from diesel buses to CNG buses and now to

electric buses. All these technologies have unique requirements and, therefore, the service, inspection and maintenance requirements will have to evolve accordingly.

As the bus technology evolves rapidly, vehicles are being produced with a lot of advanced inbuilt diagnostic and warning systems about defects and anomalies during operations. But has also been observed that safety system are sometimes by-passed, and the buzzer switches for warning are disconnected or are non-functional. In the absence of warning systems, the driver may continue to drive the bus—for instance, with low air pressure or other problems, that can further damage the components and also lead to serious accidents. Therefore, periodic maintenance schedules should check the functioning of these systems.

Thus, depot-based management can have strong bearing on several parameters of bus operations including fuel savings, improved scheduling and services, increased economic savings due to decline in bus breakdown and technical snags, optimum use of human resource especially more efficient use of skill sets. Understanding this linkage is critical for improving bus operations especially during the pandemic times.

Centre for Science and Environment, based on its engagement and consultation with several PTAs across the country, has prepared this guidance framework for bus fleet maintenance and depot-level management. The objective is to guide depot-level management and investments to support augmentation of bus fleet and services in cities. This is oriented towards system design for bus deployment and to build awareness that augmentation of bus service is not only about buying more buses but it is about improving the entire ecosystem of maintenance and operations. This manual has been designed and detailed out keeping in mind the larger linkages with the clean air and low-carbon benefits of bus operations.

This guidance document is a hands-on step-by-step guide that is divided into six different segments:

Part-1: Techniques to assess the fleet maintenance efficiency. This will assist PTAs to assess their own maintenance ecosystem and work based on selected key indicators and identify the gaps or areas to improve.

Part-2: Provides the infrastructure details including land requirements for an improved depot facility, details of physical infrastructure, equipment (particularly use of modern equipment for improving maintenance practices) and human resource and skill needs to operate maintenance activity.

Part-3: Provides the standard operating procedures (SOPs) for fleet maintenance including details of maintenance regime, battery and tyre maintenance, etc.

Part-4: Provides the details related to improving fuel efficiency of buses.

Part-5: Outlines the role of spare and inventory management in fleet maintenance.

Part-6: Provides details related to fleet monitoring which includes management information system (MIS) monitoring work and training of personnel.

To enable implementation, this guideline document provides a detailed formats for record keeping activities for tracking action, outcomes and to improve decision making. It also provides useful details on how to avoid accidents linked with poor maintenance, and mistakes that can cause fire in buses, etc. This guideline is designed to build capacity of PTAs and inform decision making and investments for infrastructure planning for improved fleet maintenance and management of depots.

TECHNIQUES TO ASSESS FLEET MAINTENANCE EFFICIENCY

There are several indicators to measure fleet maintenance efficiency of bus services which can be broadly categorized into two areas:

i) Service efficiency or measuring the physical performance of the fleet
ii) Maintenance efficiency or assessing material performance.

Improving these parameters will considerably improve the overall service quality of the bus sector. However, for ease of conducting frequent assessment, fifteen key indicators have been identified for assessing fleet maintenance work. Details of selectors are provided (see *Table 1: Indicators to assess fleet efficiency)*.

This broad list of indicators covers almost all service parameters of bus operation. The main reason behind selecting these indicators are as follows:

a. Performance of the selected indicators are directly linked to fleet management practices at the depot level.
b. Each indicator is quantitative in nature so that the changes can be measured.
c. These fifteen indicators broadly cover seven different parameters of bus services.
d. As a majority of PTAs collect this information, it is easily available and no additional survey is required.

Table 1: Indicators to assess the fleet efficiency

Broad categories	Selected indicator for assessment
Service efficiency	1. Fleet utilization per day 2. Bus utilization per day 3. Bus productivity per day 4. Percentage loss of km due to breakdown 5. Percentage loss of km for buses not being out shaded due to maintenance issues 6. Breakdown per 10,000 km
Maintenance efficiency	7. Workshop and maintenance staff ratio per bus 8. Engine oil consumption per kilometer 9. Engine oil consumption per litre 10. New tyre consumption per lakh kilometre 11. Tyre retreadibility factor 12. Bus washing ratio 13. Average battery life (in months) 14. Spring consumption per lakh kilometre 15. Availability of spares

Source: CSE compilation

PTAs have to assess the performance of their fleets based on the industry benchmark set for each indicator. If the assessed values are closer to the industry benchmark value that indicates better fleet maintenance efficiency level of an PTA and vice versa. Indicator-wise benchmark figures are provided (see *Table 2: Industry benchmark against selected indicator for assessment*).

Table 2: Industry benchmark against selected indicator for assessment

Selected indicator for assessment	Industry benchmark
Fleet utilization per day	As per the age of buses: 0–2 years = 95 per cent or above 3–5 years = 93 per cent or above More than 5 years = 90 per cent or above
Bus utilization per day	180–200 km per day
Average bus productivity	160–180 km per day
Percentage loss of km due breakdown	Till 0.5 per cent acceptable
Percentage loss of km for buses not being out shaded or late-out due to maintenance issue	Nil
Breakdown per 10,000 km	One or less
Workshop and maintenance staff ratio per bus	1.02
Kilometre per litre (diesel) or kilometre per kg (CNG)	KMPL: Minimum 3.5 km per litre KMPK: Minimum 3.5 km per kg
Engine oil consumption km per litre	2,200
New tyre consumption per lakh km	Cross-ply type tyre: 70,000 Radial type tyre: 90,000
Tyre retreadibility factor	Cross-ply type tyre: Minimum 3 Radial type tyre: Minimum 1.5
Washing ratio per bus per month	Manual wash: 10–15 (change as per seasons) Automatic wash: Daily
Average battery life (in months)	36
Spring consumption per lakh km (in kg)	24
Availability of spares	100 per cent

Source: CSE compilation

PTAs should aspire to excel on each indicator by performing better than the benchmark value. It will not only help them to identify the gaps but also identify the underperforming areas which need to be rectified.

Formulas to calculate some important indicators

Fleet utilization per day: Percentage of buses available for use on a daily basis.

Formula:
Fleet utilization = Number of buses in operation/ The total number of buses held by the PTA (in a single day)

Bus utilization per day: It is defined as kilometers operated per bus (on road) per day

Formula:
Bus utilization = Total effective km operated/ Number of buses operated (in a single day)

Average bus productivity: Number of kilometers operated by bus (held) per day

Formula:
Bus productivity = Average effective km operated per day / Average number of buses held per day

BASIC REQUIREMENTS FOR FLEET MAINTENANCE

A. INFRASTRUCTURES

Depot-based infrastructure plays a very important role in the maintenance of buses. Maintenance of buses is adversely affected by poor infrastructure facilities in bus depots. Lack of adequate physical infrastructure is not the only problem. Many a time, the depot design requirements are not well understood and that leads to badly designed depots impacting bus maintenance activities. Physical infrastructure, which includes the number of bus inspection pits and repair bays, their sizes and depths; number and location of the washing ramp; location fueling shed; availability of the bus circulation area; etc., are very important while designing a depot.

In general, depots are constructed to last for 40 to 50 years. Thus, while designing, a good thought has to be given not only for the present requirement of the fleet but also for the future requirement of buses. For example, in many cities, it has been observed that the inspection pit is designed for high floor (i.e., 1,100 to 1,200 mm) buses keeping in view of old practices or standards of that time. At present, when these high floor buses are almost obsolete and PTAs have mainly buses with a floor height of 900 mm or below, these pits are slowly becoming redundant or difficult to work due to their low depth. However, even today, due to lack of awareness, some cities have constructed new inspection pits with old design practices.

Infrastructures of the depots needs to be designed in such a way that it creates a clean and healthy working condition for workers. When bus mechanics and other maintenance workers work under an uncomfortable working condition with limited space, poor visibility and unclean surroundings, it increases the risk of injury (due to hot surfaces and sharp edges) and risk of making mistakes (due to lack of concentration) which increases the frequency of accidents.

It is important to note that the type of bus operations also effects depot designing. In the intra-city bus operations or urban bus operations, the congregation of buses is very high during in-shedding and out- shedding time, as large numbers of buses enter or exit the depot within a short time span. Thus, availability of sufficient bus maneuvering space is very important in urban bus operations. Additionally, in urban bus operations, the buses are generally operated for more than 16 hours every day. In a majority of cases, the main maintenance activity takes place during night shifts, with an effective time limit of only six–eight hours. Thus, within a very short span of time, maximum buses are required to be attended to for maintenance, hence availability of proper infrastructure at the depots plays a very vital role in the proper upkeep of buses.

Images 1 and 2: Daytime and nighttime at a bus depot

JAYANT DESHMUKH

Since the majority of maintenance activities are carried out in night shifts, it is imperative to have sufficient illumination of all major activity areas such as inspection pits, repair bays, washing and fueling areas, etc. It has been observed that sometimes bus parking areas do not have proper lighting facilities, but we should keep in mind that various small activities such as engine oil and coolant checking, tyre pressure checking etc., are generally carried out in the bus parking yard, hence proper illumination of the entire depot is very important.

List of physical infrastructures(including spaces) is required for managing and maintaining 100–120 buses in a depot:

1. Land requirement: Approximately 5 acres
2. Inspection pits: One pit for every 15 buses
3. Repair bays: One per 50 buses
4. Under chassis washing pit: One
5. Bus parking yard: Hard standing ground (concrete)
6. Fueling shed
7. Bus washing shed
8. Engineering section and building
9. Scrap bins
10. Tower lights
11. Traffic section and building
12. Security post(at main gates)
13. Compound wall and gates
14. Parking space for employees' vehicles

Design of a pit

Pit design plays an important role to facilitate proper maintenance of buses. Pits can be used for inspection purposes or to carry out repair work or to clean chassis of buses. However, one depot should have the required number of pits and bays designated for different uses. Length and depth of the pit or bay will vary depending on the length and floor height of the buses. For example, a 1.3 m depth pit or bay can be sufficient for 900 mm floor height buses but if the floor height of buses become less, then they require 1.4 m depth pit or bay. Thus, as more and more modern urban buses have 400 mm floor height, pit or bay depth should be 1.4 m to cater to the need of all kinds of buses. Similarly, standard size bus length is 12 m, thus a 13 m long pit or bay can cater to the needs of all buses easily, and at one go (without moving the buses) bus mechanics and other maintenance workers can check the full bus.

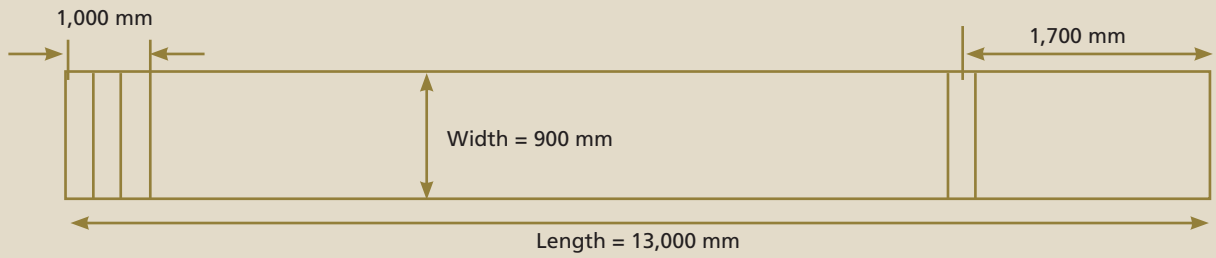
Entry or exit of a pit or bay should always be from the front side, as the back side entry may result in accidents during the reversing of buses. It is advisable to have interconnected pits for easy movement of employees and fixtures (see Images 3 and 4: Inspection pits or bays).Stoppers should be provided at the front wheels to prevent buses from over shooting. Guide railings should also be provided on the pits to prevent the entry of the wheels inside the pits.

Table 3: Approximate areas to be designated for conducting various depot activities (for a depot equivalent to manage 100 buses)

Activity area	Area required in sq. m	Area required in acres	Percentage of total area
Bus parking	5,520	1.36	27
Bus maneuvering	7,520	1.86	37
Open space required	694	0.17	3
Maintenance pits, repair bays, fueling and washing areas, etc.	1,400	0.35	7
Engineering sections and traffic buildings	5,100	1.26	25
Total area	20,234	5.00	100

Source: CSE compilation

Graph 1: Structure of a pit or bay



Top view

Longitudinal view

Note: Not in scale

Source: CSE compilation

Images 3 and 4: Inspection pit or bays

Interconnected pits

JAYANT DESHMUKH

Inspection pit covered by solar panel

Note: Both images are from a newly constructed depot by Mira-Bhayander Municipal Transport. The whole inspection and repair area consists of a completely sheltered solar panel area and generates approximately 312 kW energy, sufficient to cater to the power requirement of the whole depot. Additionally, as solar panels are transparent, it provides sufficient illumination in the pits during daytime.

B. EQUIPMENT

Equipment is an essential part of proper maintenance. It is important to take note of the list of equipment required for the maintenance of buses (see *Table 4: List of equipment required to maintain 100 buses in a depot*).

Table 4: List of equipment required to maintain 100 buses in a depot

Equipment	Quantity
Air compressors	2
High pressure bus washers	2
Pedestal drilling machine	1
Greasing machines	3
Gas welding set	1
a) Oxygen gas regulator	1
b) Acetylene gas regulator	1
c) Gas welding blow pipe	1
d) Gas cutting blow pipe	1
Electric arc welding machine	1
Battery chargers	2
Battery-operated truck (material handling equipment)	1
Floor scrubbing machine	1
Lube oil dispensers	4
Bench grinder	1
Buffing machines	2
Tube repair hot plates (not required for tubeless tyres)	3
Anvil	1
Injector test bench (for testing all types of injectors)	1
Electric hand drilling machines	3
Hydraulic jacks	20
Vacuum cleaners for air conditioned buses	2
Tyre pressure master gauge	1
Brake and clutch liner riveting machine	1
Spray painting machine	1
Brake efficiency meter	1
Clamp meters for checking battery voltage and current	2
Compression gauge to check engine compression	1
Diagnostic tool	1

Source: CSE compilation

In addition to the basic equipment listed, PTAs have also started to use more modern and advanced equipment. These advanced equipment enable improved operational efficiency with less number of human resource. In longer term, this helps PTAs to reduce their overall bus maintenance cost as the human resource cost is reduced. Detailed list of modern equipment follows.

1. Quick oil chamber clean and engine flush machine

It helps in thorough cleaning of engines, and, in turn, improves the engine life and fuel efficiency of the vehicle.

Image 5: Quick oil chamber clean and engine flush machine

Traditionally, engine oil replacement has happened by draining the burned oil through the drain plug with the help of gravitational force. The mechanic places a barrel at the end of the drain pipe to collect the oil. However, it has been observed that through this method oil does not drain completely and some residual oil always remain stuck to the engine walls.

Quick oil chamber flush, fitter and cleaning machine first suck burned engine oil through suction force. Later, they fill the cleaning fluid in the engine and drained it again through a suction force. Through this suction and flushing process engine gets cleaned completely and fresh engine oil is refilled in the engine.

Image 6: Brake drum and flywheel skimming machine

2. Brake drum and flywheel skimming machine

Generally, as per present practice, PTAs outsource brake drum and flywheel skimming activity to a third party. This is a very costly proposition for them as they have to hold up the buses till the brake drums and main flywheel is received from agencies, which effects the service. Additionally, they have to store large numbers of float units to prevent buses remaining off-road.

Therefore, a few PTAs have started to install this brake drum and flywheel skimming machine in their own workshop which can drastically reduce the overall cost and also improve the availability.

3. Nitrogen inflator

It is used to inflate bus tyres with nitrogen gas instead of air. Nitrogen gas is lighter than air and has a lot of advantages over air, i.e., improvement in fuel efficiency, reduction in tyre punctures, and improvement in tyre life.

Image 7: Nitrogen inflator

Urban bus operations require frequent stop and go kind of services which involves lot of brake usage. Frequent use of brakes generates high amount of heat in the tyres which in return negatively affects the life of tyres. Nitrogen filled tyres remain much cooler compare to air filled tyres help in improving tyre life. Thus, it is highly recommended that nitrogen be used instead of normal air in urban bus services.

Images 8 and 9: Wheel alignment and wheel balancing machine

4. Wheel alignment and wheel balancing machine

It is particularly needed for tubeless tyres. Presently, in a majority of cases, the new generation buses are fitted with tubeless tyres, thus the importance of this machine has increased immensely.

In tube tyres, the wheel alignment job is carried out with a simple wheel alignment gauge. It is also not necessary to check wheel balancing frequently. That job is also carried out sparingly.

However, tubeless tyres are very sensitive to misalignments and imbalances. Thus, they require frequent checking of both wheel alignment and balancing. Any fault in alignment or balancing shall lead to body vibration and defects in suspension systems of the bus. Thus, both wheel alignment and balancing job have to be checked through computerized machines.

