Ministry of Housing and Urban Affairs
Government of India

सत्यमेव जयते

MANUAL

FOR PLANNING, DESIGN & IMPLEMENTATION OF CITY BUS DEPOTS

EFFICIENT & SUSTAINABLE CITY BUS SERVICES PROJECT (INDIA)

Ministry of Housing and Urban Affairs
Government of India

WORLD BANK

Efficient and Sustainable City Bus Services (*ESCBS*) Project

gef

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हरदीप एस पुरी
HARDEEP S PURI

सत्यमेव जयते

आवासन और शहरी कार्य राज्य मंत्री (स्वतंत्र प्रभार)
नागर विमानन राज्य मंत्री (स्वतंत्र प्रभार)
वाणिज्य एवं उद्योग राज्य मंत्री
भारत सरकार
Minister of State (I/C), Housing & Urban Affairs
Minister of State (I/C), Civil Aviation
Minister of State, Commerce & Industry
Government of India

Message

I am pleased that the Ministry of Housing and Urban Affairs, with assistance of World Bank and Global Environment Facility (GEF) has brought out this guidance document as a Manual on Urban Bus Depots Design principles, in keeping with the Government's vision of Minimum Government and Maximum Governance. The Manual, prepared in consultation with sector experts will enable city level Special Purpose Vehicles (SPVs), State Transport Undertakings (STUs) and private operators in developing required infrastructure for efficient and sustainable urban bus services.

Buses are an important component of Urban Transport and are integral to the engines of economic growth that our cities are. It is the endeavour of the Government to promote city bus transport and in this context, the Manual for Planning, Design and Implementation of Depots assumes significance. I am sure that this Manual will enhance understanding and form the backbone of process management of bus depots efficiently by synergising efficiencies among all stakeholders.

(Hardeep S Puri)

New Delhi
03 November, 2020

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MESSAGE

My Ministry initiated the Efficient and Sustainable City Bus Services (ESCBS) Project in 2016-17 with the assistance of World Bank and Global Environment Facility (GEF) for capacity building at national level and improving city-bus services in four demonstration cities of Mira Bhayandar, Bhopal, Chandigarh & Jaipur and develop systems to improve fuel efficiency of buses and in operations by the drivers and employ ITS and MIS for enhancing overall operational efficiency of city bus services. As part of the national capacity building initiative, the project has developed a **Bus Depot Manual** as a Guidance Document to optimize utilisation of resources deployed for the purpose.

Experts have studied available international and domestic literature and worked in collaboration with city bus operators of India's various cities in developing this Manual. It will be useful for those working on the ground to provide essential transit services to the citizens. This Manual could be used for training guidance and reference to all concerned stakeholders.

I encourage State Transport Undertakings (STUs), Transport Authorities and Special Purpose Vehicles (SPVs) for City Level Bus Service and Private Bus Operators to make the best use of the Manual in designing and utilizing the services of Bus Depots.

I congratulate National Project Manager, Sustainable Urban Transport Project (SUTP), Joint Secretary (Urban Transport), Delhi Integrated Multi-Modal Transport System Limited (DIMTS) and all others who contributed in preparing and reviewing this Guidance Document so that it reaches out to all concerned.

(Durga Shanker Mishra)

New Delhi
October 28, 2020

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FOREWORD

This Manual provides end-to-end guidance in the design and construction of depots for city bus operations. Depots are long-term investments that are critical to the efficient operations of city bus services. Careful and thoughtful design of new depots is important to the long-term sustainability of city bus services.

Unfortunately, there is limited guidance on depot design and construction for Indian cities. The Ministry of Housing and Urban Affairs funded the preparation of this Manual to address this knowledge gap. The goal of the Ministry for this Manual is to ensure that new depots will be properly designed and constructed and make best use of available funding.

The Manual is written for Clients and Designers of bus depot projects. The guidance in the manual is especially important for wide range of professionals who are developing a bus depot for the first time or have not done so for several years. These professionals may include:

- Makers of transport policy,
- City and transport planners,
- Heads of transport authorities,
- CEOs, maintenance managers, and operations managers of bus companies,
- Civil engineers and architects,
- Executives in other institutions that are engaged in public transport related activities.

The guidance in this Manual is based on analysis of international best practices and of professional literature devoted to bus depot planning, designing and construction. The guidance also reflects an analysis of selected city bus depots in India to identify gaps in their design that have limited operational efficiency. This approach was used to ensure that new depots are not replicated, designed and constructed based on a business-as-usual approach but on a solid footing of achievable best practice.

The Manual sets out a step-by-step process for all the stages, from the initial scoping of suitable sites through all aspects of design and on to construction phase. It contains practical guidance based on the best experience in India and elsewhere.

The Manual will not create a depot design, you must do that yourself. Rather, it gives you a process to follow and important insights, whether you are the Client or the Designer. It introduces you to all activities and facilities that must be provided for in a depot, how they should be arranged in relation to each other, and what factors to consider into account in the specific design.

A bus depot is a very dynamic place, in which people, vehicles and items are constantly in motion. The Manual addresses this important reality. However, the real life in a depot cannot be fully conveyed on paper. It is essential that you visit some depots after reading this Manual to fully appreciate the ground realities.

The Manual is structured to help users who are looking for guidance in a specific topic area. The Executive Summary gives a bird's eye synopsis of the manual with a navigable chart to take readers to the topic of their interest in greater detail. A back-of-the-book alphabetical index lists the key topics in **bold** and the sections or annexures (*italicized*) where they occur.

ACKNOWLEDGEMENT

Various SPVs and other fleet operators that came into being in the wake of the Government's support for acquisition of buses for urban transport, and the pre-existing public transport operators, often lack appropriate infrastructure in the shape of depots which are essential for efficiently coordinated deployment of well-maintained and reliable rolling stock. Capacity to plan, design and create this infrastructure is often been limited to dependence on legacy approach, methods and designs.

This Manual on Planning, Design, and Implementation of City Bus Depots for efficient bus operations is an outcome made possible by conceptual, technical and financial inputs from several individuals and institutions; including the Global Environment Facility (GEF) and the World Bank, and the Ministry of Housing and Urban Affairs, Government of India. Studies of international best practices and analysis of existing Indian city bus depots, including aspects of design which inhibit optimal utilization, have been useful information. The guidance that it provides in a consolidated document is an important segment of the Ministry's support to Efficient and Sustainable City Bus Services Project (ESCBS).

The insights gathered by the Ministry's Consultant – DIMTS (Delhi Integrated Multi-Modal Transit System Ltd.), in association with CIRT (Central Institute of Road Transport) – from on-site discussions with functionaries of bus operating organizations in Indian cities have been vital for understanding challenges around depot capacities and designs and how to resolve them in facilities to be built now.

The Project Management Unit of the Ministry headed by Mr. IC Sharma, has been of great help in securing the support of authorities in understanding bus operating environments of the Indian case-study cities and in keeping the project on track. Preparation of this Manual gained immensely from contributions of the World Bank's Senior Transport Specialist, Ms. Nupur Gupta, Bank's expert, Mr. Brendan Finn, Mr. Sudesh Kumar, Team Leader from Mott MacDonald Private Limited, Mr. N. Sangappa, bus expert of PMC team and Mr. Abhijit Sarkar, Training Expert of the PMC's team. It would not be possible to cite contributions from individuals of eminence brought on a panel for expert advice and suggestions from various associated members of the bus fraternity, it must however be acknowledged that this is the outcome of collective endeavour.

BUS DEPOT LAYOUT - 3D ILLUSTRATION

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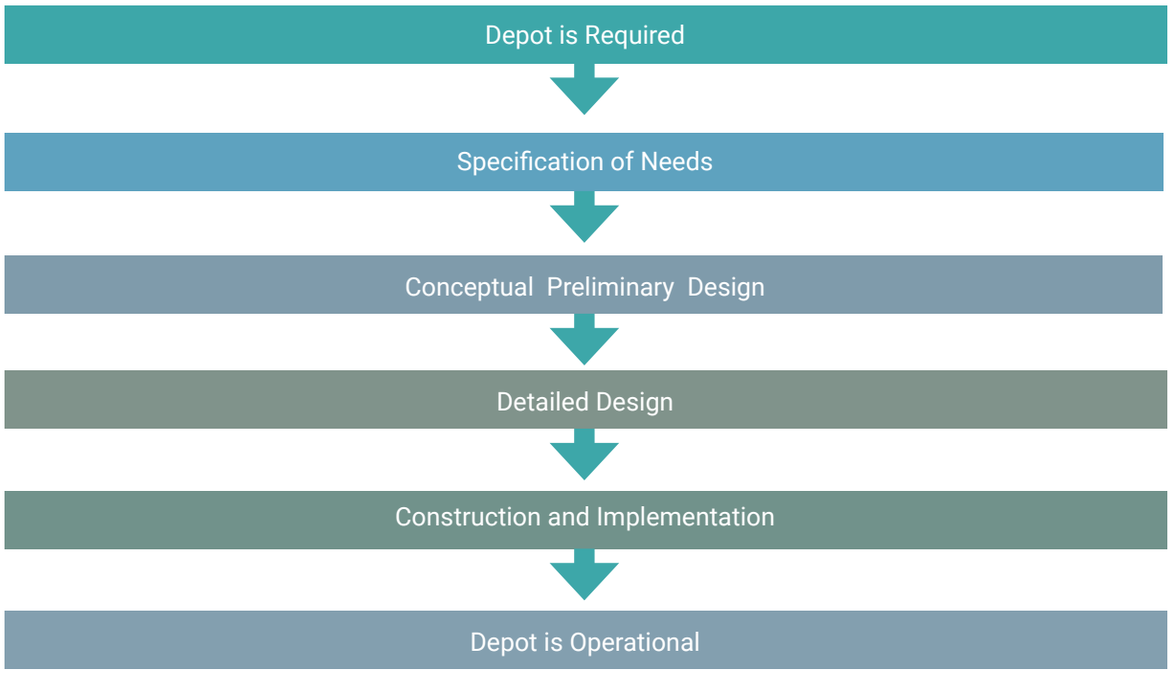
EXECUTIVE SUMMARY

The guidance this Manual provides on planning, design and construction of city bus depots is targeted at Clients and Designers of bus depot projects, especially those who are developing a bus depot for the first time or those who have not developed a depot recently. There are professionals who are on the client's side and on the designer's side. The client must specify the depot requirements and the designer must find solutions for these, the initial concept and then a detailed engineering design.

There are a number of fundamental phases from the initial identification of need to the implementation of a functional city bus depot.



In many cases, both clients and designers have limited experience in depot planning and design. The objective of this manual is to help these professionals navigate the critical phases leading to an operational depot. The manual provides a logical work process, technical knowledge on the conduct of each phase, practical guidance and caution.

Clients and designers must examine key questions in this process:

What activities should be performed at the Depot?

What size should the depot be to perform these activities?

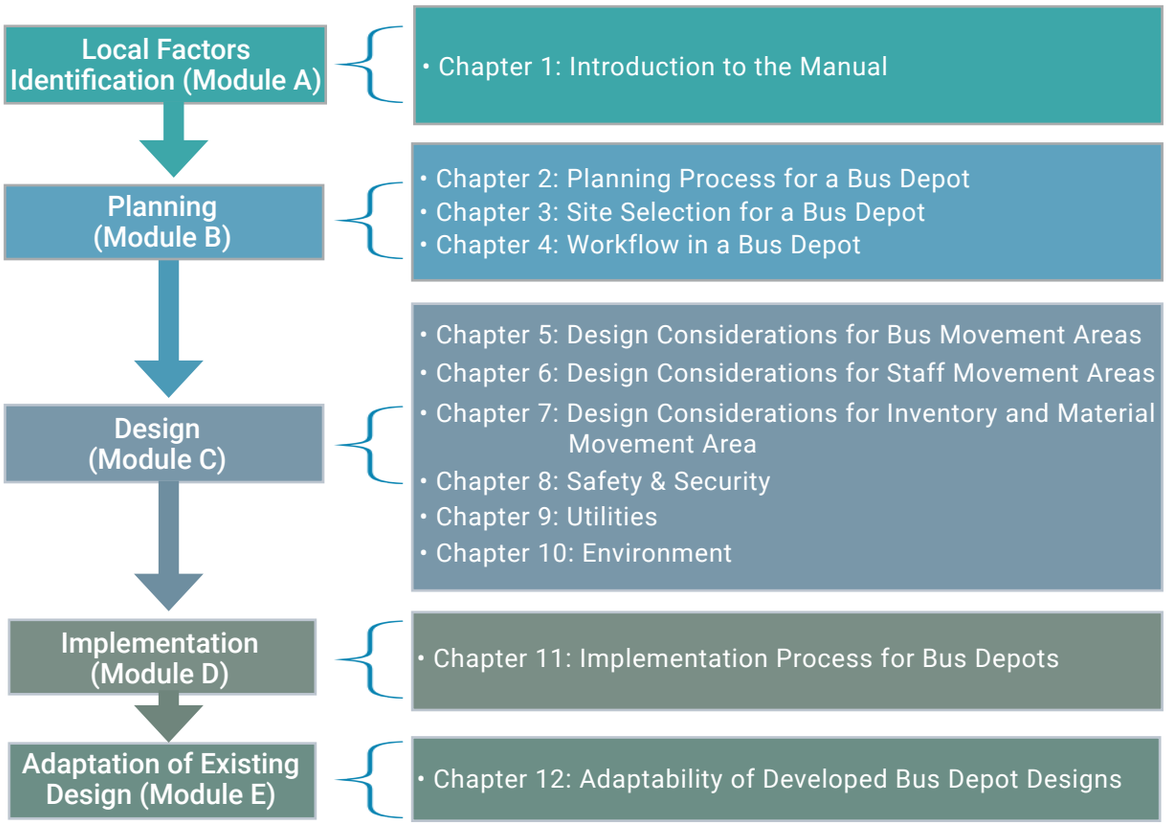
Where should the depot be located?

How should the activities be arranged in the depot?

How should the activites be performed (equipment, practices)?

How much will the depot cost?

The manual outlines a logical process for completing the phases and examining these questions. The chapters in the manual are organized according to these process steps:



The manual emphasizes the steps in the process to be followed in sequential order.

For example, the local factors must be identified such as maintenance philosophy for work carried out in the depot and buses assigned to the depot, before planning begins. Similarly, planning activities related to workflow in a depot be carried out before design and implementation begin.

The emphasis on following this process in sequential order is important. Experience in India, and in other countries, has shown that when this has not been so done, poor depot designs get implemented that do not properly take advantage of current technology, have long-term operations costs, and often cannot be corrected once the depot has been constructed.

The manual is organized according to the process steps (modules) to make it clear what work must be conducted in one step before work should begin in the next step. This organization also helps planners, designers, construction managers and others to identify the work/ activities that they should perform in the planning, design and implementation of a new city bus depot.

Summary of Process Modules

Module A comprises Chapter 1 which is an introduction to the manual. Besides providing general information on bus depots, like types of depots, it presents guidance on the factors which determine the design and size of depots and facilities to be housed in it. These factors are,

Typology of Bus Depots
Maintenance Philosophy
Types of buses
Indicative size of bus depot

- **Typology of Bus Depots:** Depots are characterized by – besides parking – the range of maintenance, repair and support activities (such as fuelling, recharging of batteries) carried out physically in-house. The typology arranges three broad types of depot in a hierarchy as under:

  a. The Night Parking Depot is at the base of the hierarchy. This model houses minor repair and maintenance plus washing.

b. In the middle is the Parking Bus Depot which has fuelling and battery charging facilities as well as scheduled, routine, unscheduled and preventive maintenance facilities, in addition to all that the one at the base is equipped to do.

c. At the apex is the Unitary Bus Depot with all the above features plus facilities for major overhauls, accident-damage repair, tyre retreading etc.

- **Maintenance Philosophy:** This refers to the maintenance practice adopted by the fleet operator. In the broadest sense, it is about whether only routine maintenance and repairs are carried out in the depot or all types of repair. The operator may outsource major repairs to a workshop located elsewhere. The depot, however, must be equipped to carry out repair and maintenance activities which will be necessary on almost a daily basis on one bus or the other – for instance, tyre repair/ inflation, replacement of lights/ bulbs, washing etc. Maintenance philosophy influences the size of the depot, the facilities to be hosted there and their design.

- **Types of buses:** This classification is based on their physical dimension, floor height, ground clearance, the fuel or source of power. These have a determining influence on the size of depots, their design to accommodate their parking and circulation and design of specific components of the facilities housed in the depot.

Module B has three chapters :

- **Chapter 2: Planning Process for A Bus Depot**
- **Chapter 3: Site Selection for A Bus Depot and**
- **Chapter 4: Workflow in A Bus Depot**

a. **The process of planning** is built around Objectives of a bus depot, Time Horizon (number of years, around 50) for which the facility is to be implemented, and stakeholders (Typically the Project Proponent, City Bus Operators, Fuel Suppliers, Equipment & Spares Suppliers, Sensitive Neighbours). The importance of addressing the concerns of stakeholders and engaging with them for the success of the project has been emphasized.

b. **Depot Lifecycle:** Keeping in view the lifetime of the depot, guidance on assessment of the demand for the depot's size, of facilities in the depot keeping in view the number and types of buses that are to be housed and operated from the depot is provided. The second kind of demand to be accommodated one for infrastructure

in the neighbourhood to cope with the traffic which the new development would eventually give rise to. Measures to minimize foreseeable traffic impact that the depot itself will generate and methods of demand forecasting and Traffic Impact Assessment have been discussed. Where more sites than one site pass the Preliminary Screening for locating a depot, it is important that an evaluation based on predetermined factors is got done.

c. **Facilities Planning** is the high-level plan for the number of depots to be built in a city and the kind of facilities to be housed in them. This ties in with the typology of depots discussed in first chapter which also outlines that depot facility are firmed up over a few iterations within the four corners of opportunities and constraints, such as access to the site. The concept is created based on the legal framework applicable for a depot project, feasibility of implementation, land use plan, environmental issues, capital and operational costs. Site selection is a critical part of the planning process discussed in Chapter 3.

d. **Setting up a Project Management Unit (PMU)** with suitable deployment of experts from different fields is recommended for executing the activities necessary to plan, design and implement a depot, including procurement of selected site design development, resource allocation, bid process management, oversight of construction based on the phasing of the project and completion, has been outlined. While an in-house PMU has been preferred, a specific activity can be outsourced.

- **Chapter 3 is devoted to the basis for Site Selection, which must be a systematic process comprising:**

a. **Reservation of Site at Urban Planning Stage**: This is suggested in view of the necessity of a depot for an efficient city bus service.

b. **Preliminary Screening:** This is meant to examine whether the available site or sites meet the necessary conditions in terms of:

   Size, Suitable shape with the minimum necessary frontage
   Access with requisite ROW (right of way)
   Encumbrance free and without land use restrictions
   Site preparation costs (low lying areas, type of soil etc.)

c. **Environmental and Social safeguards.** (Pollution impact on neighbours, presence of community assets etc.)

Should a site fail any of these tests, it may not be considered.

- **Chapter 4** is a drill-down to the activities and processes in a depot which will constitute the **Workflow in a depot**. These activities and processes are :

  a. Entry/exit of Buses
  b. Washing of Buses
  c. Fuelling
  d. Parking
  e. Maintenance activities
  f. Administrative activities including deployment of crew
  g. Inventory/storage
  h. Storage and disposal of scrap

  The location of facilities for these activities and processes must be designed to accommodate the movement of staff, inventory, buses/ other vehicles etc., minimize conflict, and facilitate efficient performance of the movements and activities in the depot, as well as in its constituent parts.

Module C contains five chapters to explain in detail the following:

a. **Design considerations to facilitate movement** of buses in the depot, of staff and of materials and inventory.
b. The facilities and their design, plant and machinery required to maintain and operate the fleet.
c. **Important design considerations related to safety, security and environment** are discussed in this module. A bus depot works round the clock and is a source of noise, emission and effluents. So, its location must avoid abutting residential units to the extent possible. In any case, there must be mitigation systems factored into the design and the construction treatments. Effective noise barriers (including landscaping) can reduce impact on the neighbourhood. It is important to note that landscaping cannot be retrofitted. It must be part of the design and construction activity. Green measures like harnessing solar energy, rainwater harvesting, effluent treatment plant etc. are to be part of the design of the bus depot.
d. **Appropriate levels of illumination** for different parts of a depot for safe and efficient functioning.
e. **Disposal of waste**, used lubricants, scraps and liquid effluent are activities that

depot-design must accommodate.

f. **Safety measures** for minimizing **health hazards** and **fire hazards**. Besides protecting life and limb, safety measures built into the design protect material assets including inventory, equipment, electronic gadgets and spares and the built structures.

g. **Security measures** by way of access control and electronic surveillance.

h. **Signage as a guide to movement.** Signage is an important feature that assists in the efficient and safe performance of activities in a depot. It also warns against danger. Hence it is important to adopt appropriate signage design and standards so that the signage are effective.

i. **Utilities:** Water and Power are essential for a depot to be able to function properly. It is important that the source of water and its reliability are worked out. The quantity of water needed must be assessed and accordingly the storage and distribution facilities must be designed and put in place. It is essential to install water recycling facility as well as rainwater harvesting and effluent treatment facility. An example of calculating the requirement of water for different purposes and areas of the depot, based on the number of staff, occupancy of dormitories, the number of buses, area under horticulture is presented in this module. Further, a bus depot works round the clock. For this, it is essential that power system planning identifies a reliable source of power (discoms) with in-house DG back-up.

j. **Rooftop Solar Power has been advised** in order to reduce operating expenses on account of power. A spin-off benefit is reduction in the temperature of the building and hence a reduction in AC requirement.

k. **HVAC (Heating, Ventilation & Air Conditioning)** requirements specific to different areas of the depot have been given a detailed treatment. Ventilation and proper airing of work and workshop areas are health and safety necessities.

l. **Environment. The last chapter of Module C** focusses on:
   i. Abatement Measures on noise and air pollution including indoor air-quality control
   ii. Wastewater & Effluent Management
   iii. Waste Oil, Solvent & Coolant Disposal and
   iv. Solid Waste Disposal

Module D discusses the implementation process of a bus depot which includes the choice of building material, list of plants and machinery and time taken for construction of a depot. Options for available construction material will need to be explored for construction of the depot. The use of locally available material can reduce construction cost and time. However, this should be weighed against possible recurring maintenance costs throughout the designed life of the depot. The Manual suggests the use of pre-engineered materials to be explored to significantly reduce the construction time and improve future adaptability of the facilities.

