SHAKTI
SUSTAINABLE ENERGY FOUNDATION

Association of State Road Transport Undertakings

BUS DEPOT DESIGN GUIDELINES

SGArchitects

SGArchitects
6151/8, Sector D, Pocket 6
Vasant Kunj
New Delhi-110 070
www.sgarchitect.in

Key Contributors:

Sandeep Gandhi
Principal Architect

Satyajit Ganguly
Senior Transport Planner

Pushkar Dhawale
Architect and Urban and Regional Planner

Bhawna Chauhan
Architect and Urban and Regional Planner

Kanica Gola
Architect and Infrastructure Planner

Acknowledgement

The authors would like to express our gratitude to Shakti Sustainable Energy Foundation.

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support sustainable mobility, energy efficiency and renewable energy. The foundation not only funded the development of these guidelines but also provided feedback and continuous support in coordinating with various Government and Non-Government stakeholders.

We would like to thank the different State Transport Undertakings (STU's) and Municipal Corporations, for their participation as case study examples, for their immense support and cooperation in making this document possible. We deeply acknowledge Delhi Integrated Multi-Modal Transit System (DIMTS), Jaipur City Transport Services Limited (JCTSL) and Chandigarh transport Undertaking (CTU) for their guidance and valuable inputs.

We would also like to thank KPIT Technologies Ltd. for their valued inputs.

Finally, we would like to thank the Association of State Road Transport Undertakings (ASTRU) for extending their support and guidance throughout the project. Their inputs have helped us immensely at various stages of development of this document.

Contents

List of Figures

List of Tables

Foreword

The transport sector contributes to 18-20% of India's primary energy demand. Rapid urbanization and population growth have led to an increase in mobility needs for passengers and goods, which is increasing at the rate of 9% each year. India's public transport services need to meet these needs based on reliability, safety and comfort of their services. With commuters preferring to use private vehicles as mode of transport, passenger transport is becoming more and more emission intensive. Promoting the use of public transport is a key strategy for reducing emissions from passenger transport, decreasing motorization and improving the quality of urban life.

An essential requirement of a good quality bus system is the availability of adequate supporting infrastructure like bus terminals and depots. However, most Indian cities do not have adequate supporting infrastructure. This reduces the passenger capacity offered by buses systems, inducing passengers to shift to high carbon modes like private vehicles. Therefore, there is a need to upgrade existing bus terminals and maintenance depots and develop new ones to ensure better bus services.

Last year, under its Memorandum of Understanding with the Association of State Road Transport Undertakings (ASRTU) for cooperation on public transport issues, Shakti supported the development of planning and design guidelines for bus terminals in India. These guidelines were well received by stakeholders.

The Bus Depot Design Guidelines, a progression of these efforts, are comprehensive planning and design recommendations for maintaining bus maintenance bus depots. The guidelines are aimed at addressing the capacity gap in optimizing the fleet handling capacity of depots as well as improving the quality of depots in India. I trust they will be of interest to policy makers, planners, designers, State Transport Undertakings (STUs) and other stakeholders and contribute to efforts to create better bus infrastructure in cities.

I extend special thanks to SG Architects, our partner, for developing these guidelines.

Chief Executive Officer

Shakti Sustainable Energy Foundation

Krishan Dhawan

Preface

India's economic development and prosperity is intrinsically dependent on provision of mobility choices that allows people easier access to activities, services and goods. A major share of the mobility surge is currently being catered by road-based transport of which a substantial component is met by buses. It is estimated that there are close to seven lakh buses operating in the country. Of these, approximately 1,50,000 are operated by the public sector through more than sixty State Transport Undertakings (STU) and Transport Corporations. These buses operate around 12.1 billion kilometres annually and carry more than 70 million passenger trips per-day. This is nearly three times the passengers carried by Indian railways.

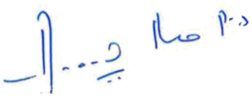
While buses form the core of the road-based transport in India, in the past few years, their services have not increased to keep pace with the growing travel needs in the country. Estimates suggest that the STUs ought to increase their fleet size by three times over the next decade to meet the increasing urban and inter-city travel demands. Such an increase in fleet size will require adding adequate supporting infrastructure like Bus terminals and Depots which are crucial to meet passenger convenience and bus fleet Operations and Maintenance (O&M) requirements.

This document a pioneering effort to develop comprehensive guidelines for bus depot development in India. While the need for upgradation and development of bus depots is recognised as a priority area by the STUs, they are hampered by their limited technical and financial capacity to develop modern bus depots. Therefore, this guideline provides detailed recommendations on planning, designing and financing bus depot infrastructure based on learnings from global best practices and their demonstration for Indian requirements.

The guideline has been developed by SGArchitects with support from Shakti Sustainable Energy Foundation. I congratulate the team for this very important initiative. I trust that this guideline will serve as an important capacity building resource for stakeholders working on bus depot development. It will contribute in making bus transport more attractive and will help us achieve our long-term vision of sustainable mobility in the country.

Executive Director

Association of State Road Transport Undertakings (ASRTU)



P.S. Ananda Rao

1 Introduction

1.1 Background

Bus based public transport remained the backbone of mobility in our cities until the mid-1980s. Post this period, with the inclusion and growth of the motor industry, buses rapidly lost ground to private vehicles. Meanwhile, new cities emerged, administrations of most of which overlooked the need to invest in any form of public mobility, giving rise to privately organised shared forms of transport, such as shared jeeps and auto rickshaws.

In 2006, policymakers, —appreciating the need to revive public transport in Indian cities—introduced the National Urban Transport Policy (NUTP) 2006 which focussed on developing organised bus based public transport systems in cities. Aided by central government grants under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), thousands of buses were made available to many Indian cities, leading to a rapid increase in the fleet size of a number of State Urban Transport Undertakings (STUs), up to 2015. Along with the renewed thrust on improving the quality and accessibility of bus based public transport, and the resultant increase in fleet strength, came the STUs' appreciation of the need to improve the supporting infrastructure i.e. bus terminals and depot facilities. Currently, these facilities are ill-equipped to handle passenger and operator requirements and present a severe capacity constraint to the STUs in terms of catering to the required number of buses and passengers.

Furthermore, large part of the public transport requirement in our country is catered to by private operators, both in the organised and the unorganised sectors. These operators are either single vehicle operators or own a large fleet of buses. Regardless of their fleet size, they typically lack access to formal bus terminal or maintenance facilities, and rely on makeshift arrangements for passengers, buses and staff. Without improvement in the level of service (LOS) by the private operators, an overall improvement in the attractiveness and accessibility of public bus systems may not be achievable. However, owing to the nature and scale of bus ownership by the private operators, investment in bus maintenance infrastructure is neither practical nor achievable. However, it may be worthwhile to explore means of accommodating the private bus operations in the infrastructure developed and deployed by different STUs, in a mutually beneficial manner. STUs must focus - on an urgent basis - on improving and expanding depot infrastructure, preferably with enhanced capacity to accommodate private operators. Traditionally, STUs have not focused on this critical (more so in recent times) aspect of bus transport systems. Additionally, they are faced with the lack of technical capacity for undertaking modern bus depot infrastructure development. This points to the need for building capacity in the country, for bus system specific infrastructure development, leading to improved LOS for operators and the passengers.

1.2 Need for the Guideline

Increased fleet size, reduced efficiency, fragmented norms, and lack of technical advancement, along with the absence of any up-to-date technical document on bus depots in the Indian context, contributed to the need for the Guideline.

The development of need specific guidelines, standards and toolkits is considered among the most effective formats of capacity building in an organisation. This method facilitates low cost and rapid sharing (and dissemination) of knowledge and experience. Additionally, it is the most promising means to ensure that the minimum standards of development are met and that no stakeholder requirement is overlooked.

1.3 Purpose of the Guideline

The Guideline is aimed at providing the stakeholders with the following, towards developing bus operations and maintenance facilities:

- basic standards in all calculation, planning, programming and designing elements involved in the development of the facilities;
- readily available standards and specifications for planning and designing the depot infrastructure; and
- assistance to ensure effective utilisation and functioning of the facilities.

1.4 Scope of the Guideline

1.4.1 Target audience of the Guideline

This guideline document can be used by the following:

- Consultants (planners and designers)
- Decision makers and STU engineers/officers
- Non-governmental or civil society organisations (NGOs/CSOs), or advocacy groups

- Researchers and academicians

The Guideline is aimed at assisting planners and designers in understanding the requirements of different depot typologies, and to provide them—and the decision makers—with the tools to finalise the functional and spatial requirements. It provides suggestions on design standards, cost implications, and equipment required, among others.

1.4.2 Application of the Guideline

The Guideline will apply to both green field construction as well as renovation projects, of bus operations and maintenance facilities. It will provide the criteria for determining requirements, for site evaluation, and for planning and design.

1.4.3 Use of the Guideline

The guideline document comprises five chapters. The first chapter provides an overview of a bus depot's requirements including the size, location, capacity, and the various components involved.

Chapter two provides details regarding depot operations, site planning, functioning (using flow diagrams) of each component of a bus depot, and interaction among the various personnel and functions involved. The operational aspects of a bus depot are addressed through discussion on intelligent transport system (ITS), management information system (MIS) etc.

Chapter three elaborates the design aspects—viz. design elements, building design, and building systems—to help determine different building sizes and overall spatial requirements of the site. It also provides details—such as basic planning, area calculations, equipment (along with specifications) used—with reference to depot service and operational requirements.

Chapter four provides an illustrative design of a typical depot layout, in accordance with the design and planning requirements listed in chapters two 2qand three.

The final chapter of the Guideline addresses the financial aspects of depot development.

1.5 Overview of a Bus Depot

A bus depot (or bus garage) is where buses are sheltered, maintained and parked. It is comprised of facilities for service/repair, washing and fuelling of buses; offices for administrative functions; and parking spaces for buses, and vehicles of staff and visitors (The World Bank Group and PPIAF, 2006). It also includes amenities like changing rooms, resting rooms, and other necessary facilities for the depot crew (drivers, conductors, and office and workshop staff).

Bus depots are among the primary infrastructural requirements for any bus system, and like the others, for a bus depot too, appropriate forms of ownership and methods of charging users should be considered, where necessary (The World Bank Group and PPIAF, 2006). This requires that special attention be paid to the components, location, size and capacity of a depot.

1.5.1 Components of a Bus Depot

The development of a bus depot involves arranging and planning the infrastructure (and other elements) with a more detailed dimensional understanding, to ensure functional efficiency and effectiveness of the facility. This also requires implementation of modern techniques, as well as planning services that will ensure smooth functioning of the system.

A bus depot includes provisions for a number of activities under different categories. During design development, the provision of the activities must be planned category-wise.

Following are the components integral to a bus depot:

1) Entrance/Exit
2) Internal Parking (bus)
3) External Parking (private vehicles)
4) Fuelling
5) Cleaning/Washing
6) Maintenance
7) Storage
8) Administrative Facility

1.5.2 Location of a Bus Depot

Location is a critical consideration in planning or designing a bus depot. Two attributes to be considered in selecting the site of a depot (in a city) are:

1. depot accessibility (for buses from the nearest terminal, and the staff), and
2. efficient utilization of space/land, equipment and manpower.

Minimising dead mileage[1] between the depot and the terminals is the primary consideration in selecting any bus depot's location. Santosh (2001) suggests planning the depot near the existing terminal facilities, can help minimise dead mileage and time lost to traffic congestion.

The city authorities should ideally disaggregate a large common facility into smaller depots, each conveniently located near the starting point of a route. However, very small depots may not be as efficient financially viable as larger ones.

In a city with only one depot, a central location should be preferred (The World Bank Group and PPIAF, 2006). In addition to minimal dead mileage, the selected site must also fulfil the criterion of integration with the existing city infrastructure, to accommodate requirements related to electricity, water, wastewater discharge etc.

1.5.3 Depot Size and Typology

The World Bank Group and PPIAF (2006) suggests that a bus depot should be economically sustainable, and manageable in size. The relationship between bus depot size and economic sustainability as well efficient management of the facility is governed by the following two factors:

1) Each depot requires a unit area per bus. This includes space for parking, for circulation and space occupied by depot servicing activities. All area requirement apart from parking requirement, tends to reduce per bus with increase in the number of buses accommodated at a site. Hence, per bus area requirement reduces exponentially with increase in depot capacity/size. This results in an inefficient use of space for very small depots.
2) The equipment used in a depot, such as gantry washers, fuelling stations, etc. have a capacity to serve a limited number of buses in an hour or a depot shift. Thus, a depot capacity in multiples of that capacity will result in an efficient use of the installed equipment and associated manpower

Understanding of the capacity served by equipment provided at a bus depot, suggests that bus depot capacity should be in multiples of 80 to 100 buses. Estimates of bus depot area requirements, based on best practice planning and design approach, reveal that per bus land requirement for depot capacity of less than 80 buses varies from 200 to 165 sq. m. approximately, decreases to 149 sq. m. for a capacity of up to 200 buses, and further decreases to 136 sq. m. when the capacity increase to 600 buses (Figure 1). This form the basis of bus depot categorization on the basis of size and may be defined as following:

1) Small size depot - less than 80 buses
2) Medium size depot - 80 to 200 buses
3) Large size depot[2] - more than 200 buses

Such a size classification has also been used in other reports and documents (Towe Ireblad, 2012).

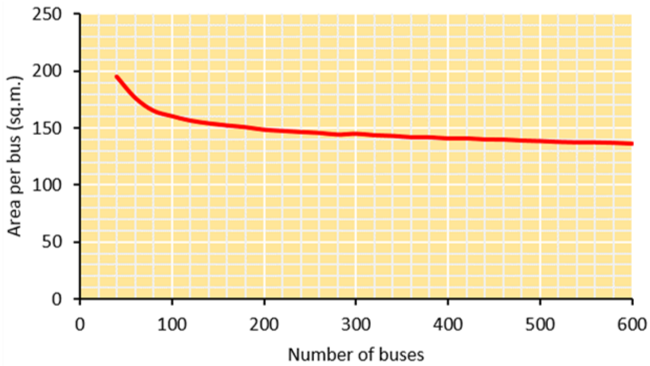


Figure 1: Area per bus requirement

Understanding of factors that lead to an efficient use of space and equipment at a depot facility coupled with the requirement of disaggregating bus depots to minimize dead mileage, suggests that medium sized depots – preferably with a capacity of 80 to 100 buses, is desirable over small and large depot facilities. Others also suggest that a bus depot's capacity should not exceed 100 buses if the depot manager is to monitor the drivers' operational activities personally (S.Ponnuswamy, 2012).

[1] In the case of public transport, dead mileage (dead running or dead heading) refers to the scenario of a public transit vehicle operating without carrying or accepting passengers, such as a bus arriving from the garage to begin the day's first trip, which is termed 'dead heading'.

[2] Multilevel bus parking is feasible only in large depots.

1.6 Operations of a Bus Depot

A bus depot's planning and designing process involves a detailed consideration of its operations. Any bus depot, irrespective of its size—small, medium or large—must host specific operational tasks inside and outside its premises. How these operations are planned is critical to the efficiency and performance levels of the depot. These operations vary according to the type of activities performed in the depot such as administrative, driver and crew operations (Minnesota Department, 2012).

1.6.1 Bus Activity Management

Management of activities of buses is the primary operation in a bus depot. It includes managing the transfer of buses between various activities/locations in the depot. The following are the principal bus management tasks carried out at a bus depot:

1) In-shedding (Entry)
2) Parking
3) Washing/Cleaning
4) Maintenance
5) Fuelling
6) Out-shedding (Exit)

While at most bus depots, the bus management tasks are performed in the above order, it may vary in some cases due to local considerations or omission of few of the activities. For example, in depots without a fuelling station within the premises, fuelling is undertaken outside the depot, and precedes all the other processes. While in depots with a fuelling station within its premises, fuelling is undertaken as per a defined sequence, between workshop visit and out-shedding.

1.6.2 Infrastructural Operations

All bus depots—irrespective of size—involve management activities in addition to the bus based operations. These include the following activities, among others (The World Bank Group and PPIAF, 2006):

- Allocating buses and their crew for each duty/trip
- Dispatching buses according to schedule
- Processing ticket sales, and cash deposited by conductors (or drivers)
- Managing parking facilities for visitors and depot staff (including bus crew)
- Limiting the activities of drivers, conductors, operating crew, and visitors to their relative area

In India's current scenario, bus depots lack planned segregation and integration (physical or operational) among personnel, equipment, and infrastructure. For example, in most of the existing depots, all parts of the depot are freely accessible to all (drivers, conductors, depot crew, and visitors). Such arrangements attract inefficiency, and safety and security issues, among other problems. Therefore, all depot activities must be identified and adequately segregated/integrated as per their role in overall depot operations. Additionally, the scope of work for each individual category of personnel accessing the depot (drivers, conductors, shunters, workshop crew, fuelling crew, depot officials and visitors) must be well-defined (Santosh, 2001). This is why a bus depot's plan and design must consider integration with the provision of infrastructure and spaces which will facilitate the required level of operational segregation and/or integration. Following are the key elements to be provided to facilitate infrastructure operations in a depot:

1) Administration Block
2) General Offices
3) Staff Facilities

These elements are discussed in detail in subsequent chapters.

2 Planning Considerations

The setting up of a bus depot involves provisions to perform several bus and crew related activities. The process demands detailed infrastructural and operational planning, to consider all the factors necessary for executing the project at site. This chapter provides an overview of three essential planning considerations of bus depots i.e. site planning, the deport operations and facility planning.

2.1 Depot Operations

Depot operations can broadly be divided into bus related operations and crew related operations Bus related operations include registration process of the bus during in-shedding (entry) and out-shedding (exit); and regular washing and fuelling; and workshop visits for service/repair. Crew related operations include allocating a crew (driver and conductor) to a bus; assigning the crew their duty schedule at exit; and collecting duty charts and cash (from ticket sales) at entry.

Figure 2 presents the sequence of activities—to be followed in the depot—to allow seamless integration of bus and crew operations. The figure also provides insights into the workshop and administrative staff activities. It needs to be noted that the sequence of activities involving bus maintenance, between the time when the bus crew leaves the bus and collects it back at the depot, may vary for diesel and electric buses. While diesel buses may be fuelled between washing, inspection and maintenance cycle, electric buses need to be charged only after inspection, washing and maintenance activities.

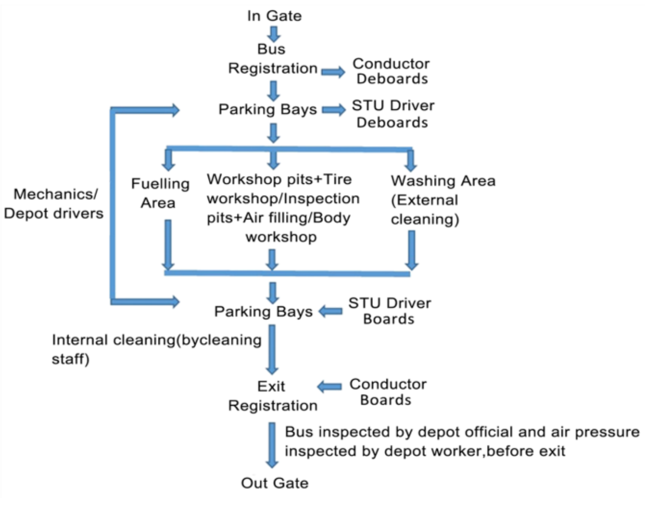


Figure 2: Operational integration in bus depots

The sequential process of the bus and crew operations is explained further in the subsequent sections.

2.1.1 Bus Registration

Each bus undergoes two-step registration daily, once on entering the depot and again on exiting. These steps are called in-shedding and out-shedding respectively, take 2-3 minutes each and are conducted at the depot's entry/exit gates. They involve recording critical information about the bus, against its registration number. The information includes crew details, odometer reading, time (of entry/exit), fuel level and tyre pressure (only during out shedding), among others. It is fed daily in the Management Information System. The registration process also involves recording the time and location of the conductor's joining a scheduled trip.

2.1.2 Management Information System

Understanding the service schedule (of the various components in a bus) is a critical element of bus servicing at depots. This schedule is based on a bus's number of kilometres operated. Thus, the depot and workshop staff must keep track of the service schedule of each bus, which is why the daily registration process is crucial. Management Information System (MIS) documentation, and service schedule reporting (i.e. recording and disseminating it to the crew) are important too. Currently, majority of the workshop tasks are performed outdoors (un-sheltered), decreasing the workers' efficiency and leading to a sub-optimal service schedule.

MIS is one of the main components of 'intelligent transport system' (ITS). It broadly refers to a computer-based system that provides tools to organise, evaluate, and efficiently manage operations. MIS is used to ensure that bus related information is recorded, stored, tracked, and used effectively, towards efficient depot operations. It also serves to record and report crew information. A depot may use one of three MIS system formats: manual (paperwork based), manual and machine (computer based), or completely automated (computerised, including Wi-Fi connected handheld tabs operated by depot staff). Needless to say, the higher the automation level (the highest being automatic tracking of vehicle, workforce and inventory) the more efficient are the depot operations.

Current depot computerisation software can include capabilities—using MIS— that include management of data resources such as databases, management of hardware resources, decision support systems, people management and project management applications, and any computerised processes that enable the department to run efficiently (Beal, 2016).

2.1.2.1 Depot Computerisation System (DCS)

Depot operations involve storing and processing a host of data apart from the fleet management related information, i.e. the store keeping, office administration, and fuelling related information. All this information can be systematically gathered through a software named depot computerisation system (DCS). The DCS deployed in bus depots includes MIS and all transactions related to finance, revenue, inventory, operations, maintenance and administration, among others (Figure 3).

Database and reports generated out of various DCS modules can be further analysed and used for decision making, performance evaluation, and improving the efficiency of vehicle operations. The various modules and reports that can be generated through DCS are listed in the following section.

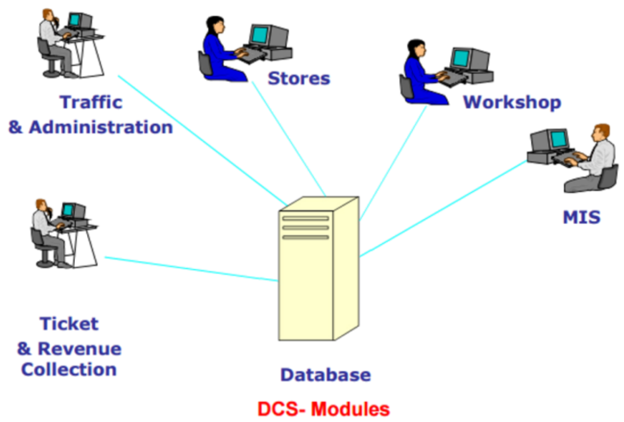


Figure 3: Depot Computerization System – Modules

Source: (KSRTC, 2013)

Ticket Accounting and Revenue Collection Module

The ticket accounting and revenue collection module stores and processes the following information (KSRTC, 2013):

- Ticket transaction receipt; issue, returns and transfer of pre-printed tickets
- Electronic Ticketing Machine (ETM) transaction download of ticket data, erasing of tickets, uploaded route and fare details
- Waybill and cash receipt processing, generation and auditing
- Trip sheet and records of revenue collected from any conductor-less schedules
- Other receipts/refund or sundry receipts and refund
- Casual contracts request, allocation chart of crew & vehicle, accepted casual contract revenue

Administration Module

The administrative module stores and processes the following information:

- Attendance abstract
- Leave orders
- Defaulters list
- Incentive-eligible employee list

Traffic Module

The traffic module stores and processes the following information:

- Crew allocation reports
- Crew timesheet
- License expiry details
- Late departure/arrival details
- Overtime hours' details
- Cancellation details

Stores Module

The stores module stores and processes the following information:

- Balance quantity and meter reading from fuel stock master
- Fuel calibration charts entries (dip cm and quantity of fuel)
- Fuel opening and closing balance (facilitates the capture of meter reading, dip reading, balance quantity etc.)
- Issued fuel (facilitates the recording of fuel issued to home/out depot vehicles, domestic vehicles, generators etc.)
- Received fuel in the depot fuelling station (facilitates the recording of tank number, quantity of fuel received, type of receipt, dip reading etc.)

Workshop Module

The workshop module stores and processes the following information, among others:

- Vehicle progressive kilometres
- Fuel efficiency statements in terms of kilometres per litre (KMPL) achieved (category wise - vehicle, driver, schedule, sector etc.)
- In case of Electric Vehicles, Efficiency in electricity consumption in terms of kilometer per kWh (kWh/km) achieved (category wise - vehicle, driver, schedule, sector etc.) and breakdown register for charging stations
- KMPL or KWh/km register
- Daily vehicle position
- Dead kilometres details
- Defects and action taken statement
- Pending maintenance schedule
- Vehicle off road details
- Breakdown register

MIS Module

The MIS module stores and processes the following information:

- Conductor wise earnings
- Daily operational statistics
- Schedule wise earnings
- Daily revenue details
- Unchecked conductors
- Unchecked schedules
- Schedule wise traffic & non-traffic revenue
- Weekly revenue details
- Weekly analysis
- ETM ticket sale details and ETM earning reports (category wise - waybill, conductor, schedule)

Various DCS solutions which are readymade or those that can be custom built to suit the specific requirements of individual depots are available internationally. DCS supports depot operations in various ways. For example, the DCS stores module can be used to probe if a particular part is being used excessively, and if this can be attributed to specific deficiencies in operations and management. Likewise, in the event that fuel records show that the average of a bus(es) with respect to a particular driver is significantly low, this data can help identify a maintenance issue with the bus(es) or a training/disciplinary issue with a particular driver (or crew member).

2.1.2.2 Daily Services Management

- On reaching the depot at the end of its daily operation, a bus must go through certain regular/daily servicing and checks, the data corresponding to which is recorded in DCS, such as: Pit inspection results (under body and outer body inspection)
- Fuelling details
- Washing and/or cleaning details (outer body and bus interiors)
- Tire pressure check details (all tires)
- Bus running inspection details (brakes, steering wheel, lights/indicators, instrument cluster etc.)

These daily servicing requirements apply to each bus in a depot and are not time intensive. Unlike workshop functions, they don’t involve specific heavy equipment and infrastructure, and are not time consuming. Therefore, they lend themselves to strategies to minimise time, manpower and resource application. One such operational strategy involves—introducing activities like dry cleaning of buses, air filling, slow fuelling for CNG buses and bus running inspection at each parking bay. This is expected to minimise the work load of depot drivers; avoid trips (between parking bays, to fuelling and air filling facilities), and thereby traffic inside the depot. Through another such operational strategy, the need for buses to be manoeuvred inside the depot can be minimised, by conducting the under-body inspection of a bus and its driver’s registration process simultaneously, i.e. immediately after the bus is driven into the depot, and before it is parked in its designated bay.

2.1.3 Bus Parking

The driver operating the bus on a designated route is considered a part of the bus crew. This driver’s role in a depot is limited to parking the bus in the designated parking spot after in-shedding and collecting it from the specified bay before out-shedding. Movement of buses within the depot for various maintenance activities is undertaken by the depot staff/drivers.

2.1.4 Crew Operations

A well-managed bus depot maintains an optimum degree of isolation and control, to ensure that only necessary personnel are present inside the bus operations and maintenance area which includes bus parking, workshop, fuelling and washing and the presence of bus crew in the area is minimised. This is essential for safety, security and efficiency in bus depot operations.

2.1.4.1 Bus Driver

The driver plays a vital role during in-shedding and out-shedding. S/he has various tasks to perform during the in-shedding and out-shedding processes as explained below:

- **In-shedding**

The in-shedding process commences with the bus's registration at the entry gate, at which point the driver also makes an entry in the complaint register about problem(s) encountered while driving the bus. From here, s/he proceeds to park the bus in the designated bay, followed by depositing the memo at the memorandum office-marking end of day's duty and subsequently retires in the depot rest room or leaves the depot.

- **Out-shedding**

The out-shedding process commences early in the morning. The driver typically reaches the depot 30 minutes in advance, and collects the duty memo assigning him/her the duty for a specific bus, for the day. S/he then reaches the parking bay where the specific bus is parked, inspects the bus, and manoeuvres it to the exit gate, for registration and exit. During registration, the bus and its tire air pressure are inspected by a depot official and a depot worker respectively. The out-shedding process concludes once the bus, with driver and conductor, exits the depot.

2.1.4.2 Bus Conductor

The conductor also plays a vital role during in-shedding and out-shedding. The conductor's activities are explained below:

- **In-shedding**

During the in-shedding process, the conductor deboards at the entry gate, withdraws the final receipt of the Electronic Ticketing machine (ETM) and surrenders it at the ETM room. The machine is then sent for recharging and resetting for the next shift. From the ETM room, the conductor heads to the waybill office and submits the cash, the ETM receipt and the waybill[3] which was handed to him/her before their duty was assigned. Hereafter, the conductor is relieved from the day's duty and can return home or to the rest room provided in the depot complex.

- **Out-shedding**

For out-shedding, the conductor must report at the depot 30 minutes before the scheduled start time of his/her trip. First, s/he collects the waybill and duty assignment from the waybill office, and the ETM (plus standby paper tickets) from the ETM room. Next, s/he waits for the assigned bus at the entry/exit gate. His/her trip commences after boarding the bus and leaving for the scheduled route.

2.2 Depot - Site Planning

Depot-site or the land allocated for the depot needs to be planned in such a way that there exists adequate provision for the various operations explained above. Figure 4 shows the typical blocking or functional arrangement of vehicle and infrastructure operations of a bus depot. This involves the provision of area to accommodate fleet vehicle parking, fuelling station, vehicle washing/cleaning area, workshop and maintenance area, administrative offices, private parking, crew facilities, and other utilities.