5. Tyre inspection machine

Earlier, for checking punctures in tube tyres, inflated tubes used to be immersed in the water tank and by observing the water bubble, a mechanic could pinpoint the location of the puncture. Once the repair work was completed, the inflated tube was again immersed in the water tank to check for bubbles.

However, this process cannot be followed for tubeless tyres, as it entails lifting the heavy tyres, immersing them in a water tank and then rotating them. To facilitate easy checking of tubeless tyres, a tyre inspection machine can be used. It is pneumatically operated equipment. Through a foot pedal operation, the complete tyre can be lifted and immersed in the water tank, the tyre can also be rotated to check the puncture spot before and after repairs.

Image 10: Tyre inspection machine

Image 11: Brake efficiency tester

6. Brake efficiency tester

This equipment is very handy to check brake efficiency to prevent brake-related accidents. Additionally, it is also very useful to investigate the occurrence of such accidents.

In numerous cases, it has been observed that the maintenance department does not agree with the driver's version of poor brake efficiency as buses are declared alright (okay) and there are no brake-related anomalies and both parties stand firm on their point. In this kind of situation, the brake efficiency tester proves to be very useful equipment as it gives exact reading of brake efficiency and uneven braking (in case the bus is pulling on one side).

7. Brake unit test bench

Brake is considered to be one of the most critical part of a vehicle. It may lead to serious accidents, if not maintained properly. The overhauling of the brake units such as dual brake valve, air drier, relay valve, system protection valve, etc., needs to be carried out in a dust-free environment. These units have to be

tested on the test bench to assess their proper functioning and leakages before being fitted on the bus.

Image 12: Brake unit test bench

However, it has been observed that many PTAs neither carry out brake unit overhauling work in dust-free environment nor are brake units tested before being fitted, which leads to increased breakdown and brake-related accidents.

8. Brake and clutch liner riveting machine

At present, brake liner riveting is done manually in many PTAs. Brake liners are riveted to brake shoes by hammering the rivets to bond the brake liners to the brake shoe. For proper brake riveting, the stem of the rivets should also swell in such a way that there is no gap between the brake shoe holes and the rivet stem when riveted. This is possible only if the riveting is done through a riveting machine.

Image 13: Brake and clutch liner riveting machine

In manual riveting, unequal pressure is exerted on the rivets. In case of excess pressure, the rivet stem gets cracked though it is not visible. If the pressure is low, then it is difficult to create a strong bonding of the brake liners and the brake shoe, resulting in separation of the brake shoe liner. It may be pertinent to note that brake liner separation may lead to serious accidents. Hence, it is strongly recommended to carry out the brake liner riveting on brake liner riveting machine only.

Similarly, the liner riveting machine can also be used for relining the clutch plates as well.

9. Self-starter and alternator test bench

Generally, PTAs themselves carry out overhauling of self-starter and alternator in depots. However, due to non-availability of the test bench, they are directly testing both while being fitted to the buses. Additionally, removal and fitment of the self-starter and alternator on the bus is a strenuous as well as time-consuming process.

Image 14: Self-starter and alternator test bench

But this also leaves the testing improper as both the units cannot be checked for various loads on bus, which results in premature failure of units. The problem become so intense during the monsoon season that a large number of failures in terms of both self-starters and alternators are being observed due to water ingress. It also led to off-roading of buses, as testing takes longer time.

Availability of the self-starter and alternator test bench will improve the availability of the required units on time and also reduce premature failure of units.

10. Oil dispensers

There are six types of oils that are regularly used in buses, i.e., engine oil, coolant, gear oil, differential oil, steering oil and clutch oil.

With the exception of the clutch oil, all other oils are procured in barrels.

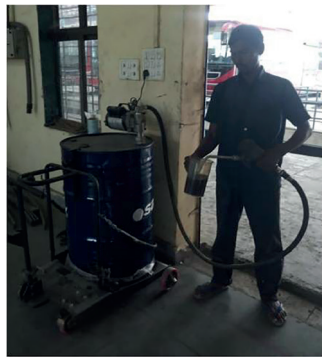
Whenever the oil level drops below a certain level, topping the same with exact quantity of oil is very important as excess topping may lead to leakages and less topping may lead to oil starvation.

However, the level to which oil needs to be topped is always left to the judgment of technicians, as oil level gauges only show the minimum and maximum levels on gauges and containers.

Extracting the exact quantity of the oil from the barrel adds up to the complexities due to its manual processing. Additionally, the manual extraction process, many times, leads to leakages during the withdrawal of oil and the technicians are unable to extract exact quantity of oil as required.

Technicians find it very simple to use digitized oil dispensers as it helps to extract the exact quantity of oil from the drum and stop oil leakages as well.

Images 15 and 16: Oil dispensers



11. Diesel exhaust fluid (DEF) pump

The diesel exhaust fluid (DEF) pump is extensively used in BS-IV and BS-VI engine buses.

Depending on the diesel consumption, technicians need to refill or top the fuel tank with the exact quantity of diesel exhaust fluid (DEF) on a daily or periodic bases. Additionally, withdrawing fluid from the diesel exhaust fluid(DEF) tank is also challenging, as one cannot use metallic components. Thus, to reduce the leakages and extract the exact quantity of the fluid, a non-metallic DEF pump is fitted with the DEF tank.

Image 17: Diesel exhaust fluid (DEF) pump

12. Digital clamp meter

The clamp meter is a very handy tool to check the charging rate of batteries.

The volts and amps both are checked through the clamp meter. The values can be checked with a load by switching on all the lights and off-loading by switching off all the lights. It is very important check the battery condition and charging alternators.

Image 18: Digitial clamp meter

13. Windscreen glass fitment machine

It is a portable equipment used to lift the front-windscreen glass and fit it on the bus.

As per urban bus specification-II (UBS-II), all buses should be fitted with a single piece front-windscreen glass. These glasses are very big in size (length: 2,485mm, and height: 1,041mmfor standard size buses), which also makes them quite heavy. Thus, they require at least three–four people to lift and fit in the bus. Sometimes, during the fitment process, the glass gets cracked due to small incidents of carelessness or

Image 19: Windscreen glass fitment machine

mishandling. As these glasses are costly, such incidents leads to additional cost burden to PTAs. Additionally, this manual process of glass fitment consumes quite a bit of time as well.

With the help of this modern machine, the entire process of removing and fitment of the front windscreen glass can be done by one technician and the turnaround time is also very fast.

14. Automatic bus washing system with water recycling plant

It is a very important equipment to improve the cleanliness of the buses.

It has been observed that even if some PTAs have already installed automatic bus wash systems in their depots, those are all with the two-brush machines. The two-brush machines can wash both the sides of the bus, but back and front portion and the roof of the bus is not cleaned.

The new generation three-brush washing system has sensors which adjusts the position of the third brush to take care of the fitments of the rear-view mirror, air conditioner on the roof, etc. These three-brush wash machines are very efficient in cleaning the outside of the entire bus from all sides.

Images 20 and 21: Automatic bus washing system with water recycling plant

Additionally, the installation of a water recycling plant is also vital, as the bus wash system consumes large amount of water. As per the estimates, a two-brush system consumes around 360 litre of water per bus and a three-brush system consumes 630 litre of water per bus. Now, water recycling plants can recycle almost 80 to 85 per cent of the water for reuse.

Image 22: Floor scrubbing machine

15. Floor scrubbing machine

It's quite natural to have mud, muck and burned oil spilling all over the pit area due to maintenance activities. Normal cleaning methods are not sufficient to remove hard and oily muck accumulated on the floor.

For removal of oily mud and muck, a scrubbing machine is very helpful. It has steel wire brushes fitted at the bottom which cleans all the mud, muck and oil accumulated in the pits and its surrounding area. Cleaning the pits is also necessary as the slippery surfaces may lead to serious accidents to the maintenance staffs. It also reduces the manpower requirement for cleaning purposes.

Image 23: Depot yard cleaning machine

16. Depot yard cleaning machine

In a depot, cleaning a bus parking yard is a very laborious work due to its big size. Generally, lot of paper bits, wrappers and other trash are left behind by users during sweeping and dry cleaning of buses at bus parking yard. It has been observed that on a number of occasions, residual waste is left littered in the parking yard which requires further cleaning.

Manual cleaning of the yard demands more manpower and supervision. Depot yard cleaning machine is much easier to operate and it cleans the bus parking yard with less man hours.

17. Tools and fixtures

In addition to the aforementioned equipment, the maintenance work require a large number of tools and fixtures. Unavailability of these tools and fixtures directly affects the maintenance of buses. A detailed list of required tools and fixtures are provided in *Annexure- 1*.

18. Safety equipment

The details of the safety equipment required for the maintenance of the buses is attached in *Annexure 2*.

C. HUMAN RESOURCE

There are no set standards for the human resource requirements for maintenance of buses. PTAs, including STUs and SPVs, follow their own norms for both number and categories of personnel required for their services. Actually, the human resource requirement depends upon several factors including the volume of work load, extent of operation (16 or 24 hours) type of the buses (air conditioned or not).However, since the majority of the bus fleets in India are non-air conditioned diesel or CNG buses, the human resource requirement for non-air conditioned diesel and CNG buses has been suggested here.

A tentative shift-wise allocation of all the human resource, based on the work load generated is provided in *Annexure 3*.

Table 5: List of manpower required to maintain 100 buses (non-air conditioned)in a depot

Manpower category	Basis of working
Workshop manager	One per depot
Assistant workshop manager	One per depot
Supervisors	Eight per depot (five mechanical, one electrical, one bus body, and one tyre supervisor)
MIS executive	One per depot
Stores clerks	Two per depot
Mechanical work (including mechanics and assistant mechanics)	14 per 11,000daily operated km
Suspension work	Two per depot
Bus shunter (drivers)	Four per depot
Electrician	One per 12 buses
Body fitter(Denting work)	One per every 15 buses
Welder	One per depot
Painter	One per depot
Fibre-reinforced polymer(FRP) work	Two per depot
Tyremen	One per every 17 buses
Tyre repair men	Two per depot
Helper	25 per cent of technical staff allocation (approximately 13 per depot)
Washing supervisors	Two per depot
Cleaners(washing, sweeping and cleaning)	15 per depot (manual washing)
Depot housekeeping cleaners	Three per depot

Note: For air conditioned buses, in addition to the aforementioned manpower list, three air conditioned mechanics shall be required. Source: CSE compilation

PROTOCOLS FOR FLEET MAINTENANCE

A. PREVENTIVE MAINTENANCE OF BUSES

'Prevention is better than cure', a popular proverb related to human health, is also applicable to maintaining the health and serviceability of buses. It evident that almost 70 per cent of bus maintenance-related issues can be resolved by following a strict preventive maintenance regime.

It's true that bus manufacturers always provide preventive maintenance details for their buses in the form of 'bus operator's manual', but the details prescribed by bus manufactures are more generic in nature and not customized as per the imperatives of city operations. It is important to note that each city has different operating conditions. Thus, the period between the two successive maintenance schedules needs to be worked out by the PTA of that city, based on its operating conditions.

There are eight types of preventive maintenance schedules, which need to be followed to ensure a healthy fleet till its end of life.

1. Daily maintenance
2. Periodic maintenance
3. Major docking maintenance
4. Unit replacement as per their stipulated life
5. Predictive maintenance
6. Low-fuel mileage maintenance
7. Seasonal preventive maintenance
8. Attention of buses for fitness certificate (FC) renewal (RTO passing)

1. Daily maintenance

As the name suggests this type of maintenance activity is carried out on a daily basis. In regular bus operations, there are certain jobs and activities that need to be carried out on a daily basis, without attending these jobs or activities, buses should not be deployed on routes. The activities included in daily maintenance as follows:

1. Inspection of buses, which includes:
    - 0.1. Engine oil and coolant level
    - 0.2. Brake and clutch fluid level
    - 0.3. Fan belt tension
    - 0.4. Condition of radiator hoses
    - 0.5. Sedimentary drain
    - 0.6. Brake and clutch pedal-free play and adjustment
    - 0.7. Working of all dashboard gauges
    - 0.8. Passenger door operation
    - 0.9. Fuel tank cap condition
    - 0.10. Smoke condition
    - 0.11. Battery connectors
    - 0.12. Alternator charging
    - 0.13. Destination boards
    - 0.14. Fitments of additional light gadgets on the outside or inside of the bus
    - 0.15. Fitment of radio and music system inside the bus
    - 0.16. All cameras on the bus
    - 0.17. Bus driver consoles (BDC)

0.18. Inspection of seats, stanchion bars and body fitments
0.19. External body damage
0.20. Display of unauthorized slogan posters on the bus

2. Fuelling of buses
3. Attention of driver complaints
4. Tyre pressure checking
5. Sweeping and cleaning
6. Washing of buses

Note: All these parameters shall be checked in the bus parking area and the buses are not required to be taken to the inspection pit.

2. Periodic maintenance

Periodic maintenance is carried out after a certain time interval or period. There are four ways to calculate the time interval or period:

a. Number of days
b. Number of hours of operation
c. Number of km operated
d. Fuel consumption

Generally, a large number of PTAs calculate the time interval based on the number of days. They either follow a seven-day schedule (also known as weekly schedule) or a ten-day schedule.

However, calculating the time interval based on the number of days of bus operation is a very rudimentary method and it might not completely be suited to urban bus operations. It is important to highlight that in the urban bus operating scenario, it is quite natural to have certain routes where buses operate for150 km per day, whereas on some routes they may operate for more than 300 km per day. Thus, considering the number of days of operation as a base to set up time intervals for all buses shall not be correct, as wear and tear of buses varies. Buses that have to be operated for more km are expected to have more wear and tear and vice versa. Hence, technically, buses that have travelled more should be given more frequent attention than buses that have travelled less.

The second option, based on the number of hours of operation, is more precise than the previous one, as the wear and tear of buses or rather bus components shall increase with increasing number of operational hours. However, the main challenge of this method is recording the exact number of hours of bus operation.

The third option is calculated based on the number of operated km. This method is expected to be correctly reflected in the wear and tear of bus components. Thus, manufactures are always recommended to have a time lag based on km travelled. For example, engine oil change or oil change of various other units in the bus is always based on the number of km operated. However, in urban bus operations, the wear and tear of certain bus components like clutch and brakes is very high as buses have to operate with frequent use of those components. But it doesn't reflect properly in the number of km operated as total operating km might be low due to lower running speed of the buses. Additionally, for calculating the distance travelled, the odometers of all buses need to be functional. However, it has been observed that due to non-functional odometers, PTAs, generally, prefer to calculate the operational km travelled based on the route length and number of trips operated on that route. Now, if

the route lengths are not updated at regular intervals, it may lead to improper calculation of bus operated km which, in turn, affects the calculation of the period or time interval for maintenance.

The final option is calculating the time interval or period based on fuel consumption. It is considered to be the most accurate way of calculating the time interval or period for maintenance. The moment an engine starts, fuel consumption also starts and the moment the engine shuts down, fuel consumption also stops. Additionally, fuel consumption can also minutely capture the nuance of urban bus operations. Generally, in urban bus operations, we observe large idling periods where the buses are stationary or moving at very slow pace, in such cases, though the operated km are lower, fuel consumption continues, irrespective of the idling periods or km operated. Furthermore, almost all PTAs maintained the record of fuel topping very meticulously on a daily basis, thus chances of giving accurate measures are very high. Due to its accuracy, this method of calculating time interval or period is highly recommended for urban bus operations.

The detail of jobs that are required to be carried out during the periodic maintenance of buses are as follows:

1. Checking oil level of all units
2. Checking oil and fuel leakages
3. Checking air pressure leakages
4. Checking pressure built-up over time
5. Inspection of fouling of brake, clutch, coolant and fuel pipes
6. Replacing of worn-out rubber hoses
7. Wheel-bearing play
8. Inspection of brake and clutch systems
9. Cleaning of radiator through air or water
10. Inspection of all suspension parts and bushes for wear-out
11. Inspection of rear bellows height
12. Lubrication of all greasing points
13. Tightening of all suspension bolts and rear axle bolts
14. Tyre pressure checking and inspection of all tyres for wear pattern and tread depth
15. Checking working condition of all electrical fitments
16. Removing the glasses of electrical fitments, cleaning and refitting
17. Battery cleaning and topping
18. Tightening of all body bolts
19. Inspection and rectification of all body and passenger seat defects
20. Inspection and rectification of all ITS units.

Note: Inspection of buses to be carried out in the inspection pits only. All minor jobs need to be attended to in the preventive maintenance schedule. All defects observed during the inspection of the bus need to be recorded properly.

3. Major docking maintenance

The major docking maintenance is proposed to be carried out twice in year after every 30,000 to 35,000 km of bus operation (shall be modified based on the operating conditions). During the major docking, the chassis of the bus needs to be washed and painted properly.