Module E is a snapshot of factors to be kept in mind about bus technology beyond the foreseeable horizon, for the depot being implemented now, to be adaptable.

Ministry of Housing and Urban Affairs
Government of India

MODULE A

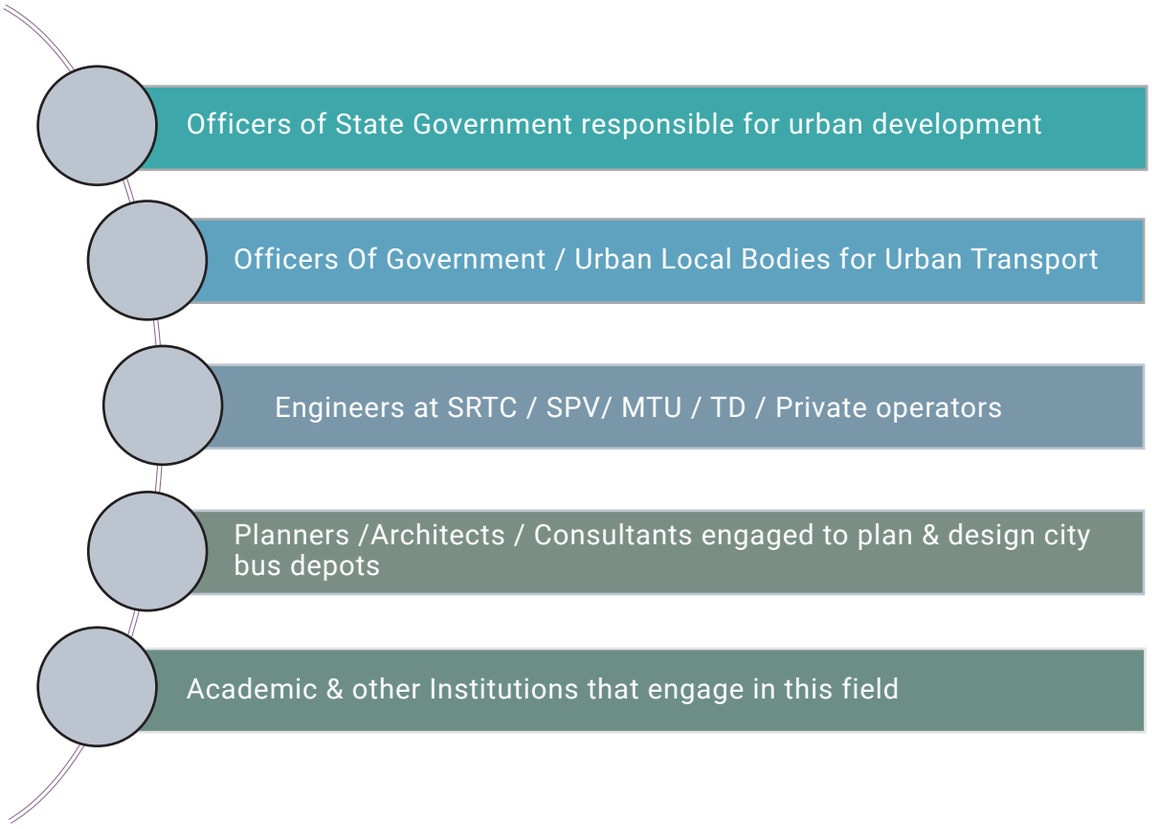
INTRODUCTION TO THE MANUAL

1. INTRODUCTION TO THE MANUAL

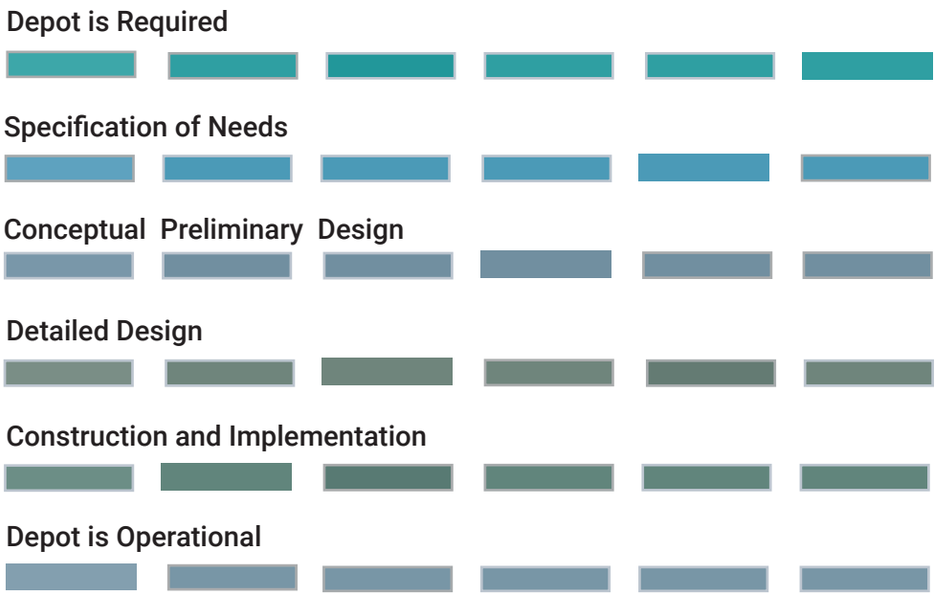
1.1 Introduction

This **"Manual for Planning, Design and Implementation of City Bus Depots"** outlines methods and procedures and provides an industry level guidance on conceptualization, site selection, development, design and construction of depots. The guidance is targeted at Clients and Designers of bus depot projects, especially those who are developing a bus depot for the first time or those who have not developed a depot recently.

These are the professionals who are the client's side and the designer's side. The client must specify the depot requirements. The designer must find solutions for these requirements — an initial concept design and then a detailed engineering design. The Manual will help the following intended users in planning and design a bus depot.

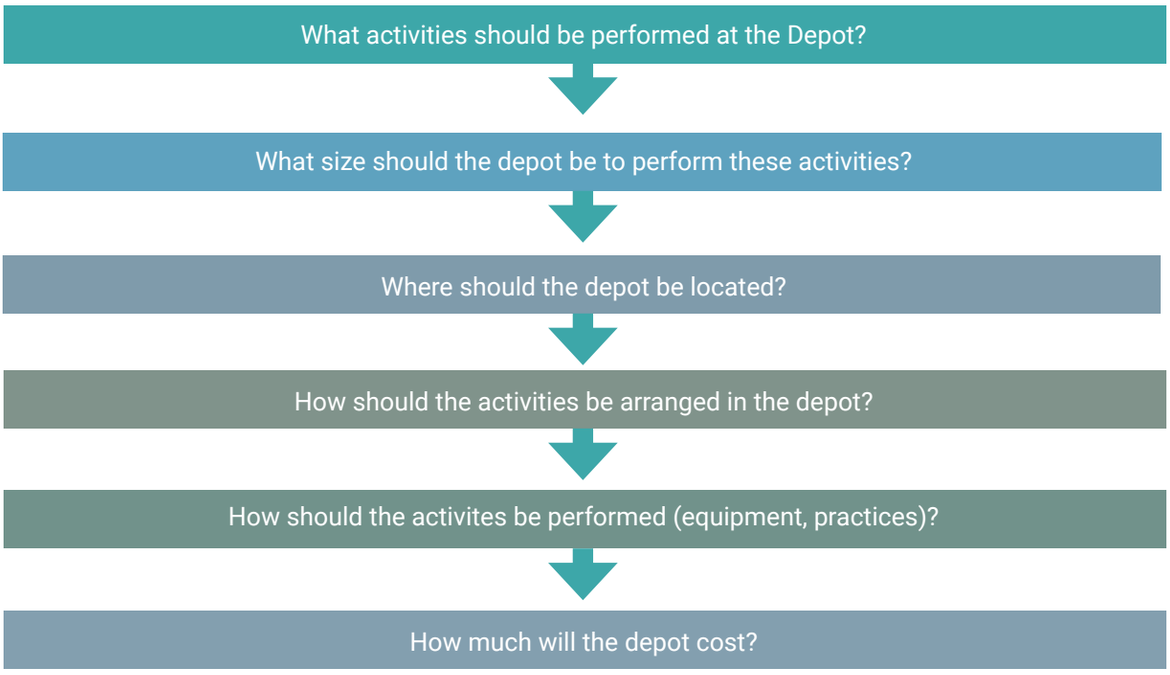


There are number of fundamental phases from the initial identification of need to implementing a functional depot.



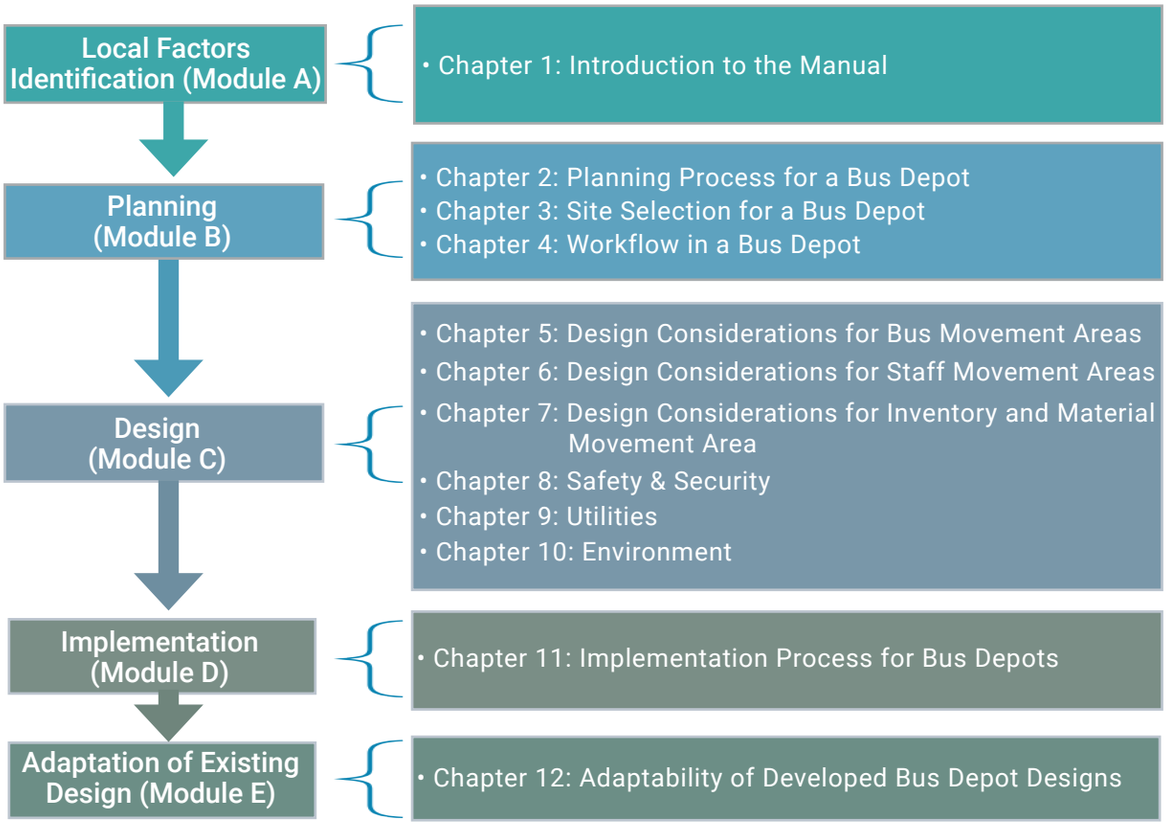
In many cases, both clients and designers have limited experience in depot planning and design. The objective of this manual is to help these professionals navigate the critical phases leading to an operational depot. The manual provides a logical work process, technical knowledge on the conduct of each phase, practical guidance and caution.

Clients and designers must examine key questions in this process:



1.1.1 Structure of the Manual

The manual outlines a logical process for completing the phases and examining these questions. The Manual is structured to deal with important aspects to be considered while planning and designing a depot, from the stage the need for a depot is recognized and agreed upon, in the following order.



Note: Refer to the index at the end of this manual to be guided to key topics nested under each other.

1.2 Local Factors Identification

The manual aims at providing its readers with a focused guidance on depot design parameters including site selection, layout of facilities, design of specific components of depot facilities, indicative list of equipment, permits and clearances needed and measures for accommodating the changes in the depot design owing to (a) emerging technology and (b) change in bus type (based on floor height, deck, comfort, length, axle-loads and fuel).

To start with the depot planning process, local factors must be identified such as activities to be carried out in a depot, maintenance philosophy and number of buses to be housed in a depot. This is done in order to understand the indicative size of land parcel required for developing such a depot.

1.2.1 Types of Depot

Bus depot design involves consideration of various activities & processes carried out in it. Based on the specific activities undertaken in a depot, depots can be categorized into:

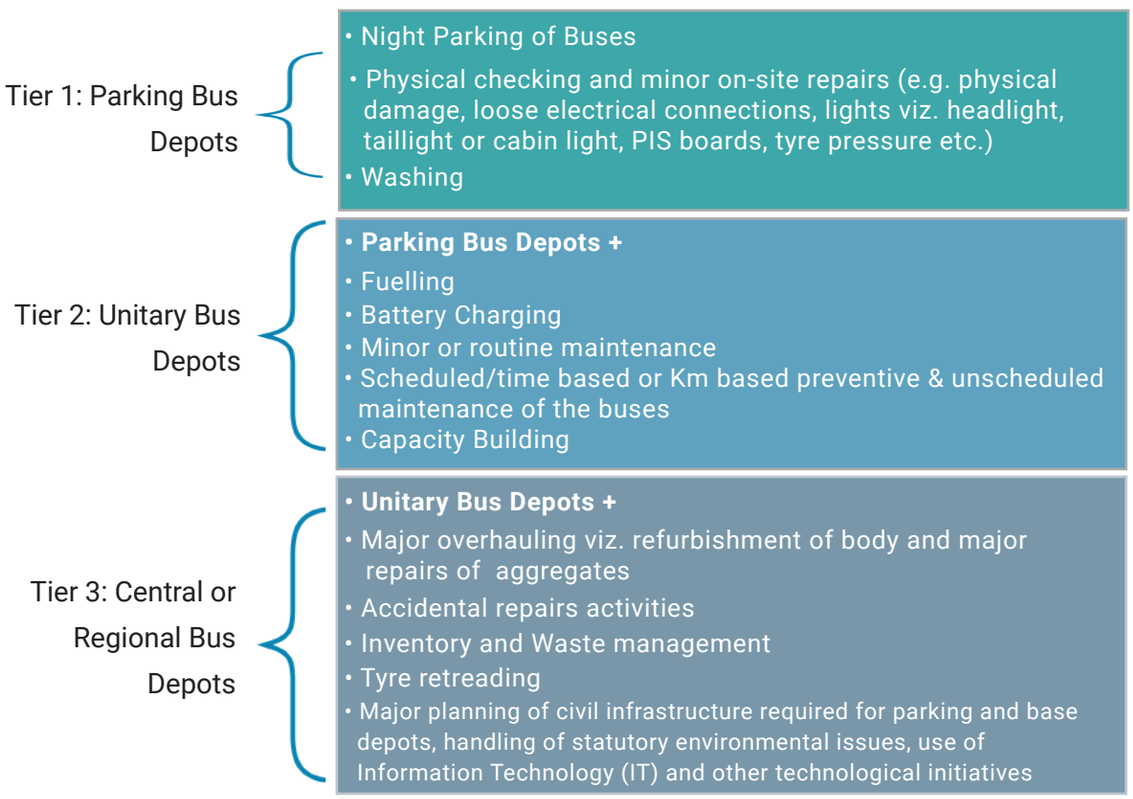


Figure 1-1: Activities in different types of depots

There can be different combinations of activities depending on maintenance philosophy and depot size. The existing number and type of buses and their projected demand over the horizon period will form the basis for determining the requirements of various facilities to be provided in the bus depot.

1.2.2 Maintenance Philosophy

Maintenance is an essential activity that is carried out in a depot and its scheduling is an important component in bus operations planning process. Therefore, for an efficient city bus operations, it is important to improve the maintenance practices, as good maintenance practices can significantly increase the availability (up-time) of buses which help in delivering the required service level benchmarks of bus service.

Every city operator needs to develop its maintenance philosophy in line with its long term goals & objectives, service level delivery standards and the type of buses. These determine the maintenance practices of the operator. As a result, various activities can either be done :

- In the depot; or
- At central workshop; or
- By outsourcing to service centers, dealers and agents; or
- A mix of the above

1.2.3 Types of Buses

The different types of buses that may be deployed from a depot will influence depot design. Deploying buses from a depot which is unsuitable for a bus type will compromise the depot's efficiency.

The following chart classifies the major bus types employed in Indian cities as of date:

Bus Variant	Bus Parameters	Sensitive Design parameters in Depot
Based on Floor Height	• Low Floor Bus (400mm) - Step-less entry / exit at passenger doors • Semi Low Floor Bus (650mm) - Entry + one step • Standard Bus (900mm) -Entry + two steps	• The pit depth and ramp gradients are the parameters which are sensitive to floor height of the bus. • In case of BRT buses, podium is required as doors of BRT buses are equipped with a sensor system that will open the door when bus door is parallel to podium.
Based on Length	• Standard Bus (12m) • Midi-Bus (9m) • Mini Bus (6m) • Articulated Bus (18m and/ or 24m)	• The length will impact dimensions of fuelling, washing, maintenance, parking, circulation and queuing area earmarked in the depot as turning radii and swept path vary. The modifications required in various areas due to this change is discussed in Module C.
Based on Fuel Type	• Diesel Bus • CNG/ HCNG Bus • Pure Electric/ Hybrid Bus	• For CNG bus, diesel fuelling station is substituted by CNG fuelling station with compressor and ancillary support equipment, but not necessarily at same location in the depot. • For HCNG bus, reformer plant for hydrogen is required. • For Electric buses, sizing of the electric substation and charging facilities will have to be specific to the type of and number of Electric buses. Moreover, in case of a depot only for electric buses, some of the maintenance facilities identified for Internal Combustion Engines would be redundant and parking areas' design may require reconsideration to meet requirements for charging infrastructure. Also, electric buses need access to roof and battery replacement facility.
Based on Deck	• Single Decker Bus • Double Decker Bus	• With the introduction of double decker bus, the height of the bus changes. Hence, while planning and designing the maintenance, fuelling and washing area in the bus depot, the additional height must be kept in mind. In addition, if parking, queuing and circulation areas are also covered then additional height should be considered while designing these facilities as well.

Bus Variant	Bus Parameters	Sensitive Design parameters in Depot
Based on Rear Axle Configuration	• Single Rear Axle bus • Multi Rear Axle bus • Rear Axle loads	• The change in bus rear axle configuration impacts the swept path for movement of bus. Therefore, the areas that are impacted by this change in a depot are fuelling, washing, maintenance, parking, circulation and queuing area.
Based On Comfort	• Air-Conditioned Bus • Non Air-Conditioned Bus	• Based on comfort, the bus can be air-conditioned or non-air-conditioned. This will lead to change in the washing area, washing equipment in the depot as AC unit is generally mounted on the roof of the bus. In addition, a special maintenance bay is required for air-conditioning.

The modifications that may be required in the depot design to accommodate the impact created by the aforesaid changes are presented in the relevant sections.

1.3 Indicative Size of a Bus Depot

The size of a bus depot depends on per bus area requirement, plant & machinery and activities in the bus depot. Both the domestic and international guidance suggests an area of about 200-210 sqm per bus for 12m length bus. Based on the number and type of the buses as well as the facilities to be provided, the approximate size of land required for bus depot may be calculated. The indicative size of land parcel required for designing a bus depot of various sizes i.e. number of 12 m length buses housed in a bus depot is tabulated hereunder.