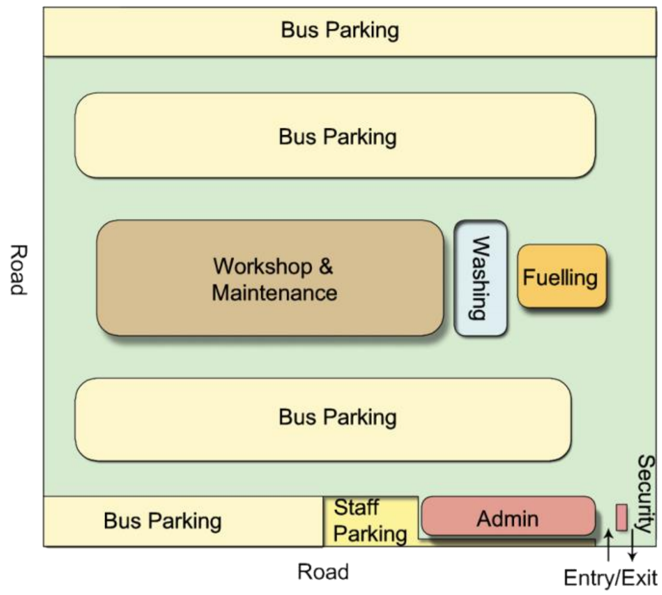


Figure 4: Site organisation for vehicle & infrastructure operation

[3] Waybill is a document / format issued to conductor of the bus giving the information related to origin-destination route assigned for the bus, driver and conductor details, fuel and cash information before the start of the trip.

2.2.1 Site Selection

Typically, inter-city and intra-city services are operated by different operators, which is why different depot facilities are required to maintain intra-city and inter-city bus fleets. Nonetheless, for both the depot types, the selection of a depot site is governed by a common requirement: the location of the depot should ensure minimal dead mileage i.e. the distance between the depot and the route terminus which is operated without any passengers. Therefore, the depot should be as close to the terminal point of routes as possible. However, as per the World Bank Group and PPIAF (2006), the selection of the depot site may be subject to other considerations, like availability and cost of suitable land.

Site selection is significantly influenced by the capacity requirement of a depot, which in turn is affected by the quantity and types of vehicles a facility maintains. Thus, fleet type and size should also be considered for depot site selection (AMC, 1999).

2.3 Master Planning

Master planning involves arranging of the functions followed by orientation of the built blocks and access to different functions in the complex.

2.3.1 Functional Arrangement

Listed below are some of the considerations for arranging and locating various functions at a depot site:

1) Administrative facility – It should be easily accessible separately for crew members and staff members, with minimum interference with vehicle operations. Additionally, the officer's or manager's room should be oriented for a complete-view of the entire complex.
2) Vehicle washing/cleaning facility – It should be easily accessible from the maintenance workshop and the parking area.
3) Vehicle maintenance facility - This facility is the nerve centre of the bus depot, and should be located centrally within the complex. The body shop zone should be oriented such that the painting operations' exhaust system vents away from the centre of the complex. The workshop requires vehicle circulation and storage around its perimeter, and as such should be set up in large paved areas adjacent to the building entrances, to support vehicle manoeuvrability, traffic flow, and parking requirements (AMC, 1999).
4) Fuelling – Diesel and CNG fuelling stations should locate so as to integrate with bus circulation at the site. Transformer/ sub-stations for electric buses can be located anywhere on the site (not necessary nearer to charging ports). Fuelling stations and electric transformers/sub stations should be located in a safe zone[4] considering the potential fire hazard.

2.3.2 Orientation

The planning of the building's orientation should take the following factors into account:

1) Protection from glare
2) Orientation of the openings in accordance with the wind's direction
3) Provision of sunshade in warm climate, and maximum sunlight in cold climate

2.3.3 Access

The planning of the access to the site and its functions should be based on the following considerations:

1) Providing a clearly identifiable access to the main entry gate
2) Locating the disabled-access parking spaces near the main entrance to facilities, and integrating accessible ramps into the building entrances
3) Segregating service traffic from other traffic and pedestrian access

2.4 Facility Planning

Depot facility planning involves planning for bus management facility, bus maintenance facility, and administrative facility. Each of these are explained in detail below.

2.4.1 Bus Management Facility

This section addresses the requirements of bus management facility including entry/exit, bus parking, fuelling, and cleaning/washing. These facilities can be set up together, in a complex called a depot or a bus garage, as presented in Figure 4. The following sections

[4] Safe zone: protected area (from flammable substances)

provide an overview of the essential planning considerations for each of them.

2.4.1.1 Entry/Exit with Security Room

The activities of the in-shedding process include registration of the bus (entering the depot), and updating the status of the bus such as kilometres covered, condition of the bus, problems in driving and functioning, fuel status etc. Given the presence of highly inflammable fuels and expensive equipment inside the depot, its entry should be controlled through a system with card/code lock and intercom for staff and visitors.

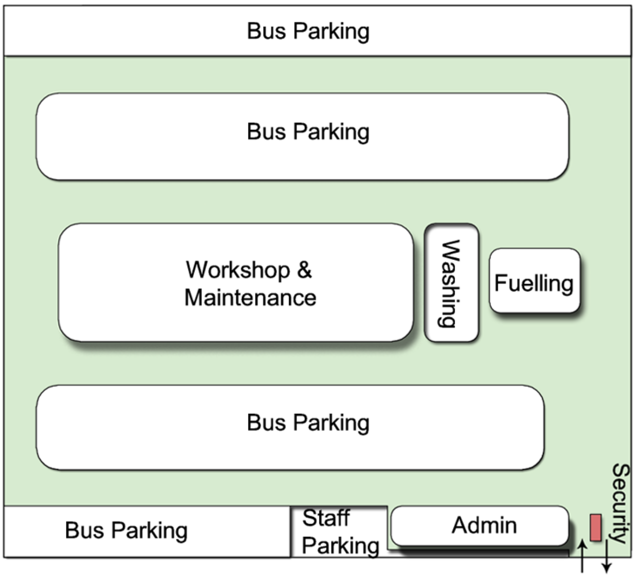


Figure 5: Schematic plan showing the location of entry/exit with the security room

Out-shedding includes activities like registration of the bus (leaving the depot); noting the status of the bus before going for the trip, including fuel status, tire condition etc.; and assigning driver and conductor etc. Both these operational stages (in-shedding and out-shedding) are comparable but pertain to a different set of activities to be performed at different time periods.

A bus depot can have separate or a common entry or exit point for buses. This depends on the internal circulation of the buses, facility layout, bus operations, and the access road network feeding the depot.
It is generally observed that buses arrive at the depot after day's operation. Thus, at night, depots serve as parking—and remain busy and occupied—while are empty during the day. As such, the buses' entry and exit periods do not overlap. Therefore, it is viable to keep a common entry/exit point and ensure efficiency in terms of space, circulation, manpower requirement, safety, and security (Figure 6). However, where buses operate night services or have staggered servicing hours and entry/exit timings, it is advisable to separate the entry and exit points of the depot with easy access (for each) to the city road network in a manner that eases traffic movement and minimises conflicts (Towe Ireblad, 2012). Separate entry and exit points are desirable in depots with multiple access through the surrounding road networks. They are also advisable in facilities where short in-depot operational hours are integrated with other functions, as in the case of a facility which serves both as bus depot and terminal.

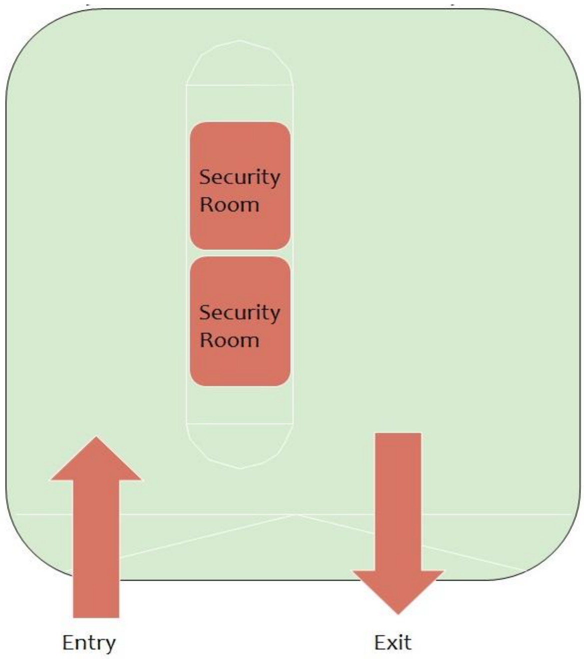


Figure 6: Functional relationship of the entry/exit with the security room

2.4.1.2 Bus Parking

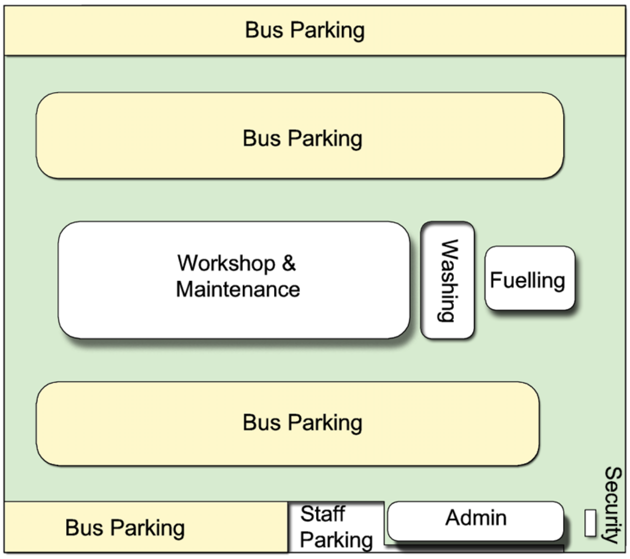


Figure 7: Schematic plan showing the location of bus parking

The next stage in bus operations at a depot is of parking. Bus parking, where a bus spends the most time, involves the highest space requirement at the depot, with a large open area unobstructed by supporting columns (may be sheltered by large span structure and high roof). It is the designated area from where buses are taken for in-depot activities (servicing, fuelling and washing) and later parked, ready for the next trip. Evidently, the bus parking is a crucial space which impacts efficiency of operations and space use at a depot and thus demands careful consideration.

Bus parking facility could be of two types: i) at-grade parking and; ii) multi-level parking. These are explained in the following section:

At-grade Parking

In recent times, a number of Indian depots have initiated the practice of a designated parking bay for each bus, with clear unobstructed driveway. These bays may be arranged in angular or 90 degrees parking alignment to the driveway. Compared with stack parking (also known as block parking) arrangement, bay based parking is more organised but offers slightly lower capacity. In bay based bus parking, approximately 12 full-sized rigid single-deck buses (12.5 metres long) can be accommodated per 1,000 sq. m. This type of parking allocation is standard in all modern depots and improves the bus handling and operations inside the complex.

Multi-level Parking

With limited availability of land for bus systems, parking for buses is a matter of grave concern in India. Multi-level bus parking system has relatively eased the situation since it optimises space use, though at a higher capital investment. The design of a multi-level parking garage can vary significantly from that of at-grade parking. The most common design is a garage with ramps to move from one level to another (Parking Network, 2010). The use of bus elevators to transfer a bus vertically between floors, is another option.

Multi-level parking comprises of vertically arranged floor plates above/below ground level. It requires a greater per vehicle area for parking due to the space occupied by ramps and columns. When scarce space does not permit building ramps, multiple elevators are provided. Only ramp based structures are recommended for bus parking given that an elevator breakdown can derail depot operations. Setting up multi-level bus parking is recommended only as elevated structures. This is because in the event of a bus breakdown in an underground depot, towing a bus up a ramp is tedious.

For elevated multi-level bus parking, open-deck parking structures are preferred over closed ones. This is because an open-deck structure with a minimum opening of 50 percent on at least two sides will not require mechanical ventilation and specialised fire protection systems.

The design of manual multi-level parking includes:

1) entry and exit ramps,
2) aisle/circulation space between the vehicles,
3) vehicle parking area

Hence, in depot-sites with space constraint, to accommodate the large volume of public buses, manual multi-level vehicle parking system should be considered, to maximise parking capacity by utilising vertical space, rather than expand horizontally.

Multi-level vs. At-grade Bus Parking

Bus parking claims majority of the area in a bus depot. Thus, optimising the parking can increase both efficiency and capacity of bus depot sites. One popular means of achieving this, currently under consideration in most Indian cities, is developing multi-level bus depots. The development of a multi-level depot requires substantial capital investment, which may or may not be offset by developing the land released for commercial purposes. Nevertheless, it is a promising means—for land constrained STUs and city bus operators—to expand the capacity of existing depot sites. Although attractive and beneficial, the development of a multi-level depot does not enhance capacity as steeply as by the number of floors in the multi-level parking. This is because: firstly, parking accounts for only a part of the depot area; and secondly, going multi-level consumes area to accommodate the structure, ramps, lifts, staircases etc., thus significantly increasing the parking area required per bus (on each floor). It is estimated that for a 300-bus capacity depot, providing a four-level (including ground) parking will reduce the total parking area requirement by 55-65% and total site area requirement by 20-30%. Since the expected space savings (by going multi-level) is proportional to the fleet size catered at the depot, multi-level parking for depots may not be financially viable unless the capacity of the facility is more than 200 buses.

2.4.1.3 Fuelling

Fuelling of the buses is a daily bus servicing activity at a depot and usually, fuelling stations are located inside the depot premises. Though some depots rely on external fuelling stations, it is a good practice—in depot development—to organise in-house fuelling, to improve efficiency and reduce dead mileage.

Broadly, two types of buses are serviced in a depot:

1) **Conventional buses** – These are the buses that run on an Internal Combustion Engine (ICE), which receives energy through petroleum fuels, i.e. gasoline, diesel, or compressed natural gas (CNG).
2) **Electric vehicle/buses (EV)** – These are the vehicles/buses than run on an electric motor, with or without ICE for propulsion. The electric motor receives energy through an on-board battery (UNEP, 2014). EVs are of comprised of four types, namely Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), and Fuel Cell Electric Vehicles (FCEV).

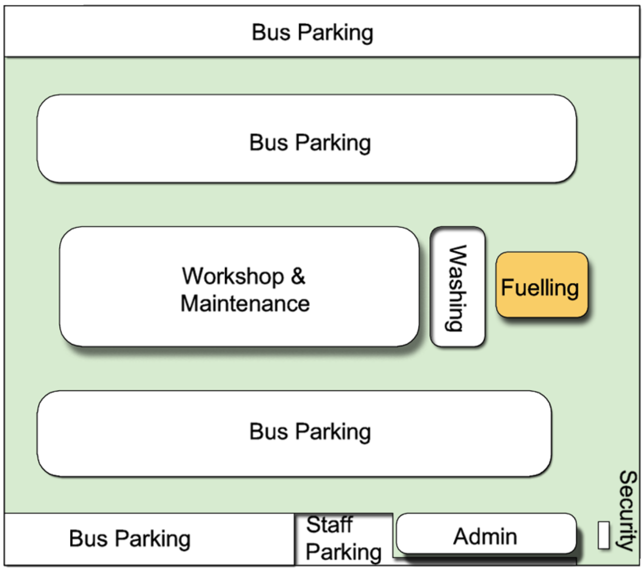


Figure 8: Schematic plan showing the location of fuelling

Petrochemicals like diesel are the most common fuel types used in bus depots but lately CNG, being environmental friendly, is being used widely as a fuel source. Other fuel types used include Liquefied Petroleum Gas (LPG), ethanol fuel, biofuels like biodiesel etc. Bus depots operating EVs have charging units (called charging stations) installed, instead of fuelling stations.

With the option of diverse fuel types (and vehicles using these fuel types), the design requirements and specifications for fuelling stations have evolved over the years. The fuelling facilities in different depots vary in design and type based on the fuel type used.

Fuelling operations are undertaken either before or after the bus is taken for servicing and washing, depending on the particular depot's operational practice. Based on the fuel type used at a depot, two types of fuelling facilities are observed: fuelling buses at a common fuelling infrastructure (fuel dispensers) in the depot, or at the bus's designated parking bay. The former is compatible with all fuel types. The fuelling stations corresponding to different fuel types are explained below:

- **Liquid Based Fuelling Station**

Liquid (diesel) based fuelling stations comprise of fuel dispensers (equipped with underground storage tanks) which pump fuel (petrol/gasoline, diesel) to vehicle tanks and calculate the cost and quantity of fuel transferred. The pumps are operated by an attendant or a team, appointed for the purpose, generally by the fuel supplying company.

- **CNG Fuelling Station**

Gas based fuels (such as CNG and LPG) can be transferred into a vehicle tank, at the vehicle's designated parking bay. Unlike at petrol or diesel stations, using CNG for catering a fleet requires calculating the right combination of pressure and storage needed for the vehicle type being fuelled. There are 3 types of fuelling stations: time-fill, fast-fill and combination-fill fuelling station (details in Table 47). Of these, time-fill type of CNG fuelling can cater to at-bay fuelling of buses.

- **Electric Charging Station**

Electric buses use electric energy from on-board sources such as a battery or electricity generator connected to ICE, or off-vehicle energy sources such as overhead lines (CStep, 2015).

  - **Charging Technologies**

This section presents an overview of the concepts and infrastructure related to battery charging that is needed for an EV fleet. Plug-in electric vehicles like PHEV and BEV require physical connections with Electric Vehicle Supply Equipment (EVSE) at the charging station. On the other hand, HEVs are charged using regenerative braking and ICE.

Batteries provide power to EVs through electrical energy as a result of chemical reactions. Charging involves the conversion of electrical energy into chemical energy and is a way to store electrical energy in the batteries (CStep, 2015).There are two types of charging technologies:

1) Conductive Charging
This technology has been historically the most popular option for accessing grid electricity for various charging applications. The automotive standard voltage plugs and sockets serve as interface between the distribution lines and the on-board sockets. All the battery systems in EVs currently use conductive charging technology (see Figure 9).

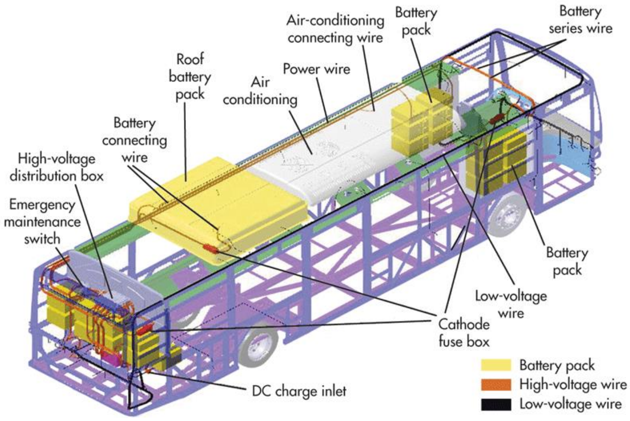


Figure 9: A schematic diagram of an electric bus showing battery and electrical layout

Source: (CStep, 2015)

2) Inductive or Contactless Charging
This is a relatively new technology that has emerged in recent years (Nizam, 2013). Inductive charging uses an electromagnetic field to enable the exchange of energy between the EV and the charging station (refer Figure 10). In this method, no physical contact is needed between the energy source and the vehicle. Inductive charging works by using an induction coil placed within a charging station to create an electromagnetic field. A second induction coil, placed on the EV, receives power from the electromagnetic field and converts it into an electrical current that is used to charge the on-board battery (CStep, 2015).

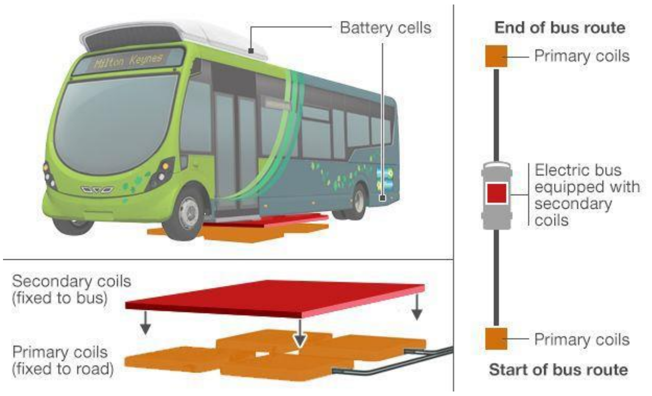


Figure 10: Inductive charging in an electric bus

Source: (CStep, 2015)

Table 1 illustrates the pros and cons of both the charging technologies.

Table 1: Comparison of charging technologies

Parameters	Conductive charging	Inductive charging
Installation cost	Low	High*
Maintenance cost	High	Low**
Safety	Low	High***
Lifetime	Low	High**
Efficiency	Very high (above 95%)	80 - 90%
Reliability	Low	High**

** Installation cost high due to power electronics components*

*** No exposed conductors, no contact between the surfaces of EV and charging point, hence no wear and tear*

**** No exposed conductors, hence lower risk of electric shock*

Source: (CStep, 2015)

2.4.1.4 Cleaning / Washing

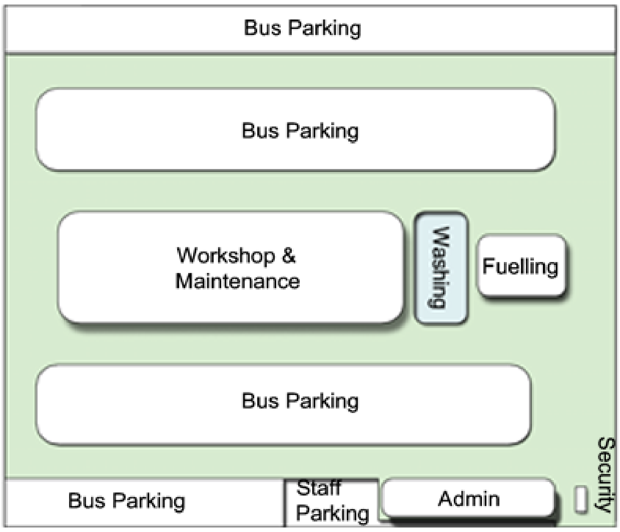


Figure 11: Schematic plan showing the location of washing area

Cleaning is one of the integral components of bus operations, be undertaken daily. It may include wet washing, or dry cleaning (internal and external) or both. The wet washing area is typically a large covered or uncovered structure provided in the depot complex, where buses are washed and cleaned, mechanically and/or manually.

This area includes a single bus bay technically termed bus envelope or wash bay. Unlike a common bus bay, the wash bay is slightly raised, with a drain channel running through its centre to carry waste water to the recycling plant. The washing area is equipped with stationary pressure washers with trolleys and hoses that carry water to the washing area. Hose reels and trigger guns are positioned close to the washing area.

The washing area should be located along the main circulation pathway, near the workshop and fuelling area, so that the buses can simultaneously go to any of the three areas depending on the availability of space.

The main components in a bus washing facility are automated brush washing machine, recycle plant, and underground storage tank.

2.4.2 Vehicle Maintenance Facility

The maintenance of buses is undertaken in the workshop area. The area includes pits for inspection and maintenance; tools and equipment for routine servicing and mechanical repairs; and facilities for changing/maintaining tires and storage.

2.4.2.1 Workshop & Maintenance

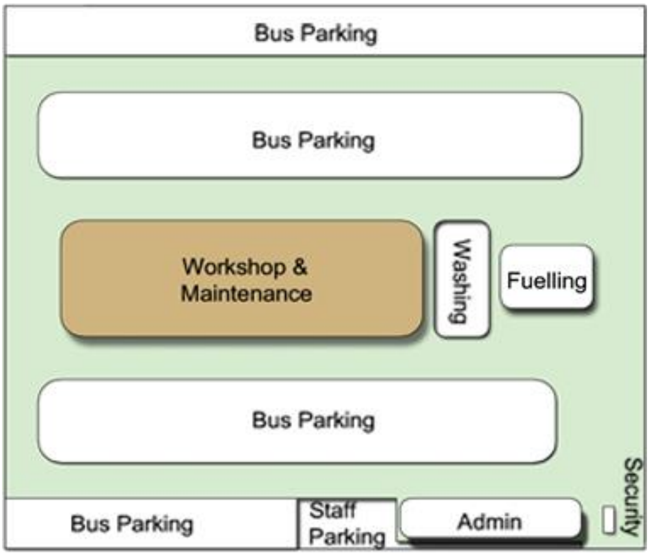


Figure 12: Schematic plan showing the location of workshop area

The workshop is a large shaded/covered, room/hall or a building dedicated for servicing of buses. Maintenance is not one of the daily activities among the bus servicing requirements, but is scheduled for each bus based on the total kilometres/days of operation. In addition to scheduled maintenance, workshops attend to driver-reported issues with a bus. These issues are generally minor and are resolved on a day to day basis. Scheduled bus servicing includes engine related activities, CNG/diesel-filter related activities, differential/oil/major tune-ups related activities and motor vehicle inspection (MVI). Since transport is a state subject, each state has its own MVI norms. The schedule for each above-mentioned activity is shown in Table 2.

Table 2: Bus Servicing Schedule

Bus Servicing Schedule	
CNG/Diesel- Engine related activities	every 10,000 km
CNG/diesel-filter related activities	every 40,000 km
differential/oil/major tune-ups related activities	every 80,000 km
Electric Bus - Motor and other parts Inspection, Tuning & Cleaning	Every 1000 km or 15 days whichever is earlier (for details refer Annexure 6.4)

Electric bus- Oil Replacement	Every 20,000 km or 6 months whichever is earlier (for details refer Annexure 6.4)
Motor Vehicle Inspection (MVI)	For each bus, overhaul / refurbish activity or MVI is conducted after 2 years for a new bus and on a yearly basis for subsequent years (Cambridge Systematics, 2016).

- **Pits for Inspection and Maintenance**

The pit is a chamber inside the floor in a workshop from where the underside of a vehicle can be examined and serviced. Traditional pits were made of bricks and concrete, but modern pits are pre-fabricated. A pre-fabricated pit is also called drop in pit. It (Figure 13) contains roller brakes, suspension testers, heavy vehicle jacking systems, lighting system, ventilation with interlocked service systems, lubrication systems, waste oil and coolant removal system, and automated pit safety covers. The advantage of this type of pit is in its movability i.e. it can be transferred to the site as pre-fabricated units which can be cast in masonry/concrete at site. Installation of a pit is quick and cost effective, and results in minimal down time to existing (servicing) activities (HARTEX Engineering, 2016).

Figure 13: Prefabricated pits

Source: (HARTEX Engineering, 2016)

A 'suspended ceiling pit' is a specialised type that works best for truck and bus operators with large fleets of articulated trailer based systems (Figure 14). This style provides an expansive uninterrupted work area under a solid steel deck approximately 2.3 m high. A suspended ceiling pit contains heavy vehicle jacking systems, lubrication equipment above and under deck, storage space for bulk oil tanks, waste oil collection systems, ventilation systems, explosion proof lighting, two sets of stairs to access the pit, roller brake tester, suspension tester, central sump for trade waste collection, and sump pump plumbed to the trade waste treatment plant. This type of pit includes a comfortable, 2.2 m wide working platform (HARTEX Engineering, 2016).

For Electric Vehicles (EVs), the same pit can be used, however, the clear space of 2.5m (between two buses) should be required to enable fitment of Battery packs from sides and for moving the special lifting equipment.

Figure 14: Suspended pits

Source: *(HARTEX Engineering, 2016)*

- **Painting, Upholstery and Body Shop Zone**

Apart from the daily maintenance workshop activities, the depots should be equipped with a body shop zone. A separate designated area is provided in the workshop for painting (known as the paint shop) and for welding, riveting, cutting, drilling etc. (known as the body shop). The absence of designated spaces for such specialised work leads to inefficiency in depot operations. It is thus recommended that a depot should be provided with the body shop zone which contains the painting, upholstery and electrical sections, apart from the welding and drilling sections.

This zone should be adequately ventilated and naturally lit.

Refer Figure 15 and Figure 16 for floor plans of workshop and maintenance area.