At first, the MIS executive shall provide the programme details of docking buses, (i.e., the bus about to get docked for major docking maintenance) to the maintenance manager or docking supervisor a week in advance. Accordingly,

the docking supervisor shall plan for the spares for the docking bus, which includes all the units that need to be changed as per the manufacture's recommendation, like brake units, hoses, etc. They should be kept ready in the stores one day in advance before bus docking. Additionally, the docking supervisor should also note down all the complaints including the complaints reported by drivers prior to giving any attention to the docked bus.

The details of the jobs required to be done during major docking are provided below:

1. All jobs as carried out for periodic maintenance (i.e., seven or 10 days) schedule to be carried out in major docking schedule
2. Chassis washing and painting
3. Oil changes: Engine oil, gear box, differential, steering, clutch, coolant as per the programme generated by the MIS executive
4. Hub greasing of all wheels
5. Brake pad replacement and overhauling of all wheels
6. Brake unit and brake hose replacement as per the programme
7. Engine tappet setting
8. Draining and cleaning the fuel tank and fuel lines, cleaning the fuel tank drain plug filter
9. Tightening the cylinder head nuts as per the sequence specified by bus manufacturer
10. Inspection and replacement of defective propeller shafts
11. Inspection and replacement of defective clutch assembly
12. Replacement of suspension pads if found worn-out
13. Replacement of antiroll bar bushes if found worn-out
14. Body maintenance (denting, painting, etc.)
15. Removal and refit of batteries
16. Checking the functioning of the ITS system and attending to it if necessary

Maintenance of the major docking bus should preferably be carried out in the first shift, so that the bus can be dispatched for operation in the second shift. Chassis washing should be done on the previous day. All jobs pertaining to mechanical, electrical, body, tyre, ITS system and air conditioner system have to be carried out during the major docking, and not just the hub greasing work which is the only work presently carried out by many PTAs, particularly those buses operated on the PPP model. After completion of maintenance of the docked bus, the docking supervisors should road test the bus for any abnormalities and get it rectified.

On the next day, the same bus should be kept for the inspection again. The maintenance manager or workshop manager shall inspect the bus. Any deficiencies observed shall be brought to the notice of the docking supervisor and the related staff. Docking bus attention needs should be given outmost importance as it is expected that once the bus is attended for docking, all related jobs including brake liner replacement, hub bearing or seal replacement, unit replacement, hoses replacement etc. shall not be required to be performed till the next docking again. All jobs such as clamping and routing of wires and pipes, etc. need to be carried out properly to avoid any repetition of work.

4. Unit replacement as per stipulated life

Units such as dual brake valve, air drier, relay valves, system protection valve, air compressor head, brake chamber diaphragms, etc. are required to be replaced as per their stipulated life, i.e., as mentioned in the bus operator's manual. It has been observed that except for oil changes, PTAs do not follow

unit replacement schedules. Generally, units are replaced only after they fail to perform. Some PTAs are not even aware of unit replacement schedules. Since the brake units are very crucial, any failures may lead to serious accidents. Hence, it is always advisable to follow unit replacement schedules strictly. Unit replacement schedules should be matched with the docking schedule as all jobs will be synchronized and the buses are not required to be held up for replacement of units.

5. Predictive maintenance

The units such as clutch assembly, self-starters, alternators and air compressors do not have any defined life-span specified by the bus manufacturer. Thus, these units are replaced only after they fail to perform. However, some PTAs, based on their own experience, have been able to derive a tentative life-span for these units as well and they periodically replace these units once they reach the end of their expected life span. Predictive maintenance drastically reduces breakdown, while improving the reliability of buses. Additionally, as units are replaced just before their failure, it helps in reducing the damage caused to units which, in turn, reduces the overhauling cost of buses.

6. Low fuel mileage maintenance

All buses with low-fuel efficiency should be inspected separately. Generally, MIS executives should compute the kilometre per litre (KMPL) value of every bus after analyzing the operated km vis-a-vis diesel-topped level. Once the KMPL value of all buses has been calculated, they should array the table from lowest to highest value to find out the buses that have the lowest KMPL value. Then the buses that are reporting low KMPL value (ideally compared with the average KMPL value of the same PTA) on repeated instances should share the details with the concerned maintenance manager or works manager. After this, these buses should be taken up for low-KMPL attention in the night shift. A detailed checklist for KMPL attention has been provided as *Annexure4*. After a detailed inspection, if any serious lapses are observed, i.e., fuel leakage, smoky exhaust, choked up filter, etc., the maintenance managers need to plan to address those issues while attending the bus for regular preventive maintenance. Buses that have been attended for low-KMPL jobs need to kept under constant observation for improvement of performance.

7. Seasonal preventive maintenance

This type of maintenance is generally carried out before the arrival of a certain season such as summer season or monsoons (in the subcontinent). Maintenance carried out before the arrival of the season will ensure minimum breakdown of buses during the season. Detailed list of jobs needs to be carried out before both summer and monsoon seasonal maintenance are attached as *Annexure 5*.

8. Attention of buses for fitness renewal (RTO passing)

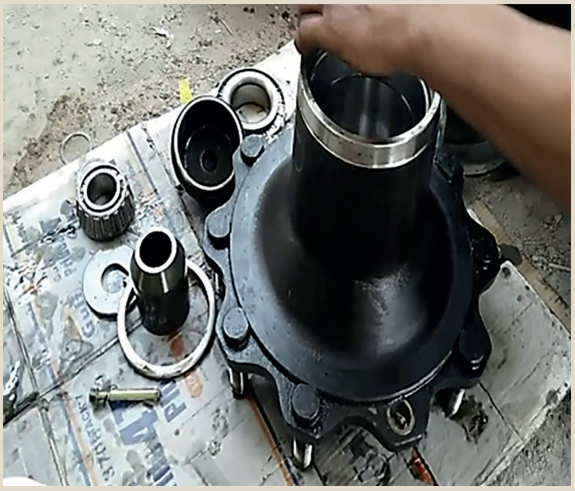
All buses are required to be produced before the RTO for the fitness renewal annually. Thus, before fitness testing, all buses need to be attended for all jobs, including mechanical, electrical, bus body jobs and checking validity of safety equipment. If all preventive maintenance schedules as stated above are studiously followed, then PTAs need not worry about fitness testing. All buses need to be painted from both sides (inside as well as outside) properly before being produced for fitness renewal.

A few important tips for better maintenance of buses

1. Always clean the hub bearings with cleaned cloth

It has been observed that in a majority cases, hub bearings are cleaned with either cotton waste or dirty cloth. Additionally, after cleaning the hub bearings are kept on the dirty floor or on cardboard.

Image 24 and 25: Cleaning of hub bearings



JAYANT DESHMUKH

Hub bearings should always be cleaned with clean cloth. Additionally, a clean tray should be used for cleaning the bearing. Hub bearings should be cleaned with turpentine oil only. It may be noted that hub bearings have a very low tolerance. Even minute dirt or a string of cotton waste can badly damage the bearing which, in turn, damage the tyres as well.

2. Use exact quantity of the grease in the hub bearings

Generally, it has been observed that cleaners or helpers assigned for the job of replenishing the grease, due to ignorance tend to use excessive quantity of grease in the hub and bearings.

Excess quantity of grease shall reduce the free rotation of the bearings, on the other hand less quantity of grease damages bearings. Hence, filling the accurate quantity of grease inside the hub bearings is very important. Generally, the actual quantity of grease required for front and rear hub is always mentioned in the workshop manual supplied by the bus manufacturer. As a standard practice, square type aluminum boxes can be fabricated in such a way that they accommodate the exact quantity of grease required for front and rear hubs (two separate boxes). Since this activity is required to be carried out during the docking schedule attention, the store department shall fill these fabricated boxes with the required quantity of grease and issue the same to the docking staff. For easy understanding, the boxes shall be clearly marked as F and R, as a reference for helpers to fill the grease in the front and rear hub. This arrangement will not only help to reduce the wastage of grease but also improve the life of bearings.

3. Clean up excess grease while lubricating chassis

It has been observed that during chassis greasing, the grease that oozes out from the grease nipples is never wiped out.

It is important to note that excess greasing not only restrict the movement but also attracts dust which in turn damages parts quickly. To ensure that grease penetrates through the grease nipple, some amount of grease shall oozes out from the other end. If the grease does not ooze out, it clearly indicates that the grease nipple is defective. The small amount of grease that oozes out from the end needs to be cleaned immediately. Excess grease should be wiped out with clean cloth and not a dirty cloth.

Image 26: Excessive greasing

4. Optimum level of oils

It has been observed that some PTAs maintain oil levels of all the units, i.e., engine, radiator, gear box, differential, steering, and clutch, above the maximum level. Additionally, due to unavailability of gauges, the gear box and differential oil level checking is carried out manually by inserting a finger.

The oil levels of all units, i.e., engine, radiator, gear box, differential, steering, and clutch should always be maintained within a specific range of high and low level. Maintaining the oil level at more than the maximum level shall lead to excess pressure in the system damaging the pipes and oil seals and packing, resulting in oil leakages. Replacing oil seals is a very tedious job and it increases the cost of maintenance. Gauges needs to be fabricated to check the oil levels of gear box and differential units to prevent human errors.

5. Always replace the clutch in assembly

In general practice, it has been observed that incase the clutch plate is found worn-out, the mechanic only replaces the clutch plate and rest of the parts, i.e., pressure plate and main flywheel, is refitted, if they are found to be okay by visual checking.

In urban bus operations, the workload of clutch replacement is very high due to continuous operation of clutch and gear. To reduce the work load, it is imperative to improve the clutch life by replacing the whole set (clutch) in assembly.

Image 27: Clutch

Whenever any bus reports for clutch defects, the complete set comprising of main flywheel, pressure plate and clutch needs to be removed from the bus and a new set needs to be fitted. Additionally, one should also check the condition of withdrawal bearing and replace it, if required.

The advantage of replacing the clutch in assembly is as follows:

a. The main flywheel and pressure plate back-plate is skimmed, hence unevenness of the surface is minimized.
b. The setting of pressure plate finger height can be done properly on the bench rather than on the bus. With a proper setting, the clutch operation will be smooth, resulting in enhanced clutch life.
c. Human error in pressure plate finger height setting is eliminated as only one person involved in the production of units is doing these jobs instead of various mechanics.

Before the fitment of the clutch assembly, it is important to check the length and thread condition of the pressure plate and gearbox surrounding bolts. It is invariably found that after repeated use, the bolts gets elongated with the uneven bolt size and the tightening is not proper, affecting clutch life. All uneven sized bolts need to be replaced with new bolts.

6. Recheck the buses after the fitments of major units

Many times, buses are not checked properly before being deployed on the road after major unit changes.

All buses should be rechecked after replacement of major units such as gear box, clutch assembly, engine, cylinder head, spring assembly and differential assembly. It is necessary, as due to vibrations and load of the bus, the bolts may loosen up and, if left unattended, might affect the unit's life. Additionally, improper fitment of bolts may lead to more vibration of buses and rapidly erode the unit life.

7. Always clean the gear box and differential breathers during every schedule

It has been noticed that, invariably, the gearbox and differential breathers are not cleaned during the periodic maintenance schedules.

Choked breathers do not allow gases to escape which, in turn, slowly creates a high-pressure situation inside the unit, causing damages to the oil seals. As a result, oils start leaking from the oil seals. It is easier to clean the breathers than replace oil seals. Additionally, replacement of oil seals also increases the maintenance cost and downtime of the buses.

Image 28: Choked breathers

8. Proper inspection of buses in case of en route breakdowns
Generally, not being practiced by all PTAs.

Buses that report en route breakdowns and rectify the same en route need to be inspected again during the night by the night supervisor. Since the breakdown rectification job is done on the road with many constraints, including limited space, illumination, unavailability of right kind of instrument, etc., so it may not be carried out perfectly. If a bus is not re-inspected, the same breakdown may occur again. A night supervisor is required to check the breakdown-attended job thoroughly and ensure that the job has been done satisfactorily. Investigation is also needed to find out the reasons of breakdowns and take necessary precautions to prevent the occurrence of such incidents. The maintenance manager should start his duty by checking the breakdown report, i.e., number of breakdowns reported on the previous day, and starts to investigate each and every breakdown thoroughly. The failed parts(that are assumed responsible for breakdowns) are to be deposited in the manager's office for further examination to find out the reason for the failures. A majority of breakdowns are avoidable, if previous ones are investigated thoroughly and action taken accordingly.

9. Brake assembly processing
PTAs always receive numerous complaints related to brake systems from drivers due to improper fitment of brake assembly

Image 29: S-camshaft

In the major docking schedule, the brake assembly comprising of brake liners and S-camshaft shall be removed. S-camshaft should always be checked for any wear on the roller portion. S-cam bushes are required to be replaced during every major docking schedule attention. During the assembly process, S-camshaft needs to be kept at a horizontal position with the 'S' profile seen in horizontal position, if viewed from the side. The S-camshaft should rotate freely and there should not be any hindrance in its rotation.

The actuator (brake booster) should be a stand-out for at least 72 mm.The S-camshaft needs to be connected to the brake actuator through the slack adjuster in such a way that neither the stand-out position of the actuator nor the horizontal position of S-camshaft gets disturbed. If the brake assembly is fitted in this position, then there is a complete synchronization between the movement of the brake actuator push rod and rotation of the S-camshaft. Whenever the brake is applied, the angle between the slack adjuster and brake push rod should not be more than 90 per cent. For the automatic brake adjusters (slack adjusters), as is very common in buses these days, to function perfectly the taper and ovality of the brake drum should be within permissible limits of 0.2mm. It is important to note that automatic brake adjusters will adjust the brake after sensing the stroke length of the brake actuator. When the brake liners start to wear out, the gap between the brake liner and the drum increases which, in turn, increases the stroke length. However, with the help of internal mechanisms of the slack adjuster, the gap between the brake liner and drum should be adjusted to 0.5 mm.

Concentricity of the brake drum is very important for proper functioning of the brakes, thus during every major docking schedule along with the brake assembly, brake drums shall also be replaced with new or skimmed drums. Brake drums are required to be checked with gauges to ensure that the taper and ovality is within the permissible limits. It is advisable not to adjust the brakes manually in automatic brake adjusters.

Image 30: Steering gap

10. Ensure steering stopper gap
Generally, this is ignored.

Presently, power steering is mandatory for all commercial vehicles. Limit switches, fitted on the steering box, hydraulically limit or restrict the right and left turn. As a back up measure, in case of limit switch failure the right and left turn is limited mechanically through a stopper bolt provided on the stub axle. Ideally, the right and left turn should be limited or restricted hydraulically, not mechanically. In case the stopper bolt is not adjusted properly, the right and left turn can be limited or restricted mechanically. In such cases, the stopper bolt touches the axle and helps in

building excessive hydraulic pressure in the steering system. As a result, steering pump fails and oil starts leaking through steering hoses. To prevent this from happening, a through checking during every periodic maintenance is required.

11. Pinch gap for tie rod and drag link arm
Generally, this is ignored.

The pinch gap in the tie rod and drag link assembly needs to be checked during every periodic maintenance schedule. In case of non-availability of the pinch gap, the ball joints may come out and cause serious accidents.

Image 31: Drag link arm

B. BATTERY MAINTENANCE

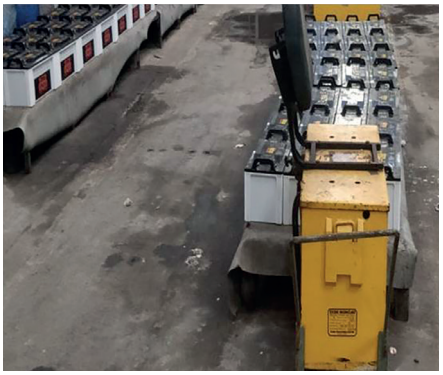
More advanced electrical applications are being designed and used in today's urban buses. It requires more power to operate these new electrical systems. Since dependency on batteries has increased significantly, the importance of regular battery maintenance has become critical in achieving both—high performance and long-life span of the batteries. A battery is only as good as the service and maintenance it receives. Often batteries are taken for granted, with the expectations that they will work anytime and anywhere, irrespective of how we are maintaining them through their lifecycle.

A detailed battery maintenance procedures has been outlined as follows.

1. Never keep batteries on the floor during charging, batteries need to be kept on a wooden stand covered with mating. Charging batteries by directly keeping them on the floor will result in current leakages, increasing the charging time and reducing the life of the batteries.

Image 32: Wrong practice
Battery is placed directly on ground while charging

Image 33: Correct practice
Battery is placed on a table while charging



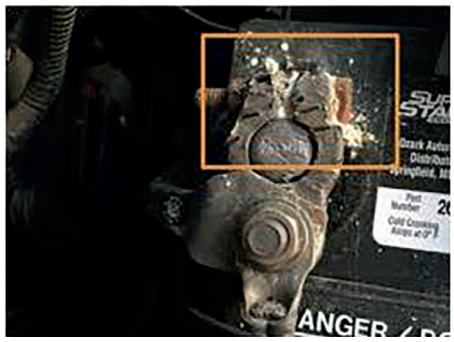
2. The gravity and water level of the batteries need to be checked during every periodic maintenance schedule.