Number of Buses	50	100	150	200
Land Area (in acres)	3.21	4.98	6.89	8.88
Land Area (in sqm)	12,970	20,137	27,875	35,930
Area Per Bus (in sqm)	260	202	186	180

Ministry of Housing and Urban Affairs
Government of India

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MODULE B

PLANNING PROCESS FOR A BUS DEPOT

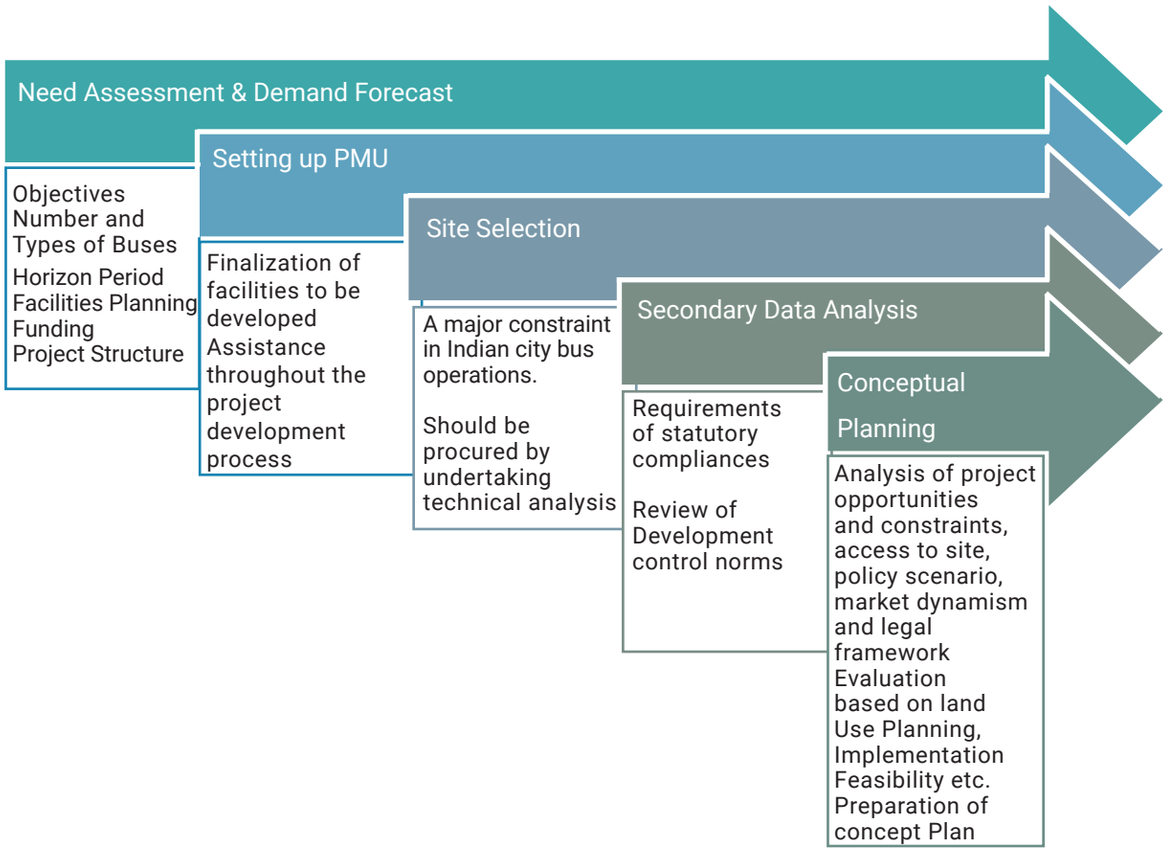
SITE SELECTION FOR A BUS DEPOT

WORKFLOW IN A BUS DEPOT

2 PLANNING PROCESS FOR BUS DEPOT

The planning of a bus depot requires consideration of various factors i.e. its integration with the city bus service, safety aspects, operational efficiency in terms of movement of resources, commercial and financial aspects, environmental considerations and at the same time be sensitive to the neighbours. It may be noted that these factors are interrelated and require consideration during the planning stage itself.

The following chart is a snapshot of the planning process.



Experts from different fields are required at various stages in the project life cycle. Some of the skills may be present in-house while the others may need to be sourced from the market. The skill-sets necessary for the development of bus depots are provided in **Annexure 1** of this chapter. A judicious decision needs to be taken by the project development agency, to identify the skills required at the various stages and ensure their timely procurement.

2.1 Stakeholders' Engagement

This section provides an overview of various stakeholders who are involved in the bus depot planning and design process. Inputs of stakeholders for planning and designing are necessary to

ensure that the depot as a facility is well suited to handle the activities in which the stakeholders, for example, city/state executives, planners, suppliers of rolling stock, maintainers, operations managers, safety experts, environmentalists, project manager, financier, service planner et al, have a role.

Typical stakeholders of a bus depot are:

(i) Project Proponent
(ii) City bus operators
(iii) Fuel suppliers
(iv) Equipment and spares suppliers
(v) Sensitive neighbours

Typical requirement of these stakeholders are:

Project Proponent	• Optimal Land Utilisation • Financially Feasible • Efficient Operations • Minimal objections from stakeholders / statutory agencies
City Bus Operators	• Minimal dead mileage • Convenient access • Availability of maintenance facilities • Fuelling and washing facility
Fuel Suppliers	• Convenient access to supplies • Storage of fuel • Provisions for prevention of fire hazards
Equipment & Spares Suppliers	• Convenient access to depot • Provision of unloading platform • Easy movement of vehicles
Sensitive Neighbours	• Minimum noise and air pollution • Minimal disturbance to private traffic

It is suggested that various stakeholders should be identified and communication channels should be opened to bring them on board for the depot development.

2.2 Need Assessment & Demand Forecast

This is the first step in the planning process which includes defining the purpose and objective of the project proponent that will have a bearing on the planning and subsequent design of the bus depot facilities. As a general rule, the project proponent defines the maintenance philosophy.

It also involves determining the number and types of buses along with their future forecasts over the horizon period that will form the demand basis for determining the requirements of various facilities to be provided in the bus depot. Also, in this step, deliberations on funding and project implementation structure i.e. Engineering Procurement Construction (EPC) or Public-Private Partnership (PPP) will also be undertaken among various stakeholders but these will be finalized after the bus depot planning step.

2.2.1 Objectives

The objectives of creating a depot must be discussed with stakeholders for factual and conceptual clarity about the objectives. Based on the inputs, the objectives need to be firmed up. The firmed-up objectives must be adhered to in order to ensure clear-sighted planning and design. This last overarching objective of adherence to firmed-up objectives assumes a mature commitment to professional advice at executive decision-making levels.

The objectives broadly address the following:

(i) Clear definition of the depot
(ii) List of stakeholders and their involvement during various steps of the depot development process
(iii) Criteria for technical evaluation
(iv) Future strategy for implementing the forthcoming steps

2.2.2 Demand Forecasts

The planning and development of a depot is a long process and the period for which the depot is envisaged to be operational is also long. Therefore, demand forecast is critical and the foremost reason is to plan or design the depot to meet the future demand requirements for the horizon period under consideration.

Horizon Period

NCTPA document used a design horizon period of 20 years. However, the seismic and wind zoning get updated every 50 years, hence the horizon period can be kept in the range of 50-70 years.

Some of the applications of forecast information include:

(i) Development of infrastructure capacity and design calculations
(ii) Estimation of the financial and/ or social viability of projects (e.g. developing benefit-cost analysis and/ or social impact assessments)
(iii) Traffic impact assessment (TIA) of the transport infrastructure (As per Annexure 2)
(iv) Calculation of environmental impacts, such as air and noise pollution
(v) Planning for the transport facility/ operations

In all the above situations, the accuracy with which future traffic is predicted is of prime importance. There are different methods available for the transport demand estimation. These are explained in **Annexure 3.**

2.2.3 Facilities Planning

The first step in facilities planning is to consider the number and type of bus depots to be developed as well as facilities to be housed in these depots.

Number of Bus Depots

Bus Depot Design Guidelines[1] and **PPIAF toolkit**[1] **recommend** a single depot at central location for smaller cities and multiple depots for larger cities, each located near the starting point of a route to minimize dead mileage.

After deciding the number of depots, the facilities to be housed in a depot or activities to be carried out in a depot will be decided depending on operational requirement, maintenance philosophy and depot size. A snapshot is shown below.

Tier 1: Parking Bus Depots

- Night Parking of buses
- Physical checking and minor on-site repairs (e.g. physical damage, loose electrical connections, lights viz. headlight, tail light or cabin light, PIS boards, tyre pressure etc.)
- Washing

Tier 2: Unitary Bus Depots

- Parking Bus Depots +
- Fuelling
- Battery charging
- Minor or routine maintenance
- Scheduled/ time based or Km based maintenance of the buses
- Washing

Tier 3: Central or Regional Bus Depots

- Unitary Bus Depots +
- Major overhauling viz. refurbishment of body and major repairs of aggregates
- Accidental repairs
- Inventory and waste management
- Tyre retreading
- Major planning of civil infrastructure required for parking and unitary depots, handling of statutory environmental issues, use of IT and other technological initiatives

The above mentioned facilities/ activities may vary based on the city bus service operator requirements and deliberations with various stakeholders.

2.3 Setting up Project Management Unit

Project management is critical for timely and successful completion of a project. A Project Management Unit (PMU) which is staffed by a team of professionals may be created by project proponent and should be positioned at the onset of the project. The role of the PMU is to finalize the deliberations, discussed in the first step like facilities to be housed in a depot as well as provide assistance throughout the depot development process.

Typically, the role could be to undertake or to ensure that the following steps are undertaken.

SN	Depot Development Stage	Role
1	Land Procurement	• Options of site • Prioritisation of sites • Procurement of site or coordination with agency which is procuring the site. • Demarcation of site • Transfer of land in the name of project proponent in land records
2	Design Development	• Documenting owner requirements & maintenance philosophy • Coordination with design consultant • Internal approval of the design • Stakeholder communication • Finalisation of procurement strategy
3	Resource Allocation	• Internal approval of resources for the project • Approaching third parties such as banks/ multilateral institutions for funding assistance
4	Procurement Process	• Finalisation of Bidding structure and bid documents • Bid process Management • Selection of contractor • Negotiations and execution of agreement with contractor
5	Approval required from various agencies	• Application to various agencies for approval and clearances • Coordination with various approvals granting agencies
6	Construction Activities	• Phasing of the project based on budget or management priority • Engagement of independent engineer or internal officials for project supervision • Assistance in release of funds to contractor based on agreed milestones. • Collection of as-built drawings • Oversee commissioning of plant and machinery • Issuance of completion certificate

2.4 Site Selection

The area needed for a bus depot depends on the number of buses to be maintained and/or parked in the depot. The area required varies with the shape of the site, the functional requirements and placement of depot's activity centres. Land availability for depots is a major constraint in Indian city bus operations. Consequently, depots are generally developed where land is available with the organization or where it can be easily procured. Site-selection for procurement of land for a depot is discussed in the following chapter.

2.5 Secondary Data Analysis

The project proponent undertakes collection and compilation of data which have a bearing on the planning of bus depot. The data would include requirements of statutory compliances, best practices, development control norms governing the development of depot etc.

2.6 Conceptual Planning

The conceptual planning process must factor in the objectives and facilities/activities to be housed in a depot. The conceptual plan has to consider the constraints of the available site and the functional requirements that the depot has to cater to.

In view of the above, in this process several iterations are undertaken, with each iteration taking feedback from various stakeholders, progressively narrowing the available options. The various iterations involve the analysis of depot development opportunities and constraints, site accessibility, policy scenario, market dynamism and legal framework.

1st Iteration Conceptual Planning

This involves the analysis of depot development opportunities and constraints as well as policy scenario, legal framework and market dynamism. All these things have equal weightage and these must be taken into consideration during the conceptual planning process. In this stage, various concepts will be developed, scrutinized and shortlisted based on

(i) Land use planning,
(ii) Implementation feasibility,
(iii) Flexibility,
(iv) Sustainability,
(v) Environmental issues,
(vi) Capital and Operational cost etc.

2nd Iteration Conceptual Planning

The shortlisted options derived after the 1st iteration are further evaluated based on detailed plans and discussions with various stakeholders so as to get their perspectives as well. In this step, weightage is given to the shortlisting criteria and additional inputs from stakeholders are considered.

Concept Refinement

In this step, the final concept shortlisted will be tested and verified before going into the design process.

The snapshot of the conceptual planning process shown below.

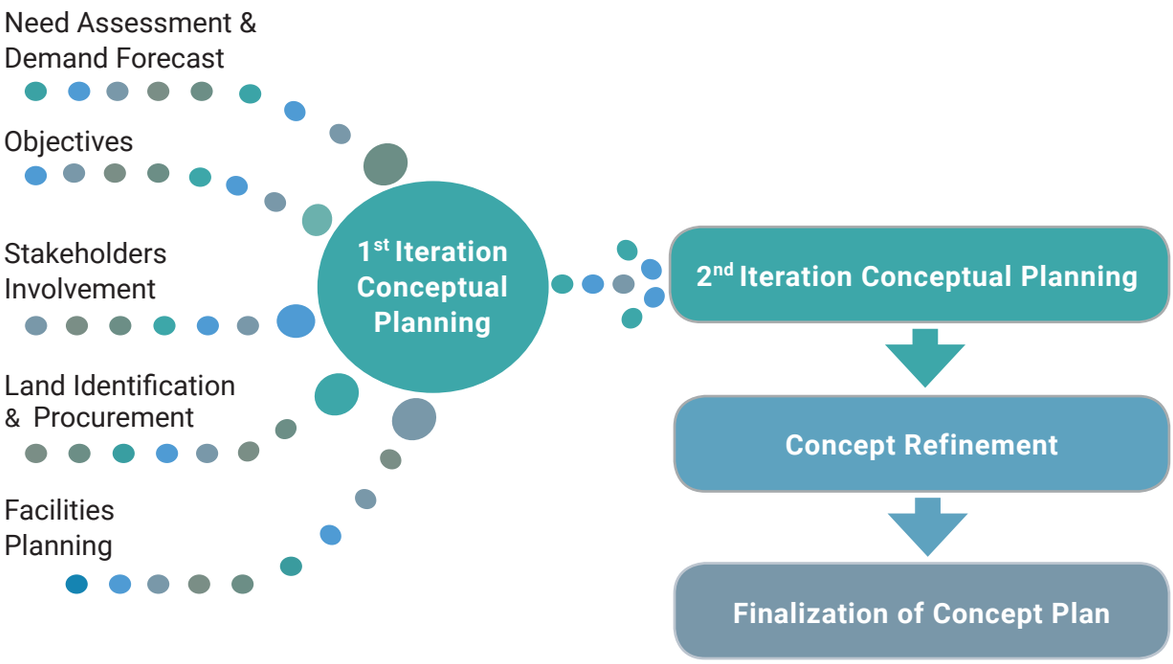


Figure 2-1: Concept Planning Process

ANNEXURE 1: TEAM COMPOSITION

The bus depot planning, design and implementation process requires experts from different fields at various stages in the project life cycle. The following skill-sets will be necessary for the development of bus depot.

Stages	Core Personnel	Support Personnel
Project Planning & Stage Design	• Urban Designer • Architect • Bus Expert • Utilities Expert/ Mechanical Electrical and Plumbing (MEP) Expert • Civil/Structural Engineer • Infrastructure Finance Expert • Health & Safety Expert	• Business Analyst/ Business Process Re-engineering Specialist • Procurement Expert • Legal Expert • Infrastructure Expert • Transport Planner • Renewable Energy Expert • Environment Expert • Social Expert • Transaction Advisor • Mechanical Engineer • IT & Network Specialist
Project Implementation Stage	• Construction Manager/ Project Manager • Project Performance and Management Specialist (PPMS) • Accountant	• Mechanical Engineer • MEP Expert • Urban Planner • Information and Communication Technology (ICT) Expert • Landscape Expert • Legal Expert • Social Expert

It may be noted that the above team composition is tentative. In addition, all the personnel are not required full time during the project cycle. Some of the personnel are required for shorter duration like environment expert, social expert etc. They can be employed as and when required. It is advised that the team to be selected for depot development to be in-house. If in-house expertise is not available, then that particular activity can be outsourced but the team leader should be from within the organization. The personnel working on the depot development should not be changed before completion of his/ her work.

ANNEXURE 2: TRAFFIC IMPACT ASSESSMENT

Even if the prospective site is outside the city residential/ business areas, over the lifetime of the asset, the city may grow around the depot's vicinity. A Traffic Impact Assessment (TIA) study helps in predicting the kind of impacts like congestion on the adjacent road, traffic circulation etc much before the actual implementation and act as a tool for identifying and estimating such effects so that appropriate mitigation measures can be taken and implemented along with the development plan of the new facility.

TIA study assesses traffic and safety implications relating to a specific new development. These studies vary in their level of detail and complexity depending on the type, size and location of the proposed new development. TIA for a Greenfield or a Brownfield development is undertaken to assess whether the road network surrounding the proposed development will be able to handle the additional traffic that is going to be generated or mitigation measures will have to be devised such as service roads, grade separators, intersections, noise-barriers, relocation of utilities etc.

The key objectives of the TIA study are:

(i) To study the existing traffic characteristics and estimate the traffic likely to be generated by the proposed new development
(ii) To assess the impact of additional traffic on the road network system
(iii) To identify necessary roadway improvements and required changes to the site plan e.g. entry/ exit of the bus depot etc.

The envisaged benefits of TIA study are:

(i) To provide decision makers with various implications due to the new development and enable them to take informed decisions.
(ii) To understand various traffic and safety issues so that appropriate mitigation measures are planned in advance in a timely manner.
(iii) To provide a rational basis for planning various allied facilities, improvements that are required to provide safe and efficient traffic, keeping in view the site specific conditions.
(iv) To address traffic circulation issues associated with development proposal that may be of concern to neighboring residents and other stakeholders.

The study is best got done by engaging a competent professional or an agency for impact assessment on the road network and intersections. Indian Roads Congress (IRC) has provided guidelines for evaluating the impact on road capacities in the IRC guidelines on "Manual for capacity analysis in urban roads in plain areas - IRC: 106-1990". It is suggested that the methodology suggested in these guidelines may be followed for assessing the congestion levels at the bus depot influence area.

ANNEXURE 3: DEMAND FORECASTING METHODS

There are different methods available for the transport demand estimation. These are:

(i) Time series Method
(ii) Econometric Method
(iii) Judgmental Method
(iv) Reference Class

(i) Time Series Method

Time series forecasting is used to forecast future events based on known past events to predict data points before they are measured. Past trend of a traffic growth is an indicative guide in determining the future trend.

(ii) Econometric Method

This method assumes that it is possible to identify the factors that influence the demand for a variable. For instance, bus technology may be influenced by public policy; the demand for city bus service may be influenced by its efficiency affordability etc; the demand for traffic will be influenced by the activities and vehicular movement a depot gives rise to.

(iii) Judgmental Method

This method incorporate intuitive judgments, opinions and subjective probability estimates. Judgmental forecasting usually involves combining forecasts from more than one source and is of following types:

a) Composite forecasts – combining forecasts from different methods
b) Statistical surveys – to collect quantitative information from the items in a population (sampling)
c) Delphi method - systematic, interactive forecasting method which relies on a panel of experts
d) Scenario analysis - process of analyzing possible future events by considering alternative possible outcomes (scenarios)

(iv) Reference Class

This forecasting predicts the outcome of a planned action based on actual outcomes in a reference class of actions similar to that being forecast. Reference class forecasting for a specific project involves the following three steps:

a) Identify a reference class of past, similar projects.
b) Establish a probability distribution for the selected reference class for the parameter that is being forecast.
c) Compare the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project.

Though there is no single forecasting technique applicable always for the similar kind of transport infrastructure facility, the appropriate choice of forecasting technique depends on the project objectives, data and resources availability.

3 SITE SELECTION FOR A BUS DEPOT

The location of a city bus depot is critical for efficient operations and maintenance activities for achieving an efficient bus service. Ideally land should be reserved in the master plan of the city or properly evaluated which is discussed in this chapter.

A city can have (i) one depot or (ii) multiple depots or (iii) a combination of several depots and small parking depots close to the revenue generating trips. The parking depots are also clubbed with the other transport infrastructure e.g. bus terminals, interchange points or other facilities which are not required at night.

Location of a Depot

According to **Bus Depot Design Guidelines** and **PPIAF document**, a single depot at central location should be preferred for smaller cities and for larger cities, several depots located near the starting point of a route should be preferred..

3.1 Reserving Site during Urban Planning Stage

The purpose of this section is to seek a greater understanding of the importance of bus depot planning not just in the context of transport planning but also as a part of urban planning, since provisions for land for bus depot(s) by the town planners is an expedient step towards efficient operations and maintenance activities for city buses.

The land for transport infrastructure in India is usually reserved in the master plan/ development plan of the cities. Therefore, city bus operators should engage themselves in the periodic revision of the master plan to ensure land is earmarked as per their requirements in terms of appropriate location, size and shape of the land parcel, and the impact of the traffic generated, in the proposed master plan. Sometimes, Comprehensive Transport Studies (CTS) are also undertaken to comprehensively map the transport requirements of cities indicating lumped land requirement for various transport infrastructure including the bus depots. The land earmarked in the master plan should be procured expeditiously to avoid escalations in the price of land.

3.2 Site Selection

The purpose of this section is to provide understanding on the site selection process, in case, a site selection for a new depot is required to be undertaken.

When land is to be procured, a two tier screening is recommended.

(i) Preliminary Screening
(ii) Evaluation of Site based on pre-determined parameters

3.2.1 Preliminary Screening of Site

Parameters which should be used for the preliminary screening are as follows:

(i) Shape and minimum size of land parcel. A square/rectangular plot is best suited for the purpose. [1]
(ii) Minimum width/ frontage [2]
(iii) Ease of procurement
(iv) Land-use restrictions if any
(v) Safe access/ egress to/ from approach roads. Minimum Right of Way (RoW) of 15m.
(vi) Mitigation measures for environmental issues/ sensitive neighbours
(vii) Low lying areas
(viii) Site preparation costs

In case, the site does not pass any of the above parameters in initial screening, then it should be dropped from the selection process. Otherwise it may lead to increase in initial investment both in terms of time and money.

3.2.2 Evaluation of Site based on Pre-Determined Parameters

After the preliminary screening, if more than one site is available, options should be evaluated based on the predetermined parameters. Each parameter should be given a weightage based on the requirement of the bus operator. The indicative parameters and their weightages are given below.