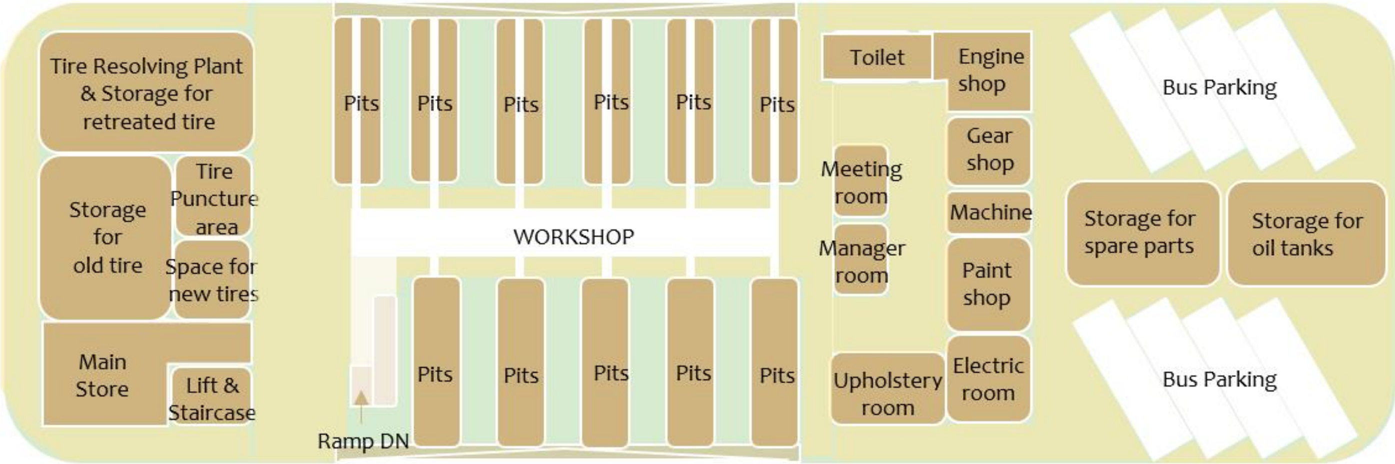


Figure 15: Functional relationship of workshop and maintenance (ground floor)

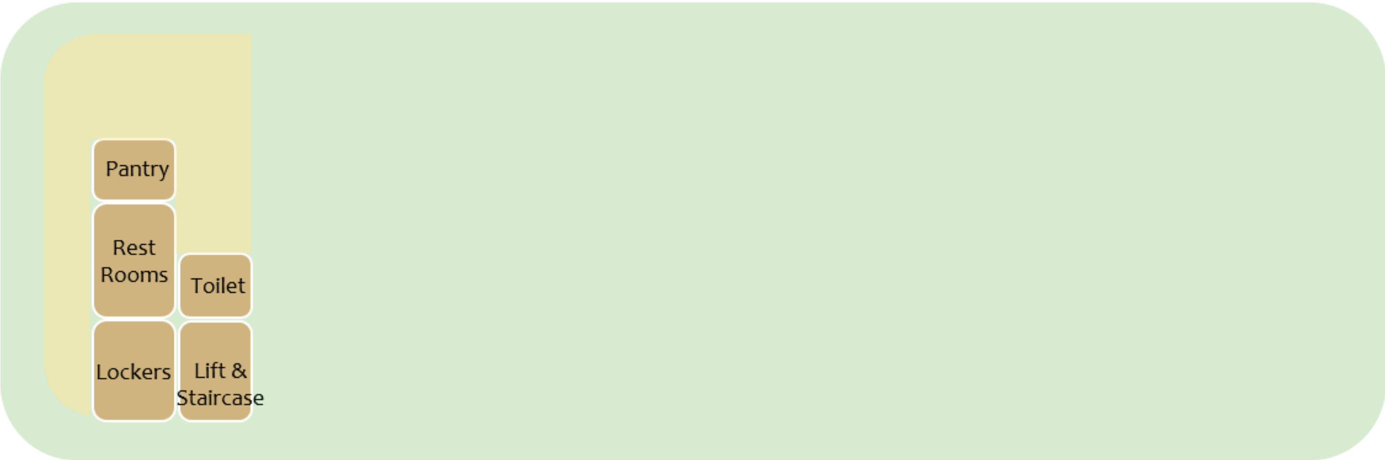


Figure 16: Functional relationship of workshop and maintenance (first floor)

Other Workshop Facilities

Other maintenance workshop facilities include manager room, meeting room, machine room, workers' room, lockers, kitchen/pantry, and toilet.

2.4.2.2 Storage

Being a facility dedicated to maintaining and servicing buses, adequate storage spaces (for equipment, tools, operating/engineering personnel etc.) are required in the bus workshop. As already mentioned, a variety of activities are undertaken in a workshop to meet a depot's operational requirements. Each of these activities has a specific storage requirement. For example, tire storage areas are entirely different from that of spares.

- **Tire Store**

It is estimated that on city services, on an average a bus covers anywhere between 200 to 300 km in a day. The tire treads typically wear off anywhere between 15,000 to 25,000 km depending on operating factors such as weather condition, condition of the road, driver behaviour etc. All the six tires of a bus need to be serviced every 30 to 50 days. Additionally, tires require regular maintenance in the form of wheel balancing, and repair of punctures. This means that a medium to large depot is required to service dozens of tires every day.

It is observed that the tires of a bus are replaced either with new tires or retreaded tires depending on the condition of the current tires and/or kilometres served (Minnesota Department, 2012). Thus, separate storage area for new tires and retreaded tires is provided. Both these storages areas should be located in close to the workshop area. The discarded tires are shifted to scrap storage for disposal.

- **Spare Parts Storage**

This is also known as the parts room, and is used to store small spare parts and maintenance supplies. It is planned preferably adjacent to the pits. The recommended minimum area for such storage is 21 sq.m. (Minnesota Department, 2012).

- **Oil Tanks Storage**

This is used for storing fluids like oil, grease, solvents etc. used in the workshop. It is recommended that this be planned at the entrance of the workshop area, to facilitate easy truck delivery of supplies. Being susceptible to fire and pilferage, oil tanks storage warrants adequate safeguards and/or access restrictions (Minnesota Department, 2012).

- **Scrap Store**

The accumulation of unserviceable materials and scrap in the depot area is hazardous and creates operational problems. For smooth depot operations, it is necessary that unserviceable materials (discarded spare parts, tires, rims etc.) are regularly transferred to a scrap yard or scrap storage. In the current scenario, depots usually store scrap in the open. This is both inefficient and undesirable. It is thus recommended that a designated and enclosed scrap storage area/room be provided in each depot. Such an area must be pilferage protected, and have adequate safety elements built in for protection against damage or accidents (explosion, fire, fall etc.).

- **Battery Storage Room**

Bus depots require special storage for batteries, considering they are expensive and made of hazardous material. It is a good practice to provide separate, specialised and protected storage to store such elements.

- **Miscellaneous Storage**

Most of the depots work around the clock, but in depots with limited operational hours, a separate emergency/temporary store facility should be provided for non-operational hours. This should ideally be planned adjacent to the main store, with separate access and an interconnecting door.

2.4.3 Administrative Block Facility

This building is at the centre of vehicle operations. It controls the operations and maintenance functions along with other administrative work for the vehicle fleet. The administrative block should be planned near the entrance/exit gate because it houses crew interaction facilities during in-shedding and out-shedding. It supports the in-shedding and out-shedding activities-related functions of ETM collection; cash and waybills submission; and supervision and memorandum exchange with the drivers and conductors. Administrative block facility should have separate access from the external edge of the depot (on which the parking is likely to be located), because it is the entry point for all the personnel to access any section of the depot, with the view to control access to the facility. Interaction with different offices for crew related functions should be facilitated through windows on the external façade (Figure 17).

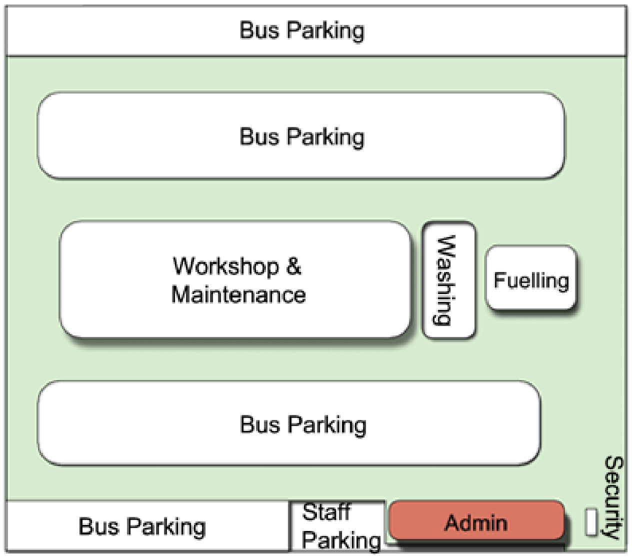


Figure 17: Schematic plan showing the location of administrative area

The administrative block should be planned and designed to cater to a variety of functions, including assigning of crew duties, handling equipment such as ETMs and serving as the office for the depot supervisor. The administrative block has three principle components: operational block, general offices, and staff facilities (Santosh, 2001).

These are generally housed in a single building that should be designed in levels (multi-storied structure) so that activities of different categories are performed at different levels. All the levels should be barrier-free and mandatorily connected through elevators (Figure 18, Figure 19 and Figure 20).

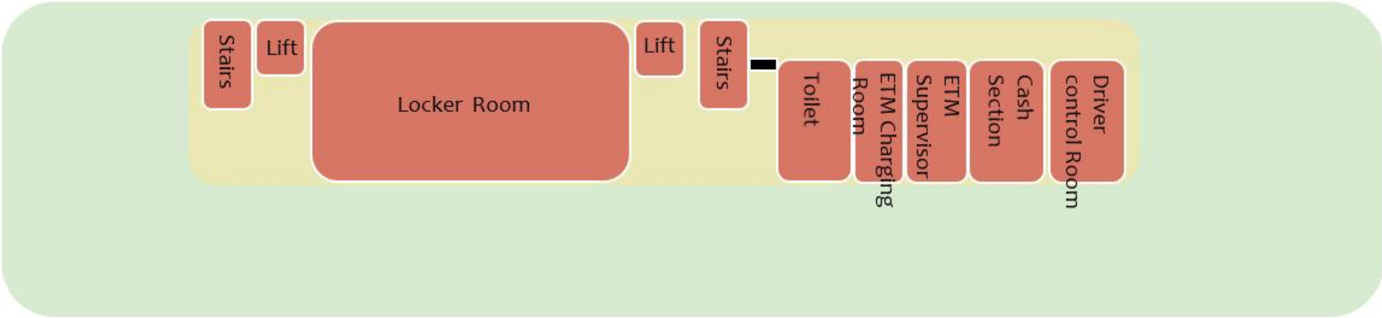


Figure 18: Functional relationship of administrative block facility (ground floor)

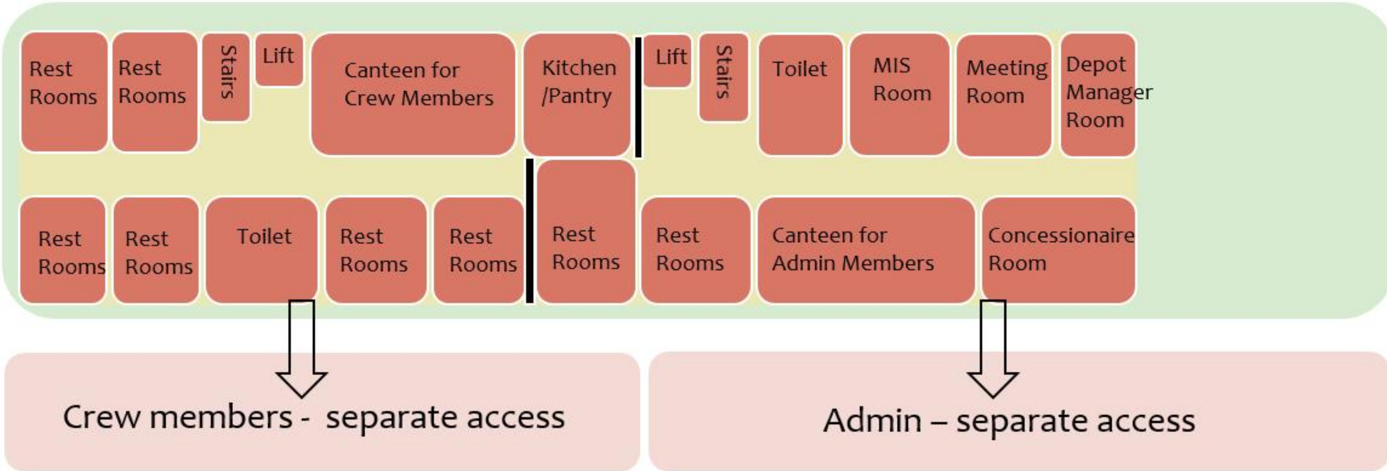


Figure 19: Functional relationship of administrative block facility (first floor)

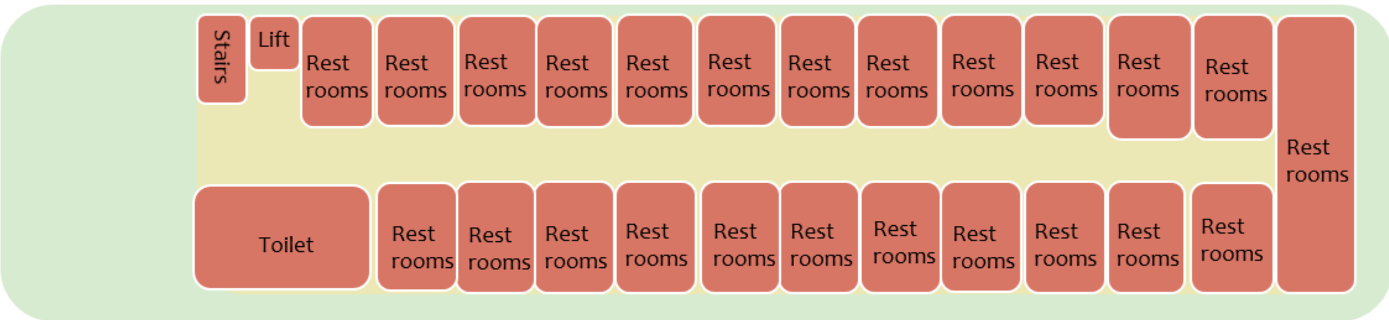


Figure 20: Functional relationship of administrative block facility (second floor)

2.4.3.1 General Offices Block

This includes the depot manager's office, offices for two or three other officers, a section for clerical activities, a meeting area, visitors lobby, toilets, and a separate area for storing records (record room). The entire general offices block can be planned on the first floor, to segregate the clerical and official documentation work from the field activities, and reduce interference and unnecessary friction. However, some activities require an overlap. For e.g., the depot manager and his staff should have visual and physical access to the field operations. Hence, the general offices block should be provided with a controlled access to the parking yard and workshop areas. The depot manager room should be planned overlooking the workshop area and parking bays, equipped with large glazed windows.

2.4.3.2 Operational Block

This section is comprised of the areas designated for the traffic control room, schedule section, waybill office-where the conductor collects the waybill before the trip and submits it at the end, the driver control room-where the driver collects the memorandum for duty, ETM office or ticket store, crew waiting area, and locker rooms for conductors, drivers and another administrative staff. The operational block should be located preferably on the ground floor as it involves regular and extensive interaction with bus crew. This will enable the bus crew to access the functions through windows on the external skin without the need to enter the building.

The facilities in the operational block, such as crew waiting area and traffic control rooms, are recommended to be planned near the depot entrance. The facilities related to conductors and drivers, such as waybill office, driver control room, ETM office, and locker room, should be close to one another and with adequate circulation space built in, to allow inter-access between all the functions. The conductors need not be provided access beyond this zone, as their duties are limited to collecting/submitting the waybill and the ETM at the respective offices. Drivers, on the other hand, require access to the parking yard so they can drive the bus back to the exit gate. Thus, an exclusive access for drivers is recommended—from the administrative office, the entrance gate, or the driver rest room—up to the parking yard.

Traditionally, conductors were provided with ticket bags, that they stored in lockers after the trip. Modern equipment like ETM and waybills have since replaced ticket bags, but some operators are yet to integrate this technology. For some operators, conductors continue to carry paper tickets in ticket bags as an emergency measure in case of a technical fault with the ETM. They leave these bags in their allotted locker after the trip, and have them replenished the next morning before commencing their duty. Apart from ticket bags, conductors need space to store clothes when they change into uniform and other belongings. It is therefore recommended that every depot provide lockers for each crew member.

2.4.3.3 Staff Facilities

Bus depots should also include additional facilities for the staff such as dispensary, resting and canteen facilities (The World Bank Group and PPIAF, 2006). These should be accommodated in the administrative block. In recent times, it is observed that the crew, buses, and various facilities (workshop, washing and fuelling) in a bus depot are mostly operated on a Public Private Partnership (PPP) model, by different partner agencies. This arrangement merits that the amenities for the staff of these facilities be provided in a manner that allows operational and functional control by the parent agency/partner for the particular function. Thus, staff amenities may be organised either on a separate level with a dedicated access, or as a separate section/part with controlled access from the external parking and the internal depot area including bus parking and workshop. Some of the facilities essential to any depot are listed below.

- **Toilets**

Toilets are foremost amongst all the amenities in a building. In the depot premises, proper toilets must be provided for male and female bus crew, and specially-designed ones for users who are differently abled (Persons with Disabilities Act, 1995). They must be maintained well and cleaned regularly, which shall help maintain sanitation and create a hygienic environment.

- **Crew Restroom/Dormitory Facilities**

This facility is required for drivers and conductors, and sometimes for workshop staff and other depot staff. As most bus depots involve late night operational hours and often buses end their trip at odd hours, providing restrooms and dormitories can boost work-force efficiency and reduce operational delays. These facilities are especially beneficial for the work-force in depots located on the city fringes. It is critical (while planning) to ensure that the access to crew restrooms and dormitories is barrier-free; they are comfortable to use; and that separate and segregated dormitory facilities are provided for the male and female staff/crew members.

- **Canteen Facility**

This facility should be provided for staff (especially resident bus crew) at all bus depots. It is advisable that apart from a large fully-equipped canteen for resident bus crew (and other staff members), small pantry facilities be incorporated in various operational areas of the depot, such as the administrative block and workshop area. A minimum area of 72 sq.m. is recommended for the canteen facility (Santosh, 2001).

- **Dispensary or Medical Facilities**

The large machines and other equipment used at depots—to service and maintain buses—involve operations by humans and by extension, the possibility of human injury. In-house depot medical facilities are essential to provide instant medical attention in case of an accident during depot operations. Such facilities also go a long way in reassuring the workforce that their well-being is assured and guaranteed by the depot operators. Depending on the size of the depot and space availability, a first-aid room (with a bed) and a dispensary may be included in the depot layout, at the ground level. This should be amalgamated with the main administrative block.

- **Parking**

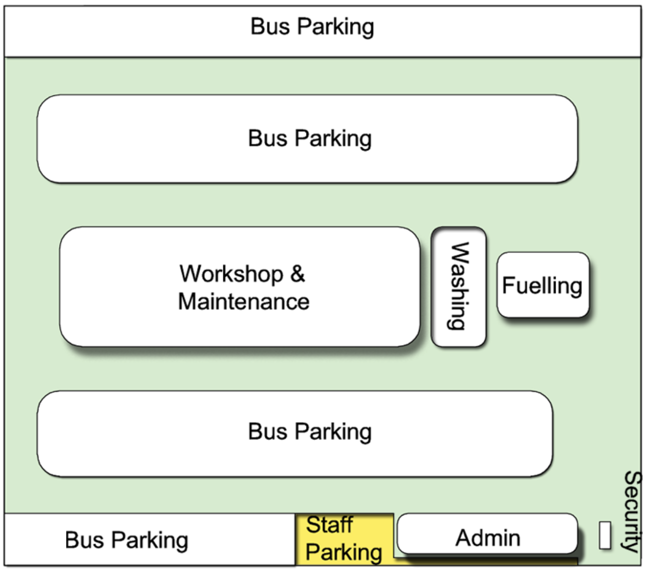


Figure 21: Schematic plan showing the location of staff parking

Apart from bus parking, a depot must include separate parking space for private vehicles belonging to visitors, crew, and other staff. The recommended assumptions (to be considered) for the estimation of the private vehicle parking requirement in a bus depot include: one equivalent car (parking) space (ECS) per bus (assuming that in India, each driver and conductor commutes on a personal two-wheeler) and four spaces (ECS) per 92.9 sq.m. i.e. 1000 sq.ft. of transportation and administrative services (built up area of the administrative block) (Minnesota Department, 2012).

2.4.4 Other Planning Considerations

This section consists of additional site planning requirements. This includes utilities and landscaping. These have been discussed below:

2.4.4.1 Utilities

The following utilities should be provided, in accordance with the local requirements and the city network:

1) Water supply, rain water harvesting and sanitary services, fuel/oil systems and CNG gas pipelines
2) Electric lines, telephone lines, water sprinklers, fire alarm, communications systems

2.4.4.2 Landscaping

Landscaping considerations (listed below) should be included early in the depot planning process, as they influence the functional efficiency of the complex, not merely its aesthetics. Soft scaping and plantations can be used for noise absorption.

1) Landscaping elements such as trees and waterbodies should be provided to define the site, and its entry/exit. They also help maintain a cool environment on warm days, through microclimate.
2) Landscaping should be used as a natural buffer for separating parking area from other functions.
3) Screen walls, in combination with earth berms and landscaping, should be provided at the perimeter of the complex, to screen visual clutter.
4) Low maintenance landscaping is preferable, and plant materials should be selected as per local context and site conditions.

3 Design Aspects

This chapter presents the considerations and details to be considered in designing a depot. It highlights the broad criteria for locating vehicle operations and maintenance, their corresponding design attributes, supporting utilities, equipment used, and technical requirements (such as area requirements) that affect the overall design of the complex. These have been elaborated in the following sections.

3.1 Design considerations

This section outlines the considerations in designing various facilities within a bus depot. These considerations include layout and circulation, universal accessibility, security, materials used, building systems, green concepts, and equipment specifications. These are useful in determining the most appropriate design for the successful development of a bus depot facility.

3.1.1 Layout and Circulation

The depot site should include facilities to support bus management, maintenance and administrative functions. Layout and circulation for these facilities should be designed as per the following principles:

1) Entry to the bus operation and maintenance areas should be restricted, considering safety concerns.
2) In the administrative facility, functional areas should be organised around a central corridor to provide convenient access. This will simultaneously allow for the independence, and controlled access (to ensure safety and security) of each function.
3) Separate and controlled access for crew and staff members should be provided.
4) The kitchen/canteen should have access to a service lane/road.
5) The crew rest room location should allow for controlled access from both the depot operational area and the main depot entry.

3.1.2 Disabled Access

The whole complex should be barrier-free and accessible to all. At the entrances to the site and other buildings in the complex, ramps should be provided to accommodate level changes for wheelchair users. Elevators should be installed in the buildings with floors/functions at higher levels. This includes the multi-level workshop buildings. Additionally, tactile pavers and audible warning signs should be included in the facility design.

3.1.3 Security

To keep track of bus movement, security rooms should be provided preferably near the entrance, adjacent to the administrative facility. The bus management facility on the other hand, should be secured inside the complex, visible from the administrative building.

3.1.4 Materials & Finishes

The architectural style and interior design of the bus depot should complement each other to enhance the functionality and efficiency of different spaces and functions in the complex. Design of the depot should be sustainable and environment-friendly in the choice of construction materials. The various considerations—while designing a depot—regarding the materials and finishes include:

1) The design should reflect the regional and local architectural character.
2) The architectural style should be consistent throughout the complex.
3) The use of modular furniture is recommended to provide flexibility, and promote a sense of organisation and visual order.
4) Natural lighting and ventilation should be provided for, where necessary. Some areas that would benefit from natural light and ventilation include the entrance corridor, rest rooms, administration related facilities, central circulation paths, service bays, toilets and workshop.

3.2 Building Systems

This section presents the specific technical guidance related to a facility’s building structures, plumbing, electrical aspects, heating, ventilation and firefighting.

3.2.1 Structural Aspects

The structural system of a bus depot should be designed as per the local context and the functional requirements. The design should take into account the soil conditions; wind direction and load; and seismic zones, as well as the space requirements, economy, and subsystem dimensions (e.g. ceiling grid, framing members etc.)

A cost-effective framing system should be suggested in the design, based on the size of the facility, projected load requirements, and availability of materials and manpower. Structural load estimates for vehicle maintenance and fuelling facilities should take into account floor slab loading, high-ceiling large clear spans requirements, overhead crane loading, and vehicle lift loading. While designing the facility, future expansion requirements should also be considered. To address this, a modular structural grid may be suggested, which is easy to implement and economical to construct. However, care should be taken to ensure that future expansion requirements are addressed in the structural design, without over-design at initial stage.

3.2.2 Heating, Ventilation & Air Condition

A bus depot should be designed according to the standards defined in energy codes. Mechanical air circulation should be provided at public areas with limited or no air conditioning. Mechanical exhausts—in addition to natural lighting and ventilation—should be provided for the workshop and rest rooms. For extremely harsh climatic conditions, provisions for protecting the depot staff and crew from the elements of weather (extreme heat or cold) should be included in the depot design.

3.2.3 Plumbing

Plumbing systems for water supply, sanitation, storm water drainage, oil-water separators, firefighting, compressed air systems, and CNG systems should be provided to meet the following requirements:

- Provision of hot and cold water for toilets, canteen/cafeteria, rest rooms' showers, sinks, janitor's closets etc.
- Shut-off valves at all branch lines from the main line
- Drainage of sewage and waste water in depots as per the estimated capacity
- All open areas should be adequately sloped, in order to avoid accumulation of water and ensure rapid run-off and drainage, especially during peak rainfall events. Failure at this aspect may impact depot performance and result in higher maintenance cost.
- All floor drains that receive water run-off from a vehicle area should be fitted with an oil-water separator (refer Figure 22).

Figure 22: Oil water separator

Source: (Eclipse, 2012)

- The fuelling, maintenance and washing/cleaning facilities should be provided with separate air compressors. The intake for compressed air should be located away from any contaminated air source, vehicle exhaust fumes, and mechanical equipment exhausts (AMC, 1999).

3.2.4 Electrical and Lighting Aspects

A bus depot must be equipped with electric service and distribution equipment; wiring, receptacles and grounding/earthing; interior and exterior lighting and controls; emergency lighting; telephones; and fire alarms.

Sufficient lighting should be provided to enable depot operators to move safely within accessible areas, during installation and routine operations. For the event of normal power failure, emergency lighting should be provided in critical areas.

The normal lighting system will be fed by 415/240V AC supply, while critical emergency lighting will be DC based in critical areas like sub-station, diesel generator (DG) room, control room, and security cabin(s).

Under normal operation, both emergency and standard lighting will be fed by regular power source. On failure of the regular supply, emergency lighting will be transferred to the emergency source until the start of the DG set within (15 seconds of power failure).

Figure 23: Lighting fixture in workshop

Source: (HARTEX Engineering, 2016)

Table 3 presents the various lux-levels[5] required for individual facilities in a bus depot.

Table 3: Recommended illumination levels

Illumination Level Requirement in Depot			
Areas	Recom-mended lux	Mini-mum lux	Type of lighting
Bus Management Facility			
Entry/Exits	150	50	General
Security Cabin	100		General
Parking Bays	75		General
Fuelling - at floor level	300-350		General
Fuelling - at face of pumps	200-300	100	
Washing	500	250	General
Bus Maintenance Facility			
Machine Shop	300-500	200	Illuminance at task
Workshop & Inspection	500	300	Illuminance at task
Work Stores	200	100	General
Toilets & Washrooms	200	100	General
Painting	1000	500	Illuminance at task
Welding Room	7500-10000	5000	Illuminance at task
Illumination Level Requirement in Depot			
Engine Room	200		General
Lubrication Area	500		Illuminance at task
Upholstery Section	1500-2000	1000	Illuminance at task
Battery Room	200	500	General
Machine Storage Area	75-100	50	General
Administrative Facility			
Offices	1000	500	General
Ticket Office	500-700	300	General
Waiting Room	150-200	100	General
Ramps	30		General
Corridors, Passageways, Stairs	100-150	50	General
Lifts	100-150	50	General
Toilets & Washrooms	150-200	100	General
Locker Room	150	50	General
Rest Room	100	200	General
Kitchen	750	500	Illuminance at task
Canteen	200-300	150	General

Sources: (NBC, 2005), (Thorlux, 2011), (Ministry of Petroleum and Natural Gas, 2012), (Danpex, 2013)

Precautions to be taken into consideration while providing lighting in bus depots are as follows:

- Low pressure sodium vapour lamps should not be installed in hazardous areas like workshop, body shop, and fuelling station. In CNG gas stations, explosion-proof lighting/fixtures should be provided.
- The lighting fixtures on various circuits should be suitably designed so that failure of any one circuit does not cause complete darkness.
- Switches controlling the lighting fixtures and exhaust fan should be installed outside the battery room[6].
- Switches controlling the lighting panels installed in hazardous areas, should include a pole to break the neutral, in addition to the poles for phases.

[5] *Lux-levels: The lighting requirement in any infrastructure is measured in lux-levels. Lux is a quantitative measure of the ability of light; it is the metric standard unit of measure for illuminance.*

[6] *Battery room: The batteries should be stored (more than 1 month) in a clear, dry and ventilated room under ambient temperature of up to 40° Celsius and should not be charged. In case the batteries will be charged at the location then the temperature of the room should be kept below 30° Celsius. It should be kept away from caustic material, combustion source and heat source. Do not turn over battery during storage; mechanical shock and stress should be avoided. If the batteries kept unused for a long time, it should be charged and discharged at the standard model every six months. Store the battery in the state of 10%~30% SOC (voltage scope: 3.215V~3.305V).*

- At least one calibrated lux meter should be available at the location.

3.2.5 Fire fighting

For bus depots, Part-IV (Fire and Life Safety) of the National Building Code, 2005 (NBC) of India should be followed, unless otherwise specified. Additionally, state and city level building codes and fire codes—available across the nation—may also be referred to. To ensure fire safety, the depot building schemes should be cleared by the chief fire officer.

The depot should be designed to incorporate efficient and cost-effective fire protection systems which are both passive and automatic. These systems are effective in detecting, containing, and controlling and/or extinguishing a fire event at early stages. Also, where electric buses are a part of the fleet, it is important to equip/ train the local firefighting teams in dealing with fires caused by electric buses. Some of the firefighting systems which should be provided include wet riser, hose reel automatic sprinkler system, fire hydrant, underground water tank with draw off connection, terrace water tanks, fire pump, terrace pump, first aid firefighting appliances, auto detection system, manually operated electrical fire alarm system, public assistance system with talk back facility, emergency lights, auto D.G. set, illuminated exit sign, means of escape or fire exits, miniature circuit breaker (MCB)/earth leakage circuit breaker (ELCB), fireman switch in lift, and hose boxes with delivery hose.

3.3 Green Concepts

The environmental perspective must be taken seriously when designing a depot. The aim is to develop a sustainable depot i.e. one with energy efficient equipment and a good working environment for the depot staff. Solar power plants, and water harvesting and recycling plants are among the prominent means of developing self-sufficient depot infrastructure i.e. one which utilises energy from renewable sources.