3. During every periodic maintenance, the mechanic should clean the batteries

properly, i.e., by removing the vent plug and cleaning it. After cleaning, one should apply petroleum jelly to the battery cable lugs to avoid sulphation. Additionally, the pinch gap at the battery lug needs to be checked for proper tightening. In case there is less gap, one should replace the battery lug.

4. **Figure 1: Properly cleaned vent plug**

Figure 2: An unclean plug causes sulphation



5. Ensure proper mounting of the batteries in the bus. Batteries need to be mounted on anti-vibration runners (for ease of access for inspection or exchange). Batteries should not incur lateral or vertical movement when a vehicle is in operation.

6. Mating should be provided below the battery to prevent rusting of the battery mounting panel in the bus.

7. Battery locks need to be checked regularly to prevent battery coming out during bus operation.

C. TYRE MAINTENANCE

Tyres are costly and contributes significantly to the overall operation and maintenance cost of buses (next only to fuel cost). Any savings in tyre cost straight away adds to the bottom line of the organization. Thus, enhancement of tyre life is very important to reduce cost. Tyre life can be optimized with an effective tyre management policy. The following measures are suggested to improve tyre life.

1. Assembling practices

A good tyre management practice is to have sufficient stock of tyres prepared in advance for use. Ideally, a sufficient float at 0.4 per bus should be provided at the depot. Advance tyre preparation is also needed to avoid mismatch of tyres. In emergencies, tyres are prepared randomly and fitted to the buses as the mechanics have no option for selection in order to match. Further, it must be ensured that a sufficient stock of nylon, radial tyres (new and RC) and tubeless tyres are kept ready after preparation for use. Following are some of the important aspects to be implemented during assembling of tyres:

a. The surroundings, where the assembling is being carried out, shall be maintained neatly to avoid dust entry into tyres.
b. Every tyre shall be checked thoroughly inside and outside for any injuries and foreign material before selecting it for assembling.
c. Only new tube and flap shall be used in a new tyre and fit-for-front tyres.
d. The tube shall not have excessive folds because the wall of the tube will become thin at the folds and is prone to leakages.
e. The valve stem shall be checked thoroughly for external and internal

threads. The effective length of the stem shall be ensured by removing the bends and maintaining proper angles to have better reach in any wheel position. If the external threads are damaged, valve caps will be frequently missing, causing dust entry and resulting in valve pins being struck up and slow air leakages. Use only new valve pins at the time of assembling, as used pins may be dirty or defective.

f. The condition of the flap at the ridges and ends shall be checked before use.
g. It shall be ensured that the wheel discs are thoroughly cleaned with twisted wire brushes before painting with red oxide.
h. Before placing the correct tube and flap inside the tyre, ensure chalk powder dusting with help of a puff made out of perforated cloth to avoid sticking of flap or tube to the tyre. Excessive dusting is not advisable as it may result in stone formation and pinch the tube.
i. After placing the tube, flap and metallic washer properly, the tyre shall be mounted on the rim and the flanges. Ensure that the lock rings are correctly seated.
j. The tyre should be gently inflated to 15 PSI (1 kg/cm^2) initially for correct seating of the lock ring and flanges.
k. Double inflation of the tyres to the operating pressure is a must (i.e., inflate to operating pressure, deflate, check seating and then re-inflate). Improper mounting of the tyre on the wheel disc causes camber wear on the tyre. This is all the more important in case of radial tyres as the irregular tread wear can be predominantly seen on such improperly mounted tyres. Checking the equidistance of rim edges to the marking on the tyre can ensure this.

2. Inflation of tyres

Inflation of tyres to the recommended pressures plays a vital role in achieving the optimum tyre life as well as conserving precious fuel. Inflation pressures are recommended by the tyre manufacturers based on the ply rating, tyre construction (bias and radial), loading pattern, etc. Tyre inflation has to be maintained strictly as per the manufacturer's recommendations. There are a number of ill-effects of under-inflated and over-inflated tyres.

a. **Under-inflation:** Under-inflation of tyres cause excessive flexing of the casing and builds up heat and weakens casing and plies. Heat is the major enemy of a tyre. The following ill-effects are observed due to under-inflation:
   i. Under-inflation increases rolling resistance, thereby more HSD oil is consumed.
   ii. It increases the possibility of ply or tread separations and patch loose due to excessive heat built-up.
   iii. Under-inflated tyres are more prone to punctures and through-cuts due to weakening of the casing.
   iv. Under-inflated tyres wear out on the shoulders only, thereby the life of the tyre is reduced.

b. **Over-inflation:** Over inflated tyres are more prone to concussion bursts. Due to less road contact, the tyre wears faster in the middle and its life is reduced. Further, the flexing characteristics of the tyre get reduced due to over inflation and affect the steering or riding comfort. The following measures are essential for maintaining correct inflation pressures:
   i. Inflation points—one for every 20 vehicles shall be provided in the depot. Inflation points shall be provided at convenient places, for example, on either side of maintenance pits, tyre preparation bay, etc. Master gauges shall be provided additionally for cross-checking these gauges.

ii. Correctness of the gauge is very important for maintaining accurate inflation pressures. Wrong gauges will result in either under-inflation or over-inflation of tyres. Correctness of the gauges shall be ensured by (a) Cross-checking with the "master gauge" once a week (b) Getting it calibrated at authorized centres once every six months.
iii. All supervisors and tyre mechanics must be provided with hand pressure gauges with flexible hoses.
iv. The adopters of all inflating points must be in good condition, otherwise every time while checking the inflation it may deflate the tyres due to leakage.
v. All vehicles in a depot must be divided into groups so as to check and correct the inflation pressures of the tyres twice a week by a tyre mechanic.
vi. At least 10 per cent of the vehicles must be cross-checked for correct inflation pressures by the shift supervisor and another 5 per cent vehicles must be cross-checked by maintenance manager or assistant maintenance manager every day.

3. Tube repairing practices

Proper application of patches on a puncture spot avoids slow leakage of air and tyre puncture due to patch failure. Following precautions are to be taken while applying patches:

a. Correct size and type (round or oval) of patch shall be selected basing on the injury on the tube.
b. Preparation of injury spot by buffing and cleaning is important for proper adhesion.
c. Correct centering of the patch on the injury will give strength to the patch. This can be ensured by 'X' marking at the injury using yellow crayon.
d. Since the patches are vulcanized by chemical action, it is essential to use patches of the same make as a set. Further, the patches must be used before the expiry date only. Otherwise, they may fail online causing tyre punctures.
e. Patches so applied must be allowed to cure for at least 24 hours before they are put to use.
f. All tubes must be checked in a water tub for leakages by inflating them with such pressure that outer circumference of the tube shall not exceed 300 cm. Normally, tubes shall be inflated to 1kg/cm^2 (15 PSI).
g. Sufficient quantity of tubes repaired of both bias ply and radial shall be kept in advance in the depot for use in the shifts.

There is an apprehension that tyre punctures are not avoidable in nature which is not correct. The majority of tyre punctures take place due to improper inflation (mostly under-inflation), pinching of tube by the flap, tube patch failure, tube fold, burrs on the metallic washer, damaged inner liner of the tyre, etc. Further, tyres are more susceptible to cuts only when the leftover NSD is around 2 mm. Thus, it is necessary to have a system of analyzing all tyre punctures in a depot for correct diagnosis and corrective actions. This will help a great extent in reducing the workload on tyre mechanics and others.

4. Matching of duals

Normally, rear outside tyres wear faster than rear inside tyres. Thus, it is suggested to use bigger diameter size tyre on the outside and smaller diameter on the inside. Additionally, the road camber also necessitates using smaller diameter tyre in the inside position. Normally, the inner tyre shall be 1/2"

(1.3cm) lesser in diameter than the outer tyre. If the tyres are not matched as above, the entire load of the vehicle will be carried by single tyre only and it will wear out faster and unevenly. The tyre, on which the load is more, flexes heavily and builds up heat, which affects the plies as well as patches. Tyres shall be checked for "matching" with the help of 'L' Square on fully inflated tyres. Further, in the weekly checks, the matching of tyres shall be done by the tyre mechanic and if any discrepancies are noticed, it shall be brought to the notice of the shift supervisor by recording the same in the register and arranging for correcting the mismatch.

Image 34: Matching of tyres

5. Avoiding mechanical defects on vehicles

Properly assembled and matched tyres can perform better in case they are used on a non-defective vehicle. In the front position, because of the steering geometry, tyres are prone to more abuse in case the alignment of the front wheels is not correct. The following angles are included in the steering geometry:

a. **Toe-in and toe-out:** Toe-in is the parallelism of the wheels when seen from the front of the bus. For both Tata and Ashok Leyland buses, toe-in of upto 3 mm shall be maintained. If this is not maintained, the front tyres wear very fast, causing 'featheredge' on the tread in one direction. This is a serious mechanical defect, which shall be checked during periodic maintenance and corrected. While checking the toe-in and toe-out, the bus shall be parked on level ground, the inflation of tyres shall be ensured for correct pressures and the alignment gauge shall be placed at the correct position in a horizontal plane on both sides of the tyre.

b. **Camber:** Camber is the vertical tilt of the wheel. Normally, the lower edge of the tyres are slightly tilted inside, which is called positive camber. The tyre tends to be straight under loading and will have proper rolling in operation with the normal positive camber. If there is too much of positive camber, the inside of the tyre will be tilted excessively causing faster wear on outer edge of the tyre. If the bus is having negative camber, then the lower edge of the tyre is tilted outside and the inner edge of the tyre will wear very fast. Thus, normally incorrect camber can be visualized from the faster wear on one side of the tyre only.

c. **Caster angle:** Caster is the backward or forward tilt of the top and bottom of the kingpin. This can be visualized by the inclination of the kingpin when viewed from the side of the bus. This is mostly provided for centering of the steering and keeps the wheels in straight-ahead position. If the caster is not correct, the steering will have one side pulling and wander which affects the wearing pattern of the tyre. Though the above angles are the design aspects of the bus, they may tend to alter with the mechanical defects like kingpin play, hub bearing play, ball joints play, etc. Following mechanical defects are normally seen on buses, which affects the wearing of tyres:
   i. Excess play in hub bearing causes spotty wear on tyres
   ii. Play in kingpin bushes changes the camber angle and causes one side wear
   iii. Weak suspension also alters the camber angle and causes one side wear
   iv. Worn tie-rod ends and bent steering linkages cause either toe-in or toe-out affecting the tyre with feather edge wear
   v. Oblong-holes-wheel disc or out-of-round-wheel disc and improper mounting of tyres on the wheel disc causes uneven wear
   vi. Brake drums with ovality or taper and mismatched brake liners cause

brake grabbing. With this, thetyre will wear faster at a particular place on the tread.

vii. Due to wrong adjustment of brakes, free rolling will not be possible, which is called brake binding. This will result in fastest wear on the tread on opposite sides of the tyre.

viii. Improper fitment of caster below the leaf spring

Tyre mechanics have to be cautious in identifying uneven wear on the tyre during the weekly programme of checking and bring it to the notice of the shift supervisor for corrective action.

6. Rotation of the tyres

If a tyre is wearing out very fast or uneven wearing out is happening due to mismatching, mechanical defects, improper inflation, etc., then it can be corrected to some extent by following tyre rotation or changing tyre positions. Thus, rotation is crucial to obtain optimum life from the tyres. Following guidelines have to be followed while rotating tyres:

a. Initially, new tyres should fit in the front position. During every major docking schedule, the tyres shall be rotated from FOS to FNS and vice versa. During this activity, the wheel disc also needs tobe rotated, so that the outer edge of the tyre becomes the inner edge and vice versa.
b. In case of tyres fitted in the rear position, they have to be rotated from the near side to off-side and vice versa. At the same time, the inner tyre also needs to rotate towards the outer side and vice versa. This will help in shifting the inner edge of the tyre to the outer edge and vice versa, even without rotating the wheel disc.
c. It is advisable to rotate the tyres as explained above on the same bus. This will facilitate in identifying the mechanical defects on the bus for taking corrective action.
d. In case of tyres that have been used on bad roads, during rotation process the same tyres shall be fitted on some other bus operating on good roads. However, one should do it once the tyre reaches50 per cent of its life.

7. Timely removal of tyres

One of the important tyre management principles is timely removal of tyres for sending them to tyre retreading shops for repair or retreading. Any delay in identifying the tyre which needs to be removed, can causes irreparable damage to the tyres. It also badly affects the tyre life. In view of this, it is desirable to provide skid depth gauges to all the tyre mechanics and supervisors. It is suggested to remove the tyres that have attained 2mm non-skid depth (NSD) and send them for retreading. It is important to mention that NSD should be checked at a place where wearing out is more. Furthermore, in case there is a deep cut or injury spotted into the tyre, including the injury where it is touching the breaker plies (in case of bias ply tyres) or steel belts (in case of radial tyres), the tyre should be removed for proper treatment. As any negligence in attending the injury shall cause further damage to the tyre, e.g., entry of dust and water into the plies damage the internal properties of rubber, so it starts to erode quickly. In case of radial tyres, the steel wires are exposed to moisture and get rusted. Timely identification of deep cuts on tyres is also necessary as weak tyres cannot withstand air pressure properly, the chances of bursting increase in such cases.

8. Ensuring availability of tyres, tubes and flaps as per norms

Additional tyres at 0.4 per bus are required to be kept as float at depots at all

times. This is basically to meet any requirement during the transactions of tyres from depot to tyre retreading shop and vice versa. Additionally, it also helps in tyre rotation. If sufficient quantities of tyres are not available in the depot, it becomes difficult to keep the tyres in advance after preparation. In case different categories of tyres are being used in the same depot, then one should ensure sufficient floats for all types of tyres (i.e., radial and tubeless), depending on the number of buses on which these tyres are being used. Availability of float tyres has to be crosschecked once in a quarter and in case of any shortages, necessary action need to be taken to procure additional tyres quickly.

9. Record keeping

Tyre census report (MIS report), which include statements related to depot stocks, store stocks, spare tyres and bus-wise tyre fitting status, etc., needs to be generated month-wise. Depot managers have to review each and every statement of the report for further actions:

a. Depot stock statement shall indicate idling of tyres (if any) on the floor for longer periods
b. Storestock statement helpto understand whether tyres are being used on a "first in first out" (FIFO) basis or not.
c. Maintenance of registers with updated entries and periodical review shall help managers or supervisors to ensure the correct tyre maintenance practices at the depot.

10. Special provisions to maintain radial tyres

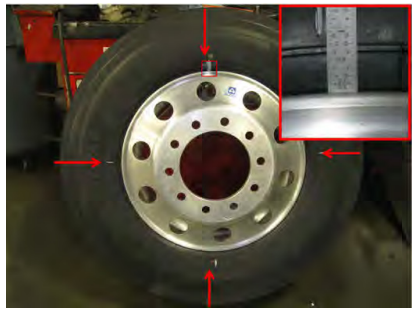
As radial tyres are sensitive to mechanical conditions of the buses, the following measures have to be taken in addition to the regular tyre maintenance practices:

a. Depot manager should ensure the use of radial tyres in all positions of a bus (including spares) to get optimum results. A combination of bias ply tyres with radials should be avoided completely
b. As radials are more sensitive to mechanical defects, one should ensure that buses do not have any defects like misalignment, kingpin play, brake binding, hub bearing play, weak springs etc., before fitment of radial tyres
c. Uneven wearing is predominantly observed on radial tyre sdue to the slightest mechanical defects of the bus. Thus, rotation of tyres is very important.
d. Unlike bias ply tyres, most of the cuts in radial tyres shall be upto the steel belts and it may not result in tyre punctures. So, there is a chance that these deep cuts on radial tyres remain unnoticed during routine check-ups by tyre mechanics. Thus, special attention has to be provided for radial tyres in identifying 'deep cuts'.

11. Special provisions to maintaintubeless tyres

The tubeless tyres are radial tyres without tubes. So, these are also very sensitive tyres. Additional details regarding tubeless tyre and basic difference between tube and tubeless tyre is provided in *Annexure 6*.