[1] Ref Section 1.4 and 3.3
[2] Ref Section 3.3

Table 3-1: Indicative Site Evaluation Matrix

Criteria	Sub-Criteria	Weightage
Distance from the transit centre	Minimize dead mileage cost	20.0% *
Access to Public Roads	Full movement access to site with limited traffic disturbance during the peak entry and exit periods	10.0%
Site capacity	Site acreage	10.0%
	Minimum width/ frontage	10.0%
	Shape of site	2.5%
	Expandability	2.5%
Real estate Issues	Ease of procurement	5.0%
	Neighbourhood sensitivity issues	10.0%
Environmental Issues	Geo technical and Seismic issues	5.0%
	Forest, wildlife, tree cutting, Wetlands, streams etc. issues	5.0%
Development Cost	Land Cost	10.0%
	Site development cost	4.0%
	Change in land use cost	3.0%
	Mitigation measures for environmental issues	2.0%
	Special design covenants that increase construction cost	1.0%
	Total	100%

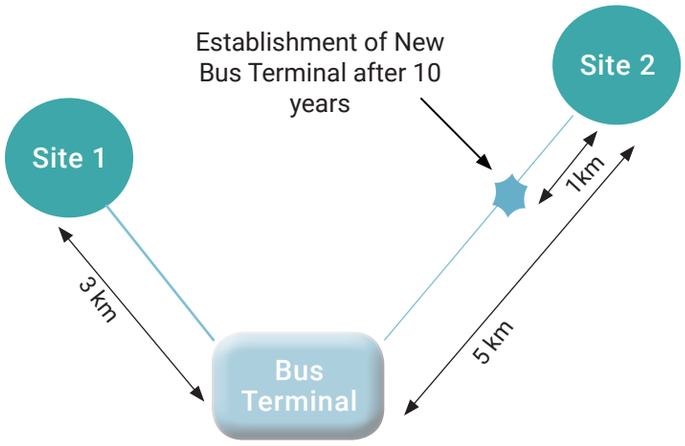
* This weight will reduce if the city expands to the depot's vicinity, bus service provisioning in the depot's vicinity becomes necessary etc

The individual sites will be compared, and marks will be attributed on a 5-point scale based on the above-mentioned criteria where higher score signifies greater preference and suitability of the land parcel for the development of a bus depot. The site having the highest weighted cumulative score should be selected for the development of bus depot. A hypothetical evaluation of two sites based on dead mileage is provided hereunder.

Hypothetical Evaluation

Consider 2 sites i.e. Site 1 and Site 2 having distance from nearest bus terminal of 3 km and 5 km respectively.

The distance travelled by a bus from depot to terminal during out shedding and from terminal to depot during in shedding is called "dead mileage".



Various costs incurred to the operator during operations include

i) fuel cost,
ii) consumables cost,
iii) manpower cost,
iv) repair & maintenance cost,
v) overhead charges,
vi) management cost and
vii) fare collection cost.

The assumed cumulative cost per km of all the afore mentioned costs came out to be approx. Rs.80/-.

Assuming bus operational days to be 300 and escalation in cost to be 2% per year, the cost per bus for 2 sites will be calculated over a period say 20 years. It may be noted that the above cost estimates take into consideration only the operational cost of bus and doesn't include the cost of the following:

i) Land cost for the depot,
ii) Cost related to availability of manpower or willingness of manpower to work or travel to the depot,
iii) Cost related to availability or relocation of utilities,
iv) Cost related to environmental mitigation measures, noise abatement measures etc.

Amount (Rs. in lakhs)

Site 1 Cost Per Bus					
Year	1	5	10	15	20
Cost	1.44	1.56	1.72	1.90	2.10
NPV@12%	12.18				

Site 2 Cost Per Bus					
Year	1	5	10	15	20
Cost	2.40	2.60	2.87	0.63	0.70
NPV@12%	15.72				

3.3 Shape of the Land Parcel

The shape of the plot for development of bus depot should ideally be rectangular or square. Based on the layout of the bus depot and facilities to be provided in the depot, the circulation area could be optimized. The space allocation and positioning of parking area in the depot and circulation within the depot will determine the optimal utilization of land parcel.

Desirable shape of the land parcel

VDV Guidelines and **NCTPA document** state that a square or rectangular plot of land should be preferred as land parcel which are too narrow or irregular in shape may be unusable.

The minimum frontage for smooth operations of the bus depot could be arrived at as follows.

Table 3-2: Site Frontage

SN	Activity	Size (meters)
1	Entry / Exit Gate – 2	30m
2	Staff/ Private Vehicles Entry Gate – 1	10m
3	Circulation, Segregation of vehicles and Operational requirements	50m
	Total	90 m ~ 90 m of Minimum Frontage/ width is required

4 WORKFLOW IN A BUS DEPOT

A bus depot's planning process involves a detailed consideration of various activities & processes carried out in it. The depot facilities comprise washing, fuelling, service/repair (both minor and major) and storage space. Various activities related to the daily operations of the buses are listed below.

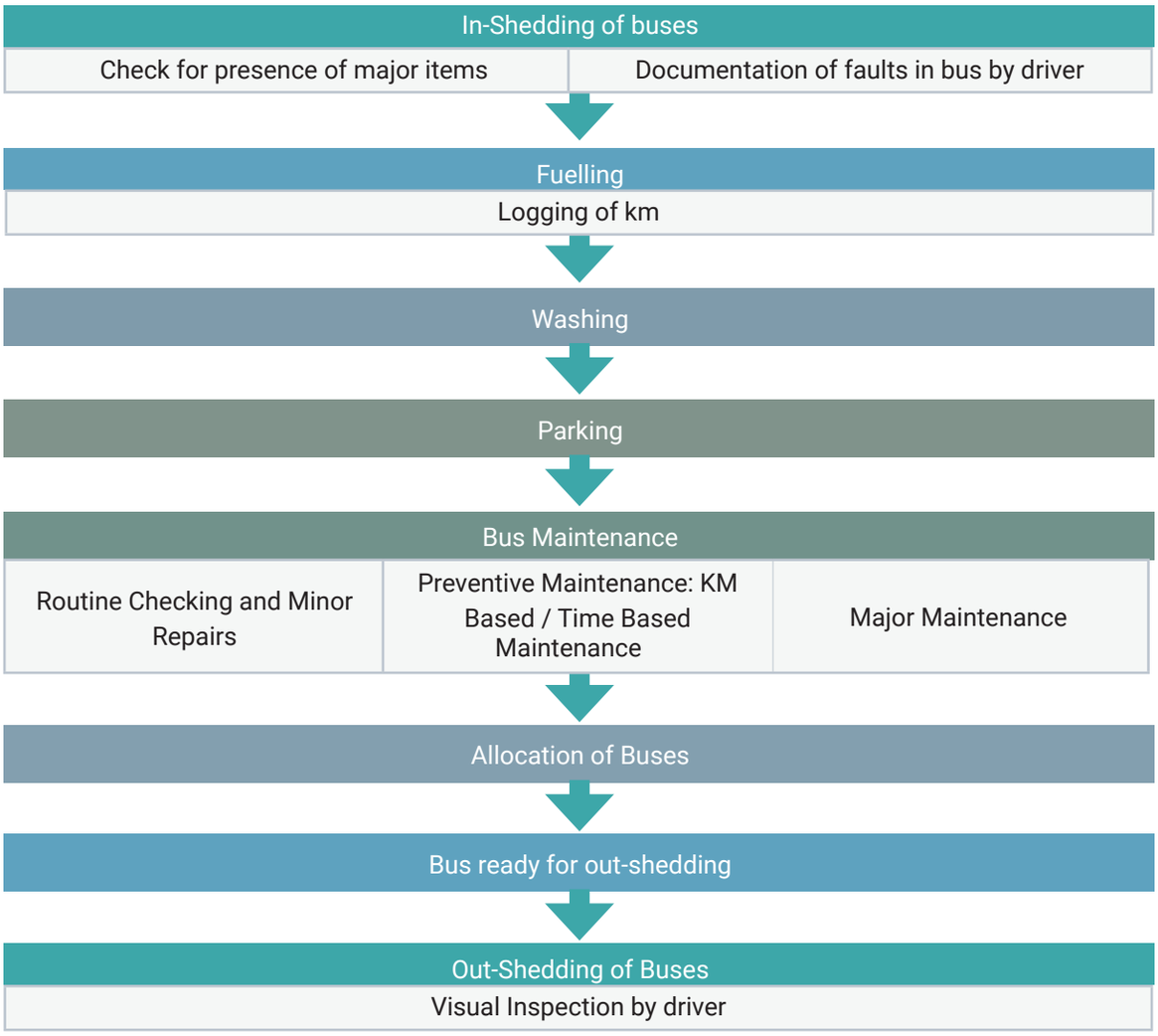


Figure 4-1: Flow chart of Activities carried out in a Depot [3]

Allocation of spaces within a bus depot needs to be done based on a detailed consideration of various activities & processes carried out therein. In addition, the (i) flow of work (ii) movement of material (iii) movement of staff and (iv) movement of vehicles are important considerations.

[3] It may be noted that based on the site constraints and the philosophy of the operator, the activities of fuelling, washing and parking can be interchanged to avoid bunching of buses at the gate or at any other facility.

Optimal movement of personnel, bus and material

VDV guidelines state that the placement of facilities should be based on the workflow i.e. sequence of activities of a bus in a depot.

4.1 Activities in a Bus Depot

The major activities performed in the bus depot are:

(i) Entry/exit of buses
(ii) Fuelling
(iii) Washing
(iv) Parking
(v) Maintenance
    (a) Routine Maintenance on buses
    (b) Maintenance in bench work areas/ machine shop
    (c) Wheel and tyre activities
    (d) Unscheduled/Major repair work on buses
    (e) Alignment testing
    (f) Brake Testing
(vi) Administrative
    (a) Duty allocation of drivers and conductors
    (b) Cash handling
    (c) ETM handling
    (d) ETM charging
    (e) Staff/Crew amenities
    (f) Administrative work
    (g) Training & Development
(vii) Inventory/ storage work
(viii) Storage and disposal of scrap

The design considerations for placement of facilities for the above activities is based on the following movement types within the depot:

(i) Staff Movement
   (a) Bus Drivers and Conductors
   (b) Maintenance Staff
   (c) Administrative Staff
(ii) Inventory movement

Illustrative layouts of the various functional elements in the bus depot should be as per the combination of processes and the resources required by them. However, the layout should be designed in a way that enables optimal movement of the resources and of the bus in undertaking the process to allow efficient functioning of the bus depot.

This manual follows the above movements of buses, staff and materials in the depot and presents the design considerations and procedures for development of the specific components of the bus depot associated with each of the aforesaid movements. These are presented in the subsequent chapters.

4.2 Illustrative Depot Layout

Illustrative layout of a bus depot is set out below. The placement of the sections follows the principle of optimal movement of the resources and the bus in undertaking the process to allow efficient functioning of the bus depot. (**Refer Figure 4-2 on next page)**

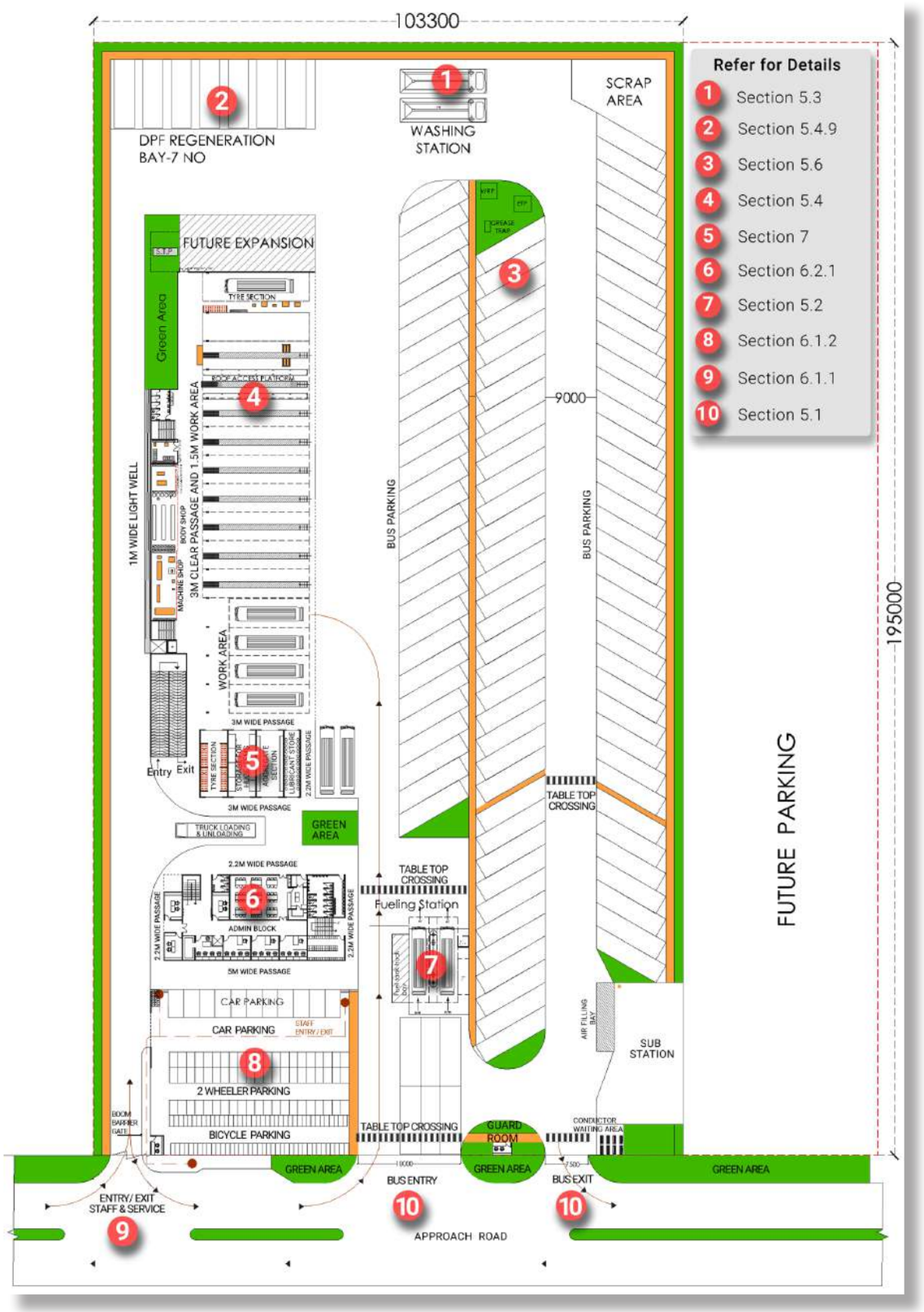


Figure 4-2: Illustrative Layout for 100 Bus Depot

Ministry of Housing
and Urban Affairs
Government of India

MODULE C

DESIGN CONSIDERATIONS FOR BUS MOVEMENT AREA

DESIGN CONSIDERATIONS FOR STAFF MOVEMENT AREAS

DESIGN CONSIDERATIONS FOR INVENTORY AND MATERIAL MOVEMENT AREA

SAFETY & SECURITY

UTILITIES

ENVIRONMENT

5 DESIGN CONSIDERATIONS FOR BUS MOVEMENT AREAS

The objectives of design and placement of the depot components associated with the movement of buses are the most efficient, smooth and safe circulation within the depot with the least possible queuing. For these, the following are necessary :

(i) Preferably unidirectional movement with least distance to be covered by the bus during in-shedding and out-shedding, and
(ii) Minimum crossflow between bus, personnel and inventory movement.

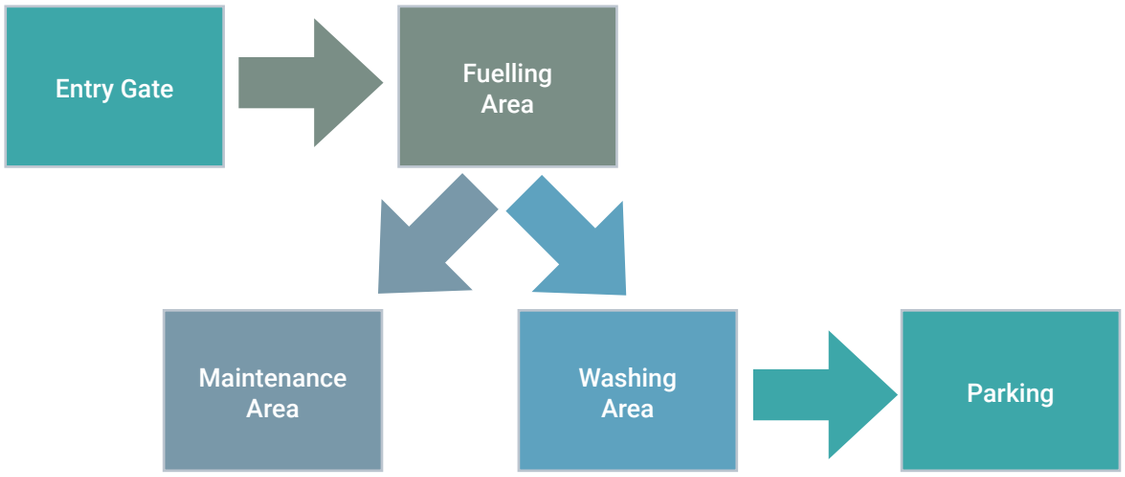


Figure 5-1: Bus Movement in a Depot [1]

The above illustration presents the movement of a bus inside the depot along with the associated activities during in-shedding.

Unidirectional movement of bus

Bus Depot Design Guidelines states that the buses should preferably follow a unidirectional movement in a depot.

Each of the above mentioned elements of the bus depot has been detailed out in the following sections. The illustrative layouts presented in the sections are of a depot for 100 buses having length of 12m, low floor and having a turning radius of 10.50m designed for maintaining AC and non-AC buses

5.1 Entry and Exit for Buses

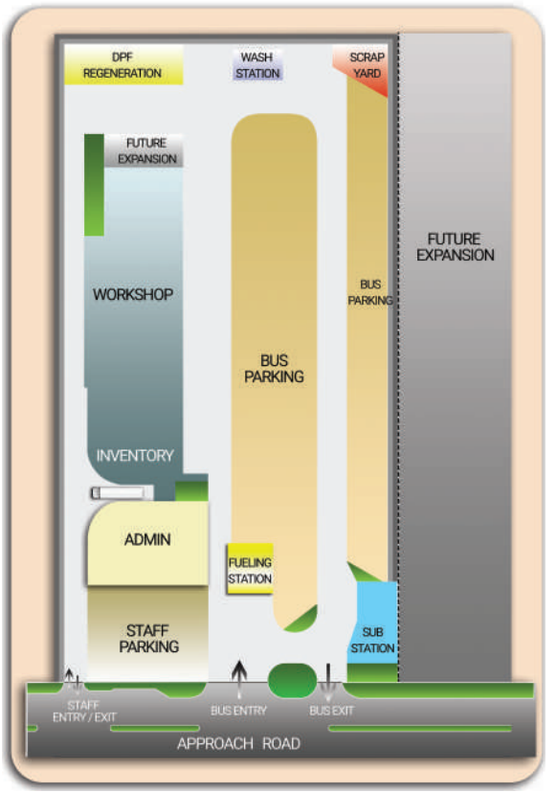
Entry/ exit gates are required for the following activities:

[1] The depicted sequence of activities can be interchanged based on the maintenance philosophy of the operator.

(i) Buses
(ii) Staff vehicles
(iii) Inventory vehicles
(iv) Visitors
(v) Pedestrians (staff and visitors)

In this section, the design considerations of the depot entry and exit specific to the bus [2] movements are discussed.

A separate entry and a separate exit should be provided for the entry and exit of buses to aid unidirectional movement of buses within the depot. These entries and exits should not be used for any other purpose but for the in-shedding and out-shedding of buses.



The shape and orientation of land parcel vis a vis the access to the main road need to be carefully examined in order to determine the design of entry and exit for the bus depot.

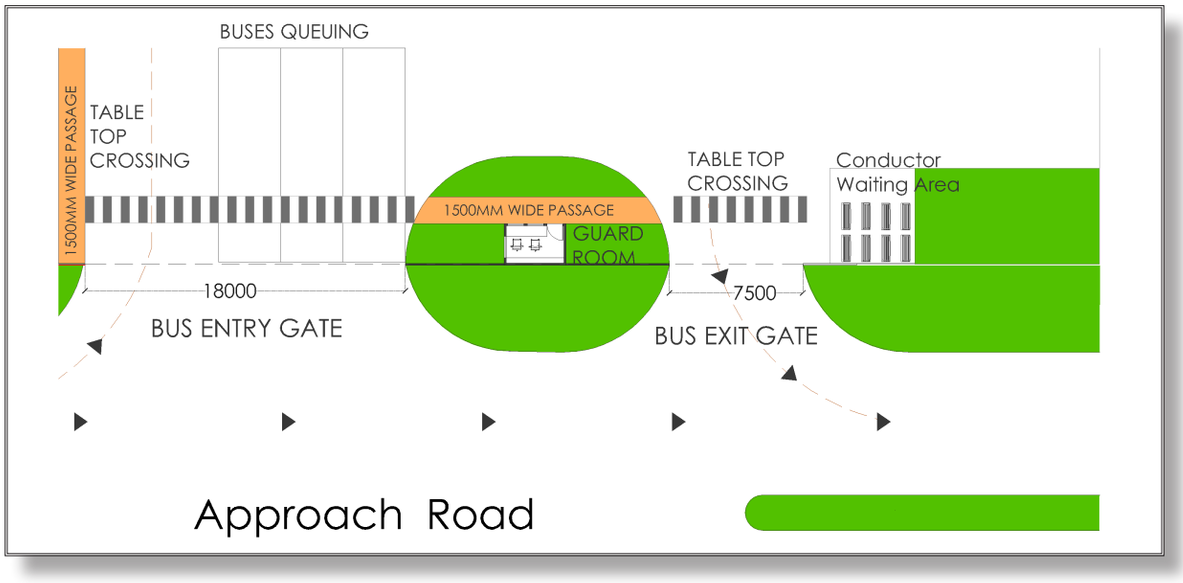
Adequate queuing space need to be provided inside the depot to ensure minimum traffic disturbance outside the depot. This ensures that the disturbance to the traffic outside the bus depot by the queued buses is minimal.

The bus conductors disembark at the entry gate after the entry of the bus in the depot. Therefore facilities required by conductor [3] should be close to the entry gate.