3.3.1 Solar Panels

Solar panels generate free power from the sun, by converting sunlight to electricity without mechanical means zero emissions, and require very little maintenance.

Power from the solar installation can be fed to the depot's electric distribution system, offsetting some of the electricity the facility receives from the power grid (Solar Liberty, 2016). A single solar cell produces about 0.5 volt of electric current. As a thumb rule, 1 kilowatt of electricity can be generated by 100 sq. ft. or 10 sq. m. of solar panels.

Figure 24: Solar panels

Source: balticbiogasbus.eu

From the environmental perspective, energy supply planning is a critical component of bus depot development. The solar panels can be accommodated on built up areas of the depot, like the roof of the operational block, maintenance facility etc.

3.3.2 Water Harvesting

Bus depots should be equipped with integrated water cycle management, that implements water conservation by utilising roof water or storm water.

Storm water run-off from depots and hardscape areas is drained into swale medians between the parking bays, forming a landscape filtration corridor network. Each swale collects storm water run-off into field outlets at its lowest point. The collected water is conveyed via conventional drainage to an underground storm water reuse tank.

Evidently, bus depots can achieve significant water savings through rainwater harvesting. It is a cost-effective solution to reduce water bills and mains water consumption. Rainwater can be utilised in toilet flushing and bus wash-down, with mains back-up. The dirty wash-down water can be recycled through an extensive treatment system (Water by Design, 2011).

3.3.3 Water Recycling plant

Water recycling is a sustainable approach of energy use, and potentially cost-effective in the long term. It provides not only dependable and locally-controlled water supply, but also tremendous environmental benefits. Recycling water on site or nearby reduces the energy needed to move water longer distances or pump water from deep within an aquifer. Additionally, it allows conservation of this valuable natural resource.

Therefore, used water (from cleaning of the buses) can be collected through pipes and sent to the water recycling plant for biological and chemical treatment. The recycled water can be re-used not only to wash buses, but also in the administrative facility for non-potable purposes such as for toilet facilities.

3.4 Equipment Specifications

The operational efficiency of bus depots is measured on the basis of safety, reliability, punctuality and quality, of the service provided to vehicles; and the comfort of the manpower employed. This requires the use of sophisticated and modern technology based equipment in the depots. Over the years, with rapid technological advancement, the requirements and specifications of bus depot equipment have been constantly evolving. Significant savings in terms of man-hours and bus down time can be achieved through the use of modern equipment and modern operational practices. This section discusses various equipment deployed in a depot. The description of the equipment is categorised based on the three major activities performed in the bus depot - workshop, washing and fuelling.

3.4.1 Equipment Used in Workshop

The workshop is where the major bus servicing and maintenance work is undertaken. This involves a variety of equipment to handle the vehicle and its components. Equipment used in the workshop include pits, lifts, lubricating equipment, wheel service equipment, and tire resolving plant. Recommendations (including specifications) related to workshop equipment are discussed below:

3.4.1.1 Pits and lifts

In the current Indian scenario, cast in-situ pits or brick pits (Figure 25) are used for maintaining and repairing buses in bus depots. Pre-fabricated pits (Figure 26) and lifts (Figure 27) are among the modern options that may be considered for bus maintenance equipment. It is recommended that out of these two options, at least 1 pre-fabricated pit must be installed, for inspection and preventive maintenance (Table 4).

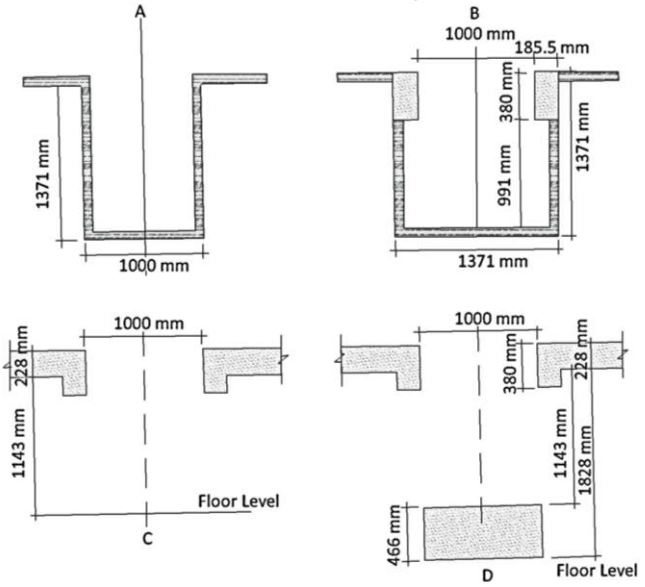


Figure 25: Concrete or brick pits

Source: (Santosh, 2001)

Figure 26: Prefabricated pits

Source: (HARTEX Engineering, 2016)

Figure 27: Sky Lifts

Source: (Stertil-Koni, 2016)

Table 4: Advantages of pre-fabricated pits over lifts

S.No.	Advantages of Pits	Disadvantages of Lifts
1.	Fitted accessories like built in brake testing units, lighting etc.	Difficult to incorporate fitted accessories into lifts
2.	Last indefinitely	Finite life and expensive maintenance
3.	Allow for a feeling of safety	A feeling of dependence upon a mechanical or electrical device

3.4.1.2 Lubricating Equipment

Lubricating equipment are required in the workshop, to lubricate different parts of the vehicle (during servicing and scheduled pit visits). They help in reducing the rate of wear, and preventing excessive stress on the bearing.

Table 5 displays the lubricating equipment commonly used in modern depots.

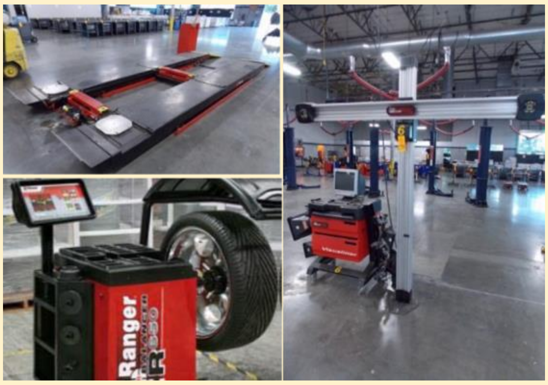
Table 5: Lubricating equipment used in workshop

Lubricating equipment		
Equipment name	Description and specifications	Image
Diaphragm Pumps	Length - 0.20 - 0.59 m Width - 0.12 - 0.29 m Height - 0.21 - 0.81 m Diaphragm pumps are connected to a lubricant container at one end and a delivery hose at the other. Fixed arrangement - Installed at a predefined location in the depot or pits)	 *Source: (Ingersoll Rand, n.d.)*
Hose Reels	Hose reels connected to pumps are used to deliver lubricants to different parts in a bus. Fixed arrangement	 *Source: (Ingersoll Rand, n.d.)*
Mobile grease pumps and spray jet	In the Indian scenario, usually mobile oil grease pumps are used (in interconnected pits as well). These are quite like diaphragm pumps and hose reels. The oil and grease are filled in containers connected to the oil grease pump and mounted on a wheel carriage. The oil and grease is pumped through a connected hose with a hand-held jet for lubricating at the end of the line.	 *Source: (Okhla bus depot, 2016)*

3.4.1.3 Wheel Service Equipment

The wheel servicing section in workshop undertakes tire related activities which are independent of the vehicle. These are tire changing, wheel balancing, and tire resolving. Each of these activities is explained below with the list of specialised equipment required Table 6.

Table 6: Wheel service equipment

Heavy Vehicle Inspection & Automotive Diagnostic Tools This testing and diagnostic activity involves an entire bus (not independent components).					
Equipment Name	Length (m)	Width (m)	Depth/ Height (m)	Area (sq. m.)	Image
Roller brake tester	1.1	1.4	0.65	1	 *Source: (Everequip inspection pits, 2009)*
3D Computerised Wheel Alignment Machine	1.3	0.58	1.6	0.8	 *Source: (Equiptool, 2016)*
Accurate & Coherent Emission Testing	0.47	0.36	0.38	0.17	 Emission Testing Machine with Smoke Metre *Source:* (Mars, n.d.)

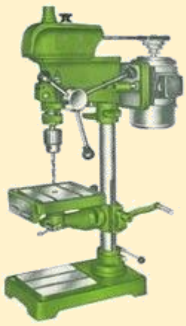
Air Filter	1.4	0.6	0.52	0.8	 Source: *(Wheel balancer alignment, 2008)*

3.4.1.4 Tire Resolving Plant

In this section of the workshop, old but usable tires are re-treaded. The various equipment used in the tire resolving plant are shown in Table 7 along with the specifications of each.

Table 7: List of equipment used in the tire resolving plant section of the workshop

Tire resolving plant					
Equipment Name	Length (m)	Breadth (m)	Height (m)	Area (sq.m.)	Image
Curing Chamber/ Tire curing Machine	5.5	2.2	2.3	12.1	 Source: *(Shandong Melion, 2016)*
Tire Retreading Machine	2.08	1.6	2.1	3.3	 Source: *(Sooner, 2014)*
Wheel Balancing Machine	1.3	0.9	1.2	1.2	 Source: *(ECVV, 2005)*

Tire resolving plant					
Equipment Name	Length (m)	Breadth (m)	Height (m)	Area (sq.m.)	Image
Tire Changing Machine	1.73	1.75	1.27	3	 Source: (NYTech, 2008)
Tire Buffing Machine	2	1.4	2.1	2.8	 Source: (Treadstone, 2010)
Hydraulic Bus Jack	1.1	2.6	1.1	1.2	 Source: (AC Hydraulic, 1958)
Air Compressor	1.3	0.58	1.6	0.8	 Source: (NEC, 1988)
Lath Machine	1.9	0.375	0.3	0.7	 Source: (Esskay, 2015)
Drill machine	1	0.5	1	0.55	 Source: (Skidrills, 2008)

Tire resolving plant					
Equipment Name	Length (m)	Breadth (m)	Height (m)	Area (sq.m.)	Image
Welding machine	0.6	0.39	0.59	0.234	 *Source:* (Techno, 2016)

3.4.2 Equipment used in washing area

In the past, buses were manually washed using hose pipes and pumps. Additionally, semi-mechanised options were used, which involved driving the buses through the washing area at a slow speed as—a combination of—water, soap, and moving brushes removed dirt. Lately, a variety of automated equipment are being installed and used for washing buses at a depot. These include fully and semi-automated external washers, with different washing capabilities like side-body only; side-body and roof; side-body, roof and under body.

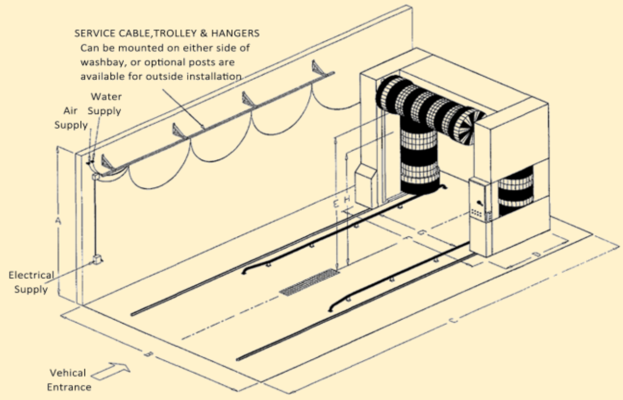
At some depots, the interior and exterior washing of the buses are done at the same wash bay but using different equipment. Exterior washing equipment include automated pressure washers, automated brush washers and automated gantry washers. Interior washing equipment include hand sweeping, cyclone cleaners, flexible hose vacuums, portable vacuums etc.

3.4.2.1 Exterior washing equipment

Exterior washing equipment used in modern depots are presented in Table 8. All other exterior washing equipment (including those which were used in the past) appear in the annexure's Table 45.

Table 8: List of external washing equipment

Exterior washing equipment			
Equipment Name	Standards	Description	Image
Trolley	Washable dimensions Width: 2.75 m Height: 3.75 m Length: 12 m	This is a moving trolley type equipment in which the bus is stationary while the trolley moves. The equipment is automatic in operation and is controlled by PLC (Programmable Logic Controller). Up to 100 buses, this system is recommended as it is cost effective.	 *Source:* (Kke Wash Systems Pvt. Ltd.)

Automated Gantry Washer	Best suited for a fleet size of 6 - 12 buses per hour	A rail based mobile gantry also known as automated trolley The bus is driven into the washer and remains stationary, while the gantry moves across its length comprises of both options of bus wash equipment i.e. high pressure and brush cost - 15 to 25 lakhs (US$ 22,332 – 37,220)	 *Source:* (Schiavone, 1995)

3.4.2.2 Interior Washing Equipment

Depots should be installed with equipment like cyclone washers and central vacuum systems (Schiavone, 1995). Cyclone washers have been around for 30 years, but not used any longer as they are bulky and expensive. The newly introduced central vacuum systems—with retractable hose and other portable vacuum systems—represent a potentially improved version of interior cleaning devices. Modern depots prefer portable vacuums (Table 9) for use in interior cleaning.

Table 9: Equipment used in interior washing

Interior cleaning systems include portable vacuums that can be carried by cleaning personnel (on their backs) to clean bus interiors. A portable vacuum is a back-pack style vacuum cleaner, weighs about 3.6 kg and operates on 110 volts via 50 ft. electric chord. It is equipped with a unique cleaning head to reach behind or under an obstruction. The head also includes a recessed magnet which helps to collect all the metal debris on the floor.

Equipment Name	Standards	Description	Image
Wetvac Type Cleaner	Length 0.625 m Width 0.590 m Height 1.015 m	a new design, high efficiency dust collector both cyclone & suction design can be adopted can be applied near dust creators non-pipe-construction required economical, mobile and convenient specifically designed for bus upholstery	 *Source:* (Hulk Lokpal, 2017)

3.4.3 Equipment used in fuelling area

The fuelling station in a depot is the facility where buses are supplied with fuel and engine lubricants. Every fuelling station (irrespective of fuel type) is equipped a common fuelling equipment - fuel dispensers. A fuel dispenser transfers fuel into the vehicle's tank, from storage tanks (where the fuel is stored in bulk). It also includes an inbuilt calculating device that calculates the cost and the quantity of the fuel dispensed to the vehicle.

Amongst the variety of fuel types available, diesel and CNG are most widely accepted for buses in India. In addition to buses run on these fuels, electric buses are being inducted in many Indian cities. This section discusses the various equipment used globally, for energising different kinds of buses.

3.4.3.1 Diesel fuelling station

Table 10 presents dispensers, the equipment used in a diesel fuelling station. Section 3.7 (Design Standards) of this chapter discusses detailed specifications of dispensers.

Table 10: List of fuelling equipment in diesel and petrol pump

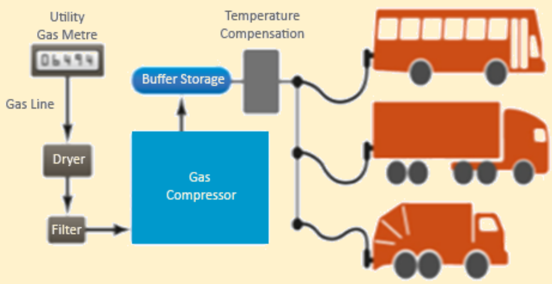
Type of fuelling station	Equipment required	Dimensions	Image
Diesel/Petrol Fuelling Stations	Dispensers (as per number of buses catered in a depot)	Length (l) 2m Breadth (b) 1 m	 *Source: royalbulletin.in*

3.4.3.2 CNG Fuelling Stations

Unlike diesel stations, building a CNG station to cater a bus fleet requires calculating the right combination of pressure and storage necessary for the types of vehicles being fuelled. There are 3 types of CNG fuelling stations namely time-fill, fast-fill and combination-fill fuelling stations.

Modern depots prefer time-fill fuelling stations, as buses can be fuelled at their designated parking bays during idle night hours. CNG is delivered to the compressor at a low pressure, and directly supplied from here to vehicle fuel tanks. It may take several minutes to many hours to fill each tank. A time-fill station allows the advantage of low heat of recompression, and a fuller fill each time. Table 11 provides the details of such a station. The details of other two fuelling stations have been presented in annexure's Table 47.

Table 11: Fuelling in CNG stations

Type	Description		Image
Time-fill fuelling station	Description: Best suited to depots where a large no. of vehicles, with large tanks, are refuelled together at a central location every night.	Size: The size of the compressor depends on the size of the fleet catered by the depot, or the number of vehicles being fuelled simultaneously.	 *Source: (ADFC, 2015)*

3.4.3.3 Charging Infrastructure

Electric bus charging infrastructure consists of charging stations with various charging options and components. The method of charging should be selected by considering the application needs after a thorough techno-economic feasibility analysis. The methods include battery charging (through two types of charging stations) and battery swapping, as explained below:

Charging: EV charging stations are either AC (slow-charging stations) or DC (fast-charging stations) based systems. An AC charging station supplies electricity to the on-board vehicle charger, that transforms the AC—from the electric grid—into DC that charges the vehicle battery pack. It provides 8-25 km of electric range per 30-minute charge. A DC charging station (very high voltage and current; maximum continuous input power 240 kW) supplies current directly to the vehicle battery and typically provides about 125 km of electric range per 30-minute charge (Business Wire, 2015). The time taken by these EV charging stations ranges from 10 minutes to 8 hours depending on the power supply

(Figure 28). The charging stations and any other related equipment can be installed where required for EV charging. They can be attached to standard electricity supply lines, after ensuring that the chargers are working properly (Hamilton, 2011).

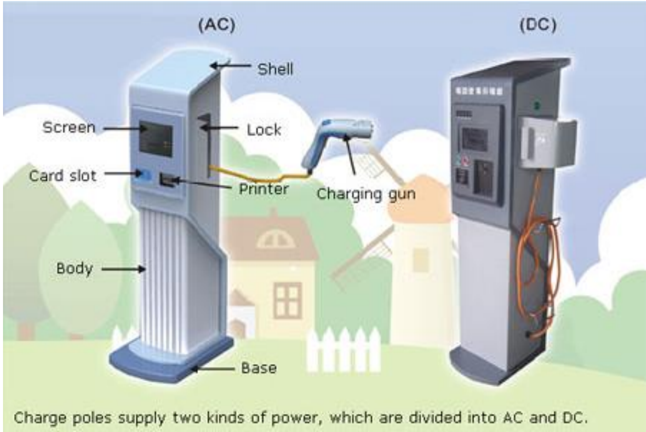


Figure 28: AC and DC charging poles at electric charging stations

Battery Swapping: This refers to replacing a discharged battery with a charged one. The stand-by charged batteries at swapping centres are not owned by the vehicle owners but are leased or rented. Battery swapping is gaining popularity due to quick turnaround. However, swapping is expensive due to the requirement of large number of stand-by batteries, excessive space for their storage, and the need of sophisticated equipment (such as robots) at the service stations for handling high volume of swapping operations.

Because of the current limitations of battery swapping for electric bus based operations, most modern depots opt for charging of electric buses. This requires depots to install charging stations; each such station includes a particular type of a charging point system. The sub sections below elaborate considerations for designing charging stations and the requirements of different kinds of charging point systems.

Charging Stations

Bus depots operating EVs are provided with charging units called charging stations, instead of fuelling stations. An EV charging station, also called electric recharging point/EVSE, is an infrastructural element that supplies electric energy for recharging EVs, such as plug-in EVs. Although for the depot personnel, charging an EV is as simple as connecting a regular electrical appliance to a power supply, this operation must be conducted with utmost safety. To ensure this, the charging system must perform several safety functions, and dialogue with the vehicle during connection and charging (Media, Wiki, 2016).

Depots can become self-sufficient and sustainable by reducing their dependence on the electricity from the grid. Rather, electricity can be produced in-house by capturing renewable sources of energy i.e. solar and wind power, by installing solar panels and wind turbine.

Figure 29 represents different options available for charging EVs.

Figure 29: Images showing EV charging stations with charging pole, wind and solar panels

Source:(Wiki,2016), (Asia-manufacturer,2007), (Plugin cars, 2001)

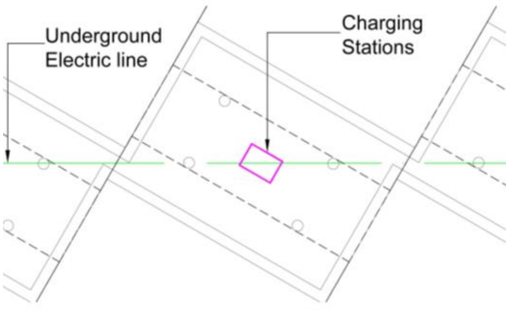
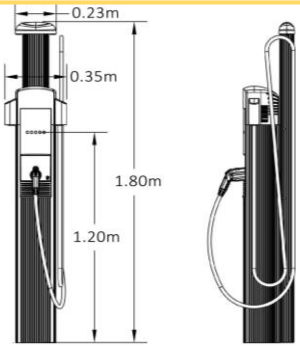
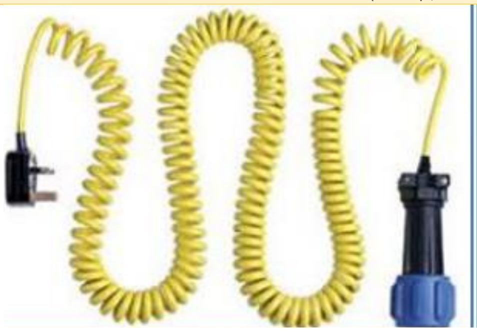
Charging point systems

Power is delivered to a vehicle's battery through an on-board charger. The Electric Vehicle Supply Equipment EVSE (or the charging station) draws electric power from the grid, and through the EV inlet, supplies power to the charger. The charger and EV inlet are hence an integral part of the EV energy pathway (CStep, 2015). As explained, electric buses can be charged through AC or DC current. This charge though can be transferred to the bus through conductive or inductive charging mechanism.

Components of conductive charging: Conductive charging components consist of the connector, electrical connection cable, and power supply from the utilities/grid, in addition to GPRS to locate charging stations. The electrical connection cable for EVs is fitted with plugs at either end, to fit into the EV inlet and get plugged into the charging point. This is normally supplied at the charging station as per the type of EV to be serviced. EVSE operators follow the international standard power circuit wiring colour-code to comply with safety norms. Table 12 presents international standard charging poles, connectors and cables.

Components of inductive or contactless charging: This technology does not require connectors and connection cables, since there are no physical connections between the EVs and the charging points. The required components include, besides induction coils, a local electricity distribution network connection; GPRS to locate charging stations; charging point display to monitor the state of charge of the battery or energy consumed; and access tag in case of restricted access consumer model. In this method, smart controllers take care of the charging process with minimum human intervention (CStep, 2015).

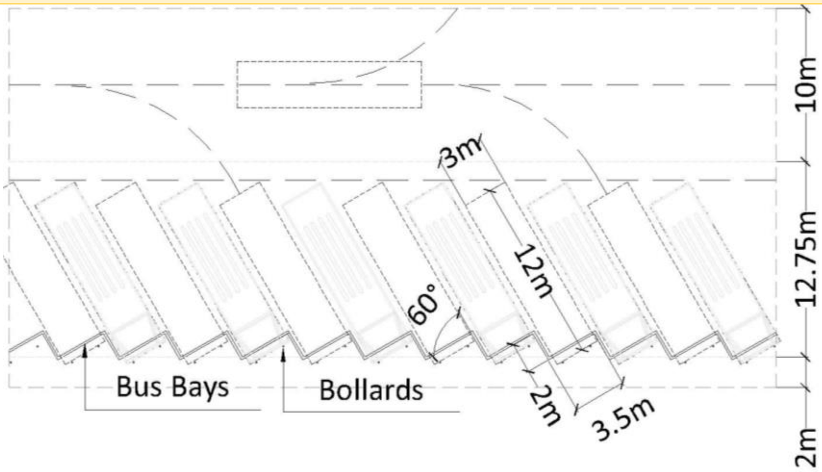
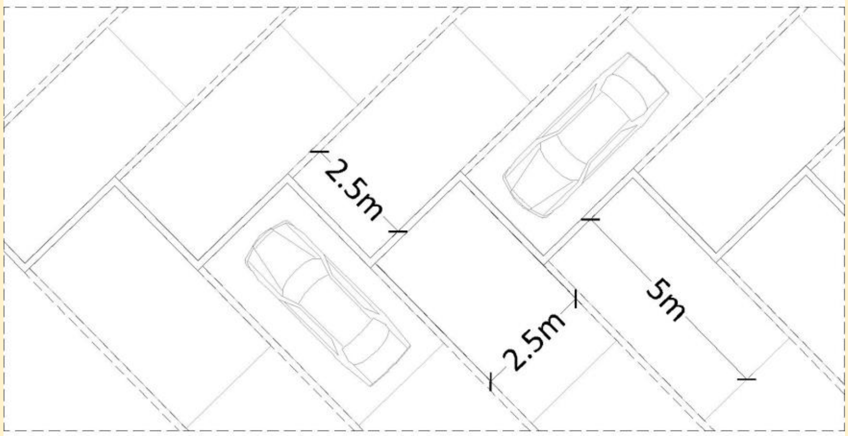
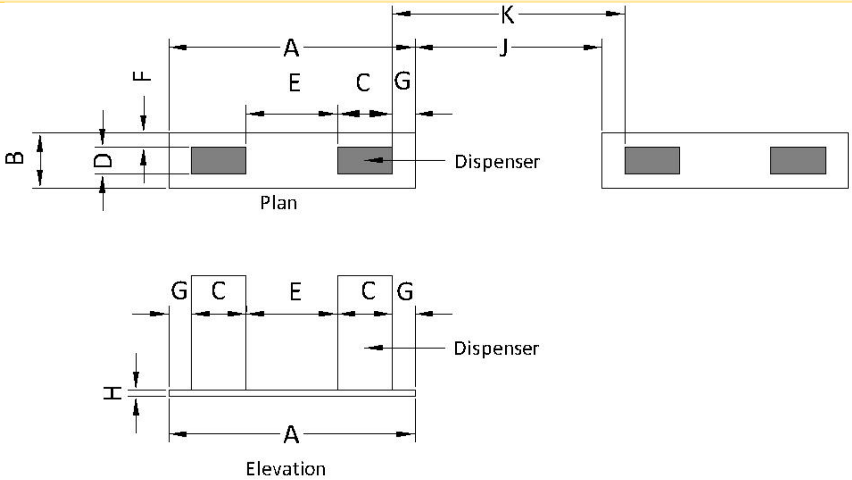
Table 12: Equipment used in electric buses charging station

Electric bus charging equipments		
Charging pole	Size for Charging poles is generally 1.7 m high X 0.75 m X 0.75m, based on this it is recommended that a space of 1 meter X 1 meter should be reserved for the charging poles.	  *Source: (Chargepoint, 2016)*
EV Connector	Description: A connector is a device that connects electrical circuits to EVs, for charging the battery.	 *Source:* (CStep, 2015)
EV Connection cables	These cables are designed to withstand extreme temperature, weather and wet conditions; and are chemical, oil and impact resistant.	  *Source:* (CStep, 2015)

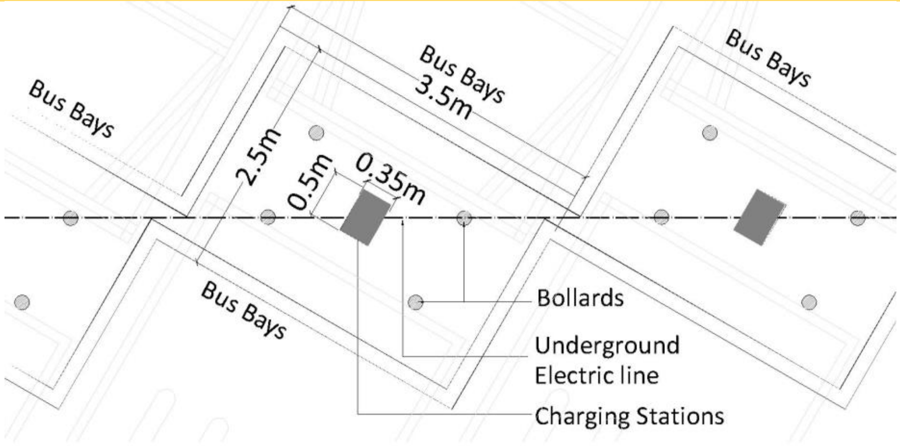
3.5 Geometric Design standards

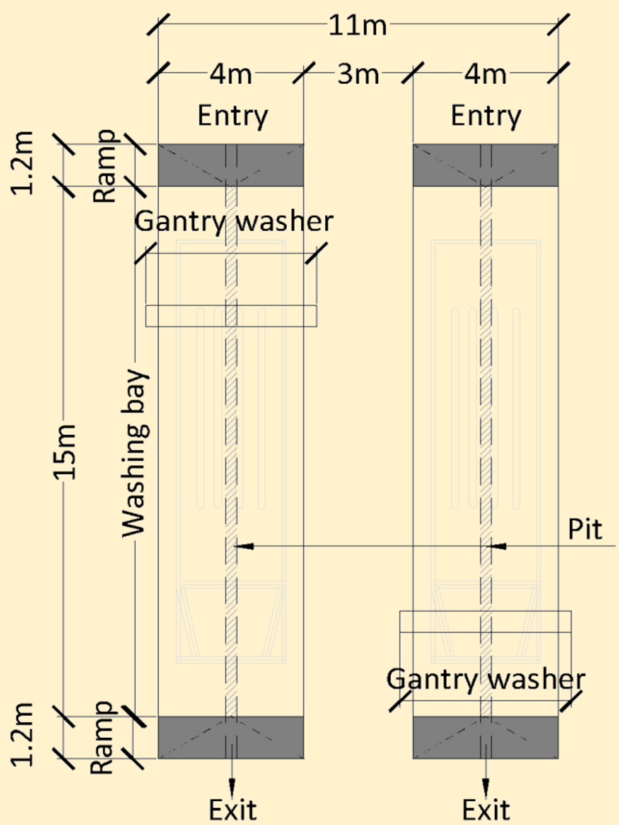
A bus depot's development (and operation) demands significant planning for bus parking bays, circulation of other visiting vehicles (cars and motorised two-wheelers) charging and fuelling infrastructure. The design for all these facilities is based on the dimensions of vehicles and related infrastructure. This section includes a few of the critical geometric design standards related to bus depots (Table 13).