Figure 3: Tyre rim centering with the help of marking



Care has to be taken while assembling tubeless tyres:

a. Since the tyres hold air pressure, the sealing of the tyre with the wheel rim should be very tight.
b. During the assembly and dismantling of the tubeless tyres, extra care has to be taken to ensure the bead of the tyre does not get damaged. It is highly recommended to dismantle and assemble tubeless tyres on the tyre changing machine rather than doing it manually

c. Tyre rim centering is very important in tubeless tyres. Once the tyre is mounted and inflated, check the distance between the tyre mounting guide ring and the rim flange. The distance should be the same all the way around the tyre, varying no more than 2/32 inch. In other words, the rim flange is concentric with the mounting-guide ring and the distance is the same on both sides of the tyre. Measure in at least four locations. Lack of tyre and rim centering may create ride discomfort and irregular wear
d. Use a non-flammable vegetable or soap-based rubber lubricant on the beads and rim surfaces to make tire demounting and mounting easier
e. Use bead setter equipment to set the bead or seal the bead to the rim flange, if the bead setting is not proper it may lead to air leakages

Image 35: Bead setter

12. Effect of improper maintenance of tyres

Improper maintenance of tyres will result in the following challenges:

a. High tyre costs due to higher wear and tear
b. Unplanned stoppage of vehicles
c. Wasted time of asset operators
d. Unplanned load on maintenance team
e. Lower utilization of expensive assets
f. High fuel consumption costs
g. High pollution and carbon footprint
h. High maintenance costs
i. Reduced safety
j. High tyre inventory locking up higher working capital

An efficient tyre management system with in-depth functionality and seamless integration to other areas is needed to remove all the challenges.

Tips to avoid accidents happened due to poor maintenance of buses

There are almost eight types of accident which mainly happen due to poor maintenance of buses. These accidents can easily be avoided by following proper maintenance protocols as explained in this part earlier. A brief detail of all the causes is provided as follows for quick reference:

1. Poor brake efficiency: It is one of the major causes of accidents, various factors attributed to poor brake efficiency are:
   a. Worn out brake liners and brake pads
   b. Brake liner rivets breakage causing separation of brake liners from the brake shoe
   c. Air leakage through dual brake during the application of brakes
   d. Air leakages from brake booster diaphragm
   e. Heavy air leakages form the brake pipes

2. Non-functioning of safety features: One of the important reason of accidents related to the brake system failure is non-functioning of safety systems. Generally, a low-pressure warning buzzer is provided to indicate the pressure drop in the brake system. In case the air pressure drops below 4.5kg per sq. cm due to any leakages, the warning buzzer starts operating through an audio beep sound. In such cases, the driver can drive the bus to the nearest bus terminal and get the bus rectified or detain the bus till relief arrives. In many cases, it has been observed that the safety system is bypassed, the buzzer switches disconnected or made non-functional. In the absence of a warning system, the driver

continues to drive the bus with low air pressure resulting into serious accidents. Hence, one of the important checks in the periodic maintenance schedules is to check the functioning of low-pressure warning buzzer. Further, low-pressure warning switch connects to the dual brake valve andhandsthe control valve; hence, after the replacement of the dual brake and hand control valve, the supervisor should reassure the fitment of the buzzer.

3. Non-functional hand brakes: It has been observed that in many buses the graduated hand control valves are not operational as rear actuator wind-off bolts are kept open. This mainly happens due to a wrong practice to resolve brake jam issues—when a driver reports a brake jam, the mechanic opens the rear actuator bolts for quick release of the brake. This practice should be stopped. Rather, the defect pertaining to brake jam needs to be rectified and wind-off nuts need to be tightened fully to ensure proper working of hand brakes. It has also been observed that, sometimes, the winds-off nuts are kept open in case of discharged batteries or defective self-starters to enable to push and start the bus. It is important to note that non-functioning of handbrake may lead to serious accidents. In the night, when the buses are parked inside the depot, the handbrake should be kept in the "on" position. However, many a time, due to defective handbrake system or negligence, buses are parked in gear. In the morning, in case the driver inadvertently releases the gear and tries to fill the air pressure, the bus moves with a sudden jerk and collides with the bus parked ahead. In case any employee is standing in the front of the bus, he will get crushed between the buses. Occurrence of such fatal accidents have already been reported by many PTAs. Hence, it very important to ensure proper working of handbrakes in daily maintenance schedules. All drivers should also be instructed to mention the non-functioning of handbrakes in the log sheet or bus card during the parking of buses.

Figure 4: Open wind off bolt

Figure 5: Accidents due to buses parked in gear

4. Defect in the steering system: Defects in the steering system may lead to serious and fatal accidents. The possible defects in the steering system are excess play in tie rod and draglink arm ball joints causing the ball joints to come out. Tie rod and drag link arm lock nut can become loose and come out. Lock-nuts of universal joints of steering rod can also become loose. These defects cause the steering to be disconnected from the wheels and driver will not have any control on the bus causing serious accidents.

Figure 6: Defects in steering system

5. Detaching of wheels: The reasons for the wheels getting detached are: Improper tightening of wheel bolts after replacement of a tyre, hub bearing breakages, stub axle breakages and axle breakages, etc. If a wheel is detached, it may cause serious injuries to pedestrians, vehicles and road side properties. Thus, maintenance of proper bearing is very important to prevent bearing failures. The process of tightening wheel bolts after tyre replacement is very labourious task. Hence, one should use pneumatic impact wrench for tightening the wheel bolts. That will ensure proper tightening and reduce the chances of accidents due to wheel detachment.

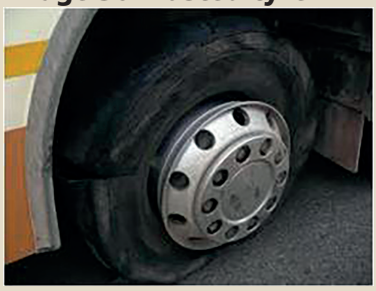
Figure 7: Detaching wheels

6. Poor illumination or defective head and rear lights: Proper illumination of headlights and their alignment is very important for manoeuvring the buses., in case the illumination of street lights is poor. Similarly, proper functioning of all rear indicators including brake lights, indicator lights and tail lights is also very important to prevent accidents. All lights are required to be checked during the daily maintenance schedule. The glasses of all lights should be removed, cleaned and refitted on every periodic maintenance schedule.

7. Windshield wipers: Proper working of windshield wipers is very important in the rainy season. A number of accidents have occurred due to improper working of windshield wipers.

8. Tyre burst: A large number of accidents occur due to bursting of tyres. The number of such cases has increased with the advent of radial tyres. As explained in the tyre maintenance section, radial tyres are very sensitive, thus proper inspection of tyres is required on a daily bases along with timely removal of tyres, checking of wheel alignment and wheel balancing on computerized machines, etc.

Image 36: Busted tyre



Tips to prevent buses from catching of fire

There are numerous cases of buses catching fire on a regular basis. In some cases, even passengers get injured while in a majority of cases, the buses are damaged badly, causing huge loss to the organization.

Following are the common reasons for bus fires:

a. Heat: There must be heat to start a fire and keep it burning. Most of this heat is generated in the engine compartment. As the temperature rises, the chances of material degradation also increase (e.g., heat causes accelerated ageing of most organic materials such as polymers), resulting in an increase in the chances of materials getting ignited.

b. Vibration: In buses, vibrations are chiefly caused by engines and wheels. Vibrations are the main reason why tubes and other vehicle components develop fatigue cracks, break, and leak flammable liquid, or why insulation of electrical systems gets worn-out so quickly, which may lead to short circuit in the system as well. Vibrations accelerate existing degradation processes of parts.

c. Material fatigue and malfunction: Narrow inaccessible spaces, causing restriction on both physical and visual access, are a potential source of fire. Poor ventilation often leads to high temperatures, which in turn reduces the lifespan of spares. Poor quality materials also create such problems.

d. Inadequate maintenance: Lack of maintenance also increase the chances of buses catching fires. In many cases, maintenance can be good overall but lacks a thorough consideration of the consequences of fire risks. Maintenance should therefore be viewed as a service combined with fire risk assessment and mitigation.

Image 37: Bus catches on fire

In 70 per cent of the cases, bus fires start in the engine compartment or surrounding areas. High temperatures, hot surfaces and a variety of combustible materials make the engine compartment a high-risk area. Thus, the engine compartment design, including all its parts, should comply with the highest design standards and quality to ensure a low fire risk. Following precautions must be taken during the maintenance of buses to prevent initiation of fires:

a. Avoid engine oil leakages on self-starters: It has been frequently observed that the self-starter area is oily, as engine oil from the tappet cover or air compressor discharge hose is dripping on the self-starter. Since the cables fitted to the self-starter have a high-volt current, any loose connections will lead to spark and cause fires.

b. Avoid loose battery cable clamps: Loose battery cable lugs will generate sparks and cause fires. The tightening needs to be checked during daily checks. Battery cable lugs with reduced pinch gaps need to be replaced immediately.

c. Ensure that only proper-rated fuses are used: Blade-type fuses are the most commonly used fuses in buses. But, a big issue with this type of fuses is that they have the same dimensions, regardless of rated current. Thus, there is no guarantee that a replacement fuse will have the same or lower rated current. It is important to highlight that a fuse carrying more than 75 per cent of their rated current produces heat which, in turn, increases the chances of a fire.

Image 38: Blade type fuse

d. Investigate a blown fuse: In case a fuse gets blown out, the common practice is to merely replace it without trying to find out the reason for the blowing out. However, it is very important to find out the reason for the fuse getting blown out to prevent further damage. It is also a common practice to join fuse blades with copper wire in the event of non-availability of fuses. But, as the copper wire increases the current conductivity power of a fuse by three–four times, it also increases the chances of fire.

e. Rubber grommets and sleeves on all electric wires and cables: Vehicle vibrations tend to peel off cable sleeves and grommets. The routing of the cables will also get disturbed during the vibration, causing loosening up of cables. Hence, it is very important to check the cable sleeves, rubber grommets and clamping of the cables during every preventive maintenance schedule and rectification action needs to be taken immediately. Proper clamping of cables with positive clamps is essential to reduce the vibration and fouling of wires with other parts. Clamping the cables with plastic ties should be avoided as much as possible.

f. Electric wires to be separated from fuel hoses, silencer, gases, etc.: Electric cables should always be kept separately from fuel hoses, silencer pipes, etc. Electric wires need to be properly clamped with positive clamping and not with plastic ties. Many cases of fires are caused due to sparks when wires fall on hot silencer exhaust pipes.

Image 39: Clamping of electrical wires

g. Avoid overheating of electric wires: When electric wires get overloaded, they become hot and burn. The cause of overloading needs to be investigated and necessary corrective actions to be taken before replacing burnt electric wires.

h. Brake jam (brake adjustment and handbrake): Initiation of fires at the wheel area is due to a brake jam. The brake jam develops excessive heat in the wheel area, causing fires. Free rotation of the wheels needs to be ensured during every preventive maintenance check.

i. Fire prone cables (heavy current wires): The three important cables which, when faulty, cause a majority of the fires are:
   a. Battery to self-starter cable
   b. Alternator to main switch cable
   c. AC alternator to AC system (passing through duct)

Proper routing, clamping and tightening of these three cables will prevent maximum number of fires.

j. Fuse box base: Fuse box base material should be fire proof, however in a number of cases it has been observed that the base material of fuse boxes is plastic. In the event of overheating, the fuse box base material is will catch fire easily. Backlite material can be used as base material for fuses boxes to prevent it from catching fire.

k. Fuses of standard quality: Electrical fuses play a very important role in preventing fires. Technically, during overloading, fuses should blow off. But if the fuses are of an inferior quality, they do not blow off at the rated current, overloading the system and causing fires. Inferior fuses also cause repeated blowing off of fuses below their rated capacity, leading to frequent detention of buses. Since the cost of fuses is very meagre, there should not be any compromise on the quality of fuses.

l. Wire-breaded compressor outlet pipe fouling with a starter: In a few cases of bus fires, it has been observed that the wire-breaded compressor outlet pipe is fouling the self-starter main cable. Vibration causes oil leakage from the outlet pipe. Since it is fouling with self-starter cables, which have a high current, sparks are generated, causing fires. Bursting of air compressor pipe also led to fires in a few cases. The bursting of air compressor pipes was due to inferior quality of the pipe and also due to the air drier being choked up, causing excessive pressure in the compressor outlet pipe.

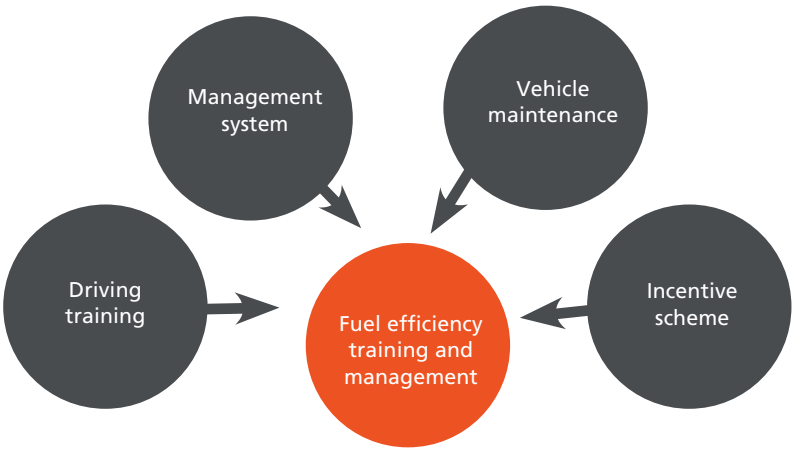
m. Location of the cut-off switch: The cut-off switch should be close to the driver and it should be easily accessible. In case a fire breaks out, the driver should be able to disconnect the supply immediately.

IMPROVING FUEL EFFICIENCY OF THE FLEET

Fuel cost is the most significant cost component of any bus operation. It accounts for approximately 50 per cent of the total bus operation cost (for diesel or CNG buses).Thus, PTAs are increasingly aware of the need and responsibility towards improving fuel efficiency. However, due to the complexity of variables impacting fuel-efficiency, including vehicle technology, fuel type, driver's behaviour etc., it is difficult to set benchmarks.

A systematic framework consists of four key areas: Driver training, management systems, vehicle maintenance and incentive schemes, can facilitate the achievement of practical improvements in fuel economy.

Figure 8: Fuel efficiency training and management framework



Source: CSE

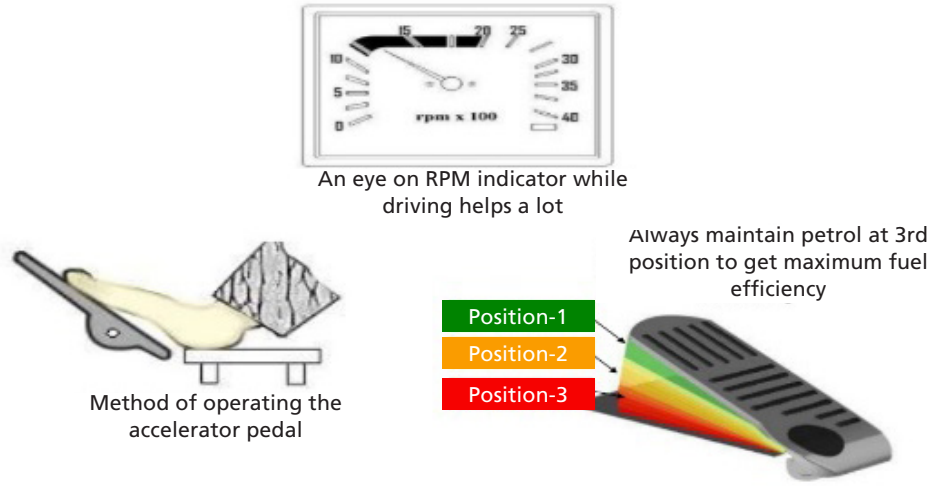
A. DRIVER TRAINING

Driving behaviour plays the most important role in fuel efficiency. Fuel-efficient driving is a technique that any driver can use and must be taught to all drivers. At present, traditional driver training programmes are mainly driven by a single objective of fulfilling legal requirements to ensure safety of people. Although the same programme can be upgraded by incorporating fuel economy driving techniques into it.

The basic steps of fuel-efficient driving are:

1. Cutting out unnecessary idling
2. Staying within the speed limit and maintaining engine RPM at optimum levels
3. Accelerating and deaccelerating (braking) using vehicle momentum to maintain cruise speed

Figure 9: Accelerator position for optimum fuel efficiency



Source: APSRTC driver training manual

4. Avoiding pumping the accelerator pedal
5. Anticipating traffic ahead to minimize hard breaking and acceleration.

Periodic retraining is also needed to ensure that drivers continued to follow best practices.

At present, a number of commercial and government sponsored courses are available for fuel-efficient driving or eco-driving of heavy-duty vehicles. Similar, course modules should be developed for transit bus drivers as well. This special course shall have separate modules including classroom sessions for public safety and fuel efficiency of buses, followed by testing on simulators (in case simulators are available) or follow up through an instructional video and lastly on-road training with a professional instructor. On-road driver training help drivers identify many inefficient driving habits (i.e., clutch riding, pumping the accelerator pedal and improper gear shift) which they have developed overtime and are of which they are completely unaware. Professional instructors can easy spot these habits and assist the driver to rectify the same.

Depot supervisors should identify the worst or low-performing drivers (i.e., ten per cent of all drivers) for training purposes. After the first training, if the driver still fails to provide the desired result, then the PTAs should send them again for re-training. However, after repeated training, if the driver still fails to perform, then the PTA can either take disciplinary action against them or discharge them.