An auxiliary nitrogen generation machine with suitable generator or accumulator can be suitably placed at the exit gate in a manner where it does not hamper the traffic flow, for emergency inflation or checking of tyre pressure.

[2] The movement of the remaining traffic from (ii) to (v) is discussed in Chapter 6 & 7.
[3] Refer Chapter 6

The illustrative layout of bus entry and exit is presented below.



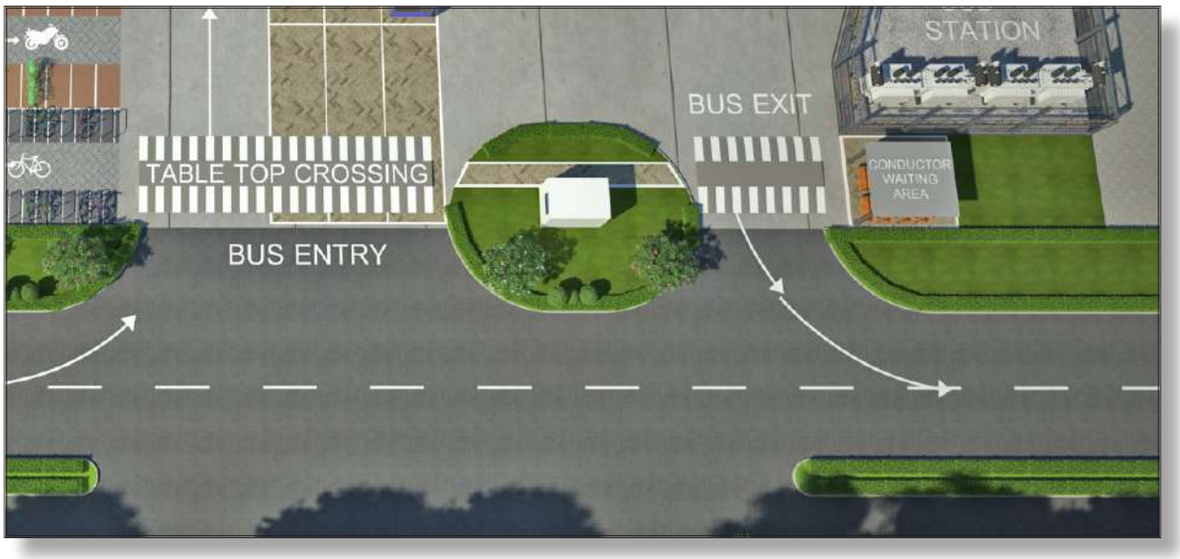


Figure 5-2: Bus Entry and Exit

Pros and Cons

The comparison between a single entry/exit for the buses and a separate entry and separate exit is tabulated below:

Table 5-1: Pros and Cons: Separate Entry and Separate Exit

Pros	Cons
Aids in Unidirectional movement of buses in a depot	Additional costs towards manned and electronic security.
Minimization of risks to security personnel and conductors especially during duty changeovers (i.e. buses coming in the depot and departing at the same time)	Has to have favorable conditions for merger with the main road (i.e. design of intersections on the main road should be such as to avoid the disruption of traffic flow on the main road)

Table 5-2: Pros and Cons: Single Entry / Exit

Pros	Cons
No additional costs towards manned and electronic security.	Unidirectional movement of buses in a depot may be compromised. Buses may have to cover longer distances within depot for exit
Minimal planning is required for the design of merger with the main road (i.e. only one merger needs to be designed)	Risks to security personnel and conductors especially during duty changeovers (i.e. buses coming in the depot and departing at the same time and place)

Separate entry and separate exit for buses, pedestrians and other vehicles

Bus Depot Design Guidelines as well as **VDV Guidelines** recommend a common entry/exit for the buses and separate access for suppliers and pedestrians to segregate service traffic from suppliers and pedestrian traffic. However, in such a scenario, the placement of facilities like washing, fuelling etc. need to be planned carefully.

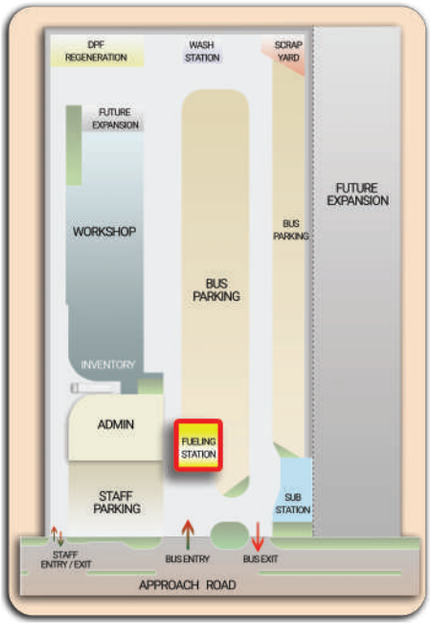
The separate entry and separate exit for buses has its advantages in terms of ease of circulation. However, the cost towards the security is higher in this case.

The minimum features are as follows:

Equipment	• Nitrogen Generator Machine • Tyre pressure gauge
Illumination	The outdoor illumination levels should be in the range of 50-150 lux and 200-300 lux is required in the security cabin.
Safety	Table top type speed breakers should be provided at the approach to the entry and exit gates to reduce the approach speed of the buses at the gates. Outdoor Day/Night CCTV cameras with IP 65 protection should be provided at the entry and exit gates. Due consideration should be given to the floor height of the bus in designing the speed breakers. Boom barriers and steel roller gates should also be provided at the entry and exit gates.

5.2 Fuelling Area

Generally, in Indian scenario, fuelling station is the first stop of the bus in the bus depot. Here the km reading is taken to analyse the usage of fuel (for administrative purposes, not done in the case of CNG buses and electric buses as chances of fuel pilferage is low) and the bus is refuelled, minor checks on the inventory of the bus along with any items left by passengers. The bus is handed over to the depot drivers after fuelling. In this section, we discuss the diesel fuelling areas and the alignment of the depot design with the type of fuel in the rolling stock, i.e. CNG/ HCNG and electricity



The space requirement and design of fuelling station have to be based on the number and types of buses to be fuelled and considerations for future expansion.

The area required for fuelling station, its underground storage tanks or cylinders for CNG storage, and its layout will require concurrence of Oil Marketing Companies (OMCs).

Fuelling area should be designed to accommodate the Diesel Exhaust Fluid (DEF) tank for the Bharat Stage VI buses. In case the OMC does not permit DEF tank within the fuelling area, it could be placed next to fuelling station. Illustrative layout is shown below.

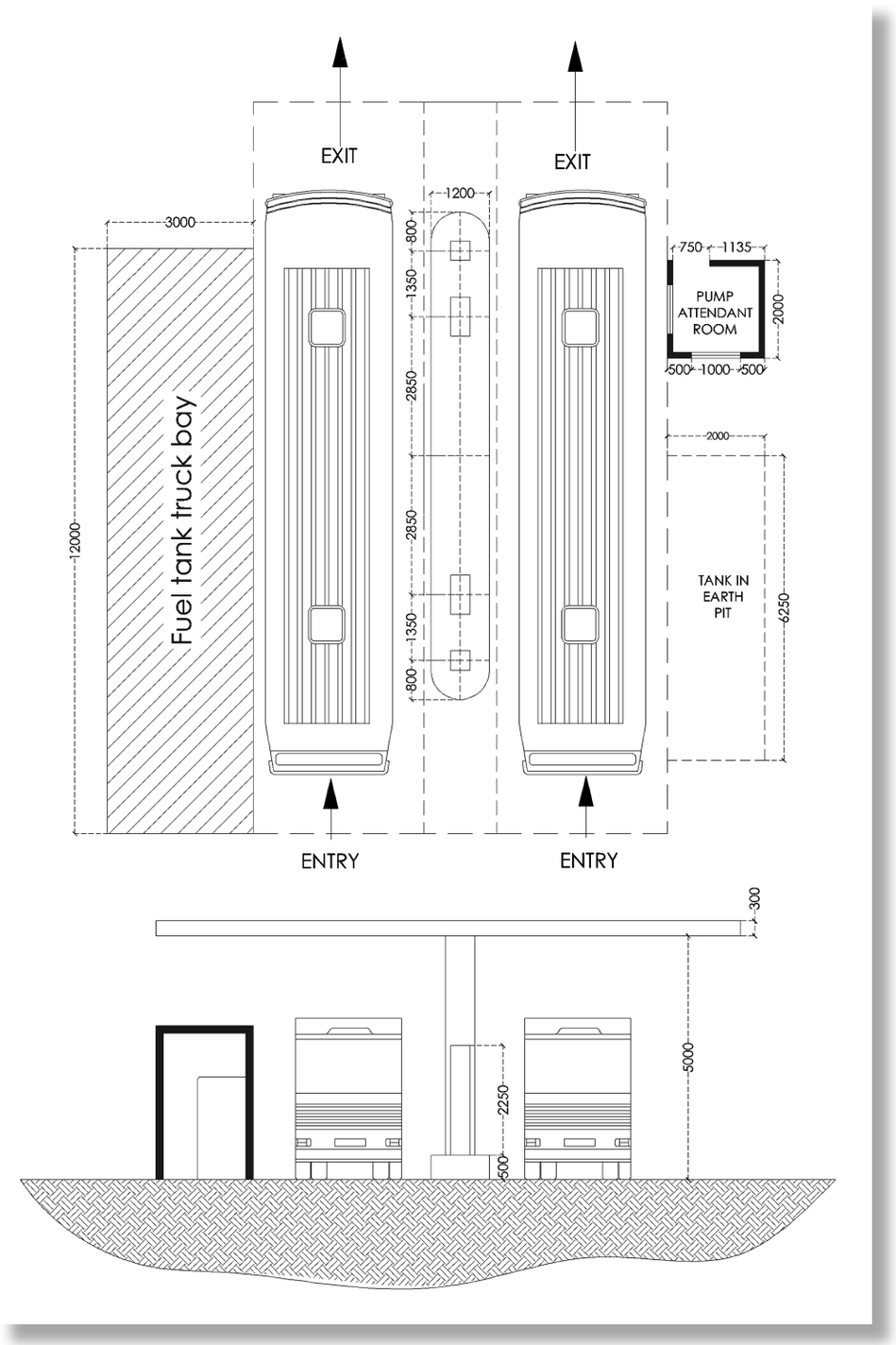


Figure 5-3: Fuelling Area

In case of CNG buses, the fuelling station can be placed along the boundary wall based upon the site layout and OMC requirement.

In case of electric buses, the fuelling station would be the charging stations which will be placed in the parking area. This area will be free and can be used for parking of buses.

The number of buses to be fuelled in a given time-frame decides the number of nozzles and fuelling bays to be provided at the fuelling station which in turn dictates the area requirement for the fuelling area at the bus depot.

The fuel dispensers with a higher flow rates should be preferred as they reduce the time to fuel a bus.

The number of nozzles/ fuelling bays required can be calculated using the formula given in Table 5-3. However a minimum of 2 nozzles should be provided. A 100 bus depot will typically require 4 diesel dispensers of 80 LPM (litres per minute) [4] capacity.

Table 5-3: Calculation of Number of Nozzles/ Fuelling Bays

SN	Description	Formula
1	Number of buses in depot	N
2	% of buses need fuelling/day	Y%
3	Time for fuelling (in Minutes)	T
4	Time (hours) in which the buses must be fuelled.	H
5	Average availability of facility	A%
	Number of nozzles/ fuelling bays required	(N x Y%) / (H x A% x (60 / T))

The quantity of fuel to be stored in underground tanks (or in cylinders for CNG) depends upon the contractually agreed periodicity of supply with the Oil Marketing Company.

[4] The dispensing units are presently available with the following fuel flow rates as per the manufacturer's specifications:

(i) Standard duty: 40 LPM
(ii) Heavy duty: 80 LPM

Space Requirement for Fuelling Station

Bus Depot Design Guidelines and **NCTPA document** suggest the following space requirements for fuelling station.

(i) Diesel Fuelling Station: 373 sqm (400 sqm in NCTPA document)

(ii) CNG Fuelling Station: 511 sqm

The above may be referred to for the depot planning purpose.

The actual space requirement and the design of the fuelling station for diesel and CNG should be as specified by the oil/ gas marketing companies.

Pros and Cons

A key decision while planning and designing a depot is whether or not to have a fuelling station within the depot or depend on third party fuelling stations. The following table presents the merits and cons of having fuelling station in house :

Table 5-4: Fuelling Area – In-house or outside

Pros	Cons
No disruption of traffic due to fuelling of multiple buses at a third party outlet	Usage of premium space in the depot which can be used for further expansion or for other purposes
Availability of fuel at all times (Time for fuelling of buses can be decided as per the operator's convenience, while most third party outlets are not functional 24x7).	Obtaining Permits and Approvals for a Fuelling station is a long-lead process
No waiting as the fuelling facility is exclusively for depot buses	Blocking of capital in fuel storage for certain period of time
No inconvenience to passengers and other customers at the third party fuelling station.	
No dead haulage for fuelling	

It is recommended that the depots should have a captive fuelling facility inside the depot premises. The minimum features are as follows:

Equipment	The equipment to be used in the fuelling area are specified by the OMCs and should be adhered to while designing the fuelling area of the depot.
Illumination	A lux level of 300-500 lux should be maintained in the fuelling area
Safety	The fuelling area falls under the category of hazardous buildings as per the NBC 2016 (Group J: Hazardous Buildings). NBC recommendations for firefighting measures are discussed in Chapter 8.

5.2.1 Modifications due to Fuel

(a) CNG/HCNG

As in the case of diesel fuelling stations, the number of buses to be fuelled in a given time-frame decides the number of nozzles and fuelling bays to be provided at the fuelling station. This in turn dictates the area needed for the CNG/HCNG fuelling area in the bus depot. The dispensing units are available with the flow rates [5] as per the manufacturer's specifications:

2 CNG dispensers with a flow rate of 10kg/min are suitable for the fuelling of 100 CNG buses and the time required for the fuelling of a CNG bus ranges from 8-10 minutes/bus (72 kg tank capacity).

For a depot housing more than 100 buses e.g. 150 buses, more dispensers should be provided to complete the fuelling in the limited time available. However, having more than 2 dispensers will require additional compressor and hence space provisioning should be made accordingly based on the guidelines from the CNG company.

An illustrative layout of a CNG fuelling facility with 4 dispensers is presented in **Annexure 1**.

HCNG fuelling stations also require a HCNG reformer plant which requires additional space over and above the space needed for a CNG fuelling plant.

(b) Electric Buses

The bus parking area has to be modified to accommodate battery-powered Electric buses by provision of a minimum of 2m space in front of bus parking bay for the placement of the trickle charging[6] stations (slow charging) along with the underground cable trenches. The depot layout has been designed keeping the aforementioned considerations in focus as presented in **Annexure 1.** Cable routes should also be designed for minimum DC cable lengths to avoid DC cable losses.

5.2.2 Modifications due to Bus Dimensions

The dimension of buses impact the area requirement for fuelling the bus.

[5] The CNG dispensing units are presently available with the following flow rates
- 10 kg/min at 210 bar
- 8 kg/min at 160 bar

[6] Or as per the specification of the bus manufacturer

While the design and the area requirements for fuelling in a bus depot are governed by the guidelines provided by the Oil Marketing Companies (OMCs), the area required for the parking of buses for fuelling i.e. the design of the parking bay in the fuelling area and the placement of dispensers vary with the change in the length of bus. These changes normally result in the increase of the overall fuelling area.

Illustrative layouts of the fuelling area with buses of different lengths are presented in **Annexure 1**. The design considerations provided by the respective Original Equipment Manufacturers (OEMs) should be followed while designing the fuelling area in a depot.

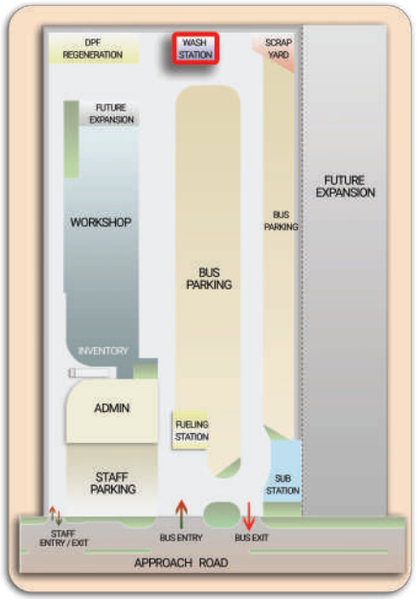
The indicative area[7] requirement for a diesel fuelling station with 2 dispensing units for different dimensions of buses is tabulated below.

Table 5-5: Fuelling Area Requirements for Various Bus Types

SN	Length of Bus	Fuelling Area Requirement (in sqm)
1	12 M	200
2	14 M	230
3	18 M	290
4	24 M	380

5.3 Washing Area

The buses may move to the washing area for the body washing and internal cleaning from the fuelling area or the maintenance area or parking area. Therefore the location of the fuelling area should be decided accordingly. It is preferred to place the washing plant along the boundary of the fuelling site. The frequency of bus washing, i.e. daily, on alternate days or on a defined schedule will depend on the Service Level Agreement (SLA) to be adhered to by the operator, weather conditions, the state of roads etc.
An illustrative layout is shown below.



[7] OMCs should be consulted before finalising the areas, as these may vary substantially with OMCs requirement.

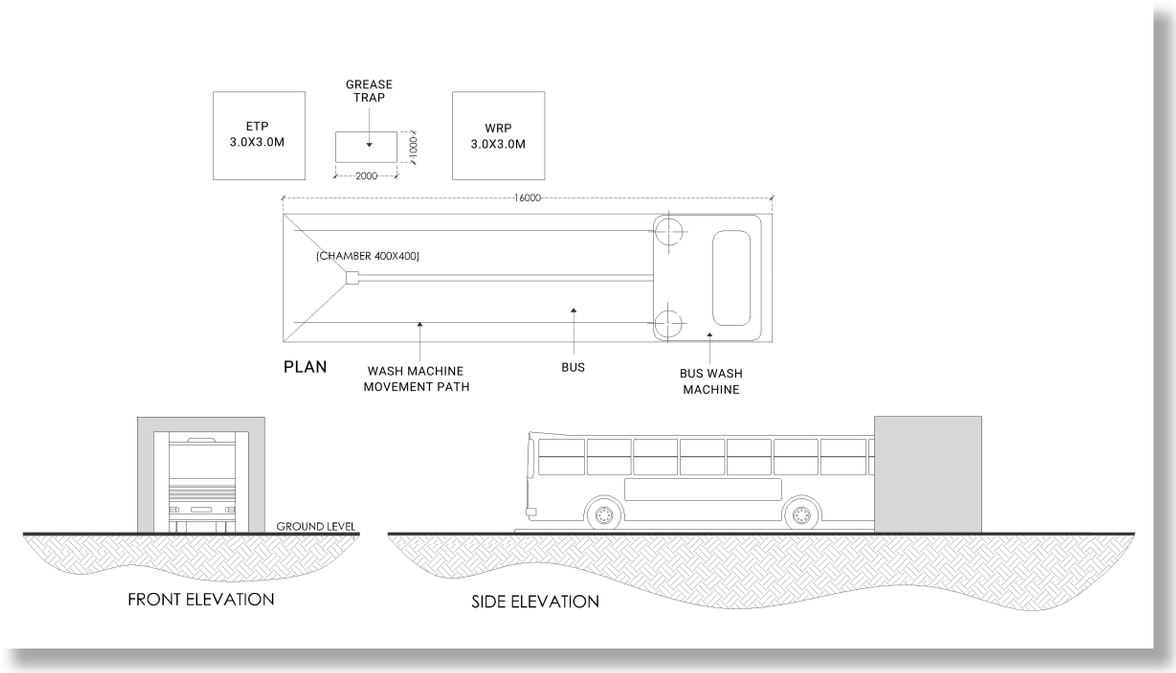


Figure 5-4: Washing Area

The space provisioning for washing area is a function of the number of bus washing bays required for washing and cleaning of the buses. The requirement of number of washing bays can be calculated based on the number of buses to be washed, time taken for washing of buses, time period available for washing of buses etc. as the parameters involved as shown below.

Table 5-6: Calculation of Number of Washing Bays

SN	Description	Formula
1	Number of buses in depot	N
2	% of buses need washing/day	Y%
3	Time for washing (in Minutes)	T
4	Number of working hours available for washing per day	H
5	Average availability of facility	A%
	Number of washing bays required	(N x Y%) / (H x A% x (60 / T))

Typically 6-8 minutes per bus is required for washing in today's scenario. Two bus washing bays fitted with automatic bus wash system should suffice for a bus depot housing 100 buses. 1 bus wash bay per 50 additional buses may be deployed for a depot having more than 100 buses.

The original equipment manufacturer (OEM) provides the customized layout based on the operator's specific requirements.

It is to be noted that equipment and washing technology may change over time leading to changes in the inputs required for washing which include water, chemicals, thermal and mechanical energy. A key decision in planning and design of the bus washing area is the choice of technology to be incorporated for the bus washing. Arguments can be made for or against the following choices between:

- Manual vs Automatic Bus washing system
- 2 brush vs 3 brush bus washing systems

A manual washing system requiring hoses and pump driven pressure nozzles for body washing requires ramps, more water in comparison with automatic bus wash systems, more time and labour. As such, this is not recommended for modern bus depots; however, if the number of buses is small (less than 40), availability of water is not a constraint and the facility is also to be for a short term (less than 10 years), this may be considered.

Automatic bus washing system employ rotating brushes and pressure sprinklers mounted on a stationary or moving gantry. The under-chassis washing is done by under chassis washing machines which may also be a part of the automatic bus washing system. The automatic bus washing machine typically comes in a 2 or 3 brush variants, the third brush being used for cleaning the front and rear ends of the bus and the roof. Many operators of CNG buses and AC buses having roof-mounted AC equipment prefer swiveling nozzles instead of the third brush which undergo faster attrition when used with such buses.