Table 13: Design standards related to bus depots

Design standards		
Terminology	Typology and Description / Consideration	Illustration
Bus parking bays	At-grade - Angular parking at 60 degrees is advisable (as compared to 90 degrees) as it allows for the ideal mix of easy pull-in and pull-out (of buses) and optimised space usage.	
Private car parking	At-grade - On hard surface at ground level	
Fuelling dispenser	• At 0.15 m above ground level • Dimensions represented below	

Dimensions of dispenser island Dispenser island is a pump in a fuelling station that draws fuel from underground storage tanks.			
Particulars	Minimum	Maximum	Description
A	2.4 m (for one dispenser); 14.9 m (for two dispensers)	NA	Island length
B	1.2 m	NA	Island width
C	1.2 m	NA	Dispenser length
D	0.6 m	NA	Dispenser width
E	0.5 m	11.5 m	Distance between two dispensers
F	0.3 m	NA	Distance from island side to dispenser
G	0.5 m	0.6 m	Dispenser from island end to dispenser
H	0.15 m	0.2 m	Island height
J	10.5 m	NA	Clear distance between two islands

Charging poles in bus parking bays	Parking bays for electric buses should be provided with infrastructure for charging of buses i.e. charging poles 0.5 m long and 0.35 m wide.	

Washing bays	• Drain pits in centre • Area: 60 sq.m. per bay (15 m length and 4 m breadth) • Accessible by ramps	

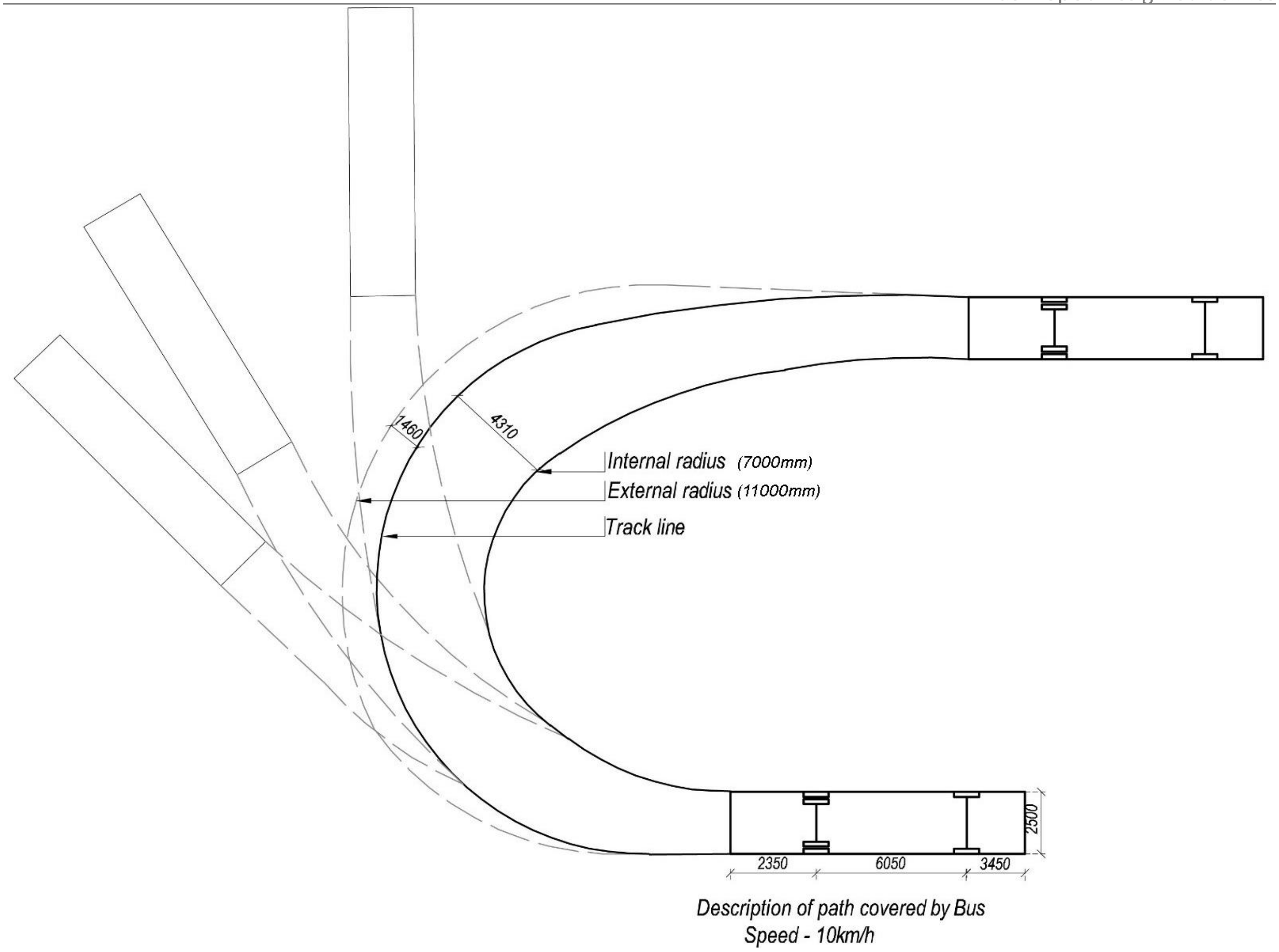


Figure 30: Bus turning radius

Note: All dimensions are in millimetre

3.6 Functional & Spatial Requirements

This section presents the functional and spatial requirements for designing each facility of a bus depot. Each function in a bus depot has a specific placement requirement, relative to other functions on the site. Information on the area requirement for the infrastructure to be developed enables the spatial arrangement of the functions, towards efficient working of the depot. Specific area requirements for each function in a depot are listed in this section. These recommendations may be modified as per the local context and other conditions.

3.6.1 Bus Management Facility Functions

Vehicle operations at a depot involve the bus registration process (during in-shedding and out-shedding) along with regular depot functions such as washing, fuelling, and all necessary workshop activities. Their functional and spatial requirements are explained below:

3.6.1.1 Entry/Exit

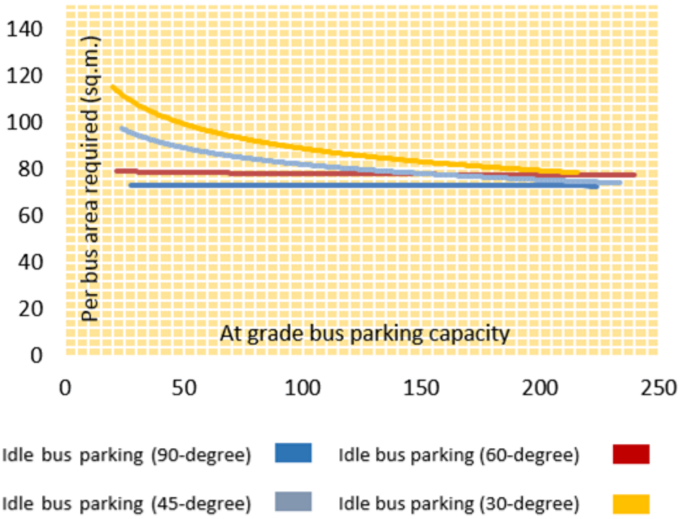
The area requirements for entry/exit and security rooms are mentioned in Table 14.

Table 14: Entry/exit and security room area requirements

No. of entry / exit gate	No. of entry / exit lanes	Security rooms (near entry/exit lane)	
Common (advisable)	1 for entry and 1 for exit	Area required per room	Total area required
1	2	9 sq. m.	18 sq. m.

3.6.1.2 Parking and Circulation – At-grade

Within the depot, there should be an assigned parking spot for each bus based on its registration or serial number, to simplify bus operations inside the depot and ensure efficiency in receiving the bus from handing it over to the assigned crew. A fixed or assigned bay is also essential for providing on site servicing of buses, such as slow filling of CNG, cleaning, and air pressure monitoring. Most importantly, fixed bays inside bus parking area ensure optimum parking layout of buses, avoiding stacking and loss of usable space due to inefficient parking. It is also observed that one-way circulation within the depot parking, coupled with angled parking, allows maximum efficiency in terms of space use and ease of operations (pulling in and out of the bays). A 60-degree angled parking is considered optimum for this advantage (refer bus parking bays in Table 13). Figure 31 presents per bus parking and circulation area requirement based on total fleet size parked and the angle of parking for at grade bus parking.



90 degree bus parking consumes the least area per bus for any parking angle or size. For angled bus parking, 60 degree parking consumes the least space up to 400 bus parking size, beyond which 45 degree angle parking consumes the lowest per unit space per bus.

Figure 31: At-grade idle bus parking requirements

Normally, the bus parking area for overnight-parking in depots is designed according to the entire fleet capacity of the depot unless a significant number of vehicles are required for all-night operation. However, bus parking should be designed for an additional 10% of the fleet size, to accommodate future expansion. Block formation is the primary method used for parking buses in Indian depots, as it maximises the use of available space by approximately 50%. As a result, 18 buses, each 12 m long, can be accommodated per 1,000 sq. m., m., including circulation space (The World Bank Group and PPIAF, 2006). The disadvantage of this parking method is that it does not allow independent and unobstructed access to every bus.

The bus parking area requirement varies with the fleet size catered by the facility. Designated bay parking - for each bus - is one of the international best practices of bus parking in depots. Since most buses don't need daily workshop visits, designated bay parking can be used to provide infrastructure for daily servicing requirements such as washing, fuelling, and air pressure monitoring in tires, thus minimising internal traffic and dead mileage of buses. However, in the Indian context, though demarcated bays exist, in some cases they may not be designated to specific buses. The current observed practice consists of parking a cluster of buses in a designated area, or parking them sequentially based on distance from the exit gate such that buses leaving early are the closest. In the absence of 'at-bay' facilities for servicing of buses, this dynamic bay arrangement for parking of buses is acceptable, to enable all buses to circulate in the depot, for washing, fuelling, and air pressure monitoring whether they are scheduled for a workshop visit.

The spatial requirements of bus parking are listed in Table 15.

Table 15: Bus parking area requirements

Area required per bus bay (sq. m.)	Total parking space required per bus (including circulation) at an angle of 60-degree
42 sq. m. (12 m x 3.5 m)	89 - 91 sq. m.

3.6.1.3 Multi-level Bus Parking

This section discusses the design and spatial aspects of developing a multi-level bus parking. These include design considerations, benefits, and spatial requirements of an elevated or above-grade multi-level bus parking.

Design Considerations:

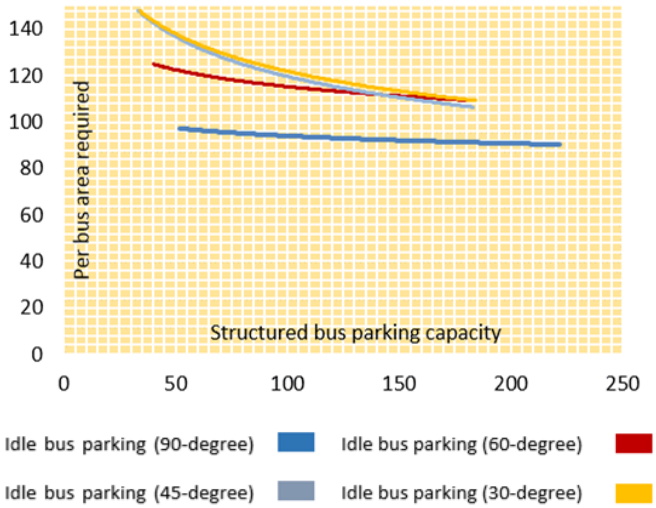
Multi-level bus parking infrastructure requires careful design considerations:

- **Clear Height –** Clear height for multi-level bus parking should be as per local standards and the bus height as per the manufacturer's specifications. In the absence of any local standards, the current observations suggest that the clear height for bus parking should be between 3.5 m and 3.8 m (accounting for the height of any sensors, light fittings, fire sprinklers etc.) or at least 30 cm more than the bus height specified by manufacturer. Accounting for these clear height requirements may result in 5.0 m floor to floor height for a bus parking structure.

- **Bus Ramp Design –** The ramps in a multi-level bus parking should be minimum 4.0 m wide with additional widening at the bends as per the turning radii. They must be gentler than those provided for cars, because of the ramp length being longer (greater height difference between floors) and the expected power to weight ratio of buses being lower. The exact design for a multi-level bus parking ramp should comply with the bus manufacturer's recommendations, but preferably not steeper than 1:20 slope. Flat landings in the ramp (longer than the bus length) may be considered, especially for steeper slopes. Additionally, all multi-level bus parking facilities should be designed for clear one-way circulation (for buses) and separate ascending and descending ramps.
- **Fire Safety –** Buses are loaded with highly combustible fuel. Any fuel leak—from a malfunction or accident—can prove catastrophic in an area packed with a number of such loaded buses. Thus, all multi-level bus parking facilities must be equipped with automated fire and leak (for CNG) sensors; as well as adequate (as per local fire safety norms, and bus manufacturers' recommendations) firefighting devices and features (including sprinkler systems, fire escapes, emergency lighting etc.).

Benefits: The main benefit of including a multi-level bus parking structure in a bus depot is that it may contribute to financial sustainability of the depot. This is achieved by significant space saving over at-grade bus parking. This space saved can be used to accommodate additional buses or can be used for real-estate development. Additionally, the surplus land can, translates into additional income, generated through levy of parking fee from private operators; leasing out spaces for commercial and advertising purposes; and imposing user charges for miscellaneous services like valet parking, car maintenance, helmet repository, night parking for private buses/cars etc.

Spatial Requirement: Although multi-level bus parking leads to considerable space saving over at-grade bus parking, the per bus area requirement on each floor plate goes up by as much as 40 to 50% because of the area occupied by the structure, lifts, staircases and bus ramps. The per bus area requirement on each floor depends on the total number of buses parked on that floor and the angle at which they are parked. Figure 32 presents the per bus area requirement in a multi-level bus depot.



Per bus parking size represents floor area occupied per bus. For a three floor structured bus parking, to estimate ground coverage per bus, the floor area value may be divided by three.

Figure 32: Multi-level idle bus parking requirements

3.6.1.4 Fuelling and Charging

The fuelling dispenser numbers are estimated based on the demand, that is in turn based on the fleet of buses catered and the depot's operational hours. As per the Minnesota Department of Transit (2012), one fuelling station can handle a total of 80 buses per day i.e. assuming 8 hours of operations in a day. However, at least two fuelling dispensers are recommended, in case one of them breaks down. The layout plan is presented in Figure 33.

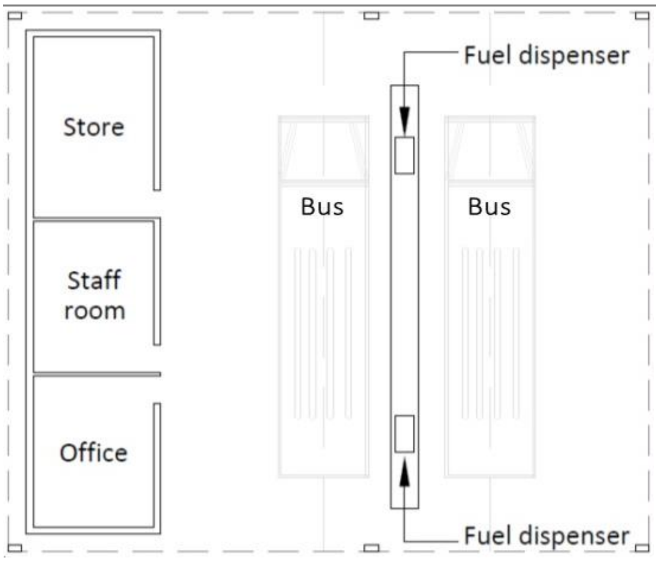


Figure 33: Fuelling area

At bus depots that use CNG as a fuel over ground cylinders are used for fuelling instead of underground storage tanks. These over ground cylinders are situated in a separate area within the complex known as the CNG fuel plant. Building a CNG station requires calculating the right combination of pressure and storage needed for the types of vehicles being fuelled. CNG stations receive fuel via a local utility line, at a pressure lower than what is used for vehicle fuelling. The CNG fuel plant in the station compresses the gas to a higher pressure for fuelling. This plant is connected to dispensers that transfer the gas to the buses. The pressure in the gas cylinders is constantly maintained through pumps connected to the main CNG supply line. It must be noted here that a separate gas station requires more space compared to conventional diesel/petrol filling stations. According to the requirement and fleet size of the buses catered by the depot three types of CNG fuelling stations can be provided.

In case of EVs, plug-in charging units are provided at-bay, allowing simultaneous charging of buses, without pulling out from the designated parking bay. Though individual at-bay charging (or fuelling) saves space and is operationally efficient, it requires high capital investment. Thus, the operating experience for such an option in the Indian context, is limited.

Amongst all the fuelling options, gas station requires the maximum area. However, this option is most favourable in terms of cost and environmental implications.

For conventional vehicle fuelling, the fuelling station should be placed along the main circulation pathway, near the workshop and washing areas, so that buses can simultaneously access any of the three areas depending on space availability. Santosh (2011) recommends a 50-kl fuel storage tank for any depot which caters up to 100 buses daily. Air inflation points are also proposed to be installed in the fuelling station area, a total of four (two at each dispenser). A separate area for the attendant and compressor room (in case of CNG fuel) must be provided near the dispensers (Table 17).

The fuelling station should be covered and well equipped with firefighting devices. Needless to say, the fuelling station should be away from heat and flame sources i.e. should be placed in a segregated area, especially away from the workshop and servicing areas. Table 16 presents the space requirement for diesel and CNG fuelling.

Table 16: List of fuelling area requirement for diesel buses

Fuelling area				
Avg. time/ bus for fuelling/ dispenser	No. of buses/ hour/ dispenser	Daily working hours	Catering capacity per dispenser (for 8 hrs) (a)	No. of dispensers required for diesel buses
5 min	12 buses	8 hrs	96 buses	No. of buses in a depot / catering capacity per dispenser
Dispenser Island area	3 sq. m. [Minimum for 1 dispenser] (refer Table 13)			
Other requirements for fuelling area				
Particulars	Area			
Administration Office	12 sq. m.			
Staff Office	15 sq. m.			
Toilet	9 sq. m.			
Storage	20 sq. m.			
Underground Tank Capacity	0.45 cu.m. per bus			
Total km/bus/day	240 km			
Litres consumed/day/bus	160 litres			

Table 17: List of fuelling area requirement for CNG buses

CNG fuelling pump – '2-dual hose' CNG Pump	
Office	18 sq. m.
Control Room	
Warehouse	
Washrooms	
Compressor & Cascade/Cylinder Storage Room and Underground Gas Pipes	23 sq. m.

Table 18: List of fuelling area requirement for Electric vehicles

Nos.	No. of Electric buses	Transformer requirement
1	200	11 MVA (area- 2mx1.2m)
2	100	5 MVA (area- 1.5mx1m)

EVs can be charged at the parking yard or without pulling out of their designated parking bay. Charging units are provided at each bay, allowing simultaneous charging of buses by installing sockets and plugs.

The dimensions of a charging pole in the charging station may vary (as per vendor) from 1.2 to 1.8 m in height, 0.35 m in width and 0.5 m in depth (refer 'Charging poles in bus parking bays' in Table 13). All charging poles are connected to underground electric grid network from where electricity is drawn.

The detailed layout of bus parking bays with charging stations is explained in Figure 34.

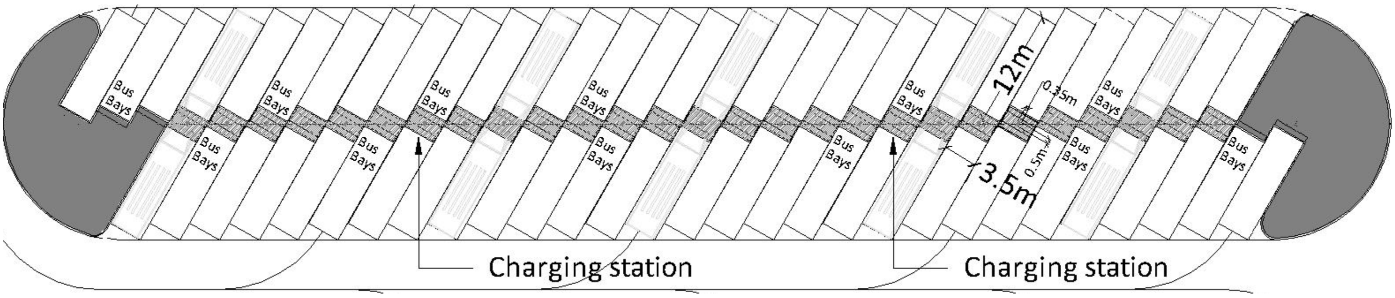


Figure 34: Detailed layout of bus parking bays with electric charging stations for electric buses

3.6.1.5 Washing

Cleaning of buses is a daily essential activity, as it protects all exterior and interior surfaces from dust elements and corrosive contaminants. A clean bus is safer, easier to maintain, and stands a better chance of a longer operating cycle (BUSRide, 2015). Different bus washing systems prevalent in the Indian context have been discussed in previous sections including fully and partially mechanised systems. A review of global best practices indicates that external washing of buses should be mechanised, and include all surfaces i.e. sides, top and bottom of the bus. A fully mechanised washing system using gantry washers with width 2.75 m, height 3.75 m, and length 12 m is recommended for use in depots. This may be enclosed or open, with under-body cleaning undertaken manually through hose pipes. Such a washing system requires an area of 60 sq. m. approximately.

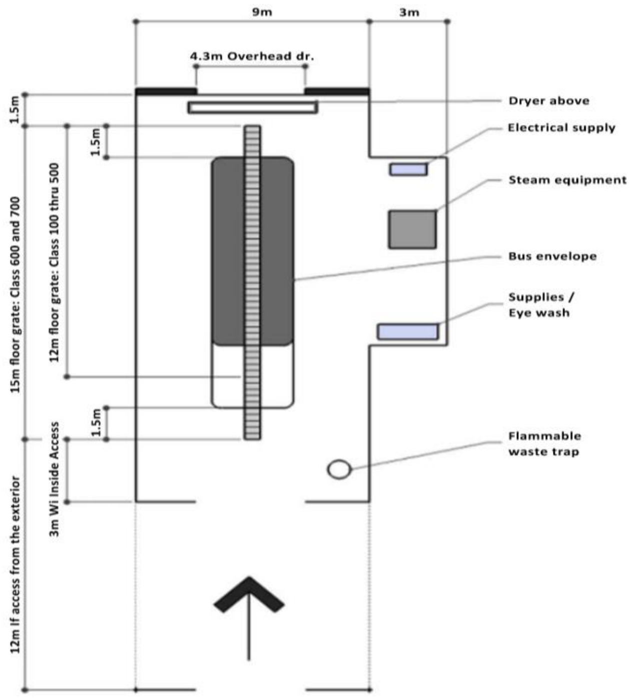


Figure 35: Typical washing area layout

A single bus washing facility can cater to an average 40 buses per day (assuming 8 hours of washing operations every day) (Minnesota Department, 2012). However, one wash bay is recommended to be provided for every 72 - 75 buses accommodated at a depot Such an arrangement will suffice for a maintenance activity limited to 8 hours during a day, if buses are washed every alternate day. This practice is often preferred to save both water and energy. It requires buses to go through gantry washers every alternate day, while on other days they are manually cleaned both externally and internally. Table 19 presents detailed washing requirements.

Depots facilities should employ specialised personnel for washing of buses. These personnel drive the bus from the parking lot to the wash bay area, wash it, and clean it. Per bus mechanised washing takes an average 3 to 6 minutes per bus and will consume 150 litres of water (Zhongda Industrial Group Co. Ltd., 2016).

3.6.1.6 Bus Maintenance Facility Functions

The workshop and maintenance area for a bus depot is comprised of two sections, namely main workshop area and storage area. It should be located near the washing and fuelling areas.

Main Workshop Area - The workshop area consists of pits, preventive maintenance rooms, administration rooms, inspection zone, and body shop zone.

a) **Pits** - Most of the area in a workshop is occupied by pits. Three different types of designated pits should be provided in each workshop: inspection pits for major as well as minor inspection; maintenance pits for scheduled bus maintenance work; and driver complaint pits to address unscheduled driver complaints (Figure 36).

Pit and bay dimensions, and their required number based on the inspection and maintenance time taken for each bus, are further explained below:

b) **Inspection pits -** All buses need to be inspected every day. Of these about 15% are inspected as a part of their scheduled or unscheduled workshop visit. This leaves 85 percent of the fleet which needs a pit visit only for inspection. Total number of pits required for inspection depends on time taken by each bus per inspection pit visit. Table 20 presents estimation for inspection pit requirements in a bus depot. The area required for one pit is 14 sq. m (14 m length and 1 m width), accessible through ramps. Sufficient circulation space should be provided for easy movement of various equipment used for maintenance of vehicles.

Table 19: List of washing area requirement

Washing area	
Avg. time / bus for external washing	7 min
No. of buses / hour/ bay	9 buses
Daily working hours	8 hrs
Catering capacity per dispenser	72 buses
Washing frequency for every bus	Alternate days (50% of buses washed daily)
Fleet catering requirement per bay	Total fleet size/2
No. of bays required	(Total fleet size/2) / 72
Other requirements	
Washing bay Dimension 15 m x 4 m (l x b)	Area = 60 sq. m.
Average water consumption per bus per wash	150 litres
Total water requirement per day (a) (litres)	150 litres x no. of buses washed (total fleet size/2)
Volume requirement for water storage (b) (1 cu.m. required for 1,000 litres)	a / 1000
Proposed storage capacity period of water tank (c)	2 days
Proposed underground storage tank capacity (cu. m.)	b x c

Table 20: Pits required for inspection

Inspection Chamber	
Average time taken/bus/pit	10 min
No. of buses/hour/pit	6 buses
Working hours	8 hours
Catering capacity/pit/day (a)	48 buses
Percentage of fleet due for inspection per day (b)	85%
Pits required	b/a

- **Maintenance pits -** A bus is due for preventive work after every 3,000 km or 10 days, as it covers a maximum of 300 km per day. This means that every day, 10% of the total operating buses would be scheduled for preventive maintenance. The average time for catering one bus is 2 hours. Therefore, one preventive maintenance pit can cater up to 4 buses in an eight-hour shift. Table 21 illustrates the calculation for estimating the number of preventive maintenance pits in a depot.

Table 21: Pits required for preventive maintenance

Preventive maintenance pits	
Preventive maintenance required after every:	3,000 km
Daily bus coverage (maximum)	300 km
Frequency of preventive maintenance required for each bus	after every 10 days
Area required per pit (only the depressed portion)	14 sq. m.
% of buses catered per day (a)	10%
Time taken/bus /pit	2 hours
No. of working hours	8 hours
Catering capacity per pit per day (b)	4 buses
No. of pits required	Depot capacity (buses)* a/b

- **Driver complaint pits –** Drivers' complaints, regarding their bus's condition, are registered during in-shedding. It is observed that daily, on an average 5% of the total buses catered at a depot face such complaints. The average time devoted to each bus at a driver complaint pit—for resolving the problems—has been observed to be 1.5 hours i.e. in a 12 hour[7] period, one pit can cater 8 buses. Hence, the total number of pits required can be calculated as 5% of the operational bus fleet at the depot (Table 22).

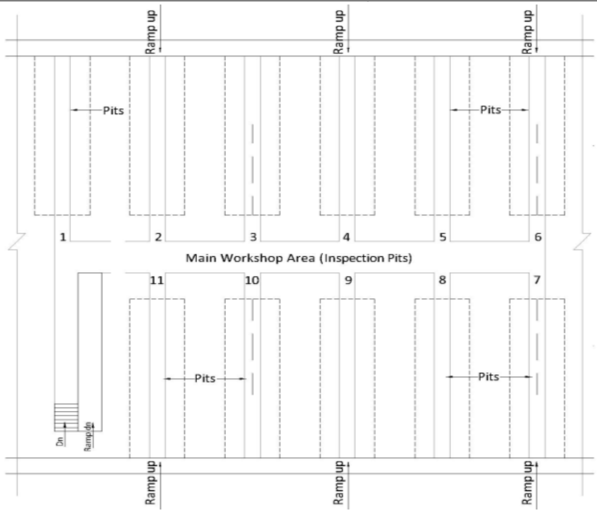


Figure 36: Layout of inspection pits

Table 22: Pits requirement for catering driver complaints

Drivers' complaint pits	
Breakdown complaints per day (a)	5% x fleet size
Daily working hours (b)	12 hrs
Avg. service time required /bus (c)	1.5 hrs
No. of buses serviced /pit (d)	b/c = 8 buses
Pits required	a/d

b) **Administrative areas and preventive maintenance area -** In workshop and maintenance areas, rest rooms are provided for 10% of the total night shift workers and lockers are provided for all workers (including morning, evening and night shift).

Table 23 presents the area requirements for administrative and preventive maintenance areas.