B. MANAGEMENT SYSTEMS

Adopting better bus operation and management practices also improves the fuel efficiency of buses as follows:

1. **Allocation of buses to fixed drivers and (preferably) on fixed routes:** It is one of the essential factors to improve fuel efficiency. It has been observed that drivers driving on the same routes with same bus substantially improve fuel mileage. Since both the route and the bus is familiar to the driver, the chances of breakdowns and accidents are reduced.

2. **Route-wise fixing of fuel consumption:** After fixing drivers to buses and routes, the next step would be to fix the fuel topping quantity according to route. It has been invariably observed that different buses on the same route consume different amounts of fuel. In a few cases, the variation is very large. The variation would be either due to faulty buses or defective driving.

3. **Formation of a dedicated KMPL cell:** For continuous monitoring of various fuel efficiency improvement measures, a separate KMPL cell needs to be formed. The cell shall be formed with the following personnel:
   a. Traffic officer: One
   b. Maintenance officer: One
   c. Expert drivers: Three
   d. Expert mechanic: One

On a daily basis, the KMPL cell shall closely monitor KMPL data of all bus. Additionally, they shall monitor driving habits of the drivers by moving on routes and checking condition of the buses, etc. The cell should directly report to the head of the department, and put up all report to him or her with copies to concerned depot manger(s).

C. VEHICLE MAINTENANCE

The following initiatives needs to be taken in bus maintenance to improve fuel mileage:

1. **Air pressure drop:** PTAs should carry out a survey of all buses, early in the morning between 4:30 to 5:00 a.m. to check air pressure drops on a weekly basis. Any bus found with air pressure less than 5kg per sq. cm should be checked thoroughly for air leakages. Even a small leakage should be identified and rectified quickly, as low air pressure restricts handbrake from getting released which, in turn, forces the driver to build up the air pressure first, to make the handbrake free while moving the bus. Due to this, a majority of drivers have the tendency to build up full air pressure, without even checking the pressure level, before moving out the buses from the depot which, in turn, consumes a lot of fuel. To avoid this from happening, it is important to ensure that the air pressure in any bus should not be less than 6 kg per sq. cm. At this kind of air pressure, the driver can easily move the bus. All drivers should be strictly instructed not to build any air pressure in case the air pressure is already above the 6 kg per sq. cm level, as before reaching the first bus stop the air pressure will built up to its full capacity.

2. **Pressure-built time**: Buses attended for preventive maintenance schedule need to be randomly inspected for pressure-built time. To carry out this activity, first, one should deplete the entire air pressure of the brake system by pumping the foot brake, then drain all air tanks and release the handbrake. Start building air pressure with full throttle, the time taken to build up the air pressure from 0 to 8.25 kg per sq. cm should be noted down. The pressure-built time should not exceed the time specified by the bus manufacturer for the given model of the bus.

3. **Brake pressure leakage**: The brake pressure leakages should be checked with the brake "on" position by pressing the brake pedal for two minutes and checking for any pressure drop and also with brake-off position. It may be noted that for every brake application, the pressure drop should not be

more than 0.5kg per sq. cm. If the drop is more, then there is leakage in the system which needs to be rectified immediately.

4. **Wheel temperature**: A few PTAs check the wheel temperature during in-shedding of buses at night as a good practice. If the temperature of the tyre is found abnormally high then that needs to be rectified quickly. There might be several reasons for high temperature of wheel, which includes improper release of brakes, i.e., footbrake or handbrake, improper brake settings, hub bearing jam, etc. All these factors negatively impacted the fuel efficiency of buses.

Image 40: Measuring wheel temperature

5. **Tyre pressure**: Maintaining correct tyre pressure is very important for improvement of fuel efficiency. As per a study conducted by Goodyear tyres, 15 per cent under-inflated tyre result in 8 per cent less tread mileage and 2.5 per cent reduction in fuel economy. On a daily basis, PTAs should check the tyre pressure of 25 per cent buses with pressure gauge and rest can be done through hammering. Drivers should never be allowed to fill air pressure from outside or within the depot as they have the tendency to excessively inflate tyres.

6. **Smoky exhaust:** During every schedule, buses should to be checked for their smoke condition. Any deficiencies observed needs to be rectified promptly.

7. **Wheel free:** During every periodic maintenance and major docking schedule, all wheels need to be jacked up properly and then checked for free rotation. A tool can be used to check the free rotation of wheels as shown in *Images 41 & 42* as it is helpful to eliminate human errors. Front wheels should get free with 2.5 kg of weight and rear wheels with 3 kg of weight.

Image 41 and 42: Checking wheel free rotation of both front and rear wheel

8. **Brake pedal and clutch pedal play:** Proper adjustments of brake pedal and clutch pedal play is very important to ensure maximum life of the units as well as to improve fuel efficiency. Ideally, the brake pedal play should be

12 mm. In case it is lower, then the brake will remain in slightly applied position and more power shall be required for driving the bus resulting to higher fuel consumption. Same is true for clutch pedal play as well. Clutch pedal play should be maintained at 12mm for hydraulic clutch and 3.5 inches for mechanical clutch. If the clutch play is lower, fuel consumption shall be higher than normal due to improper working conditions of the clutch.

9. **Clutch slippage:** An engine will not be able to generate enough torque in case there is a clutch slippage. In such a situation, the driver tends to use accelerator more while driving which, in turn, increases the fuel consumption. The simple way to check clutch slippage is to apply handbrakes while engaging the bus in third gear and then suddenly leaving the clutch pedal. Now, if the engine stops running, then there is no clutch slippage whereas in case it does not, then for sure clutch slippage is happening and clutch assembly needs to be replaced.

10. **Cleanliness of air filters:** Cleanliness of air filters plays a vital role in ensuring fuel efficiency. Choked air filters lead to reduced air flow to the engine, resulting in poor engine combustion. During the daily maintenance, the mechanic should check for red band in the vacuum indicator, in case it is visible, then the air filter needs to be replaced immediately.

11. **Provision of driver footrest:** Clutch riding is one of the major reasons for drop in fuel efficiency. Due to non-availability of any support to rest their foot, the drivers have the tendency to keep their foot on the clutch pedal. To prevent drivers from resting their foot on the clutch pedal, a footrest needs to be provided near the clutch brake and accelerator pedals. Some PTAs have already used this method to improve the fuel efficiency of their buses.

Image 43: Driver footrest

D. INCENTIVE SCHEMES

1. **Employee communications and rewards:** Employee motivation is a key part of any strategy to create a culture of fuel economy. Empirical evidence from the industry has shown that management and employee motivation play a bigger role in ensuring fuel-efficient operations than technology. At the systemic level, the officer-in-charge for improving fuel economy should be rewarded for attaining system-wide fuel economy goals and targets.

2. **Communicate fuel economy data:** The weekly or monthly average of fuel economy performance of the top ten drivers must be posted at a visible location of each depot, where all employees can see it. In addition, average fuel economy by bus type and depot should be posted across all depots so that each depot's employees can be aware of their relative performance. In-house communications in the form of posters at highly visible locations have been found to be very effective by the Andhra Pradesh State Transport Corporation (APSRTC) in India. Publicly recognizing fuel economy

performances of a driver is instrumental in motivating an individual to perform well. This type of information sets up friendly competition among the employees implementing the recommended action towards fuel economy.

3. **Mechanic and driver awards**: Awards for mechanics are recommended for depots with the best fuel economy performance. However, it is difficult to reward individual mechanics for fuel economy performance as they perform the repair activity in many buses which are randomly assigned to them. In view of this, the depot mechanics can be jointly rewarded for achieving the fuel economy goals. Note that successful implementation of this step relies on proper setting up of fuel economy goals at the bus type or depot-specific levels.

Similarly, drivers should be rewarded for good performance in both safety and fuel economy. Generally, as per current practices, drivers are rewarded by many PTAs for safe driving and for having an accident-free and consumer complaint-free record, but rewards for fuel economy performance are relatively rare, often because it has been difficult to separate driver performance from that of the bus (model and age) and route. To successfully provide driver awards for fuel economy, the following are required:

- Driver's performance rating must be adjusted based on the route and the bus
- The adjusted performance of all drivers must be publicly posted
- The adjusted factors and their fairness can be evaluated by the drivers so that they will accept them over time

The simple averaging method by route is useful if buses and drivers are typically allocated to the same routes most of the time. Clearly, statistical fluctuations in fuel economy leads to some uncertainty in the estimates of fuel ranking and to avoid such problems, the top 10 per cent of drivers should be recognized and rewarded.

SPARE AND INVENTORY MANAGEMENT

Spare parts management plays an important role in achieving the desired bus availability at an economical cost. The bus is a mass transit option, and the downtime and non-availability of buses due to inadequate spares badly affects fleet utilization. In turn, this affects the headway and causes inconvenience to commuters. Due to non-availability of spares, the cannibalization of spares becomes rampant. It is a paradox to note that the maintenance department always complains about the non-availability of spare parts to meet their requirement and the finance department is facing the problem of increasing locked up capital in spare parts inventory. This amply signifies the vital importance of spare parts management in any organization. The unique problems faced by the transport organizations in controlling and managing the spare parts are as follows:

1. Firstly, there is an element of uncertainty to when a part is required and also the quantity of its requirement. This is due to the fact that the failure of a component, either due to wearing out or due to other reasons, cannot be predicted accurately.

2. Secondly, spare parts are not that easily available in the market as they are not fast moving items. The original equipment manufacturer has to supply spares in most of the cases. New models are introduced to incorporate the design improvements and old models are phased out. Hence spares for old models are not readily available. This is more so in case of imported equipment as the design changes take place faster.

3. Thirdly, the number and variety of spare parts are too large due to the variety in models of buses, making close control more and more tedious.

4. Fourthly, there is a tendency from the stage of purchase of spares to the stage of the use of spare parts, to requisition more spare parts than actually required, resulting in accumulation of spares.

5. Finally, the rate of consumption of spare parts is very uneven.

These problems can be resolved by systematic spare parts management. The objective of spare parts management is to ensure availability of spares for maintenance and repairs of buses as and when required at an optimum cost. Also, spares should be of the right quality. Many actions are required to ensure spare parts management is effective. There is a need for systematic action while managing spare parts as given below:

1. Identification of spare parts
2. Forecasting of spare parts requirement
3. Inventory analyses
4. Formulation of selective control policies for various categories
5. Development of inventory control systems
6. Stocking policies for capital and insurance spares
7. Stocking policies for units and sub-assemblies
8. Replacement policies for spare parts
9. Spare parts inspection
10. Indigenization of spares

11. Reconditioning of spare parts
12. Establishment of float units
13. Computer applications for spare parts management

Spare inventory analysis

For successful spare parts management, it is essential to analyze the spare parts inventory based on various characteristics such as frequency of issues, annual consumption value, criticality, lead time and unit price. This analysis is essential as it would not be possible to exercise the same type of control for all items and it may not really be effective. Inventory analysis aids selection of policies for selective control. Commonly used inventory analyses are:

1. **FSN analysis (classification based on frequency of issues and use):** F, S and N stand for fast-moving, slow-moving and non-moving items, respectively. This form of classification identifies the items frequently issued, items less frequently issued, and items which are not issued for longer periods, say six months. This classification helps in deciding the procurement policy for various spares.

2. **ABC analysis(classification based on consumption):** Another method of classifying spares is on the basis of annual consumption value. As is true of any inventory situation, Pareto's principle can be applied to classify maintenance spares based on consumption value. Pareto principle: The significant items in a given group normally constitute a small portion of the total items in a group and the majority of the items in the total will, in aggregate, be of minor significance. This way of classification is known as ABC classification.

   Class A: 10 per cent total spares contributing 70 per cent total consumption value.

   Class B: 20 per cent total spares which account for about 20 per cent total consumption value.

   Class C: 70 per cent total spares which account for only 10 per cent total consumption value.

   In a specific spares control system, it is quite possible that in a single year, many spares would not have been consumed at all. In such cases, it is better to perform ABC analysis on longer consumption period data, say three years. Then only spares will not be left out in this classification.

   Policy for 'A' items x Maximum control x Value analysis x More than one supplier x Control by top executives.

   Policy for 'B' items maintenance engineering and management x Minimum control x Bulk orders x More items from same supplier.

   Policy of 'C' items bulk orders, less lead time, more stocking.

3. **SDE analysis (classification based on the lead time):** This classification is based on the lead time required to procure spare parts. The classification is as follows:

Scarce (S): Items that are imported and items that require more than six months' lead time.

Difficult (D): Items that require more than a fortnight but less than six months' lead time.

Easily available (E): Items that are easily available, i.e., with less than a fortnights' lead time.

This classification helps in reducing the lead time required at least in case of vital items. Ultimately, this will reduce stock-out costs in case of stock-outs. A comprehensive analysis may ultimately bring down lead time for a greater number of items. This will also result in streamlining the purchase and receiving systems and procedures.

4. **VED analysis (classification based on criticality):** Spare parts are conventionally classified into three classes, viz. vital, essential and desirable. Several factors contribute to the criticality of a spare part.

   Vital items: If without the availability of a spare the bus cannot move, the spare part could be of vital importance. A spare part will also be termed vital if on account of its non-availability a high loss due to vehicle downtime or high cost on emergency procurement will be incurred. If the day-to-day work comes to a standstill due to non-availability of spares such spares may be regarded as vital items.

   Essential items: Essential items are those that are equally important as vital items but due to non-availability of the same the work is not affected instantly. However, non-availability of desirable items for more than a specified time will badly affect efficiency.

   Desirable items: Desirable items are those where work can be carried out for a few days with alternative parts and the parts can be replaced as and when available.

5. **HML analysis (classification based on unit price):** This classification is as follows:

   High cost (H): Items whose unit value is very high, say Rs 1,000 and above.

   Medium cost (M): Items whose unit value is of neither high nor low, say, above between Rs 100 and Rs 1,000

   Low cost (L): Items whose unit value is low, say less than Rs 100

   This type of analysis helps in exercising control at the shop floor level, i.e., at the user point. Proper authorization should be in place for replacing a high value spare. For the high value spares, one-to-one replacement policy needs to be followed. The technician will deposit old spares only when new spares are issued to him. Efforts may be necessary to find out the means for prolonging the life of high value parts through reconditioning and repair. Also, it may be worthwhile to apply the techniques of value analysis to find out a less expensive substitute.

Spares procurement procedures

The procurement process to be followed is as under:

1. Whenever the stock level of any item reaches a minimum, the indent for the item has to be raised. The AMC of the item should be worked out based on the last one-year's consumption, the requirement for the next year to be predicted based on AMC and future necessities. While predicting future requirements, care has to be taken to ensure so that spares do not get overstocked and, at the same time, spares do not remain out of stock.

2. If the requirement given is more or less than 10 per cent of the past AMC, justification is required to be given for the variation in requirement

3. To ensure optimum stocking of spares, it is proposed to place purchase orders for all critical spares for 12 months quantity with a staggered delivery schedule. This arrangement will reduce the administrative cost of repeated ordering of spares

4. While indenting the spares, following details are required to be mentioned clearly on the indenting form to avoid complications during comparison of rates
   - Approved brands
   - Make and model of the vehicle
   - Category of the items (VED)

5. The sample format for the recoupment slip is attached in *Annexure 7* (values are indicated for guidance)

6. For A-class spares, it is proposed that procurement happen of individual spares. However, if the requirement is less, the spares can be clubbed together. While clubbing spares, care has to be taken to ensure similarity of spares. For example, procurement of all types of oils, clutch spares, friction material, etc. can be clubbed together. This will help the vendors to quote the rates properly.

7. The vendor category such as proprietary nature and authorized distributors need to be mentioned clearly on the indent form.

8. If the requirement of the item increases or decreases based on the actual consumption ±25 per cent order quantity can be operated and provisions for the same should be made in tenders.

9. In many small SPVs and STUs, if in-house testing facility is not available, the brands of all spares should be standardized to prevent procurement of inferior quality of spares. Supply status of spares to other reputed STUs can be recalled to ensure reliability of spares.

10. Spares can also be procured from the ASRTU rate-contracted firms where rates are fixed.

Inventory policy

To ensure smooth functioning of spare parts and their availability, it is essential to develop a suitable inventory control by which optimization of spare parts costs. With regard to fast moving and slow-moving items, the following procedure can be followed taking into consideration various cost elements.

While managing the spare-parts inventory, basically there are four cost elements to be considered:

1. Cost of the spare part: The cost of the spares, includes the individual cost of the spare

2. Cost of ordering, including:
   - Depreciation for office facilities
   - Salaries
   - Postage and telephone expenses
   - Stationery expenses
   - Travel expenses
   - Incoming inspection
   - Miscellaneous expenses

3. Cost of storage includes:
   - Depreciation on storage and handling facilities
   - Handling charges
   - Salaries of store staff and clerks
   - Taxes
   - Insurance
   - Costs of stationery

4. Cost of stock out: The cost of stock includes the cost of buses remaining off-road for the want of spares, cancellation of travel, delay in periodic maintenance due to non-availability of spares (oil, filters, etc.) and idling of manpower due to non-availability of spares.