An Automatic Bus Washing System shall be designed for a modern bus depot. A comparison between a 2 or a 3 brush bus washing machine is tabulated below.

Table 5-7: 2 Brush Vs 3 Brush Automatic Bus Washing System

2 Brush Washing System	3 Brush Washing System
Consists of 2 vertical brushes, with or without swiveling nozzle arrangement for cleaning the roof.	Consists of 2 vertical brushes with an additional horizontal brush
Vertical brushes can only clean the sides of the buses.	Additional horizontal brush can clean the top of the bus as well. The third brush is for the front, rear and the roof of the buses.
Comparatively lower cost than a 3 brush system	Comparatively higher cost than a 2 brush system
Additional apparatus like ladders may be required for access to the bus roof for cleaning.	Horizontal brush requires programming to handle the contours (in case of AC buses) on the top of the bus
Relatively higher turnaround time as additional time is required for cleaning the bus roof	Quicker turnaround time.

The provision for alteration in the water tank capacity and access to energy and ducting should be kept in mind while designing the washing bay.

Another factor to consider in the process of identifying an appropriate bus washing system is conservation in the use of water, a resource which will become increasingly scarce over time. Vehicle washing involves use of chemicals, generates wastewater with a high concentration of surfactants, oils, greases, waxes and other contaminants requiring effluent treatment plants (ETP) which are mandatory. However, ETP generally installed, only decontaminates the wastewater before discharging wastewater into drains. Hence, a Water Recycling Plant (WRP) [8] is better and environment friendly alternative to an ETP. WRP decontaminates and recycles the effluent generated in the depot to a degree where it can be reused for bus washing and other operational purposes (depending upon the degree of filtration) in the depot thereby reducing the usage and dependency on the fresh water supply.

The equipment and illumination requirements are tabulated below

Equipment	An automatic bus washing system is an integration of multiple equipment and the Automatic Bus Washing System is best got installed and commissioned by the OEMs.
Illumination	A lux level of 300-500 lux should be maintained in the bus washing area.

[8] Modern WRPs with the present technology can recycle water at the rate of 4000 liters/hour. Capacity required may be estimated from the number of buses to be washed per hour and requirement of about 110 to 160 liters of water to wash one bus.

A WRP technology presently has the potential to reduce the fresh water requirement for bus washing by 70-80%.

5.3.1 Modifications due to Bus Type

Washing area requirements must match the bus length. The layouts are presented in **Annexure 2.** The requirement [9] of bus washing area with 2 bays for different dimensions of buses is tabulated below.

Table 5-8: Washing Area Requirements for Various Bus Types

SN	Length of Bus	Washing Area Requirement (in sqm)
1	12 M	275
2	14 M	305
3	18 M articulated	365
4	24 M articulated	455

5.4 Maintenance Area

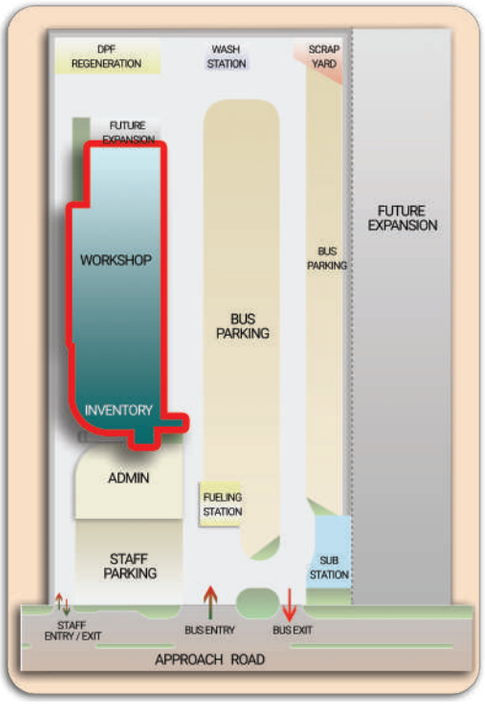
The availability of the maintenance facilities, number of pits/bays in the maintenance area primarily depend on the following.

(i) Maintenance philosophy of the operator, as defined in Chapter 1, Section 1.3
(ii) Number of buses to be maintained in the depot
(iii) Function of the depot (i.e. Parking Depot, Unitary Depot, Central/Regional bus depot)

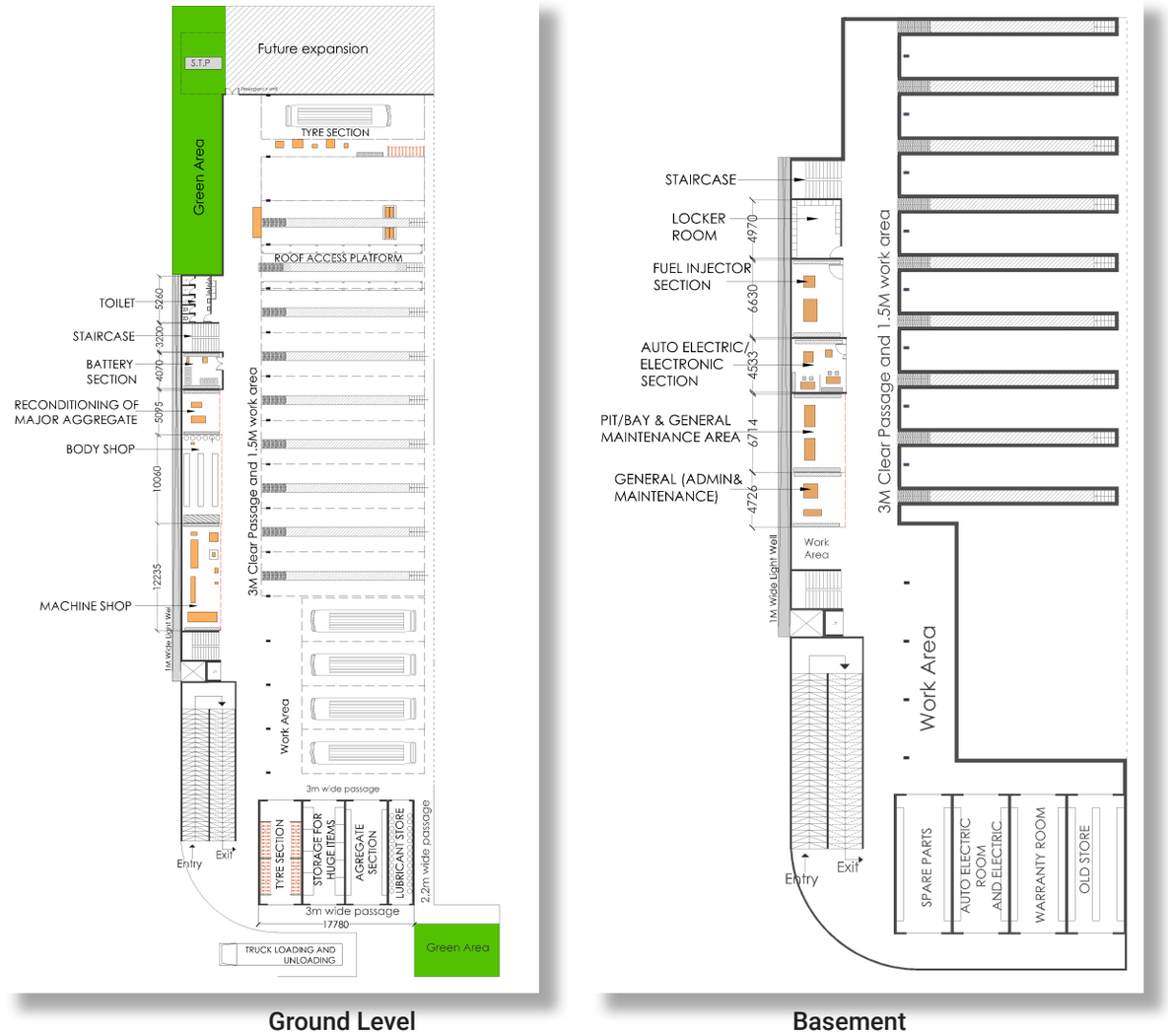
The workshop space allocation also depends on the activities to be performed in-house or outsourced. It also depends on the type/ tier of the city in which the depot is developed i.e. the level of maintenance infrastructure and expertise available in the city to outsource bus maintenance work.

Maintenance Philosophy
The utilization of maintenance facilities housed inside the depot would depend on the maintenance philosophy of the operator.

Illustrative layout of maintenance area is shown below.



[9] This generally varies with the OEM.



Ground Level **Basement**

Figure 5-5: Maintenance Area

The bus maintenance area for a central/ regional workshop catering to all major maintenance activities in-house typically requires appropriate allocation of area for the following sections:

(i) Tyre Section
(ii) Battery Section
(iii) Auto Electric / Electronic Section
(iv) General (Admin & Maintenance)
(v) Pits/ Bays & General Maintenance Area
(vi) Machine Shop
(vii) Body Shop
(viii) Fuel Injector Section
(ix) Reconditioning of Major Aggregates Section

The illustrative layout of the aforementioned sections is shown in **Annexure 3.** The above list consists of maintenance facilities required in a regional depot. The maintenance area in the unitary bus depot may contain some but not all the above facilities, based on the maintenance requirement and the maintenance philosophy of operator.

It is also recommended that in the case of smaller cities having only one depot, it should be an integrated bus depot having all the facilities listed above. However, in the case of larger cities having more than one depot, capacity utilisation and cost should be considered while deciding on the facilities to have in the depot.

According to Neufert Architects' Data, the non-individual spaces are defined as the areas where fittings and equipment sizes are more important than number of personnel for calculating the area requirement. e.g. workshop area, server/MIS section etc. The calculation for non-individual spaces as specified by Neufert is:

Non-individual Space = informed estimates based on existing good practice or comparable examples
+ an additional factor for primary circulation

Facilities to be made available in maintenance bays such as pits/ ramp/ lift/ stilt will depend on the unloaded kerb weight.

Space Requirement for Maintenance Area

ATPA Document suggests the space provisioning of maintenance area based on the space requirement for equipment to be housed. Based on discussions with equipment manufacturers, it was informed that the equipment manufacturer generally provides the estimates of space and power requirements.

5.4.1 Tyre Section

The Tyre section typically has facilities for wheel alignment, wheel balancing, tyre maintenance and management including nitrogen inflators.

Equipment	The tyre section will have wheel aligner, wheel balancer, electro hydra tyre changer, nitrogen generator and inflation machine, reciprocating compressor, tyre safety stands, tyre spreaders and tyre racks.
Illumination	Wheel section require lux levels of 500-750 lux. Fluorescent lights should be avoided in the tyre section as emitted UV rays are injurious to rubber. Storage of tyres near battery chargers, welding equipment and electric generators should be avoided as they produce ozone which is harmful to the tyres.

5.4.2 Battery Section

The battery section houses the battery charger for automotive batteries (not batteries of Electric vehicles) along with battery racks to place the batteries for charging along with storage for charged batteries. The following illustrative layout for the battery section presents the placement of the battery racks along with the battery chargers and circulation space for the depot personnel.

Equipment	The battery section houses the battery chargers and the battery racks
Illumination	A lux level in the range of 200-500 lux is required in the battery section.
Safety	• The battery section should be well ventilated to mitigate the risks of fumes emanating from the batteries. Air changes per hour (ACH) in the range of 15-30 should be maintained in the battery section. • Fire extinguishers to counter electric fires i.e. Category E fires should be installed in the battery section. • The batteries stored in this section give out fumes which are hazardous to health of the personnel. The section should have an exhaust to vent out these hazardous fumes. The exhaust fumes should be let out atleast at the height of the roof to avoid any risk of inhalation by the depot staff. • The flooring of battery section should be made alkali and acid proof.

Modifications due to Bus Type

In case of electric buses, the space provision has to be made for storage of the batteries. The space will depend upon the availability of the batteries in the local market, lead time and the maintenance philosophy of operator.

5.4.3 Auto Electric / Electronic Section

This section handles maintenance and reconditioning of auto electrical parts like switches, contacts, relays, wiring tests, self-starter motors, alternators, wiper motors, electric horns etc. This section also houses an area for storage and testing/ repair of electronic components. Requirement of the auto electrical section is presented below.

Equipment	The equipment to be housed in the Auto Electric / Electronic Section are head light aligner, alternator testing machine and auto electric bench.
Illumination	A lux level in the range of 750-1000 lux is required in the Auto Electric / Electronic section.

5.4.4 General Admin & Maintenance Section

This section houses the general equipment for cleaning and upkeep of the depot workshop.

Equipment	Fogging machine, floor scrubbing machine, portable ladders etc. are placed in this section.
Illumination	The General Admin and Maintenance Section should have a lux level range of 500-750.

5.4.5 Pits/ Bays & General Maintenance Area

Dedicated places are required for specific maintenance activities of buses, though some minor maintenance can also be undertaken at the parking bays itself. The bus is taken to a shed with a depressed chamber below ground level called “pits” for maintenance. The design and number of the pits vary with the (1) number of buses and (2) maintenance requirement of the buses in the depot. The type and make of buses decide the number of pits.

Maintenance activities where the access to the under body of the bus is not required are carried out on the bays in the maintenance area (maintenance bays).

It is recommended that the number of pits/ bays for inspection, maintenance and repair be kept at a minimum of 15% of the number of buses to be housed.

The following indicative breakdown may be used for the pits/ bays for a unitary bus depot housing 100 buses.

Number of maintenance pits/ bays

International Guidance suggests a minimum of 15 pits/ bays per 100 buses.

Table 5-9: Indicative Number of Maintenance Pits/ Bays for a 100 Bus Unitary Depot

SN	Type of Pits/ Bays	Number
1	Maintenance Bays (with 1 pit for AC buses)	4
2	Maintenance Pits	8
3	Tyre section (with one for roller brake testing facility)	3
4	Movable column lift	1

A pit depth of 1400 mm is considered appropriate for the ergonomic convenience of the maintenance personnel working in the pit. However, special consideration should also be given to the specific physical anthropology of the personnel in the geography where the depot is planned.

Roller Brake Tester

Both **VDV and BRT** Planning Guidelines recommend the use of roller brake testers.

An illustrative layout is shown below.

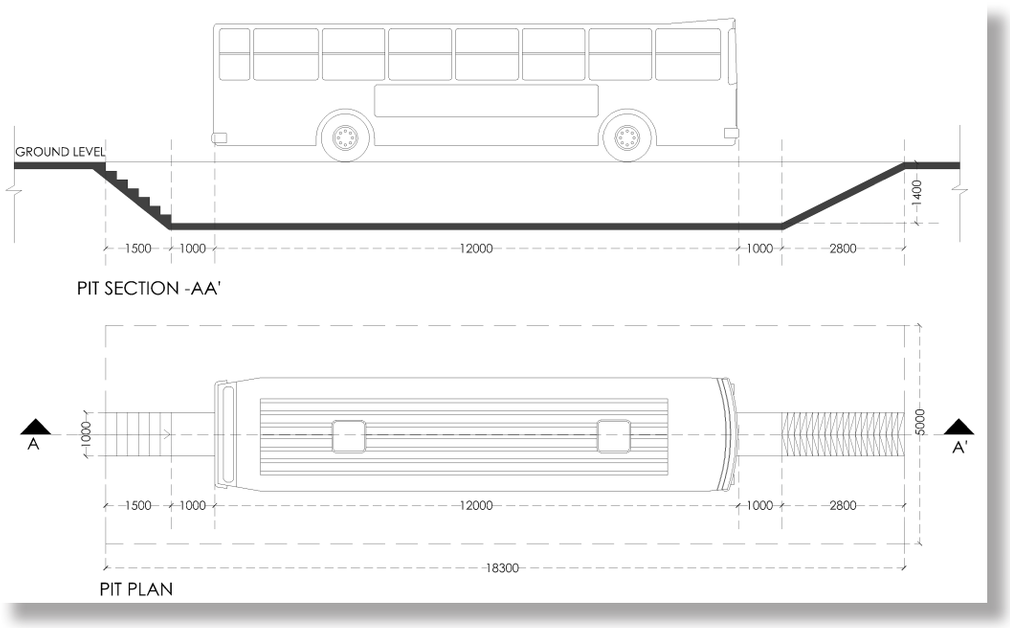


Figure 5-6: Maintenance Pit

Equipment	The equipment placed in the pit area are greasing machines, Hydro pneumatic jacks, puller for gear boxes, pit sump pumps, electric chain pulley blocks etc. At least 1 bay should be fitted with a roller brake tester.
Illumination	Lux levels of 500-750 should be maintained in the pit area with IP 65 rating.
Safety	Pit stoppers and guide railing should be provided in all the pits.

Modifications due to Bus Type

The length of the maintenance pits and bays also increase with the bus length while the depth changes with the floor height and ground clearance of the bus. The layouts are presented in **Annexure 4.**

5.4.6 Machine Shop

Machine shop houses the facilities for the machining of parts/equipment. The facilities for grinding, drilling, buffing, pressing and riveting of parts are undertaken in the machine shop.

Equipment	Machine shop typically houses bench grinder, buffing machine, brake disc facing/brake drum turning lathe machine, engine lifting/mounting crane, gearbox removal and fitment equipment, lathe machine, pedestal drill machine, hand grinder, hydraulic press and brake shoe riveting machine.
Illumination	Machining as a process require precision. A lux level of 750-1000 is suggested for the machine section.

5.4.7 Body Shop

The repair and maintenance work towards the bus body is carried out in this section. Activities like welding, buffing grinding, painting, fitment and contouring are carried out in this section. The body shop is accompanied by a paint booth for bus painting.

Equipment	The body shop houses the arc and oxy acetylene welding machine, hydraulic press, handheld drilling machine, buffing machine, spray painting machine and paint booth.
Illumination	A lux level of 500-750 is suggested for the body shop.

5.4.8 Fuel Injector Section

This section handles reconditioning and recalibration of fuel injection pump (test bench), ultra-sonic cleaning machine and pressure testing of injector nozzles.

Equipment	Diesel smoke meter (for diesel buses), fuel injector pump test bench and ultrasonic injector cleaner and tester
Illumination	The Fuel injector section should have a lux level range of 750-1000 on the injector repair bench.

5.4.9 DPF Regeneration for Bharat Stage VI Buses

This section is used for undertaking regeneration of BS VI buses. The exhaust in the area will be at a high temperature. So proper ventilation and safety precaution should be in place.

The Regeneration process at high temperature requires segregated space to prevent accidental injury to depot personnel. The following considerations should be adopted for planning of Regeneration area at the depot.

SN	Criteria	Value
1	Time taken for Regeneration per bus	20-45 minutes
2	Heat generated at the exhaust	600^0
3	Frequency of Regeneration	24 – 48 Hours
4	Minimum clearance area from bus body	3m

The following are the equipment and illumination requirement for the DPF Regeneration area

Equipment	Spring driven hose reel (150mm diameter) with 1.5 HP exhaust fan.
Illumination	This section requires lux levels of 500-750 lux.
Safety	The exhaust in the area will be at 450^o -600^0. So, personnel involved should be equipped with heat protective gear.

The manual presents a Regeneration area for 7 buses. A brief discussion and illustrative layout is attached as **Annexure 5.**

5.4.10 Reconditioning of Major Aggregates

This section handles the maintenance and reconditioning of major aggregates such as engine, gear box and rear and front axle assemblies. Illustrative layout and requirement of this section are presented below.

Equipment	Cleaning and repair of major aggregates require the tools cabinet for handheld tools, air/ water washing station and work benches
Illumination	This section requires lux levels of 500-750 lux.

5.5 Circulation of Buses within the Bus Depot

The movement of the bus within the depot should ideally be unidirectional and placement of facilities within the depot should facilitate unidirectional movement.

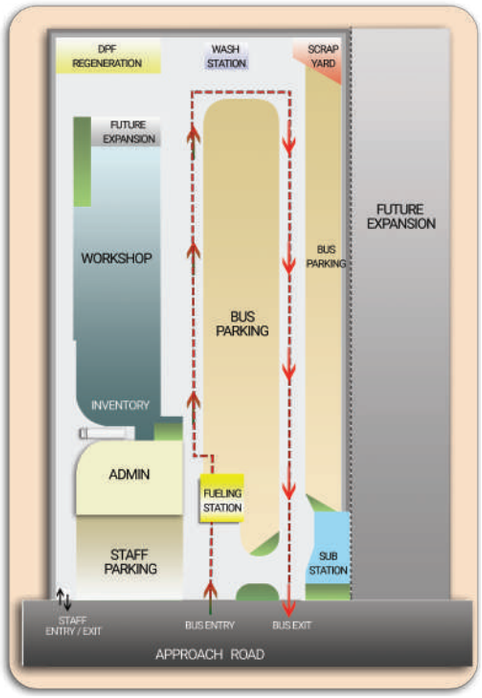


Figure 5-7: Bus Circulation Area

The circulation pattern of the buses must be designed keeping in mind the principle of unidirectional movement in the bus depot. The pros and cons of such a pattern is presented below.

Unidirectional Circulation of buses	
Pros	Cons
No conflict in the bus movement by way of oncoming vehicles	Longer driving distances in a depot
Less area requirement for the circulation of bus.	
Less chances of collision as buses require minimum reverse movement	

The illumination levels and the safety measures required are presented below:

Illumination	A lux level of 75 lux should be maintained in the circulation areas.
Safety	• Table top crossings suitably designed for low floor buses must be provided at specific points where the crossflow of pedestrians and buses cannot be avoided. • Bollards must be provided at the sides of the bus circulation areas to segregate the vehicle and pedestrian flows. • Thermosetting resin is best suited for road markings on the circulation roads.