Table 23: Area details of admin and preventive maintenance areas

Components	Area (sq. m.)	Considerations (if any)
Workshop Office	20	--
Meeting Room	15	--
Main Store	90	--
Gear Shop	30	--
Engine Shop	40	--

[7] 1 Eight-hour shift at full strength and; 2 eight hour shifts at 1/4th strength or 1 eight-hour shift with half strength

Components	Area (sq. m.)	Considerations (if any)
Lockers	0.25	0.25 sq.m. area per person including circulation (for all workshop workers)
Rest room	6.5	6.5 sq.m. per person including circulation (Provision of rest rooms only for 10% workers of evening shift)
Machine Room	18	--

c) **Inspection zone -** In the inspection zone, designated rooms should be provided for tire resolving plant, and tire storage. Separate space should be provided for the puncture section, to repair punctured tires, and for new and old tire storage (Figure 37).

d) **Body shop zone -** The body shop zone consists of the upholstery section where the upholstery of buses is maintained; the electrical section where the batteries of buses are stored; as well as the painting section where painting equipment required for painting bus body are stored (Table 24 and Figure 38).

Table 24: Area details of the body shop zone

Components	Area (sq. m.)	Source
Welding Machine	1.2	(Rongbiao Welding Machine, n.d.)
Painting Room	40	(Santosh, 2001)
Electrical Room	40	
Upholstery Section	40	
Compressor	0.21	--

Storage area - There are 3 types of stores, namely tire store, body and spare parts store, and oil tanks store.

Table 25 explains the functional spaces and area requirement of all three types of storage areas.

Table 25: Area details of storage area

Components	Area including circulation (sq. m.)
Tire Changing Machine	4
Wheel Balancing	2
Inspection Spreader	4
Tire Buffer	2
Curing Chamber	16
Air Compressor	0.3
Roller Brake Tester	2
Oil Greasing Pumps	0.3 sq. m.
Hydraulic Machine	1
3D Computerized Wheel Alignment Machine	1
No. of New Tires	13% of total no. of buses per month
No of Retreated Tires	22% of total no. of buses
No. of Scrap Tires	65% of total no. of buses
No. of Punctured Tires	0.067 times of total no. of buses per day
Corrected Puncture tire	0.067 times of total no. of buses per day

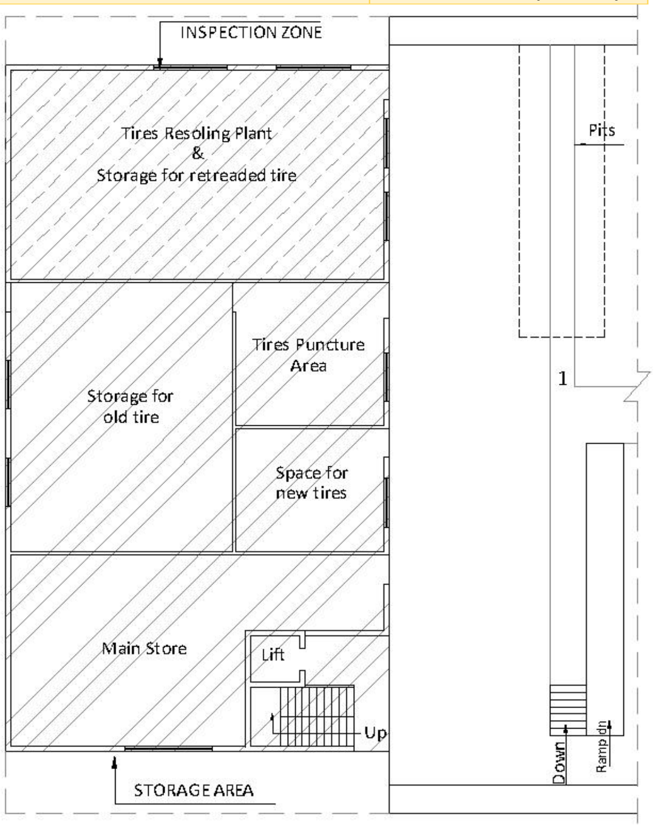


Figure 37: Part plan of workshop showing inspection zone and storage area

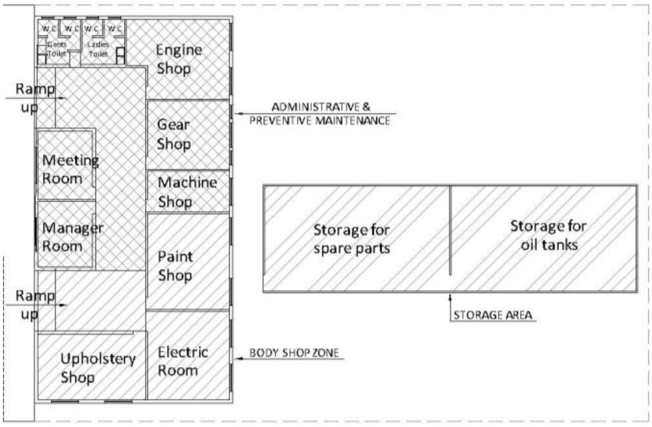


Figure 38: Part plan of workshop showing body shop zone, administrative & maintenance zone, and storage area

3.6.2 Infrastructural Operations

All good depots infrastructure maintains a degree of isolation and control of various functions, to ensure that only required and authorised personnel are present in the operational area including bus parking, workshop, fuelling, washing etc. This is necessary to ensure safety, security and efficiency in bus depot operations. Such isolation in depot operations and infrastructure is also important in the context of different organisations/institutions participating in bus services and thus co-existing in the depot. For instance, bus operations may be handled by a separate concessionaire, ticketing by another, workshop and washing by a contractor, fuelling by a separate agency, and overall administration by yet another agency. On the basis of the above considerations, the functional and spatial requirements for administrative infrastructure in a depot are discussed below:

3.6.2.1 Administrative Block Facility

Administrative block facility consists of general offices, operational block, and supporting staff facilities, for administering and managing bus depot operations. The area requirements of each of these components are shared in subsequent paragraphs.

a. General Offices - General offices can be provided at the first floor of the administrative building. Table 26 presents the area requirements of various offices.
b. Operational Block - The operational block should preferably be located on the ground floor of the administrative building. This is because it involves close interaction with bus crew, who may access functions through windows, without having to enter the building. Table 27 lists the functional and spatial requirements of the operational block.

Table 26: Area requirements of general offices

Requirements	Area (sq. m .)
Depot Manager room	15
Concessionaire room	30
MIS room	30
Meeting room	20

Table 27: Area requirements of operational block

Operational block	
Requirements	Area (sq. m.)
Driver Control Room/ Memorandum room	15
Waybill Office/ Cash Room (Conductor Control Room)	15
ETM Supervisor Room	15
ETM Charging Room	10

c. Staff Facilities - Because of varying nature of working hours of bus crew i.e. early commencement or late conclusion of services, they require a number of specific facilities in a depot. The functional and spatial requirements for staff facilities are listed below:
Crew Infrastructure - The crew locker rooms, rest rooms and canteen should be provided near the entrance of the administrative block) with access from outside the depot. This is essential for keeping the STU drivers and conductors out of the operational area of the depot. Additionally, one controlled access to the bus entrance and exit should be provided such that drivers and conductors can board/de-board the bus during out-shedding/in-shedding. It is observed that after the duty shift, around 50 percent of the crew members do not return to their residence. Crew infrastructure is provided for them. However, out of these 50% only 25% percent of these members desire to stay at the depot. Others prefer to stay at their rented accommodation near the depot. Table 28 lists the area requirements of staff facilities.

Table 28: Area requirements of staff facilities

Requirements	Area (sq. m.)	Description/Source
Rest room	6.5	One person requires 6.5 sq. m. of area (only 25% of the crew members stay at night)
Locker Room	0.25	0.25 per person including circulation (for total crew)
Canteen	40	(No. of 50% crews/2) For 100 buses, area required is 72 sq. m. *Source: (Santosh, 2001)*
Kitchen	11 (minimum)	10% of 25% of total crew who will stay in depot (taking 0.1 sq. m. area per person)
Toilet		
Water Closet	1.8	Staff: For males - One for every 25 persons or part thereof For females - One for every 15 persons or part thereof *Source: (NBC, 2005)* Crew: For males - One for every 8 persons or part thereof For females - One for every 8 persons or part thereof *Source: (NBC, 2005)*
Urinal (for staff)	0.6	Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons For 101-200 persons - add at the rate of 3% For over 200 persons - add at the rate of 2.5% *Source: (NBC, 2005)*
Ablution Tap	1 in each WC	*Source: (NBC, 2005)*
Wash Basin	1	Staff: Both for males and females - One for every 25 persons or part thereof 1 in each WC Crew: Both for males and females - One for every 8 persons or part thereof 1 in each WC *Source: (NBC, 2005)*
Bathroom (for crew)	2 (minimum)	1 per 8 persons *Source: (NBC, 2005)*
Toilet for differently-abled	3.5	3.5 sq.m. of area for 1 toilet including circulation *Source: (NBC, 2005)*

Staff Parking - Depots require parking facilities for not only buses but also private vehicles belonging to visitors, crew, and other staff (Table 29). These should be parked in a designated area, outside the operational area. To estimate the private vehicle parking requirement in the Indian context, assuming that each driver and conductor commutes on a personal two-wheeler, the recommended consideration includes one ECS per bus and four ECS per 100 sq.m. (1,000 sq. ft.) of transportation and administrative services i.e. the built-up area of the administrative block (Minnesota Department, 2012).

Table 29: Area requirements of staff parking

Standards		Area requirement (sq. m.)
2-Wheeler	25% of (Crew + Workers) (excluding Officials)	0.25 ECS (1 ECS = 23 sq. m.) [0.25 x 23 sq. m.] per two-wheeler X (25% x {no. of workers + crew members}[8])
4-Wheeler	10 parking spaces (including officials and visitors)	1 ECS (1 ECS = 23 sq. m.) per four- wheeler X 10 (no. of officials and visitors) = 230 sq. m.
Bicycle	10% of total workers (including supporting staff) + crew	0.25 ECS [0.25 x 23 sq. m.] per bicycle X (total workers (including supporting staff) + crew

[8] Total crew = depot capacity (buses) X 2; total workers (including supporting staff) = [depot capacity (buses) X 0.33] + 8 (average number of workers for fuelling and washing)

4 Design Illustration

This chapter shall guide the reader/user through the entire bus depot planning and design process. It describes a typical design layout of a large size bus depot (maximum capacity of 220 buses; refer chapter one, section 1.6).

4.1 Introduction

The proposed design (in a hypothetical setting) discussed in the following section is based on an understanding of best practices in operations and infrastructure planning. The following characteristics and provisions have been assumed in the hypothetical bus-depot:

- a diesel based fleet;
- at-grade parking of buses;
- depot capacity of 220 buses (200 operational and 20 stand-by buses, considering 10% stand-by);
- site area of 29,660 sq. m. (7.3 acres) having 191 m length and 160 m width; and
- facilities for 440 crew members (220 drivers and 220 conductors), 133 workshop staff, 3fuelling staff, 3 washing staff, and 10 administration staff[9].

4.2 Design Parameters

As mentioned earlier, this bus depot layout is developed to cater 220 buses. The infrastructure required for this capacity is summarised in Table 30.

Table 30: Infrastructure required for 220 buses

Main Infrastructure	Number
Bus parking bays	220 bays
Private parking	2W - 147 4W - 10 Bicycle - 59
Fuelling area	2 dispensers
Washing area	2 bays
Inspection pits	4 pits
Preventive maintenance pits	5 pits
Driver complaint pits	1 pit
Operational, administration block, and crew infrastructure	1 (3 floors)
Security room	2 (3 m x 3 m each)
Workshop office	1 (2 floors)
Fuelling office	1 (1 floor)

4.2.1 Bus Management Facility Functions

Bus operations are the major process undertaken in a bus depot. All functions associated with bus operations are explained in the following section.

4.2.1.1 Entry/Exit

Entrance should be provided at an edge of the major access road leading to the depot. The proposed depot is planned with two separate openings, segregating the bus entry/exit and staff entry/exit. A separate entry gate is provided for staff and visitors, to access the administration block and parking. For buses 15 m wide, single entry/exit gate with two parallel operational lanes with a check post each, is provided. This allows simultaneous entry/exit for in-shedding/out-shedding for two buses (Figure 40).

4.2.1.2 Parking and Circulation

The standing space required per bus is 3.5 m x 12 m i.e. 42 sq. m. (CROW, 1998), whereas inclusive of circulation space, the total area required for one bus is approximately 89 sq. m. at an angle of 60-degrees (refer Figure 31 of chapter 3). So, a minimum area of 19,580 sq. m. should be provided for bus parking, that amounts to about 66% of the total depot area. One-way circulation for buses is planned with a 60-degree angled parking along the east-west, axis of the site. The 60-degree angle is used for ease of pulling in and out of the bays and to optimise parking area. Parking bays should be aligned in a linear manner and oriented in the direction that allows maximum uninterrupted driveway length. This minimises per bus parking area requirement, which is why the rows of bus parking bays are arranged in the east-west orientation. The bays are planned with a 3.5 X 2.5 m central raised platform, which can accommodate charging docks in case electric buses are inducted in the fleet. Thus, the layout allows the depot to be future ready. Figure 39 illustrate the choices made in the proposed depot layout.

[9] The number of staff assumed for the design proposal is based on the calculation worked out for the given depot capacity. For further understanding, a ready reckoner determining requirements according to depot capacity is provided in the annexure, with all details.

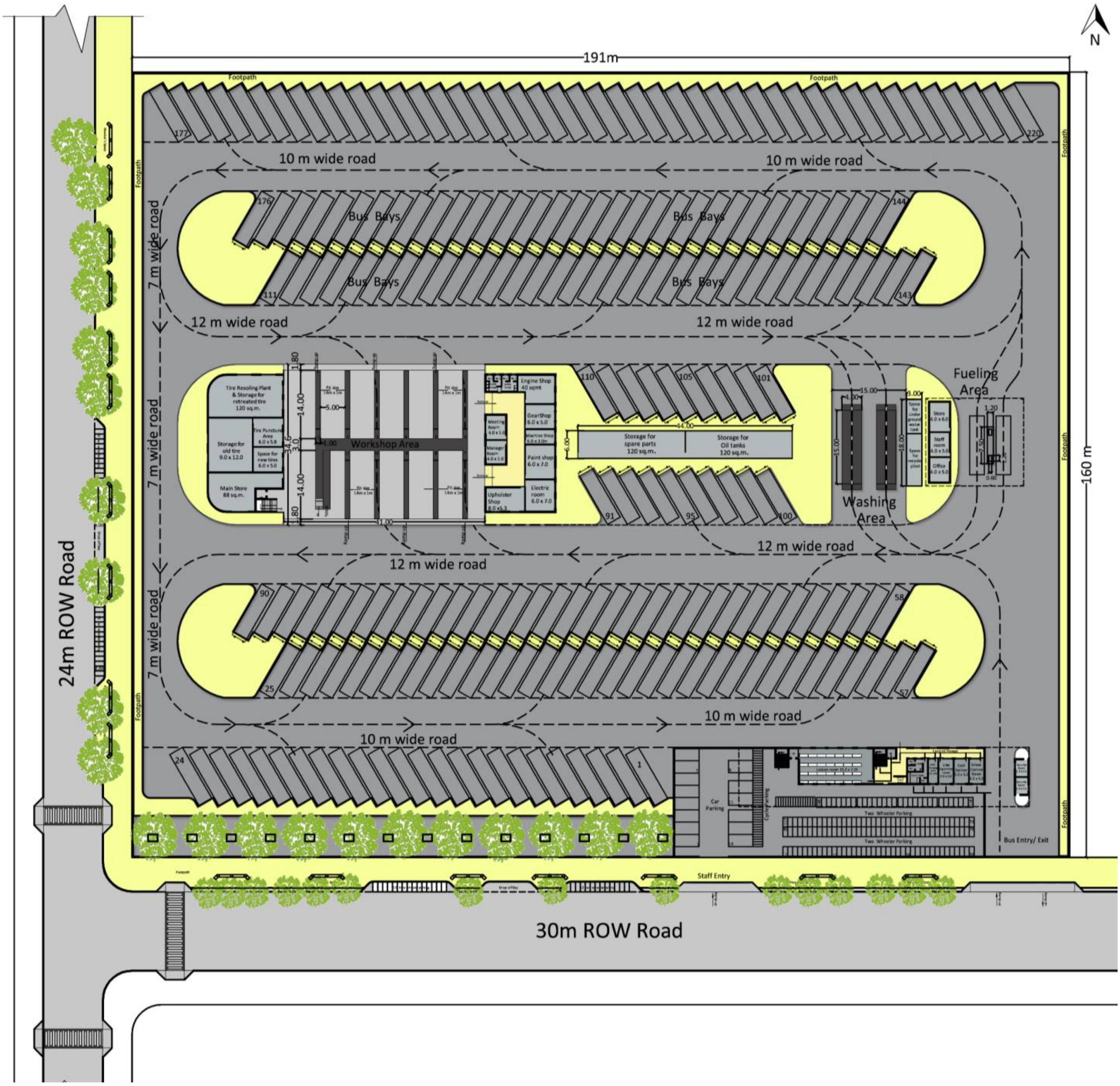


Figure 39: Site Plan of typical layout

Figure 40: View showing entry/exit gate

4.2.1.3 Fuelling

One diesel fuel station with two dispensers is located in the east direction of the site. As observed, it takes about 5 minutes to refuel one bus, i.e. one fuel dispenser can cater 96 buses in a day (8 working hours). Hence, 2 dispensers will be required for fuelling 220 buses per day (Table 31). Although the size of the dispenser island may vary as per the specific context, an area of 18 sq. m. is the minimum requirement for 2 dispensers. Please note that although only two dispensers are provided in this design, STUs may opt for a third standby dispenser in case of a breakdown, especially at sites where ready maintenance help is not provided by the fuel/fuelling equipment supplier. Figure 41 and Figure 42 offers plan and view of a fuelling station.

Table 31: Calculations of fuelling station

Fuelling Station	Value	Unit
Total no. of buses to be refuelled	220	Nos.
No. of dispensers required	2	Nos.
Designed/Provided dispensers	2	Nos.

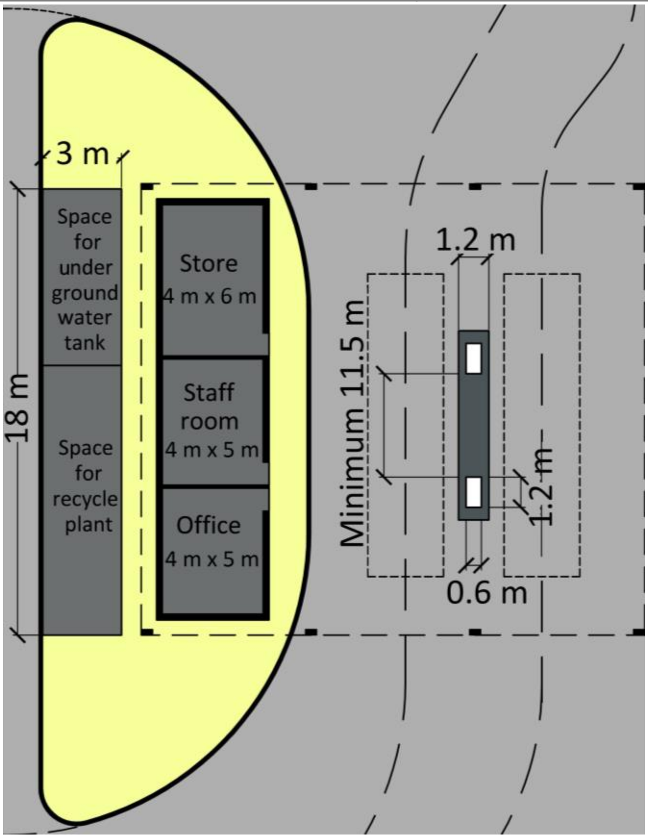


Figure 41: Plan showing fuelling area

Along with dispensers, complete fuel station should be provided, that includes store room, staff room, and an office. Table 32 presents the functional area details of the fuelling station.

Figure 42: View showing fuelling station

Table 32: Area requirements of fuelling area

No.	Rooms	Length (m)	Breadth (m)	Area (sq. m.)
Fuelling Bays				
1	Dispenser Island	7.5	1.2	9
2	Bus Circulation Area	--	--	228
Fuelling Building				
3	Station Office	4	5	20
4	Staff Room	4	5	20
5	Storage Room	4	6	24
		Total Fuelling area		301

4.2.1.4 Washing

Washing facility is located towards the east of the site along with the underground water tank and recycled water tank storage. The buses would be cleaned internally on a daily basis at their respective parking bays. The washing time required for each bus is 7 minutes i.e. 72 buses can be washed on one bay per 8 hours' work-day. Usual practice suggests that each bus be washed externally every second day, to save water. Manual wet mopping is undertaken on days when the bus is not washed. Hence, 50% of the total buses i.e. 110 buses should be washed daily, thus requiring 2 washing bays.

Table 33: Area calculations of washing bays and underground water storage tank

Rooms	Length (m)	Breadth (m)	No. of bays	Area (sq. m.)
Washing Bays				
Washing bay	15	4	2	490 (including circulation)
Storage tank	7	3.1	--	21.7
Recycle plant	10.7	3.1	--	33.2
		Total Washing area		545 sq. m.

For washing each bus, 150 litres of water are consumed i.e. for 110 buses, 16,500 litres of water are required. The storage of this water requires underground water storage tank of volume in excess of 33 cu.m. Total ground coverage for washing area is estimated as 490sq. m. which includes 2 washing pits, 150 sq.m. each (15 m X 4 m each plus 30% circulation), underground water storage tank of volume 33 cu. m. and water recycling plant area covering 33.2 sq.m. (Table 33). Figure 43 and Figure 44 illustrates the plan and view of the washing area.

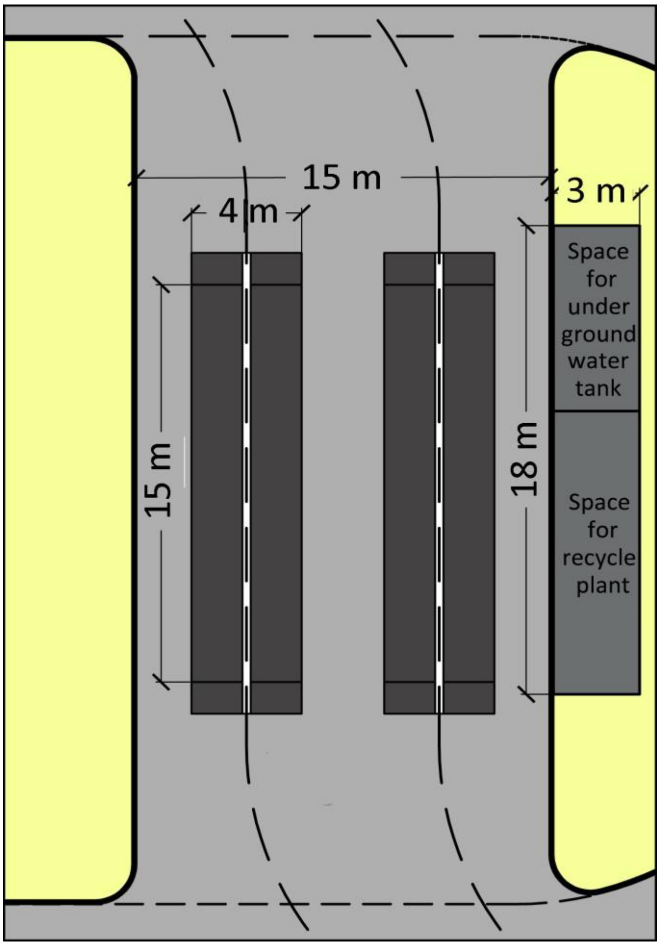


Figure 43: Plan showing washing area

Figure 44: View of washing area showing gantry washers

4.2.2 Bus Maintenance Facility Functions

Bus maintenance in a depot is carried out in the workshop area. Workshop and maintenance zone is facilitated with mandatory infrastructure elements like pits (inspection pits, preventive maintenance pits, and driver complaint pits); stores; and workshop sections (body shop, gear shop, tire retreading area). This bus maintenance related infrastructure is incorporated in the design proposal as per the requirements listed in the following sections.

4.2.2.1 Workshop and Maintenance Area

In the proposed layout design, the workshop is located on the west side, adjacent to the washing area, and in the middle of the bus parking area. Parking bays are arranged on the northern and southern side of the workshop area. All the functional spaces required in a workshop are accommodated in two floors (Figure 45 and Figure 48). It covers an area of 2,194 sq. m. on the ground floor and 180 sq. m. on the first floor.

- Pits required for inspection chamber - 100% of the operational fleet should be inspected daily. Since the buses scheduled for servicing/workshop visits due to driver complaints will in any case be inspected on a given day, it is estimated that 85% of total fleet strength will need to visit the inspection pit on a daily basis. Inspection of each bus requires 10 minutes; thus, one inspection pit can cater 48 buses in an 8 hours' shift per day. To cater 85% of total buses operated per day (170 buses), four inspection pits are required (Table 34).

Table 34: Calculations for inspection pits

Inspection Chamber	Value	Unit
Total no. of buses operated/catered	200	Buses
No. of buses visiting inspection pits daily (85%) (a)_	170	Buses
No of buses one pit can cater in one day (b)	48	Buses
No. of inspection pits required (a/b)	4	Pits

- Pits required for preventive maintenance - As mentioned in the previous chapter, 10% of the total operating buses require preventive maintenance per day. Given that the estimated time for catering one bus is two hours, one preventive maintenance pit can cater four buses in an 8 hours' shift per day. Thus, five preventive maintenance pits are required in all, for catering 10% of the fleet i.e. 20 buses (Table 35).

Table 35: Calculations for preventive maintenance

Preventive maintenance pits	Value	Unit
Total no. of buses operated / catered	200	Buses
No. of buses visiting workshop pits/preventive maintenance pits daily (10%) (a)	20	Buses
No of buses one pit can cater in one day (b)	4	Buses
No. of workshop pits/preventive maintenance pits required (a/b)	5	Pits

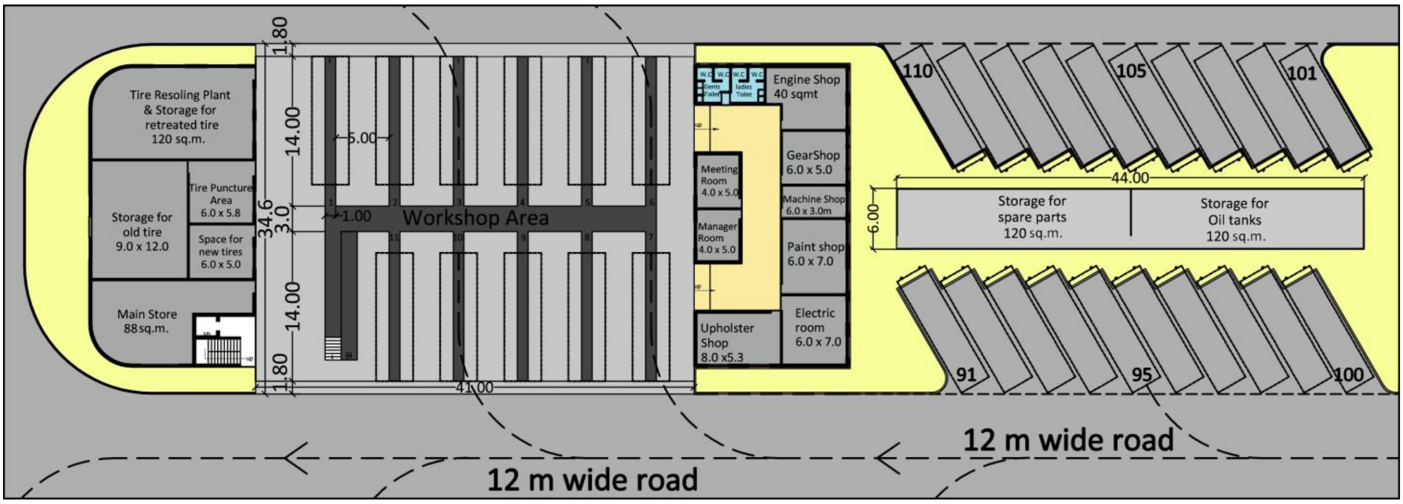


Figure 45: Plan showing bus maintenance facility (ground floor)

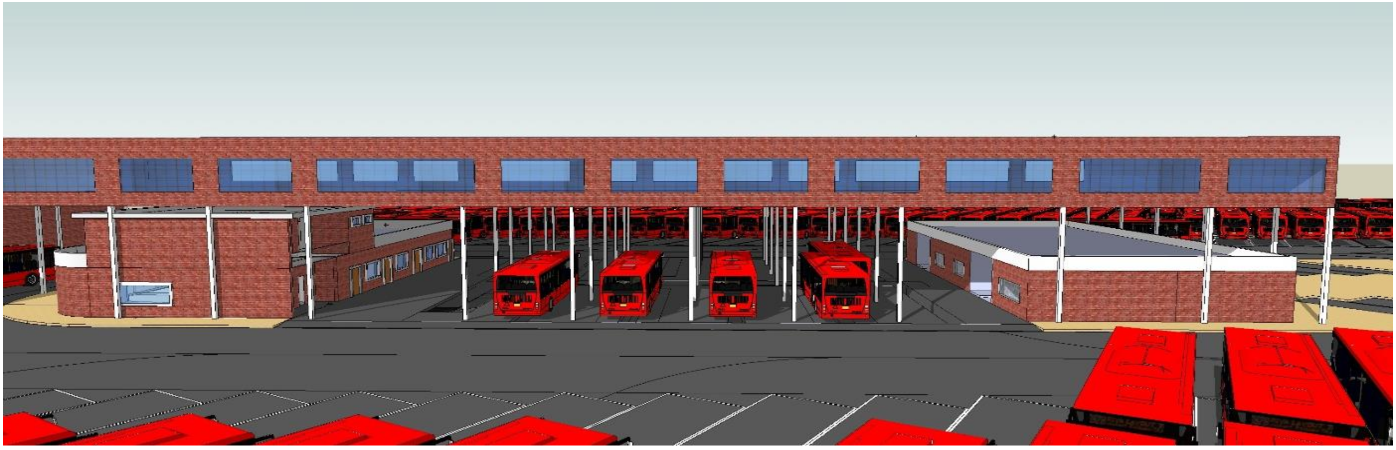


Figure 46: View of bus maintenance facility

Figure 47: View showing body section

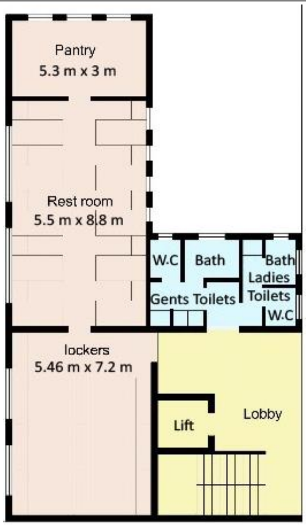


Figure 48: Plan showing bus maintenance facility - first floor

- **Pits required for catering driver complaints -** On an average, 5% of the operational fleet strength registers driver complaints per day. It takes an average of 1.5 hours to repair each bus. Thus, in a 12 hours' slot for workshop activities per day, one pit can cater eight buses (Table 36).