In the concept of economic order quantity, under ideal conditions there should be no stocks at all. Every item should arrive just before it is required and in the right quantity. This is not practical for two reasons. Firstly, the supplies and requirements are not so certain. Secondly, the costs of placing orders and follow-up work will shoot up very high, if ordering in such small batches is resorted to. In fleet maintenance, the requirement of spares cannot be accurately predicted, as in some months the consumption of spares is very high and in some months it is low. Hence, forecasting the requirement is very important during the procurement of spares. Wrong forecasting may lead to overstocking or under-stocking. In both cases, there is financial loss to the public transport organizations.

Indenting of spares from central stores

In many STUs, a centralized procurement system is followed. Spares are procured at the central stores and distributed to the depots based on their requirements. The process to be followed for distribution of the spares is as under:

1. The depots need to be given specific dates for indenting spares (programmes need to be prepared for all depots accordingly).

2. The depots will prepare demands as per the average monthly consumption for all the items.

3. Central stores will supply maximum spares as per the requirement of the depot based on the average monthly consumption.

4. In case of spares that are not available during the monthly indent, central stores will arrange the supply at the earliest.

5. Material lorry of depots should report to central workshop every alternate day for collecting units and spares that were not available during the monthly indent.

6. The statement pertaining to the number of spares indented and number of spares supplied by the central stores on the monthly supply date should be prepare and sent to Chief Controller of Stores.

It is pertinent to note that the efficiency of stores and purchase department does not depend on the percentage of availability of the spares. Their efficiency depends upon how many times the mechanic goes to the stores and comes with the spares. More the times the mechanic comes with the spare more the efficient the stores are and vice versa. It does not depend on the quantity of the spares stocked.

FLEET MONITORING

A. USE OF MANAGEMENT INFORMATION SYSTEM (MIS)FOR RECORD KEEPING

Management information system is a very important tool with the management for effective monitoring of bus maintenance. It is pertinent to note that bus maintenance activities are carried out 24/7 for 365 days. Various maintenance activities are carried out in all shifts. For effective monitoring, it is very important to capture all activities carried out in various shifts. This can be possible only with effective MIS(see *Table 6: MIS reports for effective monitoring of bus maintenance*).

Table 6: MIS reports for effective monitoring of bus maintenance

Name of the report	Importance of the report	Frequency	Format attached as Annexure
Daily maintenance report	All major parameters are captured in the report. It a very important report for all senior officers	Daily	Annexure 8
Breakdown investigation	To investigate all breakdowns and record findings	Daily	Annexure 9
Daily bus off report	Details of buses off-road and expected date of attention is mentioned	Daily	Annexure 10
Control charts	Monitors the performance of various parameters	Daily	Annexure 11
Preventive maintenance schedule record	Records the defects of buses attending for preventive maintenance schedule	Daily	Annexure 12
Preventive maintenance progress report	Records the progress of preventive maintenance schedule	Daily	Annexure 13
Driver complaint record	Records all driver complaints and their attention	Daily	Annexure 14
Group-wise driver complaints	Driver complaints are grouped in different categories for proper investigation	Daily	Annexure 15
Repeated driver complaints	The same driver complaint which is reported thrice in a week is called repeated complaint. The report is helpful to analyze the repeated driver complaints	Weekly	Annexure 16
Daily work done report	Records the daily work done and attention of buses	Daily	Annexure 17
Bus-wise KMPL	Bus-wise KMPL records help check low- KMPL buses and get them attended promptly	Daily	Annexure 18
Bus history	It is very important record which keeps details of all units fitted on the bus	Daily	Annexure 19
Drained engine oil records	It helps to keep check on proper engine oil replacement and wastage of oil	Daily	Annexure 20
Statuary compliance report	The details of expiry dates of fitness renewal, PUC and fire extinguishers are maintained	Daily	Annexure 21
Tyre history	Maintains the history of all the tyres fitted on buses	Daily	Annexure 22
Tyre life statement	The life obtained from various makes of tyres is recorded, premature scrapping of the tyres is also recoded and analyzed	Monthly	Annexure 23
Tyre wear statement	Records the non-skid depth of tyres. Very important statement to monitor the wear on tyres	Weekly	Annexure 24

Name of the report	Importance of the report	Frequency	Format attached as Annexure
Tyre pressure checking	25 per cent of buses to be checked for tyre pressure on a daily basis. The records to be maintained in a proper format. Helps to prevent breakdowns due to tyre punctures	Daily	Annexure 25
Tyre puncture analysis	Analysis of tyre punctures is done to find out the reasons and take necessary corrective actions	Daily	Annexure 26
Unit life statement	The life obtained by various units replaced in the month is recorded, which is helpful to analyze premature failure of units	Monthly	Annexure 27
Unit and oil replacement schedules	This statement helps to understand whether units and oils are replaced as per their stipulated life	Monthly	Annexure 28
Spare part cost statement	The statement helps in understanding the material expenses incurred in maintenance of buses for that month	Monthly	Annexure 29
Bus-wise performance	Very important statement to check the bus-wise performance for the month	Monthly	Annexure 30
Spares indented and supply position	Helpful to check the performance of the central stores	Monthly	Annexure 31
Body damage report	The cases of body damages are recorded and action taken is recorded	Monthly	Annexure 32

Source: CSE compilation

B. PERIODIC TRAINING AND CAPACITY BUILDING OF THE BUS MAINTENANCE STAFF

Training is an extremely powerful and cost-effective investment in an organization. Yet, training is the most neglected aspect in public transport organizations. As vehicle technology is fast changing, training plays a very important role. It has been observed that once new buses are inducted, the bus manufacture impart training only as a formality with no follow up afterwards. Technicians learn through trial and error, and experience. Regular training from the bus manufacturer, aggregate manufacturer (tyre, batteries, steering system, brake system, etc.) is essential so that employees can share the issues and concerns faced during routine maintenance for possible resolutions. In regular trainings, one of the important topics of discussions should be breakdowns, possible causes and preventive steps to avoid breakdowns.

c. Brief description of the training contents:
i. Infrastructure requirements for bus maintenance
ii. Depot equipment requirements—new generation depot equipment
iii. Technical manpower requirements
iv. Emerging bus maintenance practices
v. Emerging bus technologies
vi. Defect diagnosis and remedial actions
vii. Fuel-saving techniques practiced by bus transport organizations
viii. Incentive schemes for improvement in productivity
ix. Use of safety equipment and safety measures in the workshop
x. Stores and inventory management
xi. Passenger complaints pertaining to maintenance of buses

Table 7: Training schedule for the maintenance officials

a. Training details of bus maintenance officials

Title	Target audience	Expected outcome	Duration of each session	Suggested group size	Frequency
Training—bus maintenance officers	Technical officers and technical supervisors	Updating good industrial practices and latest techniques for bus maintenance and to achieve improved efficiency in bus maintenance by applying some of the good practices in bus maintenance	One day	15	Once a year

Source: CSE compilation

b. Training programme itinerary

Topic of discussion	Duration in hours	Resource
Emerging practices in bus maintenance	1.5 h	Bus operation expert
Concept of fleet maintenance	1 h	Bus manufacturer (Ashok Leyland and Tata)
Fuel and oil economy	1 h	PCRA and representatives of oil company
Maintenance of bus aggregates	1.5 h	Aggregate manufacturers (Lucas, Wabco, ZF, Rane, Cummins and TVS)
Tyre and battery maintenance	1.5 h	Tyre and battery manufacturers
Safety in workplace	0.5 h	Safety officer

Source: CSE compilation

Table 8: Training schedule for technicians (i.e., mechanics, electricians, etc.)

a. Training details of technicians

Title	Target audience	Expected outcome	Duration of each session	Suggested group size	Frequency
Task management by technicians	Technical supervisors, mechanics, electricians and tyre men	Awareness of standard maintenance practices, knowhow of new technologies. Benefit of improved bus maintenance practices in improving reliability of buses	One day	20	Once in year

Source: CSE compilation

b. Programme itinerary

Topic of discussion	Duration in hours	Resource
Best practices in bus maintenance	1.5 h	CME and technical officer
Preventive and predictive maintenance practices	1 h	Bus manufacturer (Ashok Leyland and Tata)
Breakdown analysis and remedial measures	1 h	Maintenance manager and bus manufacturer
Maintenance of bus aggregates	1.5 h	Aggregate manufacturers (Lucas, Wabco, ZF, Rane, Cummins and TVS)
Tyre and battery maintenance	1 h	Tyre and battery manufacturers
Safety measures in workplace (analysis of accidents and remedial measures)	1 h	Industrial safety officer

Source: CSE compilation

C. A BRIEF DESCRIPTION OF THE TRAINING CONTENTS

i. Types of preventive maintenance schedules
ii. Checklist to use for inspecting buses for preventive maintenance schedules
iii. Equipment, tools, jigs and fixtures required for proper maintenance of buses
iv. System-wise analysis of en route breakdown and remedial measures to reduce breakdowns
v. System-wise analysis of driver complaints and remedial measures
vi. Maintenance of various aggregates on the bus
- Engine
- Gear box
- Clutch assembly
- Propeller shaft
- Brake system
- Steering system
- Electrical system
- Fuel system
- Sign boards (LED boards)
- ITS components

vii. Maintenance of tyre and batteries
viii. Attention of low-KMPL buses
ix. Attention of smoky exhaust buses
x. Analysis of buses reported for accidents due to mechanical failures and preventive measures to prevent accidents
xi. Analysis of accidents reported in workshops due to unsafe workmanship and safety measures to be taken to prevent accidents

Endpoint: standard maintenance practices

This hands-on manual highlights the importance of standard bus maintenance practices and implementation for improvement in the reliability of bus operations, reduced emissions levels, improved safety and reduction in cost of operation. The various parameters of standard maintenance practices highlighted include:

- Availability of adequate infrastructure
- Thrust on preventive maintenance schedules
- Minimum unscheduled maintenance
- Design of preventive maintenance schedules based on operating conditions
- Availability of adequate skilled manpower
- Standard plant, machinery and equipment
- Proper recording all jobs
- Efficient stores and procurement system
- Generation of MIS for effective monitoring of bus maintenance
- Periodic training of officers and staff

This manual is a guidance for not only improving depot-based service and maintenance but also to guide depot infrastructure and investments, human resource management and overall bus operations to bring more resource efficiency in the system. Such interventions in each and every depot can cumulatively lead to significant fuel savings and reduce the overall energy and carbon footprints of bus operations, improve economic efficiency of operations, enhance service availability for commuters and lead to increase in ridership.

Annexures

ANNEXURE 1:

List of tools and fixtures required for maintenance of 100 buses in a depot

Types of tools and fixtures	Quantity
Matra jack	1
Electric impact wrench	2
Pneumatic impact wrench	2
Pneumatic nut runner	3
Dial gauge for drum ovality checking	2
Digital micrometer	1
Torque wrenches	3
Toolbox set with pneumatic tools	20
Hub pullers	2
Fan belt tension measuring gauge	2
Brake chamber bend push rod checking gauge	3
Front hub bearing play adjustment gauge	2
Tube repair stands	3
Tyre safety stand	2
Tyre racks (12 tyres cap.)	4
Radiator repair stand	2
Radiator soldering stand	1
Oil drum stands (four drum cap.)	4
Spring racks	4
Spring removing trolley	3
Spring carrying trolley	2
Engine oil tank topping trolley	2
Portable ladders (SD)	2
Portable ladders (SD) for painters	1
Chassis stands (SD)	6
Prop. shaft stands	4
Pit planks	5
Pit jacks (square type)	2
Pit jacks (hub type)	6

Source: CSE compilation

ANNEXURE 2

List of safety equipment required for maintenance of 100 buses in a depot

Items description	Images	Quantity required
Staff uniform		200
Safety shoes		190
Fluorescent jacket		95
Gloves		88
Safety helmet		88

Source: CSE compilation

ANNEXURE 3

Tentative shift-wise allocation of manpower in a depot with 100 buses

Humanpower category	Daily maintenance	Periodic maintenance	Day shift	Docking	Running defects			Fitness renewal	Fuel efficiency checking	Sweeping and cleaning	Bus washing	Electrical section	Tyre section	Unit overhauling	Stores			Reserve personnel for weekly-off and leave	Total
	Night shift	Day or night		Day shift	Day shift	Evening shift	Night shifts	Day shift	Night shift	Night shift	Night shift	Day shift	Day shift	Day shift	Day shift	Evening shift	Night shifts		
Workshop manager			1																1
Assistant Workshop Manager			1																1
Supervisors	1	1		1	1		1			1		1						1	8
Mechanics	2	1		2	1	1	1							1				2	11
Assistant mechanics	2	1		2	1	1	2		1					2				2	14
Stores clerk			1												1				2
MIS executive			1																1
Suspension work					1	1													2
Electrician	1	1		1	1	1	1							1				1	8
Body fitter (denting work)	1	1		1			1	1										1	6
FRP work					2														2
Welder					1														1
Painter					1														1
Tyre men	3				1	1												1	6
Tyre repair men													2						2
Bus shunter		1					1				2								4
Helpers	1			1	1	1	1	1				1	1	1		1	1	2	13
Washing supervisor										1	1								2
Cleaners (without auto-washing machine)										9	4							2	15
Depot housekeeping cleaners			3																3
Total	11	6	7	8	11	6	8	2	1	11	7	2	3	5			1	12.2	103

Assumptions	
Total number of buses	100
Operated km per bus per day	200
Monthly operated km	600000

ANNEXURE 4

Checklist for buses being inspected for low-KMPL

Tier-1 checks

Components	Checks required
Fuel	Fuel line leakages
	Strength of fuel return
	Fuel cap condition and fuel tank leakages
Tyres and wheels	Tyre inflation
	Free rolling of wheels
	Wheel bearing lubrication
Brakes	Free play of brake pedal
	Gap between the brake liner and drums
	Brake retraction after the brake release
	Air pressure leakages in brake on and off position
Drive shaft and axles	Lubrication of the propeller shaft joints, stub axle and bearings
	Tightness of the propeller shaft and gearbox mounting bolts
Clutch	Clutch pedal-free play
Accelerator and clutch pedal	Clutch pedal linkages
	Accelerator linkages
Engine-related	Air cleaner for clogging
	Silencer and exhaust pipe for blockage
	Onboard diagnostic for the engine parameters
	Visible smoke on the snap acceleration
Electrical	Alternator charging
	Battery and self-starter condition to avoid push-start

Source: CSE compilation

Tier-2 checks

Components	Checks required
Wheels	Wheel alignment
	Tyre camber
Clutch	Condition of the clutch facings
	Clutch release bearings
Fuel system	Fuel lines and tank for leakages
	Strength of fuel return
Engine (diesel)	Fuel injection timings and maximum fuel stop
	Fuel injection pipe (FIP) pressure
	Pull and check injectors for the leakages or clogged spray holes
	Turbocharger bearings
	Cylinder compression
	Cylinder head for cracks or bolt tightness
	Piston rings if the oil consumption is high
	Engine coolant loss and over-heating
Exhaust system	Exhaust brake valve if used

Note: These checks to be carried out at the initial stage; if there is no improvement in the fuel efficiency, then the checks pertaining to Tier-2 need to be carried out

Source: CSE compilation

ANNEXURE 5

Checklist for seasonal preventive maintenance

A. Attention needed before summer

1. Before the arrival of summer, the intercoolers of buses should be removed, the radiator should be cleaned thoroughly with water (pressure 1kg/cm^2), the intercoolers should also be cleaned with water. This activity should be started in February so that all buses are completed by April.
2. On all preventive maintenance schedules, water circulation systems should be thoroughly checked and attended. Wherever necessary, fan belts, radiator hoses, etc., should be replaced.
3. Check the working of viscous fan clutch and replace if found defective.
4. Check and ensure correct specific gravity of the coolant.
5. Ensure correct procedure for coolant changing and flushing of engine blocks.
6. Ensure proper pressure rating of the radiator cap.
7. Buses consuming excess engine oil or having blowing engines should be thoroughly checked.
8. Whenever buses are docked in the depot, a survey should be taken to check for leakages of the water circulation system. Report the buses that consume excess quantities of water.
9. The temperature of the wheels to be checked during the in-shedding of buses, promptly attend if the temperature of any wheel is high. Tyre burst cases in summer are on the higher side due to excessive heat.
10. Check the engine bonnet for proper sealing to prevent hot gases from entering the driver compartment and passenger saloon.