5.5.1 Modifications due to Bus Type

The radius of curvature of the roads in a depot is to be designed based on the following factors:

(i) Design speed (the assumed speed at which the bus will approach the road curve)
(ii) Length of the bus
(iii) Turning Radius of the bus (Type/Make of bus specific)
(iv) Swept path of the bus (Type/Make of bus specific)

The design speed should be in the range of 10-15 km/hr. Illustrative guidance relevant to the determination of turning path for 12m low floor bus and articulated vehicles is presented as **Annexure 6.**

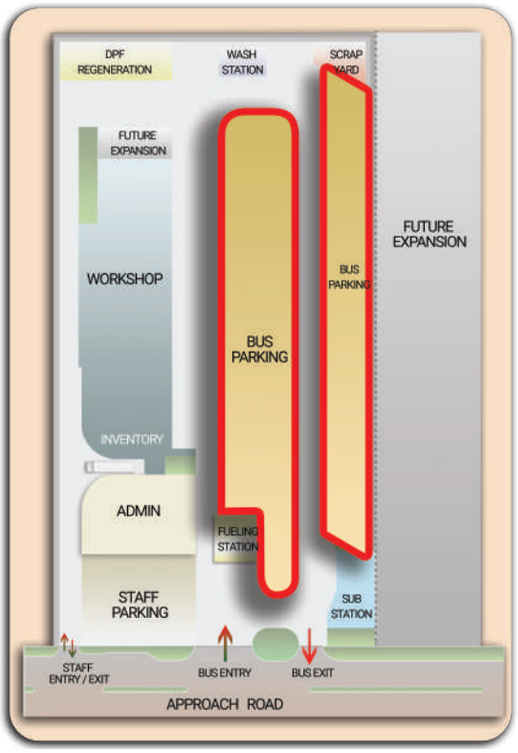
5.6 Bus Parking

After the washing, the buses proceed to the parking area. The Bus Parking could be either at-grade parking, in the basement or a multi-level parking with different configurations i.e. inline and angular. Parking appropriates a significant proportion of the available bus depot area and hence should be designed judiciously to ensure that sufficient space is available for other key activities in the bus depot.

Parking bays should be designed for easy to and fro movement of the bus with minimal area. The design of the bus parking area must ensure the following:

(i) Minimum maneuvering for bus parking and retrieval
(ii) Ease of circulation within the parking area
(iii) Marking and signage for identification of bus in a depot.
(iv) Safety for pedestrians in the parking area with pedestrian access to each bus.

Illustrative layout of parking area is shown below.



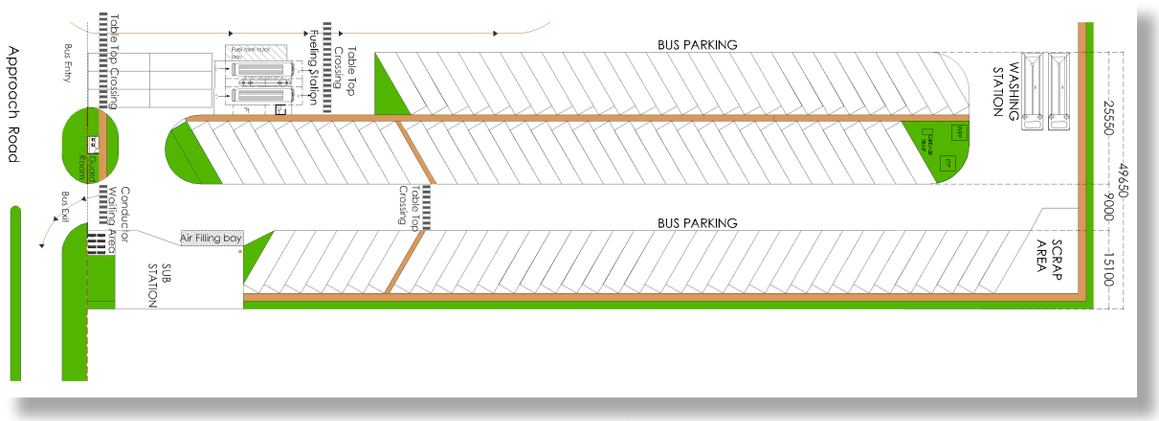


Figure 5-8: Bus Parking Area

The dimensions of the parking bay vary with the types of buses using the depot. Different types of parking configurations are described below (Illustrations are attached as **Annexure 7**).

Table 5-10: Types of Parking Configurations

SN	Type of Parking Configurations	Description
1	Angular – 30^0	This configuration requires buses to enter and back out from the bus bay. Area requirement for parking per bus is 110-120sqm.
2	Angular – 45^0	This configuration requires buses to enter and back out from the bus bay. Area requirement for parking per bus is 90-100sqm.
3	Angular – 60^0	This configuration requires buses to enter and back out from the bus bay. Area requirement for parking per bus is 85-95sqm.
4	Row Parking	Buses are parked at an angle of 90^o. These are used when buses have to be parked for a longer duration. Area requirement for parking per bus is 80-90sqm.
5	In line Parking	Buses are parked back to back. This is used when buses get out in the order in which they area parked. In line parking is space efficient and is used when buses have to be parked for a longer duration. Area requirement for parking per bus is 80-110sqm.

Angular parking with 60° parking angle is recommended as it provides an optimum balance between space utilized for parking and ease of to and fro movement of the bus in the parking area. A comparison between above mentioned type of bus bays is provided in **Annexure 7**. The bus depot parking design should include designated parking slots. On arrival at the depot , buses must be guided to their respective pre-determined parking lots. Parking of buses is the last activity after in-shedding. The driver must be informed of his/her bus's parking slot. This communication can be done with ITS as well.

In the interest of the future scalability of the bus depot, the depot components like maintenance, washing, fuelling and administrative area should be given significance in the space allocation vis-à-vis parking space. In case there is further space requirement for bus parking in the future, options like satellite parking or multilevel parking may be explored.

The illumination requirements are tabulated below.

Illumination	Lux level of 75 lux should be maintained in the bus parking area

5.6.1 Modifications due to Bus Type

The parameters impacting the bus parking are bus dimensions and the use of electric buses. The area per bus required for parking increases with the increase in the size of the bus.

The space provision has to be made for the accommodation of charging stations for the overnight charging of electric buses in the parking area as shown in **Annexure 1.**

5.7 Multilevel Bus Parking in Depots

In case of non-availability of a land parcel of adequate size to accommodate all the buses in the bus parking area or an expansion requiring more bus parking, developing Multilevel Bus Parking in bus depots can be considered as an alternative.

As the cost of the land and difficulty in its procurement are increasing, multilevel depots present a viable solution. Therefore, adequate cost benefit and technical analysis of the site in terms of bus circulation and placement of facilities should be part of the decision-making process.

Procurement of land and its cost are expected to be even more prohibitive in future, therefore to make the bus depots future proof, it is suggested that even if the bus depot is not designed as a multi-level depot, provisions in planning should enable conversion to multilevel depot in future.

Design Philosophy Tenets

Eliminating potential barriers in planning which might discourage conversion to multilevel depot, in future

Seamless integration of the facility on different floors and corresponding bus circulation	Minimising turnaround time per bus	Development of associated infrastructure for ease of entry/exit	Safety and security aspects

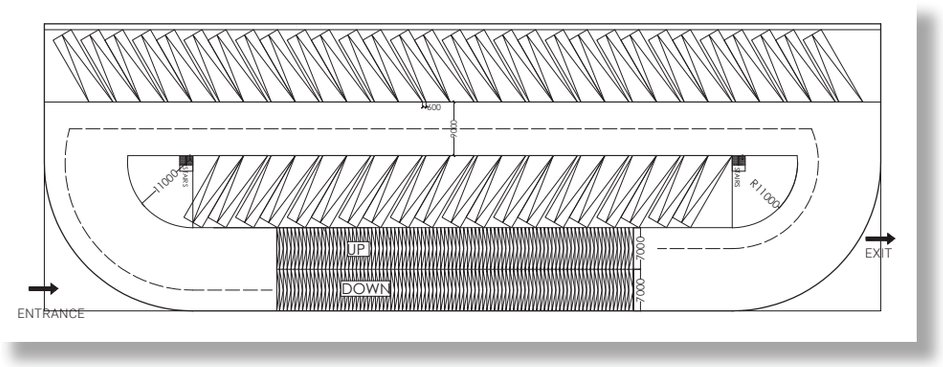
A simple rule to go for multilevel depot is when per square meter cost of the procurement of land plus the cost of dead mileage is more than the cost of construction of flyover deck.

SN	Parameter	Value
1	Cost of procurement of additional land	A
2	Dead mileage for all the buses for the horizon period	B = Cost of dead mileage per bus per day [10] X Number of buses X Number of days per year for which the bus is operational X Design period
3	Cost of construction of multilevel depot at the same site	C
	Whenever, C is less than (A + B), a multilevel depot can be constructed	

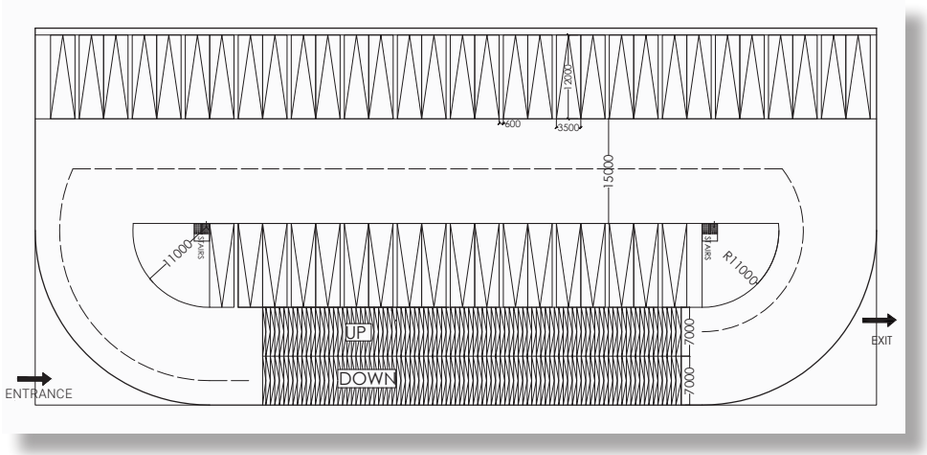
[10] Including capital cost, fuel cost, manpower cost and maintenance cost

The illustrative layouts for Multilevel Bus Parking are shown below. It is to be noted that the minimum ramp gradient of 1:10 should be provided.

Figure 5-9: Multilevel Bus Parking



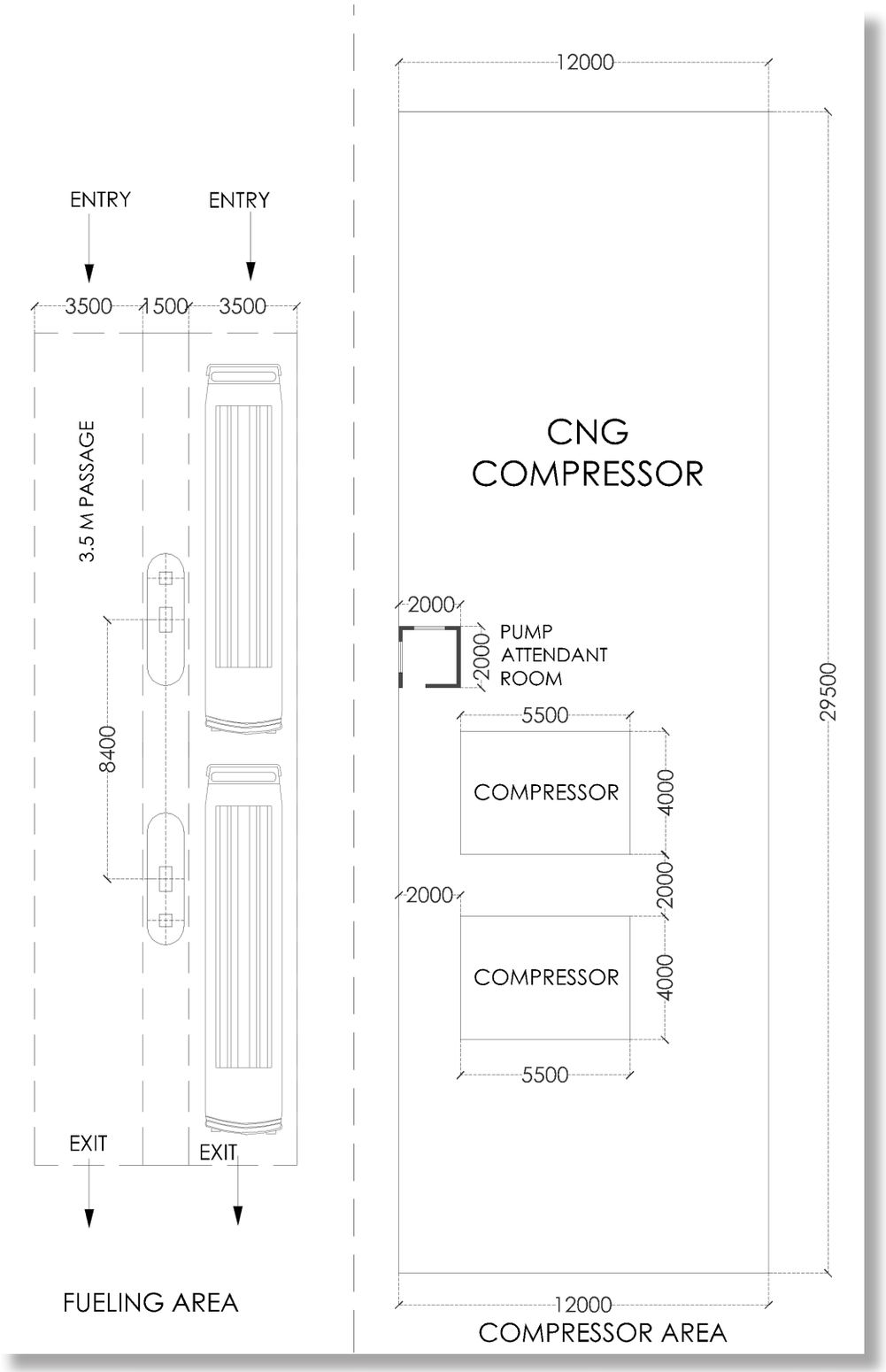
Option 1: Angular Parking 60^0



Option 2: Angular Parking 90^0

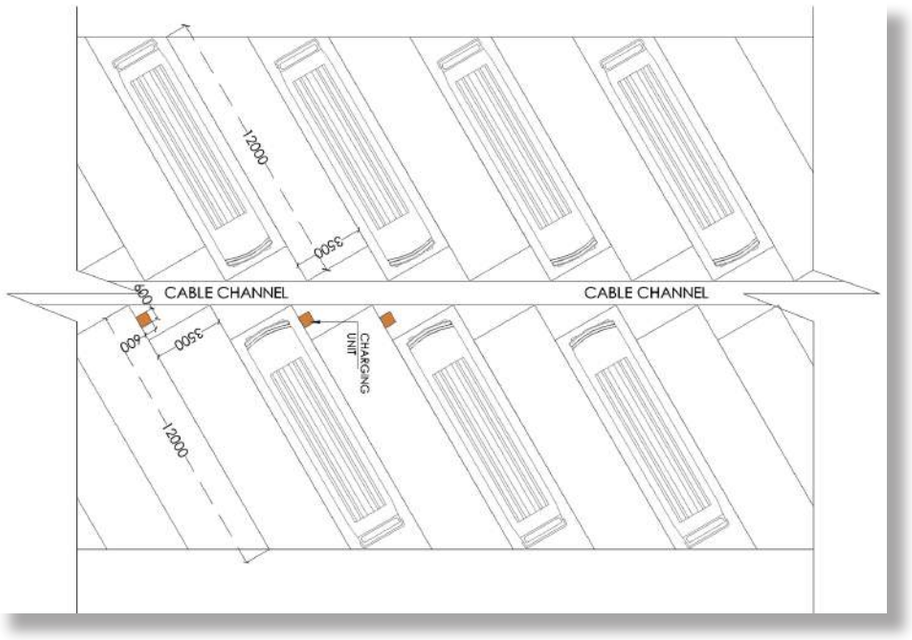
ANNEXURE 1: FUELLING AREA

CNG Fuelling Station for 12m bus

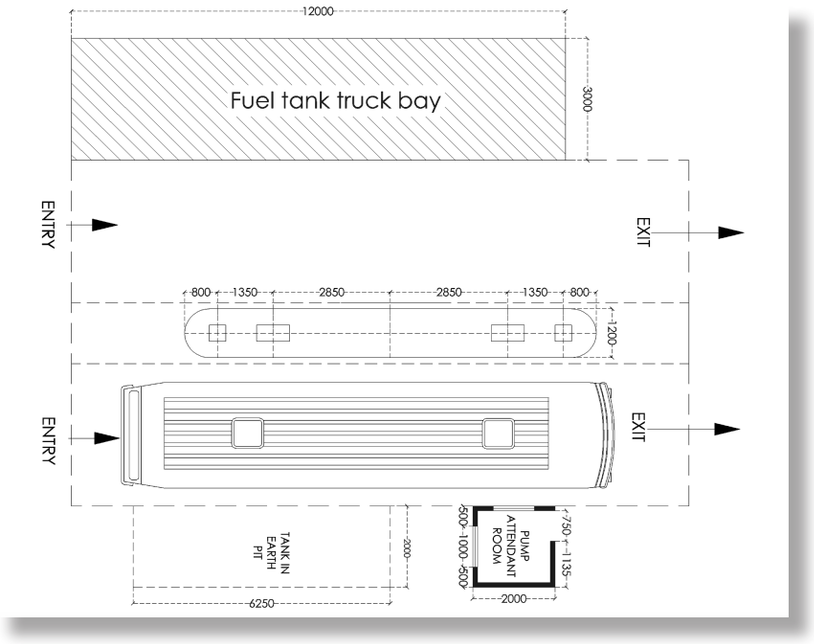


CNG Fuelling Station for 12m bus - 3d Illustration

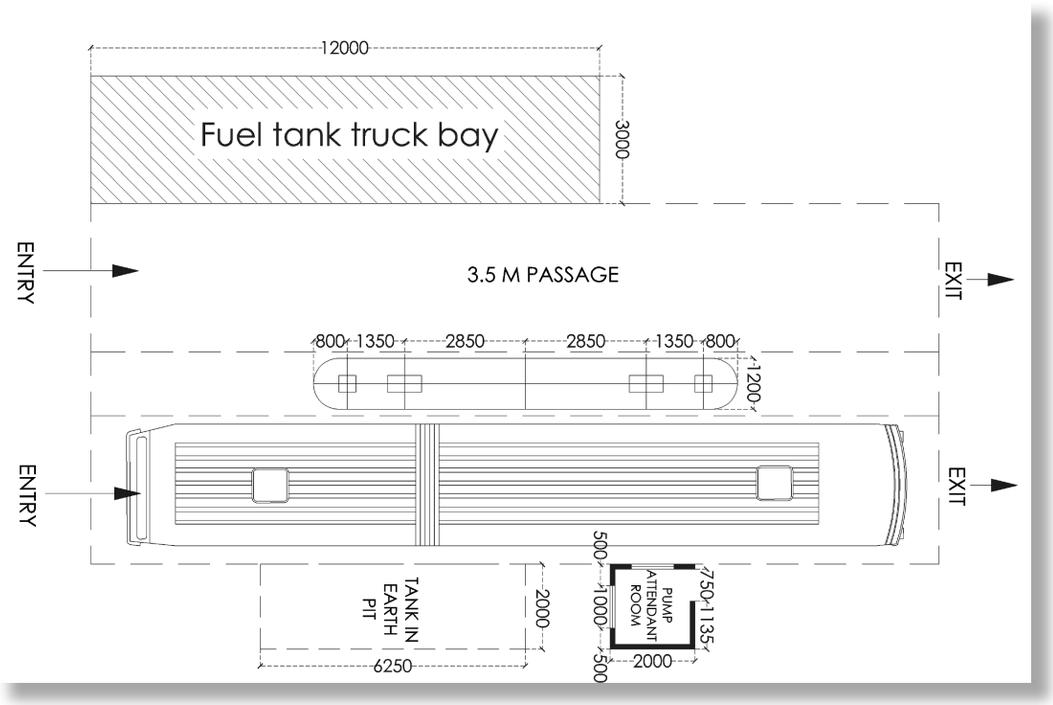
Electric Bus Charging Station for 12m bus