Table 36: Calculations for driver complaints pits

Driver's complaints/breakdown buses	Value	Unit
Total no. of buses operated/catered	200	Buses
No. of buses per day	8	Buses
No. of driver complaint pits required	1	Pits

Basis the above estimate a total of 10 pits have been provided in the workshop.

- **Workshop Administrative Zone -** Area details of pits, administrative area, inspection zone, body shop zone, and preventive maintenance zone are presented in Table 38.
- **Storage area -** Tire storage area consists of two rooms i.e. new tire storage room and old tire storage room (Table 37).

Table 37: Area requirements of storage area

No.	Area	Length (m)	Breadth (m)	Area (sq. m.)
1	New tire storage	6	5	30
2	Storage for old tire	9	12	108
			Total area for storage	138 sq. m.

Table 38: Area calculations of workshop and maintenance facility

Nos.	Particulars	Length (m)	Breadth (m)	Area (sq. m.) Including circulation
		Ground Floor		
		Pits - Total no. of pits - 11		
1	Pits + Circulation area	14	1	1,344
		Inspection zone		
2	Tire Resolving Plant & Storage	15	8	120
3	Puncture Section	6	5.8	34.8
		Body shop zone		
4	Upholster section	8	5.3	42
5	Electrical section	6	7	42
6	Painting section	6	7	42
		Preventive maintenance/Workshop area		
7	Gear shop	6	5	30
8	Engine shop	6.9	5.8	40
9	Machine room	6	3	18
		Administrative facilities		
10	Toilet	6.35	3.3	21
11	Workshop store	11.2	7.85	88
12	Manager room	4	5	20
13	Meeting room	4	5	20
			Total carpet area of ground floor	1,863
			Circulation area	192
			Total built up area of ground floor	2,055
		First Floor		
1	Workers' Rest Rooms	5.3	8.9	47
2	Lockers	5.5	7.2	40
3	Pantry	5.3	3	16
4	Toilet	5.7	3.4	19
			Total carpet area of first floor	122
			Circulation area	58
			Total built up area of first floor	180
			Total workshop built up area	2,235

4.3 Infrastructural Operations

Operational infrastructure includes facilities for depot management, as well as crew and staff facilities.

4.3.1 Administrative Facility Functions

The administrative block can be planned in a manner that controls the entry/exit of administrative staff and crew members, yet allowing important transactions between them for registration, in-shedding and out-shedding activities. The crew cannot enter the administrative staff seating area and the administrative rooms unless desired by administration, but can interact through a window provided towards the crew circulation corridor on the ground floor. Entry/exit to the crew rest rooms is provided from the external façade of the depot. This ensures controlled access to the depot (through the administrative block) and avoids unnecessary intrusions. Floor plans of administrative block are presented in Figure 51, Figure 52 & Figure 53.

4.3.1.1 Operational Block and General Offices

Operational block and general offices are located on the first floor of the administrative block. These are served through an exclusive lift and staircase. Functions provided for in the operational block as well as their respective areas are listed in Table 39.

Table 39: Area requirements for operational block &general offices

Operational block (ground floor)			
Requirements	Length (m)	Breadth (m)	Area (sq. m.)
Driver Control/Memorandum Room	3	5	15
Waybill Office/Cash Room (Control Room)	3	5	15
ETM Supervisor Room	3	5	15
ETM Charging Room	2	5	10
Lockers Room	15	7.15	107.3
Toilet	4.2	5	21
Area on ground floor			183
Circulation			132
Total area on ground floor			326
General offices (first floor)			
Depot Manager room	3	5	15
Concessionaire room	6.5	4.5	29
MIS room	8.3	5	42
Meeting room	4	5	20
Toilet	4.15	5	21
Canteen for depot staff members	9.9	4.5	45
Kitchen	3.3	3.6	12
Area on first floor			184 sq. m.
Circulation			89 sq.m.
Total operational block area			273 sq.m.

4.3.1.2 Staff facilities

Staff facilities include dedicated infrastructure for crew (including dormitories, cafeteria, lockers etc.) and for other depot staff (including parking, toilets, pantry etc.)

Crew and Other Staff Infrastructure - Crew rest rooms, locker rooms, and canteen are located on the first and second floors of the administration block. The crew is provided window access to administrative offices (for registration, in-shedding and out-shedding processes) through a covered veranda, at the ground floor on the southern edge of the administrative building (Table 40, Figure 49 and Figure 50).

Table 40: Area of staff facilities

Nos.	Rooms	Length (m)	Breadth (m)	Area (sq.m.)
1	Staff Restroom	--	--	165
2	Toilet	5.16	4.8	24.8
3	Canteen	10.8	5	54
4	Kitchen	4.4	5	22
Circulation Area				70
Total built-up area of first floor				336

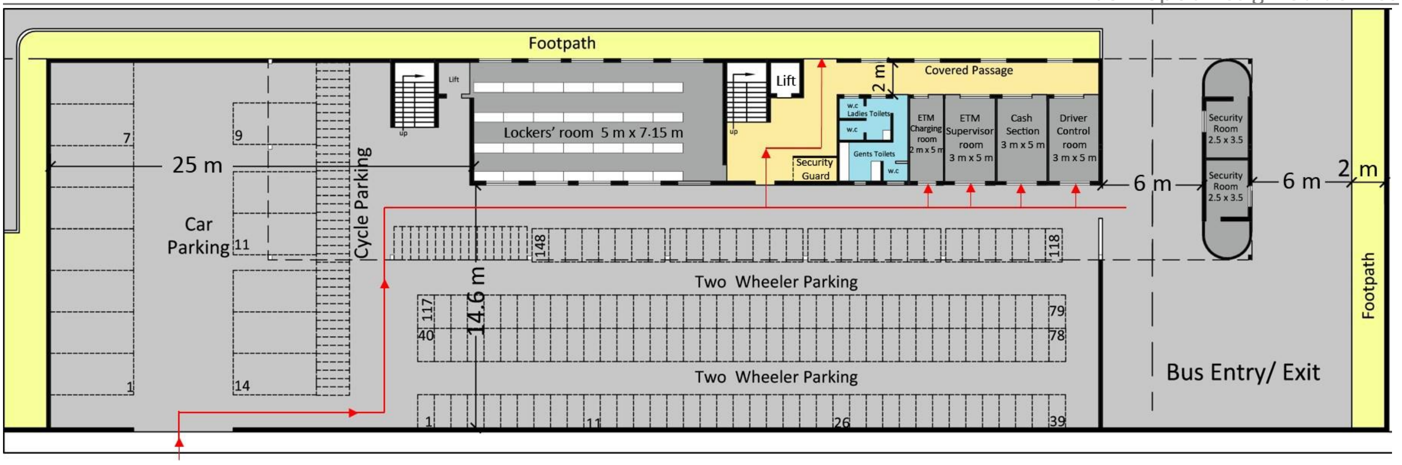


Figure 49: Part plan of operational block showing flow of crew in depot

The capacity for crew infrastructure is estimated based on the observed usage by 25% of the crew strength. This is because after the duty shifts, around 50% (of 25%)of the crew members opt to stay at the rest rooms (dormitories) while the rest return to their residence. Area estimates are presented in Table 41.

Table 41: Area of crew infrastructure

Nos.	Rooms	Area (sq. m.)
1	Crew Rest Rooms	467
2	Toilet	41
3	Circulation Space	120
	Total built up area of second floor	628 sq. m.

Figure 50: View of administration facility

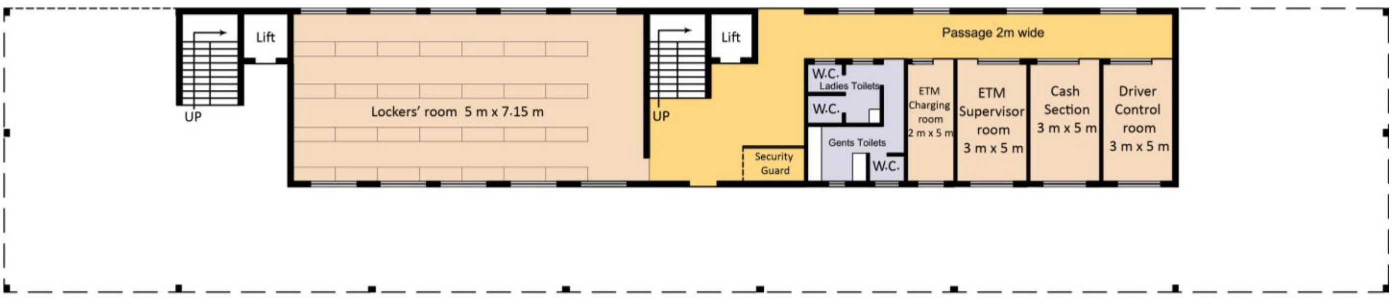


Figure 51: Administration block ground floor plan

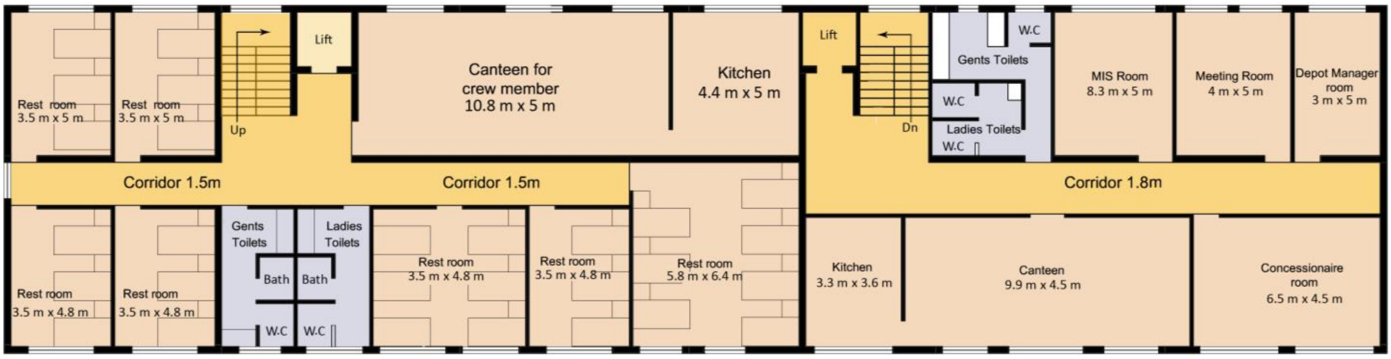


Figure 52: Administration block first floor plan

Figure 53: Administration block second floor plan

Figure 54: View showing staff and private parking

Staff Parking - Staff parking facility is located in front of the administration block within the setback. The capacity requirement for parking is worked out based on the number of workers employed. The workers are comprised of all drivers, conductors, shunters, workers and officials. Of the total workers and crew, approximately 40 to 50% are likely to be nearby residents and 25% access the depot by bus or other forms of public transport. Thus, only 25 to 35% require parking facilities at the depot. Of these, it is expected that 25% shall use motorised two wheelers and 10% may use bicycles. A depot usually employs a minimum of 5 depot officials who commute mainly by official or personal cars. Thus, five car spaces for depot officials, and five for visitors, i.e. a total of 10 four-wheelers parking spaces, are required. The rest of the area can be assigned for two-wheelers' parking for the remaining 148 staff members. As per parking norms, 1 ECS per car, 0.25 ECS per two-wheeler, and 0.1 ECS per bicycle is considered for staff parking area. Parking area estimates are presented in Table 42.

Table 42: Parking requirement estimation based on staff numbers

Item	Data for primary shift
Workshop staff	67[10]
Fuelling staff	3[11]
Washing staff	3[12]
Crew numbers	400[13]
Admin support staff	10[14]
Total Staff	523
Minimum 2-wheeler parking requirement (25% of total no. of staff)	131[15]
Minimum 4-wheeler parking requirement	10[16]
Minimum bicycle parking requirement (10% of total staff)	52[17]
Total staff parking numbers required (ECS)	48[18]
Total Staff parking area required (sq. m.)	1,104[19]

Figure 55: Another view showing administrative facility with private parking

[10] 1 staff member for every 3 buses catered at the depot (excluding standby buses)
[11] 1 per fuel dispenser plus 1 supervisor
[12] 1 per washing bay plus 1 supervisor
[13] 2 crew members per bus (including standby buses)
[14] Admin support staff requirement is standard 10 for any depot size
[15] 25% of total crew and workers (in the primary shift)
[16] 5 for administrative officers (or senior admin staff) and 5 for visitors
[17] 10% of total crew and workers (in the primary shift)
[18] 10 x 1(ECS) + 131 X 0.25(ECS) + 52 X 0.1 (ECS)
[19] 48 (ECS) X 23 sq. m.

Figure 56: Site of typical design layout of bus depot

5 Financing

Supportive infrastructure like bus depots play a critical role in the success of the public transport system. Sound financial planning is significant for long term viability of any public transport infrastructure. Effective strategies must be developed towards ensuring that the system is as financially independent as possible and entails little or no funding from the government. This enables the public transport authority to take important decisions with less influence from dogmatic parties. Revenues can be used to improve the infrastructure subsequently resulting in various benefits. This chapter discusses the financial aspects involved in bus depot development. It covers the funding mechanism as well as various financial models which could be considered for processing the capital, operations and maintenance cost.

5.1 Funding Mechanism

Depots in India have traditionally been developed under 'Public Ownership'. The public transport operator is typically the sole funder, developer and operator of the depot. However, increasing financing needs of public transport and its quality of service has raised the demand for private financing of depot infrastructure.

Financing structuring of a bus depot presents multi-dimensional challenges (Kharola, 2008). Unlike other urban transport infrastructure elements like bus terminals, bus stations and stops; bus depot development involves continuous engagement on operation and maintenance (O&M). Therefore, they require greater engagement of the developer compared to mere infrastructure development. This is why bus depots have not been able to attract adequate investment or generate financial resources as build operate and transfer/own (BOT/BOO) method of Public Private Partnership (PPP). Bus depots' low potential to attract investments is attributable to several causes - unsupportive policy environment, fragmented institutional framework, poor planning, operational inefficiencies, use of outdated technology and equipment, managerial inadequacies, and to some extent labour unrest. Financing of depots in a design and build mode (DB), in which the developer retains a portion of land and/or FAR to finance the development of the depot, is also found problematic given that land is scarce for most depots, and the development faces regulatory hurdles such as Floor-Area ratio (FAR) restrictions.

But in recent times, the introduction of modern and smart maintenance techniques, advanced architecture, and attractive facilities such as commercial development within the depot has inspired fresh interest in developing a financial model based on aligning the interests of private investors and the publicly owned transport undertakings. Towards this, the Indian government is considering the approach of private participation in the funding of capacity building in depots, through PPPs, commercial banks' lending, take out financing, infrastructure financing institutions, infrastructure debt funds, external commercial borrowing, foreign direct investments etc. (UMTC, 2013).

However, the potential to raise investments through these options may still be limited because currently the financial structure of a bus depot is characterised by limited recourse funding i.e. investors can be repaid only through the revenue generated by the project (Department of Industrial Policy and Promotion). Despite the limitation, depots can be turned into a potential investment attractor by increasing efficiency and using modern technology to reduce land requirement and O&M costs. Efficiency in a depot depends on the efficiency of its operations, fleet size catered, operational hours, type of equipment used, and manpower deployed. These factors also play a critical role in land requirement for a depot and thus also influence depot financing and revenue generation. The following sections discuss means of improving financial efficiency of depots and options for raising private sector financing.

5.1.1 Improving Financial Efficiency

Bus depots are highly labour, fuel and equipment intensive (Kharola, 2008). These amount to about 80% of the depot operating cost. Obsolete technology, inadequate maintenance, inappropriate fuel pricing mechanism, and insufficient investment in manpower are among the issues to be mitigated, to improve depot efficiency. Policies and practices directed to mitigate these issues are likely to lead to significant cost savings, making bus depot development an attractive option for private investments.

One such way in which policies can be helpful is by treating depots as privately-operated workshops, under a contract (such as BOT) on the land owned by the Public-Sector Undertaking. This will allow a private developer to improve the utilization of depot infrastructure by catering to private operators during day time or off-peak hours. The developer will recover his capital and operational cost by charging for service and maintenance of each bus under a mutually agreed arrangement – such as annual monthly or kilometre operated. Such an approach will not only improve the maintenance and service quality of buses (including private buses), it will significantly increase the financial efficiency of the depot, making investments in its development, an attractive option for private investment.

5.1.2 Private Sector Financing

Several forms of PPP arrangements can be considered for construction and O&M of depot infrastructure. In each of these arrangements, the government authority (such as the STU) is responsible for acquiring land for depot development, planning the design, setting standards for operations, acquiring requisite clearances, and preparing request for proposals (RFPs) for procurement of private operator services.

For modern bus infrastructure including terminal and depots, there are different models suggested for private sector financing (Deloitte, 2016) . The models are presented below:

5.1.2.1 Build-Operate-Transfer (BOT) Model

In this model, the concerned authority acquires land, provides specifications for the design and layout of depots, and hires a private player that constructs the facility and operates it over the concession period before transferring it to the authority. The construction and operational costs are borne by the private player, and revenues accrue to the same.

Bidding Parameter - Bidding parameters are based on the net present value (NPV). The highest NPV of upfront and recurring premiums payable by the operator is considered the winning bid, with the premium payment terms defined by the authority.

Project Feasibility - A positive NPV for a 30-year concession period indicates that the project is financially feasible.

5.1.2.2 Activity-wise Service Contract

In this model, each activity in depot operations (depot management including security, commercial exploitation of depot space including advertisement, management of revenue collection etc.) is outsourced separately to private players. Revenues accrue to the authority and private operators are paid a fixed, pre-determined monthly fee.

Bidding Parameter - The least cost quoted for each activity is considered the winning bid.

Project Feasibility - A positive NPV for a 5-year concession period indicates that the project is financially feasible.

5.1.2.3 Composite Service Contract

In this model, all O&M activities in the depot are outsourced to a single private player. The revenue generated is retained by the authority and private operator is paid a fixed, pre-determined monthly fee.

Bidding Parameter - The least cost quoted for the entire operational component is considered the winning bid.

Project Feasibility - A positive NPV for a 5-year concession period indicates that the project is financially feasible.

5.1.2.4 System Management Contract

In this system, the selected competent private operator is given complete responsibility for O&M and all other activities of the depot, as per standards set by the authority on an assigned piece of land (owned by the government agency). The operational costs are incurred and revenue is collected by the private operator. Revenue is typically collected from the operator on a per bus per visit basis (or a per bus basis). Additionally, the operator may generate revenue through other non-depot activities such as real estate development, advertisements etc. This model is beneficial in that it allows multiple operators to use the same facility.

Bidding Parameter - The least system management fees or bus management fees quoted by the private player, or the maximum revenue sharing promised to the authority is considered the winning bid.

Project Feasibility - A positive NPV for a 5-year concession period indicates that the project is financially feasible.

5.2 Leveraging Private Sector Financing

Private sector financing supports in easing budgetary constraints, improving value for money, sharing of risks between public and private partners, reducing overall project cost, improving efficiency in project delivery, and providing technologically advanced services (Shakti Foundation, 2016).

For this, a variety of financing and funding options related to operations and infrastructure can be explored. These include techniques for generating resources through allied activities, that can make the bus depot financially sustainable. Each of these options is discussed in detail below:

5.2.1 Commercial Utilisation of Land

Commercial utilisation of vacant land can be used to leverage private sector financing in depot development, through the following means:

a. Adding commercial/office spaces in the depot complex and utilising the property rentals and advertisement charges to help finance operations.

b. Some depots generate revenue from parking charges by operating as private vehicle parking lots in non-operational hours.

c. Revenue can also be generated through parking rentals of private buses, by allotting a designated area for a limited private fleet in the depot complex.

5.2.2 Transfer of Development Rights

Transfer of Development Rights (TDR) and FAR transfer is only permissible if the depot falls under the municipal corporation under state law. This points at the need for representation of urban local bodies in the depot institutional frame work. Where applicable, TDR transfer can be an effective mechanism to leverage finances for depot development. Land area under the depot can be augmented by acquiring land through transfer of additional FAR to the transferring parties. The augmented land can be used for increasing capacity and/or for use as a resource to raise finances.

5.2.3 Revised Institutional Arrangements

There are known inefficiencies in current institutional structure. This increases cost burden (for depot development, management and operations) and limits access to funds. These issues may be addressed through the following means:

1. Creation of dedicated depot fund - One organised body such as an established Special Purpose Vehicle SPV shall pool all the revenues generated by the depot, and use the same for development (and O&M) of the depot.

2. Reducing the burden of taxes such as taxes on acquisition of the land issued for depot provisions, taxes on importing equipment, property tax etc.

6 Annexure

6.1 Other Equipment

This section mentions the various equipment that were used earlier but were discarded following technology advancement, and the modern equipment being used in bus depots in other countries.

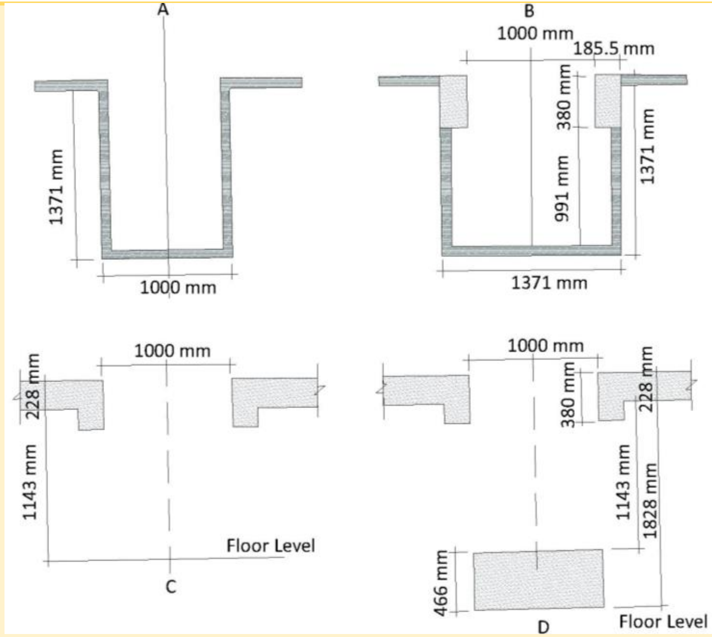
6.1.1 Workshop Equipment

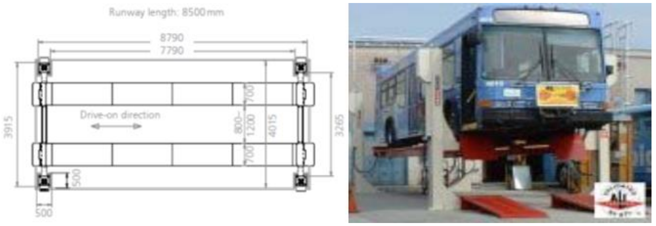
Various types of equipment are used in the workshop. Many of those applicable or recommended in the Indian context are mentioned in the equipment section in chapter three. A few types of equipment that have either been discarded or are quite new in terms of modern technology are mentioned in Table 43.

6.1.1.1 Lifts and Pits

Table 43: List of other workshop equipment

Name of equipment	Dimensions			Area (sq. m.)	Image
	Length (m)	Width (m)	Depth (m)		
Pits - A chamber inside the floor from where the underside of a vehicle can be examined and serviced					
Suspended ceiling pits	14	0.95 -1 (opening) 2.2 (overall width)	2.3	30.8	 *Source: (Everequip inspection pits, 2009)*
Pre-fabricated pits (or drop in pit)	14	0.95 (opening) 1.4 (overall width)	1.4	13.3	 *Source: (Everequip inspection pits, 2009)*
Cast in situ concrete (or brick pits)	14	1.1 (opening)	1.6	15.4	

Name of equipment	Dimensions			Area (sq. m.)	Image
	Length (m)	Width (m)	Depth (m)		
		1.6 (overall width)			 *Source: (Santosh, 2001)*
Lifting Equipment - Used for lifting the vehicle					
Sky Lift	Lifts vehicle of configuration up to 30 meters (100 feet) in length and weight of around 70,500 kg				 *Source: (Metro Magazine, 2016)*

<table>
<tr><th rowspan="2">Name of equipment</th><th colspan="3">Dimensions</th><th rowspan="2">Area (sq. m.)</th><th rowspan="2">Image</th></tr>
<tr><th>Length (m)</th><th>Width (m)</th><th>Depth (m)</th></tr>
<tr><td>Four Post Lift</td><td colspan="4">It is usually 304 m wide and can lift up to a height of 1.9 m.
Dimensions of one four post lift - 6.19 m (l) x 3.2 m (w) x 2.3 m (h)</td><td>

Source: (Stertil-koni, 2016)</td></tr>
<tr><td>Mobile Column Lift</td><td colspan="4">It can lift a load of about 7,000 kg to 18,000 kg per column. Its mechanical locking system locks at just 12 cm and continues up the entire height of the lift every 3 cm.
Dimensions of one mobile column – 1.22 m (l) x 1.13 m (w) x 2.65m (h)</td><td>
Source: (Stertil-koni, 2016)</td></tr>
<tr><td>Eco Lift</td><td colspan="4">Its total lifting capacity is about 27,000 kg to 40,000 kg. It is designed with mechanical locks.</td><td>
Source: (Stertil-koni, 2016)</td></tr>
<tr><td colspan="6">In India, pits are preferred over lifts, for servicing. However, lifting solutions may be included (especially external mobile lifts) as standby arrangement for when bus servicing demand exceeds the number of pits available.</td></tr>
</table>

6.1.1.2 Lubricating Equipment

Mobile lubrication systems are being used in various countries but are relatively new and not used in Indian cities yet (Table 44).

Table 44: Mobile lubricating equipment

Mobile Lubrication System	• Can move around the workshop and lubricate vehicles at different locations • Comes in various sizes • Smaller mobile systems are mounted on a wheel carriage that can be pulled manually, while larger systems can fit at the back of a vehicle. • Beneficial for depots with external (outside the depot) bus parking yard	 *Source: (Levanta, 2016)*

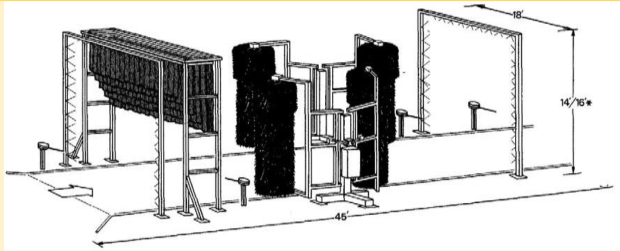
6.1.2 Washing Equipment

As mentioned earlier, there are two sets of washing equipment, one for interior washing and another for exterior washing.

6.1.2.1 Exterior Washing Equipment

Apart from automated gantry washers, washing equipment include drive through automated brush washers and mobile brush washers (specifications in Table 45). In India, this technology is yet to be explored.