B. Attention needed before monsoon

1. Check and attend all buses for broken and missing wiper blades, window or fixed glasses and leaky roofs.
2. Thoroughly clean water drainage holes on the flooring of buses.
3. Fuel tank caps must be checked to ensure that they are properly secured and 'O' and washers are in good condition.
4. Wiper wiring, air pipes and switches on buses should be kept in good working condition and the words, "Put off the wiper when not in use" properly stenciled near the wiper switch.
5. Rexene or cloth covers must be fitted to the flooring near the steering box column and handbrake assembly to prevent water splashing into the driver's cabin.
6. 'Lip tyre rubber channels' should be fitted on the bottom of top windscreen and on top of the bottom fixed glass to prevent water seeping into the driver's cabin.
7. Remove front wheel hubcaps at every schedule to check grease for water contamination and attend.
8. Fit mud flaps on the rear arch panels on both the front and rear wheels.
9. Check engine mounting and radiator mounting bushes and radiator stay rod bushes and attend.
10. Whenever there is flooding or heavy rains, instructions to be followed:
    a. All buses should be checked and attended for water ingress in HSD tank and engine oil on the very next day
    b. All buses should be checked and attended for water ingress in hub grease, self-starter, gear oil, and differential. Oil and any other damages to be attended on a special programme within four–five days.
11. During monsoons, a survey should be taken every night for identifying dirty

buses and they may be taken for washing on the auto-washing machine.

12. Route-wise or location-wise analysis of tyre punctures shall be carried out and route and location where high numbers of tyre puncture take place shall be brought to the notice of traffic counterparts.

ANNEXURE 6

DIFFERENCE BETWEEN TUBE AND TUBELESS TYRES

The construction of a tubeless tyre is similar to that of a tube tyre. The only difference is that the former do not have the inner tube to hold pressurized air. Instead, the rim of the wheel and the tyre form an air container to hold air. The inner wall of the tyre is lined with an air tight membrane to seal the air within the tyre and the rim. This air resistant layer is called the inner liner. There is a non-return valve on the rim side for inflating the tyre. This valve is permanently fitted to the rim. If a sharp object pierces through the tyre the air in the tyre escapes out slowly.

Difference between tube and tubeless tyres

Parameter	Tube tyres	Tubeless tyres
Weight	Heavy compared to tubeless tyres	Light weight
Fuel efficiency	Less fuel efficient due to the weight	More fuel efficient due to light weight and better heat dissipation
Handling and comfort	Less handling performance and comfort	Improved handling and comfort
Puncture repairs	The tube has to be plucked out of the tyre to locate the leakage. Puncture repair is time-consuming. However, tube tyres can be repaired by any roadside puncture repair shop or garage. Every local mechanic has the knowledge to repair a tube tyre	Mostly, there is no need to take the tyre off the rim for puncture repair. Though easy, special equipment is required to repair punctures of tubeless tyres, which not many will have. It needs trained tyre men
Number of parts	A larger number of parts (tube, flat, metallic washer, etc.)	Smaller number of parts due to absence of a tube
Cost	Less cost	Cost more compared to tube tyres
Maintenance	High maintenance and highly prone to punctures	Low maintenance and less prone to punctures
Safety	Less safe—instant loss of air after a sudden puncture results in loss of control.	Enhanced safety—even if a puncture takes place, the air moves out gradually and the driver has control over the vehicle

Source: CSE compilation

ANNEXURE 7

Stock recoupment slip

Name of the organization		
Purchase department		
Stock recoupment slip		
R.S. number		
Date		
Code number		
Material description		
Unit (numbers/sets and litres)		
Part number		
Class	A/B/C	
Item category	V/E/D	
Brand or make		
Vehicle type		
Seasonal item	Yes or no	
Vendor category: Manufacturers or authentic distributors or general traders		
Availability of approved sample, if quotations are required as per approved sample: Yes or no		
Stock in hand	Quantity on order	Total quantity and cover
Last consumption details (MM/YY to MM/YY)	Stock out(months)	AMC
1. Forecasted quantity: As per approved policy for six months		
2. Forecasted AMC		
3. Minimum stock level= 0.66 x AMC (lead time 21 days)		
4. Quantity to be ordered =SR No.1 - Total quantity/ cover		
Note: Justification for +/- 10% requirement		
Proposer (purchase officer)	Indented officer (Maintenance manager*)	Audited By

Source: CSE compilation

ANNEXURE 8

Daily maintenance report (DMR)

Parameter	Date	Date	Date	Date	Date	Date	Date
Total fleet							
Number of on-road buses							
Number of buses defective at the depot							
Mechanical defects							
Body defects(accidents)							
RTO passing							
Under-warranty defects							
Buses held in the depot for more than three days							
Daily breakdowns (mechanical and electrical)							
Daily breakdowns (tyre)							
Daily breakdowns (AC)							
Daily breakdowns (ITS)							
Loss of km due to breakdowns							
Daily driver complaints							
Daily maintenance attended buses							
Periodic PM schedule attended buses							
Docking attended buses							
Engine oil consumption (topping)							
Coolant consumption (topping)							
KMPL achieved							
Low-KMPL attended buses							
Number of buses attended for tyre pressure checking							
Number of buses attended for deep cleaning							
Number of buses washed							
Cases of accidents and incidents within depot premises							
Spare part consumption							
Tyres scraped							
Total employees reported on duty							

Source: CSE compilation

ANNEXURE 9

Breakdown investigation

S. no.	Date	Bus no.	Driver ID	Sub-group	Com-plaint	Loc-ation	Time of break-down	Time of report by mecha-nic	Time the bus was okayed	Time taken for attend to the bus	Missed km	Fin-dings	Date on which last service was done	Report of the last service	Driver comp-laints in the last 10 days	Rectifi-cation	Investigation and rectifiying actions
1	dd/mm/yy e.g., 07/05/2018	e.g., 1,584	e.g. 1122	e.g., brake	e.g., brake jam	e.g., Tara chowk	e.g., 20:43	e.g., 23:00	e.g., 03:00	e.g., 06:17	e.g., 27.3	e.g., Brake caliper jam found	e.g., 10 days ago: 10/06/2018 Docking: 26/06/2018 (126,000 km)	e.g., 10 days: NIL Dock-ing: NIL	e.g., NIL	e.g., calliper piston lubricated	e.g., The caliper piston jammed due to excessive rust accumulation. The problem was first reported at the beginning of operation of the buses. However, a survey of all buses was taken to determine the condition of calipers. Calipers were found slightly jammed in two buses and the problem was rectified.
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	

ANNEXURE 10

Daily off-road bus report

Bus number	Defect reported	Reported date*	Action taken	Expected date of repair*	Remarks (if any)

*Date in dd/mm/yy format

Source: CSE compilation

ANNEXURE 11

Control chart format

1) Engine oil topping control chart

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: Topping quantity to be entered on the respective dates. On the dates that the buses attended preventive maintenance schedules, the blocks should be indicated in yellow.

Source: CSE compilation

2) Coolant topping control chart

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: Topping quantity to be entered on respective dates. On the dates that buses attended preventive maintenance schedules, the blocks should be indicated in yellow.

Source: CSE compilation

3) KMPL control chart

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: KMPL figures to be entered on the respective dates. On the dates that the buses attended preventive maintenance schedules, blocks should be indicated in yellow.

Source: CSE compilation

4) Preventive maintenance schedule control chart

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: The dates of preventive maintenance schedule should be entered at each respective date. On the dates on which docking schedule was attended, blocks should be marked in red.

Source: CSE compilation

5) Driver complaints and breakdowns control chart

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: Driver complaints to be mentioned on each respective date. The breakdowns should be indicated in red colour.
Source: CSE compilation

6) Tyre pressure checking

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: The dates on which tyre pressure is checked with pressure gauge areto be tick marked in the blocks.

Source: CSE compilation

7) Bus washing control charts

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Note: Buses washed should be indicated in the blocks.

Source: CSE compilation

ANNEXURE 12

Preventive maintenance schedule attention records

Date	Bus number	Defects noticed	Action taken	Reasons for balance job (if any)	Spare parts used	Name of employees

Source: CSE compilation

ANNEXURE 13

Periodic maintenance schedule progress report

Week	Number of buses due for the 10 day schedule	Number of buses attended	Number of buses remaining	Reasons for remaining buses
E.g., week 7				

Source: CSE compilation

Docking schedule progress report

Week	Number of buses due for 10 day schedule	Number of buses attended	Number of buses remaining	Reasons for remaining buses
E.g., week 7				

Source: CSE compilation

ANNEXURE 14

Driver complaint record

Serial number	Date	Bus number	Driver number	Complaint details	Findings	Action taken	Name of the mechanic	Remarks of supervisor

Source: CSE compilation

ANNEXURE 15

Group-wise driver complaint record

Items	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date
ABS										
AC										
Accelerator										
Air pressure										
Belt										
Brake										
Fuel-related defects										
Coolant leakage										
Electrical										
Engine										
Front wheel										
Gear										
Horn										
Passenger door										
PIS (KPIT)										
Rear wheel										
Starting trouble										
Steering										
Suspension										
Tyre										
Wiper										
Body										
Grand total										

Source: CSE compilation

ANNEXURE 16

Repeated driver complaints report

Week	Date	Bus number	Driver complaint	Action taken
E.g., 1 June 2020 to 7 June 2020	E.g., DD/MM			

Source: CSE compilation

ANNEXURE 17

Daily work done record

Date	Bus number	Shift	Reported defects	Source of defect	Attendance details	Spare parts used	Name and number of the employee

Source: CSE compilation

ANNEXURE 18

Bus-wise KMPL

Bus number	Date	Date	Date	Date	Date	Date	Date	Date	Date	Date

Source: CSE compilation

ANNEXURE 19

Bus history

Bus number: _____

Name of unit	January	February	March	April	May	June	July	August	September	October	November	December
Engine oil												
Coolant												
Gear box oil												
Steering oil												
Differential oil												
Clutch plate												
Pressure plate												
Main flywheel												
Lube filter												
Diesel filter												
Water separator												
Fuel strainer												
Air filter prim												
Air filter sec												
Steering oil filter												
Brake liner F/L												
Brake liner F/R												
Brake liner R/L												
Brake liner R/R												
Slack adjuster F/R												
Alternator												
Starter												

Bus number: _____												
Name of unit	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Tappet cover packing												
PTO valve front												
PTO valve rear												
Balloon R/R/F												
Balloon R/R/R												
Balloon R/L/F												
Balloon R/L/R												
Engine												
Engine cylinder head												
Cylinder head gasket												
Radiator												
Intercooler												
Turbocharger												
FIP												
Gear box												
Steering box												
Steering pump												
Differential												
Front axle												
Propeller shaft 1												
Propeller shaft 2												
Propeller shaft 3												
Injector 1												
Injector 2												
Injector 3												
Injector 4												
Injector 5												
Injector 6												
Slack adjuster F/R												
Slack adjuster F/L												
Slack adjuster R/R												
Slack adjuster R/L												
Shock absorber R/R												
Shock absorber R/L												
Shock absorber F/R												
Shock absorber F/L												

Bus number: _____												
Name of unit	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Dual brake valve												
DDU												
Master cylinder												
Slave cylinder												
Air filter unit												
Relay valve												
Quick release valve												
Unloader valve												
NRV												
Brake booster (R)												
Brake booster (R) diaphragm												
Brake booster (L)												
Brake booster (L) diaphragm												
RWO unit (R)												
RWO unit (R) diaphragm												
RWO unit (L)												
RWO unit (L) diaphragm												
Levelling valve (R)												
Levelling valve (L)												
Wheel drum F/R												
Wheel drum F/L												
Wheel drum R/R												
Wheel drum R/L												
Air compressor												
Air compressor Head												
Reed valve plate												
Wiper motor												
Battery 1												
Battery 2												
Fan belt												
Tie rod kit												
Push rod kit												
Feed pump												

Source: CSE compilation

ANNEXURE 20

Drained engine oil records

Date	Type of oil	Number of oils changed	Capacity	Total oil consumed	Total new oil issued	Total drained oil collected	Percentage of drain oil collected

Source: CSE compilation

ANNEXURE 21

Statutory compliance report

A. PUC check report

Month: _____/ 202_					
Serial number	**Bus number**	**PUC expiry date**	**PUC T test done**	**Reasons for delay, if any**	**Rectification action taken**
1					
2					
3					
4					
5					

Source: CSE compilation

B. MVI RTO passing report

Month: _____/ 202__						
Serial number	**Bus number**	**RTO passing due date**	**Date of bus attention for RTO passing**	**Actual RTO passing date**	**Reasons for any delays**	**Rectification action taken**
1						
2						
3						
4						
5						

Source: CSE compilation

C. Fire extinguisher report

Month: _____/ 202__					
Serial number	**Bus number**	**Fire extinguishers expiry date**	**Fire extinguisher replacement date**	**Reason for delay in replacement**	**Rectification action taken**
1					
2					
3					
4					
5					

Source: CSE compilation

ANNEXURE 22

Tyre history

Serial number	Tyre number	Fitted date	Tyre make	First remold date	New tyre life	Second remold date	Third remold life	Second Remold life	Scrap date	Total casing life	Reason for scrapping

Source: CSE compilation

ANNEXURE 23

Tyre life statement

Month: (e.g., September 2021)

Serial number	Tyre number	Make of tyre	Life of new tyre before remold	First remold life	Second remold life	Total casing life of scrapped tyres	Reason for scrapping	Action taken(if any)
1								
2								
		Average life						

Source: CSE compilation

Summary (as per the make)

Serial number	Make of tyre	Total number of tyres scrapped	Average new tyre life obtained	Average first remold life obtained	Average second remold life obtained	Total premature scrap tyres	Life of premature scrap tyres	Average casing life of all tyres

Source: CSE compilation

ANNEXURE 24

Tyre wear statement or NSD statement

Bus number	Make of tyre	Tyre fitted date	NSD reading in mm					
			F/O	R/O/O	R/O/I	F/N	R/N/O	R/N/I

Note:

1. NSD to be checked at position where the tyre wear is maximum.
2. NSD readings to be taken twice a month.
3. Buses whose NSD is less than 5 mm to be kept for checking on a daily basis.

Source: CSE compilation

ANNEXURE 25

Tyre pressure checking

Date	Bus number	F/O	R/O/I	R/O/O	F/N	F/N/I	F/N/O	Tyre condition

Note: Pressure found during the checking to be recorded and not the pressure after filling.

Source: CSE compilation

ANNEXURE 26

Tyre puncture analysis

Date	Nail puncture	Valve pin leak	Stone cut	Bead damage	Side wall damage	Tyre burst	Tyre tread worn out	Total

Source: CSE compilation

ANNEXURE 27

Unit life statement

Serial number	Name of the unit	Bus number	Condition of the unit		Fitted on (date)	Removed on (date)	Life of the unit	Reason for failure of the unit
			New	R/C				

Source: CSE compilation

ANNEXURE 28

Unit and oil replacement schedules

Serial number	Unit and oil details	Replacement due date	Schedule (in km) of replacement	Replaced on date	Replaced km	Remarks for any early replacement or delays

Source: CSE compilation

ANNEXURE 29

Spare parts cost statement

Month	Regular maintenance spare parts consumption	Warranty part	Accident part	Local purchases	Total parts consumption	Operated km	Per km cost

Source: CSE compilation

ANNEXURE 30

Bus-wise performance statement

S. no.	Bus no.	Number of days the bus was on road	km operated	Breakdowns reported	Driver complaints reported	kmpl	Number of times scheduled performance maintenance attended	Number of times the bus washed	Number of times tyre pressure was checked	Engine oil consum-ption	Coolant consum-ption	Accidents reported	Passenger complaints related to the bus	Bus main-tenance cost (labour + spares)

ANNEXURE 31

Spares indented and supply position

Serial number	Date of indent	Total number of spares indented	Total number of spares received	Number of spares out of stock	Number of spares under inspection	Percentage of spares received as per the indent

Source: CSE compilation

ANNEXURE 32

Bus-body damage report

To
The Traffic Manager

Following buses were reported for body damages:

Serial number	Date	Bus number	Driver number	Details of damage	Estimated cost of damage

You are requested to take necessary actions against the concerned driver and inform us accordingly

Technical officer

References

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3. Anon 2017. *State Transport Undertakings Profile and Performance 2016-17*, Central Institute of Road Transport

4. Ibid

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Bus transit agencies are facing the crippling challenges of reduced ridership and earnings, and deteriorating bus services. This has been aggravated by the pandemic that has further eroded bus ridership. A quick turn around is needed. To make that happen, the bus sector requires urgent revival and expansion. A new national bus scheme is expected to add 20,000 buses to the urban fleet soon. But the current and augmented fleet can deliver on their service goals only if several crucial steps are taken to reform the bus service. One such measure, which is also one of the least understood, is the role of depot-based bus fleet management and maintenance practices. These practices have a significant impact on the overall performance, cost of operations and enhancement of reliable services.

This bus guidance framework has been prepared to inform and support infrastructure planning for improved fleet maintenance and management of bus depots. This is a detailed step-by-step manual.

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