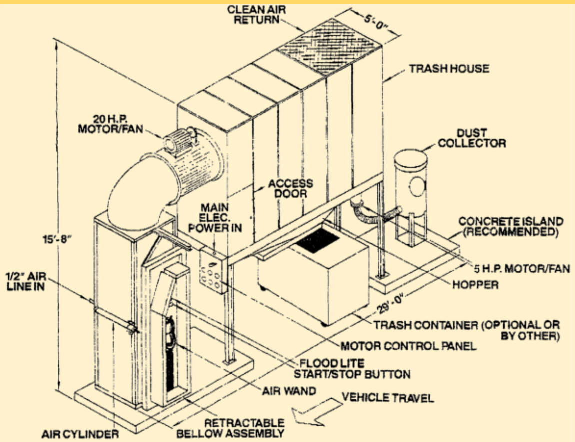
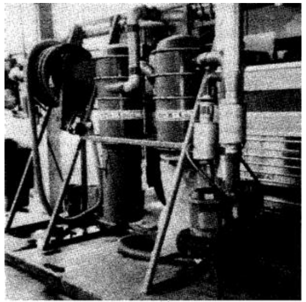
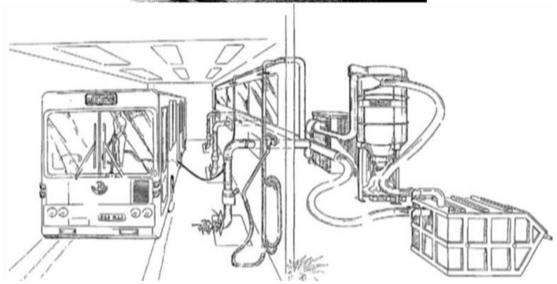
Table 45: Exterior washing equipment

Name of equipment	Dimensions	Description	Image
Drive through Automated Brush Washers	Equipped with 2-8 brushes	• used for exterior cleaning purpose • washer remains stationary, and the bus drives through it at a very slow speed • typically uses combination of rotating brushes and water/soap spray to clean the bus exterior • cost: INR 25 lakh (USD 37,220) *(Source: Kke Wash Systems Pvt Ltd.)*	 *Source: (Schiavone, 1995)*
Mobile Brush Washers	• Consume about 75 litres water and one litre cleaning solution per bus • Dimensions: 0.43 m (l) x 1.42 (w) x 2.29 (h)	• portable vehicle washing system • compact in size and can be transported from one location to another on a trailer or another vehicle • consists of a self-contained and self-propelled mobile brush washer that is driven around the bus while it remains parked in the storage area • cost: INR 2 lakh (USD 2978) *(Source: Kke Wash Systems Pvt. Ltd.)*	 *Source: (Vandamme, n.d.)*

6.1.2.2 Interior Washing Equipment

Interior washing equipment – As per Schiavone (1995), depots use equipment like cyclone washers and central vacuum systems. Of the two, the cyclone washer technology is around 30 years old. On the other hand, the newly introduced central vacuum systems with retractable hose (and other portable vacuum systems) represents a potentially improved version of interior cleaning devices (Table 46).

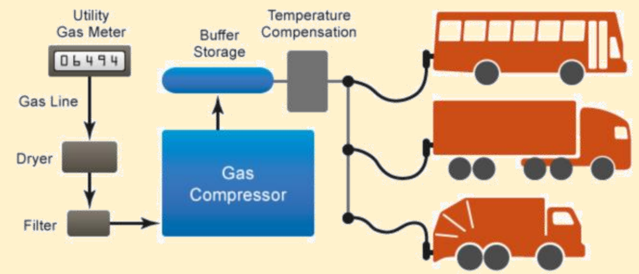
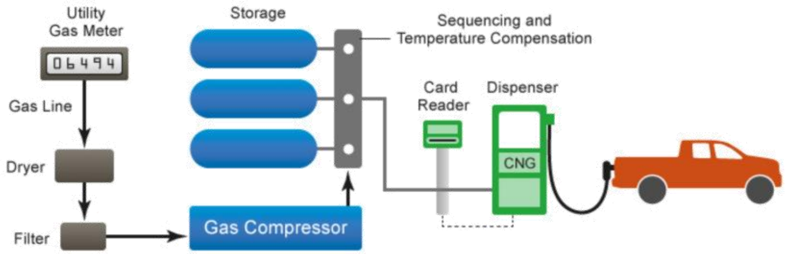
Table 46: Washing and cleaning equipment

Name of equipment	Dimensions	Description	Image
Cyclone Cleaners	Length - 8.8 m Height - 4.8 m	• used for cleaning the interior of buses • works on the vacuum and suction mechanism	 *Source: (Schiavone, 1995)*
Central Vacuum Systems	Total floor space occupied by the complete assembly: 4.4 m (l) x 1.75 m (w) x 5.8 m (h) (above the service island)	• an improved version of cyclone cleaners • equipped with a vacuum generator, fine filter, piping, and retractable reel mounted directly on the service line, all together as a self-contained unit • can be configured in a variety of ways to suit depot needs	  *Source: (Schiavone, 1995)*

6.1.3 CNG Fuelling Stations

In CNG fuelling station, there are three types of fuelling station which is being used in various depots have been explained Table 47.

Table 47: CNG fuelling station

Type of fuelling station	Description	Image
Time-fill fuelling station	• Best for depots where large no. of vehicles with large tanks refuel together at a central location every night • The size of the compressor depends on the size of the fleet catered by the depot, or the number of vehicles being fuelled simultaneously.	 *Source: (Alternative Fuels Data Centre, 2015).*
Fast-fill fuelling station	• faster than a conventional gasoline fuelling station; takes only 5 minutes to fill a 20-gallon tank • CNG fuel is often stored in vessels at a high service pressure (4,300 psi), due to which fuel is delivered speedily in the vehicle. The dispensers used to transfer CNG into the tank are equipped with a sensor system to calculate pressure and control the temperature (Alternative Fuels Data Center, 2015) • most suitable for lighter vehicles, therefore not recommended for bus depots; but can be provided as substitute to time fill stations for emergency service	 *Source: (Alternative Fuels Data Centre, 2015).*
Combination-fill fuelling station	- provides the option of time-fill or fast-fill, on demand: Many fleet use the convenience of time-fill as the primary method of fuelling, with fast-fill available (as needed). - This type of filling station suits depots that handle diverse functions. - For instance, if the depot includes a terminal facility, the discharge rate of the buses may be high during a particular time of the day. In such cases, the depot may need to be provided with a combination fill station.	

BFB

6.2 Electric Vehicles

EVs are powered by electricity and propelled by traction motors. They use electrical energy from on-board sources such as a battery or electricity generator connected to an ICE, or off-vehicle energy sources such as overhead lines (CStep, 2015).

According to the UNEP report (2014), there are basically four types of EVs:

1) Battery EVs (BEV): These are EVs that use only an electric motor, powered by on board- batteries, for propulsion.
2) Hybrid EVs (HEV): These are EVs that use an electric motor (secondary propulsion source) in combination with an ICE (primary propulsion source). On-board batteries provide energy to the electric motor while gasoline or diesel powers the ICE. In HEVs, batteries get recharged through either power from ICE or from regenerative braking (essentially, the small battery size allows for this continual recharging). HEVs that allow external charging of batteries are called Plug in HEVs.
3) Plug in Hybrid EVs (PHEV): These are HEVs with batteries of higher capacities and generally an electric motor as the primary propulsion source. These allow charging of on-board batteries.
4) Fuel cell EVs (FCEV): These are advanced EVs that are powered by energy obtained from a fuel cell instead of a battery. The fuel cell generates electrical energy by converting the chemical energy of a fuel such as hydrogen.

The advantages of electric buses are: reduced emissions (environment friendly), lower maintenance costs by eliminating expensive infrastructure, and greater flexibility. In contrast to more common buses (for instance with diesel engine), the battery buses offer zero-emission, quiet operation, better acceleration, and the ability to recover braking energy by a regenerative brake.

The disadvantages of electric buses are: limited range, higher weight, higher procurement costs and partly the additional downtime for charging or replacing the battery Table 48 presents the general comparison of all four types of buses.

Table 48: Comparison of four types of buses

Parameters	Battery electric bus	Hybrid bus	CNG bus	Diesel bus
Power source	Electricity	Electricity + fuel (diesel or CNG)	CNG	Diesel
Power generator	Battery	ICE + Battery	ICE	ICE
Costs (INR)	2.6 crores	> 3 crores	20-88 lakhs	20-88 lakhs
Fuel efficiency	1.5 kWh/km	2.75-4 km/L	2-3 km/kg	2.2-3.3 km/L
Fuel tariff	6.95 INR/kWh	50 INR/L	40 INR/kg	50 INR/L
Fuel cost (INR)	10/km	13-17/km	13-20/km	15-23/km
Emissions	Zero (local)	Low (less CO2, SOx, NOx &Non-Methane Hydrocarbon)	Low (equal CO2, Less SOx, NOx & Non-Methane Hydrocarbon)	High (baseline)
Noise	Minimum (at slow speeds)	Low (at slow speeds)	High	High (baseline)
Benefits	High	Moderate	Low	Low
Major cost share in TCO	Depreciation & financing cost	Depreciation & financing cost	Fuel	Fuel
Maintenance	Lowest	High	High	High
Components	EV propulsion system, transmission, battery charging system, power accessories, body	ICE propulsion & EV propulsion system, transmission, battery charging system, power accessories, body	ICE propulsion system, transmission, power accessories, body	ICE propulsion system, transmission, power accessories, body

6.3 Ready Reckoner

The following ready reckoners apply to small to large bus depots.

Table 49 includes the areas of bus management facility i.e., parking, fuelling and washing area.

Table 49: Ready reckoner for parking, fuelling and washing facilities

No. of buses	Buses catered or operated	Total buses	Bus Management Facility									
			Parking		Fuelling					Washing		
					Diesel buses			CNG buses				
As per Depot requirement	(Total buses + 10% future expansion) - 10% standby buses	No. of buses for which all facilities except workshop should be de-signed	Total parking space required in a depot for buses (Sq. m.) **A**	Total area required for staff and pri-vate parking (Sq. m.) **B**	No. of dispensers	Building foot-print of fuelling area (Sq.m.)	Underground tank capacity (Cu.m.)	No. of dispensers	Building foot-print of fuelling area (Sq.m.)	No. of bays required	Proposed under-ground storage tank capacity (Cu.m.)	Building foot-print of wash-ing facility (Sq. m.) **C**
40	40	44	3980	440	1	227	20	1	227	1	10	210
60	60	66	5960	540	1	227	30	2	366	1	10	210
80	80	88	7920	640	1	227	40	2	365	1	10	210
100	100	110	9890	730	2	373	50	3	511	1	20	210
120	120	132	11850	830	2	373	60	3	511	1	20	210
140	140	154	13810	930	2	372	70	4	649	2	20	420
160	160	176	15760	1020	2	372	80	4	648	2	30	420
180	180	198	17720	1120	2	372	90	5	785	2	30	420
200	200	220	19670	1210	2	372	100	5	785	2	30	420
220	220	242	21620	1310	3	517	110	6	930	2	40	420
240	240	264	23570	1410	3	517	120	6	930	2	40	420
260	260	286	25520	1500	3	517	130	6	929	2	40	420
280	280	308	27470	1600	4	662	140	7	1074	3	50	630
300	300	330	29410	1700	4	662	150	7	1074	3	50	630
320	320	352	31360	1790	4	662	160	8	1211	3	50	630
340	340	374	33300	1890	4	661	170	8	1210	3	60	630
360	360	396	35240	1980	5	806	180	9	1355	3	60	630
380	380	418	37190	2080	5	806	190	9	1355	3	60	630
400	400	440	39130	2180	5	806	200	10	1491	4	70	840
420	420	462	41070	2270	5	806	210	10	1491	4	70	840
440	440	484	43010	2370	6	951	220	11	1636	4	70	840
460	460	506	44950	2470	6	950	230	11	1635	4	80	840
480	480	528	46890	2560	6	950	240	11	1635	4	80	840
500	500	550	48820	2660	6	950	250	12	1771	4	80	840
520	520	572	50760	2750	6	950	260	12	1771	4	90	840
540	540	594	52700	2850	7	1094	270	13	1915	5	90	1050
560	560	616	54640	2950	7	1094	280	13	1915	5	90	1050
580	580	638	56570	3040	7	1094	290	14	2051	5	100	1050
600	600	660	58510	3140	7	1094	300	14	2051	5	100	1050

Table 50 includes the areas of bus maintenance facility i.e., workshop, storage, areas of administrative block facility and total building footprint, built up and site area.

Table 50: Ready reckoner for workshop, storage, administrative block facilities and site area

No. of buses	Buses catered or operated	Total buses	Bus Maintenance Facility								Administrative Block Facility				Total area			
			Workshop & Maintenance			Storage of tires	Total area of tire re-solving plant (Sq. m.)	Total area for storage of oil tanks (Sq. m.)	Total built-up area of bus maintenance facility (Sq. m.)	Building footprint of vehicle maintenance facility (Sq. m.)	Area for administrative block (Sq. m.)	Total area for crew infrastructure (toilet, canteen, kitchen, restrooms and locker room) (Sq. m.)	Total built-up area of administrative block facility (Sq. m.)	Building footprint of administrative block facility (Sq. m.)	Total building footprint of depot (Sq. m.) **D**	Site Circulation (sq. m.) **E**	Total built-up area (Sq. m.)	Total site area (Sq. m.) **(A+B+C+D+E)**
As per Depot requirement	(Total buses + 10% future expansion) - 10% standby buses	No. of buses for which all facilities except workshop should be designed	No. of pits required (breakdown pits, preventive maintenance pits, inspection pits)	Total area required for pits (Sq. m.)	Area of workshop (locker room, rest rooms, body section and toilets) (Sq. m.)	Total storage area (storage of new, retreaded, scrap, punctured and corrected tires) (Sq. m.)												
40	40	44	3	360	360	260	30	120	1130	1270	300	200	500	270	1770	1410	1860	7810
60	60	66	4	490	360	280	30	120	1280	1480	300	300	600	290	2000	1890	2110	10600
80	80	88	4	530	370	300	30	120	1350	1570	300	400	700	310	2110	2340	2280	13220
100	100	110	6	720	390	320	30	120	1580	1860	310	490	800	320	2550	2840	2750	16220
120	120	132	6	740	390	360	30	120	1640	1930	320	590	910	340	2640	3260	2920	18790
140	140	154	7	900	400	380	30	120	1830	2200	320	660	980	350	2920	3750	3180	21830
160	160	176	8	940	410	400	30	120	1900	2280	330	760	1090	370	3020	4150	3360	24370
180	180	198	9	1120	420	420	30	120	2110	2560	340	850	1190	380	3310	4570	3670	27140
200	200	220	10	1180	430	450	30	120	2210	2690	350	970	1320	400	3460	4950	3900	29710
220	220	242	11	1350	440	470	30	120	2410	2970	350	1070	1420	420	3910	5380	4350	32640
240	240	264	12	1410	440	490	30	120	2490	3080	360	1160	1520	430	4030	5740	4530	35170
260	260	286	13	1590	450	520	30	120	2710	3370	370	1250	1620	450	4340	6120	4850	37900
280	280	308	14	1650	470	540	30	120	2810	3480	380	1350	1730	460	4600	6520	5200	40820
300	300	330	15	1820	470	560	30	120	3000	3760	390	1440	1830	480	4900	6870	5490	43510
320	320	352	16	1880	480	590	30	120	3100	3880	390	1540	1930	490	5030	7180	5690	45990
340	340	374	17	2060	490	620	30	120	3320	4170	410	1640	2050	510	5340	7510	6030	48670
360	360	396	18	2120	500	640	30	120	3410	4270	420	1740	2160	530	5610	7820	6380	51280
380	380	418	19	2290	510	660	30	120	3610	4550	420	1830	2250	540	5900	8130	6670	53930
400	400	440	20	2350	520	680	30	120	3700	4660	430	1930	2360	560	6030	8430	6870	56610
420	420	462	21	2530	530	710	30	120	3920	4960	440	2020	2460	570	6340	8710	7190	59230
440	440	484	22	2590	540	730	30	120	4010	5070	450	2120	2570	560	6580	8980	7530	61780
460	460	506	23	2760	550	750	30	120	4210	5350	450	2210	2660	570	6870	9230	7820	64360
480	480	528	24	2820	550	780	30	120	4300	5470	460	2320	2780	590	7010	9450	8030	66750
500	500	550	25	3000	570	800	30	120	4520	5750	470	2410	2880	600	7300	9690	8350	69310
520	520	572	25	3060	580	820	30	120	4610	5870	480	2510	2990	620	7440	9890	8550	71680
540	540	594	27	3230	580	850	30	120	4810	6150	490	2600	3090	630	7870	10150	8990	74620
560	560	616	27	3290	590	880	30	120	4910	6270	490	2690	3180	650	8010	10330	9180	76980
580	580	638	29	3470	600	900	30	120	5120	6550	500	2790	3290	660	8300	10520	9500	79480
600	600	660	29	3530	610	920	30	120	5210	6660	510	2890	3400	680	8430	10670	9700	81800

6.4 Maintenance schedule for electric bus

Periodic Maintenance Schedule													
Category	Activity	1000km	5000km	10000km	20000km	40000km	60000km	80000km	100000km	120000km	14000km	160000km	200000km
		15Days	2months	3months	6months	12months	18months	24months	30months	36Months	42Months	48Months	54Months
PTU Assembly													
PTU Assembly Casing, motor Condition	Inspect for any damages	I	I	I	I	I	I	I	I	I	I	I	I
PTU Front & Rear Casing Allen Bolt	Inspect & Tighten PTU Front & Rear Casing Allen Bolt	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T
PTU Assembly Oil Seal Condition (seals on Main gear, Pinion & PTU front and rear housing interface)	Inspect for leakage, Correct and top-up Oil if required.	I & C	I & C	I & C	I & C	I & C	I & C	I & C	I & C	I & C	I & C	I & C	I & C
All Motor Flange Mounting Bolts	Tighten Motor Flange Mounting Bolts.	T	T	T	T	T	T	T	T	T	T	T	T
All Motor Condition (Abrupt Noise, Damages etc.)	Inspect for Any Damages or Abrupt Noise.	I	I	I	I	I	I	I	I	I	I	I	I
PTU Assembly Mounting Brackets (Inspect Torque Marking)	Tighten PTU Mounting Bracket Bolts.	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T
PTU Assembly Bush Condition	Inspect for Any Damage If Require take Necessary Action	I	I	I	I	I	I	I	I	I	I	I	I
PTU Extended housing mounting bolts	Tighten to the specified torque	T	T	T	T	T	T	T	T	T	T	T	T
Center bearing on 1st propeller shaft	Inspect for any damage & replace if damaged	I	I	I	I	I	I	I	I	I	I	I	I
PTU Output flange bolts	Tighten to the specified torque	T	T	T	T	T	T	T	T	T	T	T	T
Extended housing bearing retainer nut & Flange retainer nut	Inspect if it has moved from initial tightened position	I	I	I	I	I	I	I	I	I	I	I	I
PTU Main gear Allen bolts	Tighten to the specified torque	T	T	T	T	T	T	T	T	T	T	T	T
PTU Oil Level	Inspect for Leakage. If required Top-Up.	I	I	I	R	R	R	R	R	R	R	R	R
PTU breather Condition	Inspect Breather Choke up Condition.	I	I	I	I	I	I	I	I	I	I	I	I
	Inspect for Leakage. If required Top-Up.												
PTU drain plug Condition	Inspect for Leakage. If required Top-Up.	I	I	I	I	I	I	I	I	I	I	I	I
PPU Assembly													
PPU Mounting Bracket Condition	Inspect for Any Damage. Tighten Mounting Bolts.	I	I	I	I	I	I	I	I	I	I	I	I
Battery Pack Mounting condition	Inspect for Any Damage. Tighten Mounting Bolts.	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T
All electrical component mounting base bracket condition	Inspect for Any Damage. Tighten Mounting Bolts.	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T
ECU mounting Condition	Inspect for Any Damage. Tighten Mounting Bolts.	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T

Fuse & Relay Box, contactor, fuse Mounting Condition	Inspect for Any Damage. Tighten Mounting Bolts.	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T	I & T
All Power Cable Condition	Inspect For looseness, if observed take necessary action.	I	I	I	I	I	I	I	I	I	I	I	I
All Wiring Harness condition	Inspect for Any Damage.	I	I	I	I	I	I	I	I	I	I	I	I
BUS Dashboard													
HMI display Working Condition	HMI Functionality.	I	I	I	I	I	I	I	I	I	I	I	I
System ON-OFF switch Working Condition	ON-OFF Functionality.	I	I	I	I	I	I	I	I	I	I	I	I
Brake Pedal Connection Condition	Inspect Brake Paddle Sensor for Damage	I	I	I	I	I	I	I	I	I	I	I	I
Throttle Connection Condition	Inspect Brake Paddle Sensor for Damage	I	I	I	I	I	I	I	I	I	I	I	I
Cluster Interface unit	Inspect for all Indication Functionality	I	I	I	I	I	I	I	I	I	I	I	I
BUS Dashboard													
HMI display Working Condition	HMI Functionality.	I	I	I	I	I	I	I	I	I	I	I	I
System ON-OFF switch Working Condition	ON-OFF Functionality.	I	I	I	I	I	I	I	I	I	I	I	I
Brake Pedal Connection Condition	Inspect Brake Paddle Sensor for Damage	I	I	I	I	I	I	I	I	I	I	I	I
Throttle Connection Condition	Inspect Brake Paddle Sensor for Damage	I	I	I	I	I	I	I	I	I	I	I	I
Cluster Interface unit	Inspect for all Indication Functionality	I	I	I	I	I	I	I	I	I	I	I	I

Source: (KPIT Technologies Ltd., 2017)

Note:

1. I - Inspection, C - Cleaning, R- Replacement, and T - Tuning.
2. Maintain your electric vehicle or its parts as per the defined schedule to achieve the best in class range at or by authorized service provider only.
3. In case of vehicle maintained or service by non-authorized personnel may lead to void of warranty.
4. Maintenance of the Non EV Components should be done as per the base vehicle manufacturer recommendations and Impact is not responsible for Base Vehicle Maintenance.

7 References

AMC, A. M. (1999). *Vehicle operations and vehicle maintenance facilities design guide.* Directorate of Civil Engineering and Directorate of Logistics. Retrieved February 2016, from https://www.wbdg.org/ccb/AF/AFDG/vehicleoperationsmaintenance.pdf

Beal, V. (2016). Retrieved 05 2016, from Webopedia: http://www.webopedia.com/TERM/M/MIS.html

Bose, A. (2011). Retrieved 06 03, 2016, from http://www.nbmcw.com/products/car-parking/24450-multilevel-car-parking-systems.html

BUSRide. (2015, August 13). *www.issuu.com*. Retrieved from https://issuu.com/powertrademedia/docs/buswashing_ebook

Cambridge Systematics. (2016). *Improving Bus Fuel Efficiency Through fleet Management and Maintenance.* Cambridge Systematics.

Center, A. F. (2015). *afdc.energy.gov*. Retrieved from http://www.afdc.energy.gov/fuels/natural_gas_cng_stations.html

CROW. (1998). *ASVV.* The Netherlands, The Netherlands: CROW. Retrieved 10 05, 2016

CStep. (2015). *Electric Buses in India :Technology, Policy and Benefits.* Seoul.

Danpex, P. (2013). Retrieved from http://pilux-danpex.gr/downloads/Required_Light_LevelsEN.pdf

Deloitte. (2016, June 7). PPP in Urban Transport. India.

Eclipse, E. S. (2012). *http://eclipsephilippines.com/*. Retrieved from http://eclipsephilippines.com/hydroflow-oil-water-separators.php

Gupta, P. D. (2009). *Urban Mobility India.* Retrieved 06 03, 2016, from http://www.urbanmobilityindia.in/upload/conference/a0956f5d-467e-4bb0-bf67-787e04bdf6ec.pdf

Hamilton, J. (2011). *bls.gov*. Retrieved 06 07, 2016, from U.S. Bureau of Labor Statistics: http://www.bls.gov/green/electric_vehicles/

HARTEX Engineering. (2016). *hartexengineering*. Retrieved from www.hartexengineering.com.au: http://www.hartexengineering.com.au/workshop-pits/prefabricated-steel-pits.html

Ingersoll Rand. (n.d.). *ARO*. Retrieved 06 01, 2016, from http://www.arozone.com/content/dam/aro/aro-marketing-literature/diaphragm/exp/irits-1215-200_exp-catalog.pdf

JCTSL. (2015). *Promoting Public Private Partnerships (PPP) in Sustainable Urban Transport Infrastructure.* Jaipur.

Kashyap, A. (2012). *Slide share.* Retrieved 06 03, 2016, from http://www.slideshare.net/maverickadhar/multi-level-car-parking-in-india

Kharola, P. (2008). Financing Urban Public Transport . *IUT Journal* .

KPIT Technologies Ltd. (2017). *Periodical Maintenance Schedule.*

KSRTC, P. N. (2013). Public transport planning and data management. Karnataka: KSRTC. Retrieved 05 2016, from http://www.urbanmobilityindia.in/Upload/Conference/d0f7ee36-bccf-4543-8c65-f917f85708e7.pdf

Manvcac. (n.d.). *Alibaba.com*. Retrieved 06 02, 2016, from http://wholesaler.alibaba.com/product-detail/2-2kw-single-phase-220V-vacuum_60030649008.html?spm=a2700.7724857.29.143.iMSBFq

Mars, T. (n.d.). *Mars Technologies Inc.* Retrieved 06 01, 2016, from http://www.marstechnologies.co.in/emission-testing-equipmentautomobile-industry.html

Media, Wiki. (2016). *Wikipedia*. Retrieved 06 07, 2016, from https://en.wikipedia.org/wiki/Charging_station#Infrastructure

Ministry of Petroleum and Natural Gas. (2012, 09 05). *Storage and handling of petroleum products at depots and terminals.* Government of India, Oil Industry Safety Directorate, Noida, Uttar Pradesh, India. Retrieved 06 16, 2016, from http://oisd.nic.in/pdf/oisdstddraft244.pdf

Minnesota Department. (2012). *Greater Minnesota Public tansit facily,Guidebook.* Minnesota Department of transit.

NBC. (2005). *National Building Code of India.*

NBMCW. (2010). Retrieved 06 03, 2016, from http://www.nbmcw.com/products/car-parking/17803-r-r-parkon-multi-level-car-parking-systems.html

Parking Network. (2010). Retrieved 06 03, 2016, from http://www.parking-net.com/about-parking/parking-facilities

Prof. Madhuri K. Rathi, M. V. (2012). *Civil Engineering Portal*. (P. U. Department of Civil Engineering, Editor) Retrieved 06 03, 2016, from http://www.engineeringcivil.com/different-types-of-parking-spaces-and-multiple-level-car-parking.html

Rongbiao Welding Machine. (n.d.). Retrieved 03 2016, from http://www.slideshare.net/sueshung/rongbiao-welding-machine

S.Ponnuswamy, (. D. (2012). Urban Transportation : Planning ,Operation and Management. *Public Transportation - Bus Transport (MCgraw- hill Professional)*.

Santosh, K. (2001). *Productivity in Road transport.* New Delhi: Association of State Transport Undertaking (ASRTU).

Schiavone, J. J. (1995). *Transit Bus Service Line and Cleaning Functions.* Washington: Transportation Research Board.

Shakti Foundation. (2016, June 07). Promoting Public Private Partnerships (PPP) in Sustainable Urban Transport Infrastructure. Delhi, Delhi, India.

Stertil-Koni. (2016). Retrieved from http://www.stertil-koni.com/en/: http://www.stertil-koni.com/en/products/platform-lifts/skylift/platform_lift_sky250

Techno. (2016, January 11). *Techno Tools & Equipment SDN BHD*. Retrieved from Techno.com: http://techno.com.my/online/index.php?main_page=product_info&cPath=272_281_282&products_id=26436&zenid=9judqb475qovb9n6ueu7e5ea46

The World Bank Group and PPIAF. (2006). *Urban Bus Toolkit*. Retrieved from http://www.ppiaf.org/: http://www.ppiaf.org/sites/ppiaf.org/files/documents/toolkits/UrbanBusToolkit/assets/3/3.1/35(vii)b.html

Thorlux, L. (2011). Retrieved from canolux.com: http://www.canolux.com/howto

Towe Ireblad. (2012). *Design for new bus depots and adapt existing depots for biogas buses and hybrids.*

(2010). *Transport Planning & Design Manual.*

UMTC. (2013). *Financing options for urban transport projects - UNEP.* Retrieved from http://www.unep.org/transport/lowcarbon/Pdfs/Financing_options.pdf

UNEP. (2014, November). *unep.org.* Retrieved from United Nations Environment Program (UNEP): www.unep.org/transport/lowcarbon

Vandamme. (n.d.). *vendamme.eu*. Retrieved 06 02, 2016, from http://www.vandamme.eu/product/wasinstallaties/autonome-mobiele-wasborstel/

Wikimedia. (2016). *https://en.wikipedia.org/wiki/Hybrid_electric_vehicle*.

Wikipedia. (2015). *Wikipedia*. Retrieved 06 06, 2016, from https://en.wikipedia.org/wiki/Battery_electric_bus

Wikipedia. (2016, March 7 - 3- 2016). *Bus Garage.* Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Bus_garage

Zhongda Industrial Group Co. Ltd. (2016). *Bus Washing Machine*. Retrieved from www.tradeindia.com: http://www.tradeindia.com/fp21553/Bus-Washing-Machine.html

Abbreviations

AC	Alternating Current
BEV	Battery Electric Vehicle
BOT	Build Operate Transfer
BOO	Build Own Operate
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
DB	Design and Build mode
DC	Direct Current
DCS	Depot Computerization System
ECS	Equivalent Car Space
EIA	Environment Impact Assessment
EV	Electric Vehicle
EVCP	Electric Vehicle Charging Point
EVSE	Electric Vehicle Supply Equipment
FAR	Floor Area Ratio
FCEV	Fuel cell electric vehicles
FSI	Floor Space Index
GPRS	General Packet Radio Service
HVAC	Heating Ventilating and Air Conditioning
HEV	Hybrid Electric Vehicles
ICE	Internal Combustion Engine
ITS	Intelligent Transportation Systems
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KSRTC	Karnataka State Road Transport Corporation
KWH	Kilowatt-hour
LPG	Liquefied Petroleum Gas
MIS	Management Information System
MVI	Motor Vehicle Inspection
NBC	National Building Code
NPV	Net Present Value
O&M	Operations and Maintenance
PHEV	Plug in Hybrid Electric Vehicles
PLC	Programmable Logic Controller
PPIAF	Public Private Infrastructure Advisory Facility
PPP	Public Private Partnership
RFP	Request for Proposal
NUTP	National Urban Transport Policy
SPCB	State Pollution Control Board
STU	State Transport Undertaking
TDR	Transfer of development rights
UMTC	Urban Mass Transit Company Ltd.