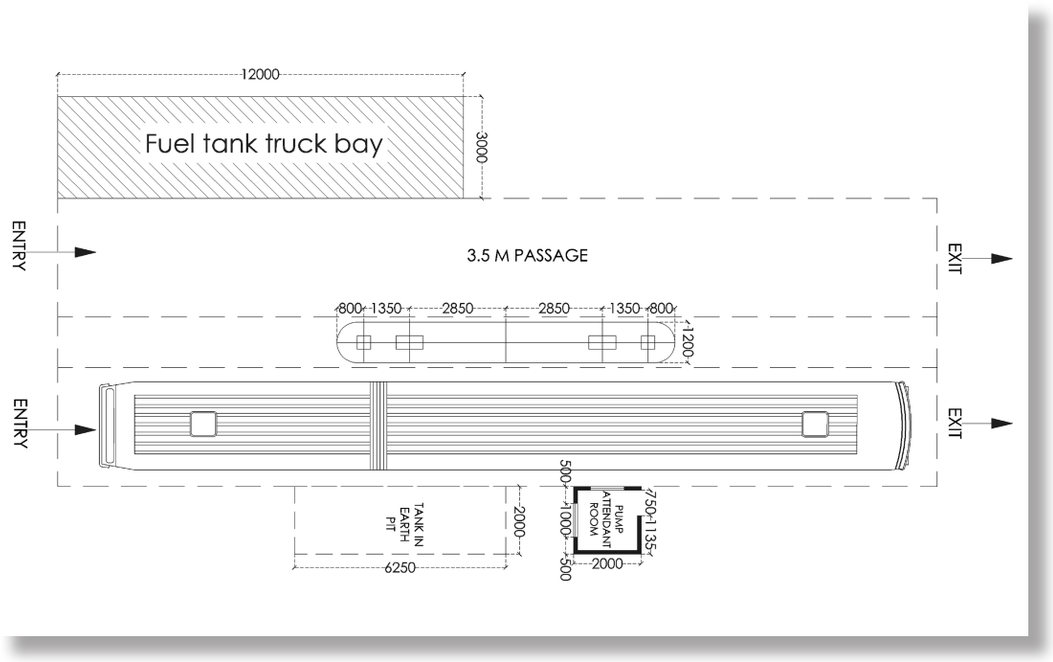
Diesel Bus Fuelling Station for 14m bus



Diesel Bus Fuelling Station for 18m bus

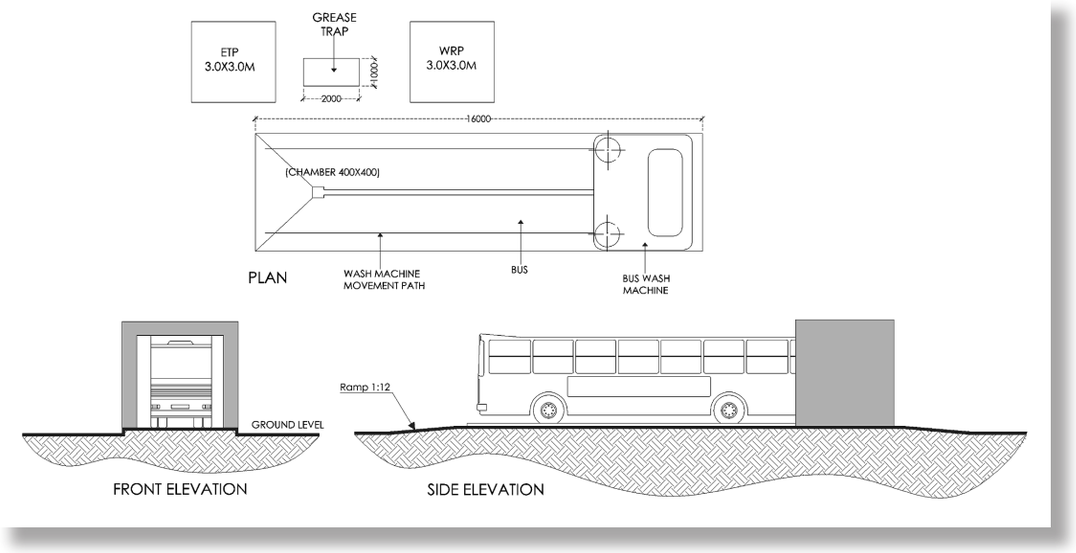


Diesel Bus Fuelling Station for 24m bus articulated bus

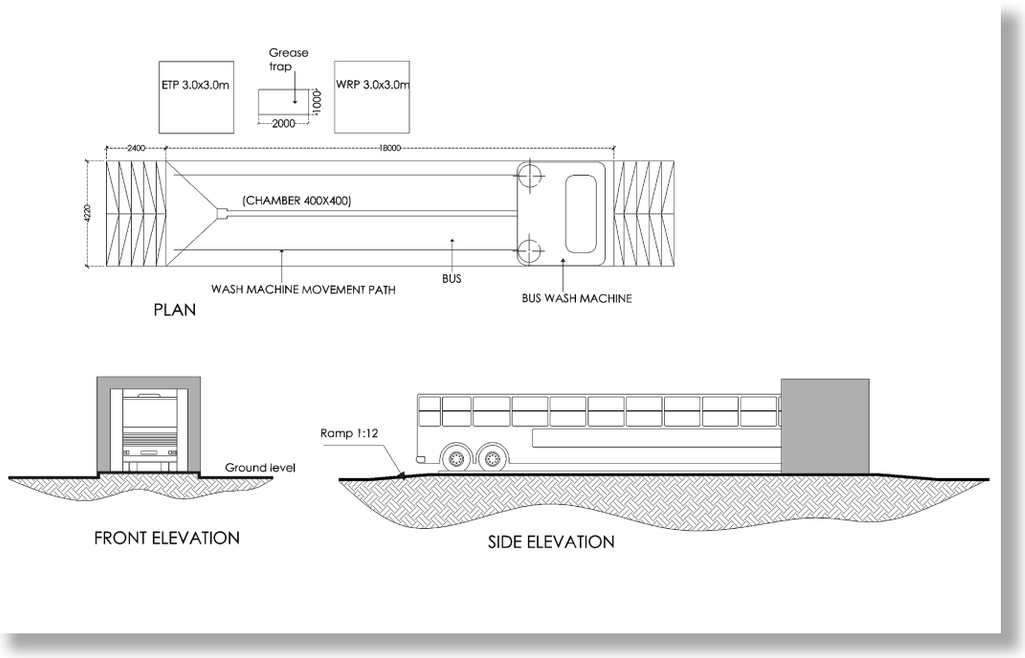


ANNEXURE 2: WASHING AREA

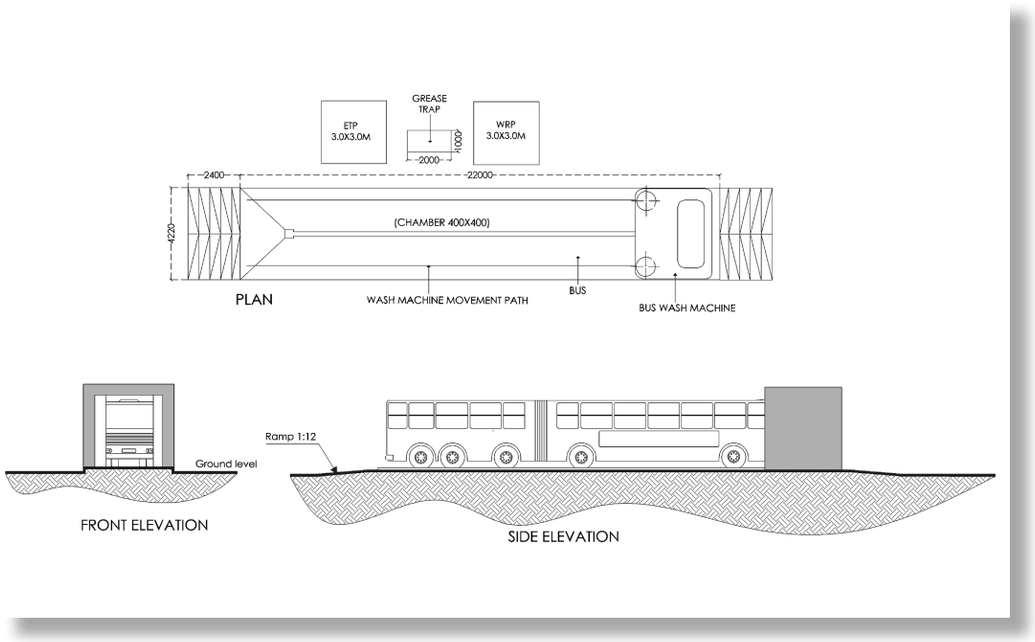
Washing Area for 12m bus with ramp



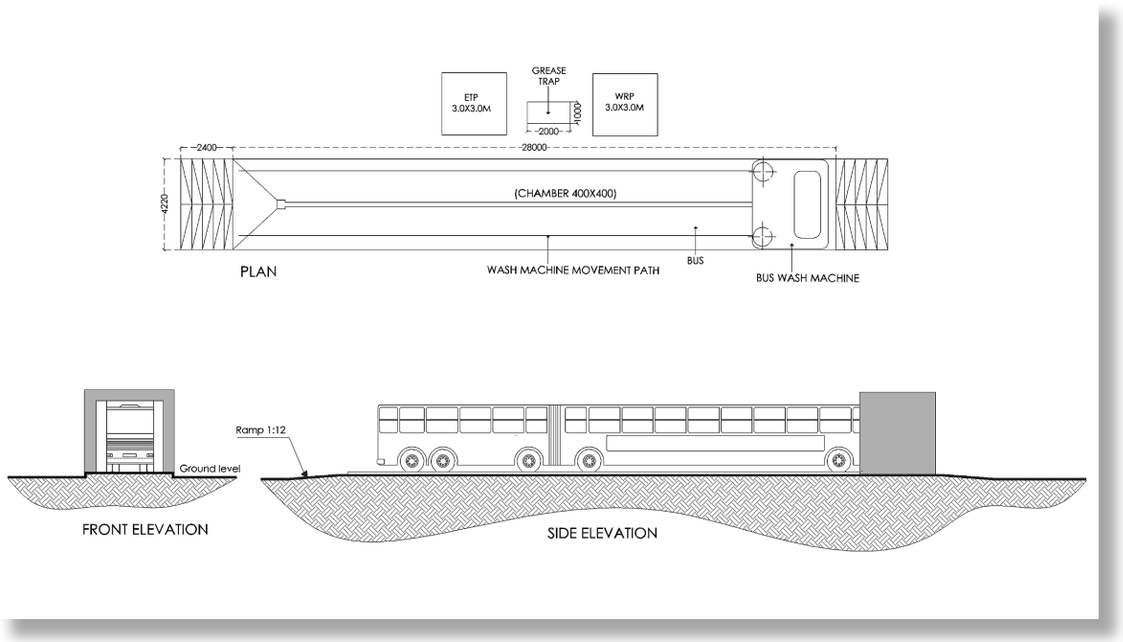
Washing Area for 14m bus with ramp



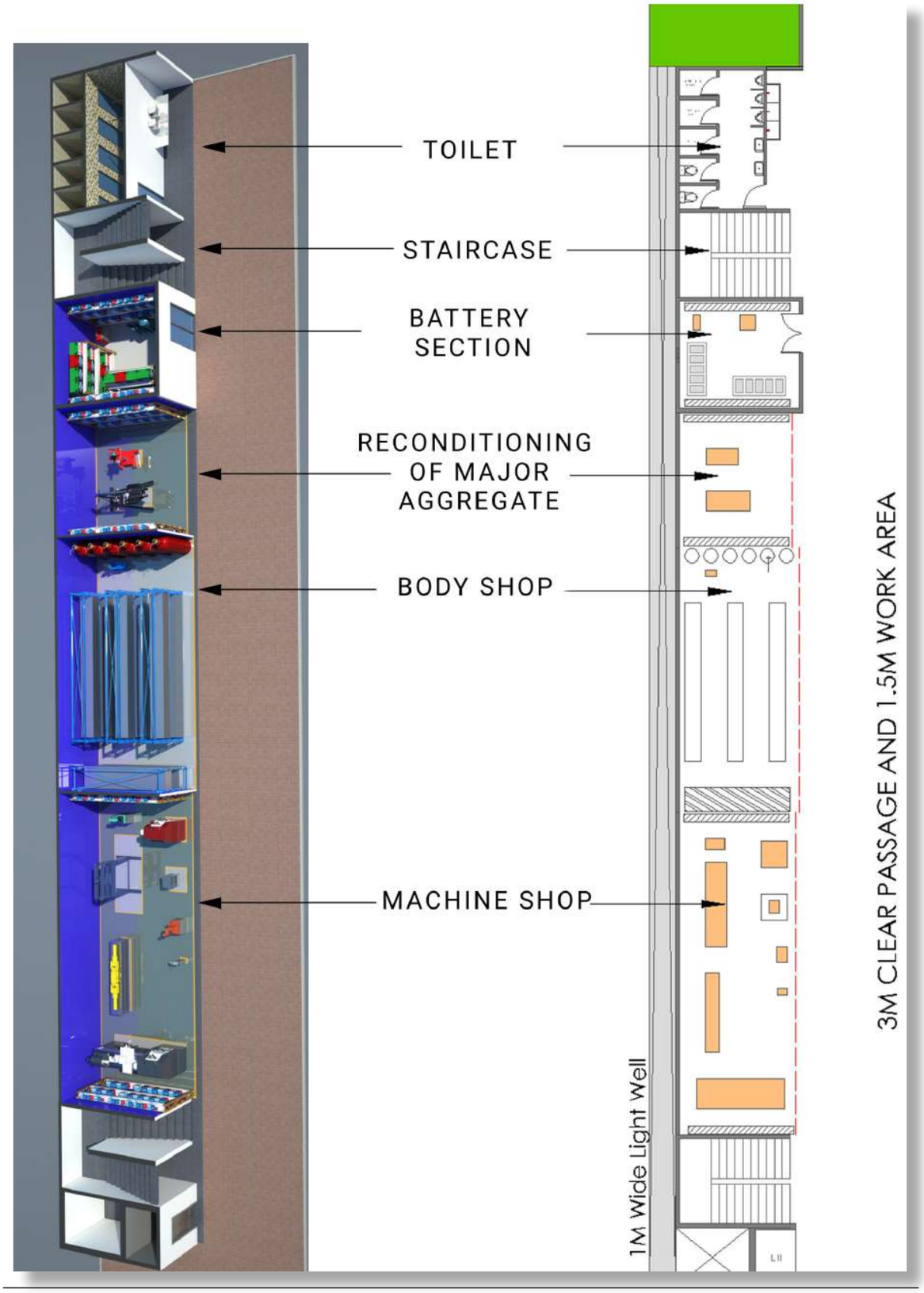
Washing Area for 18m bus with ramp



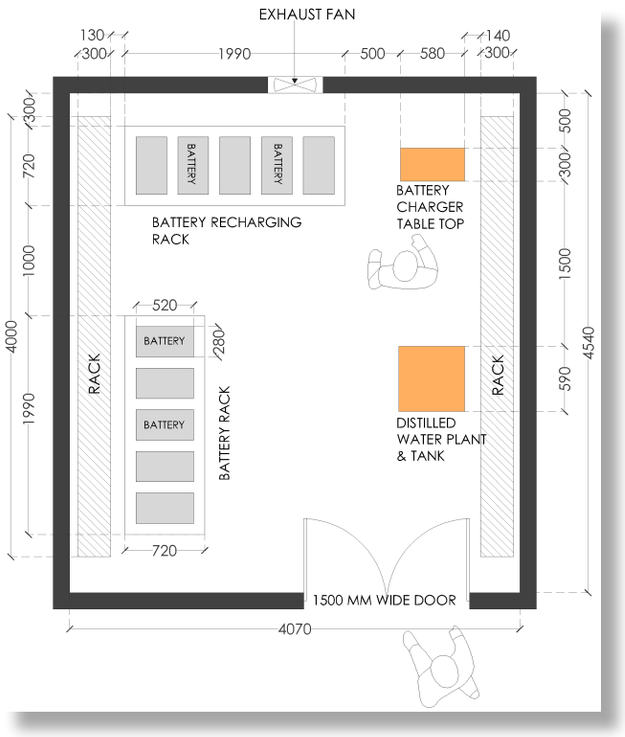
Washing Area for 24m bus with ramp



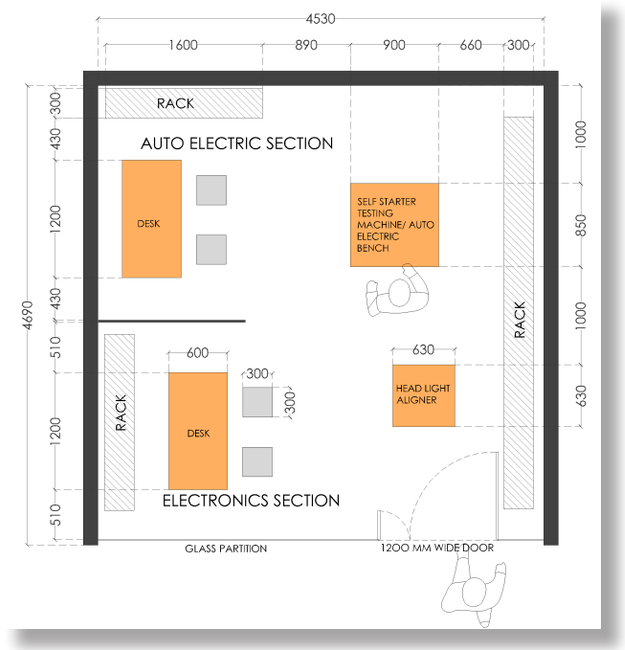
ANNEXURE 3: MAINTENANCE AREA SECTIONS



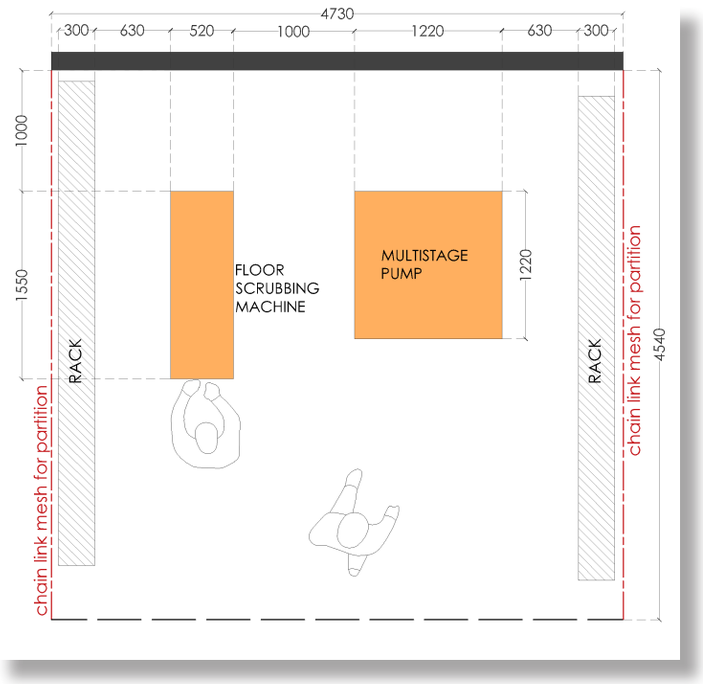
Battery Section



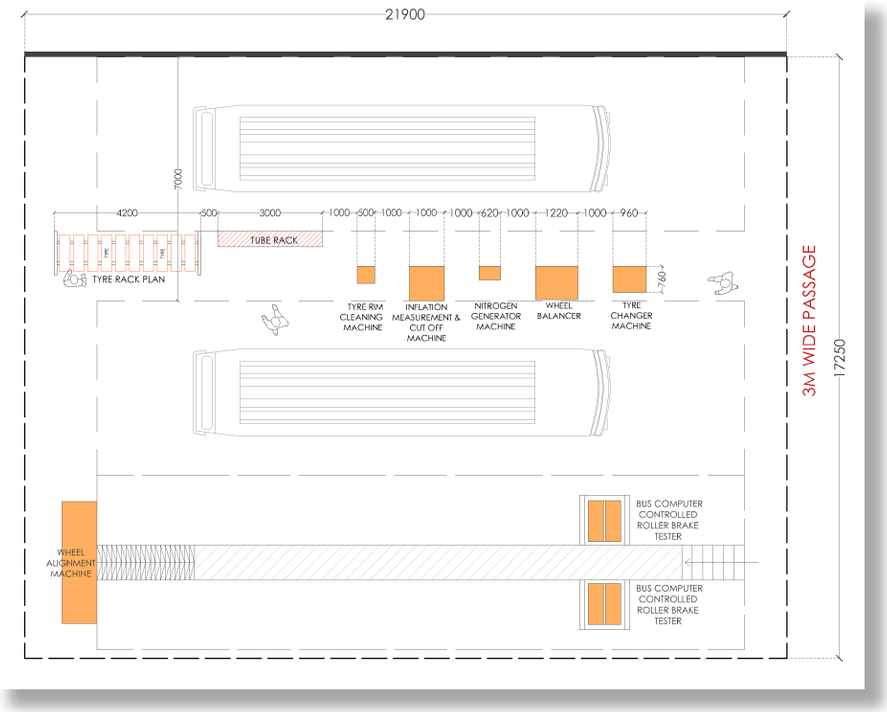
Auto Electric / Electronic Section



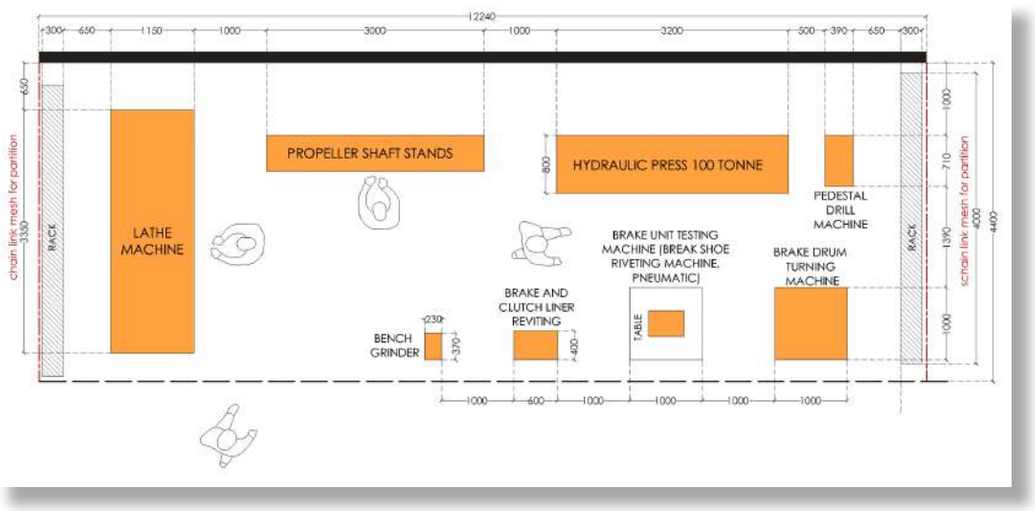
General Admin & Maintenance Section



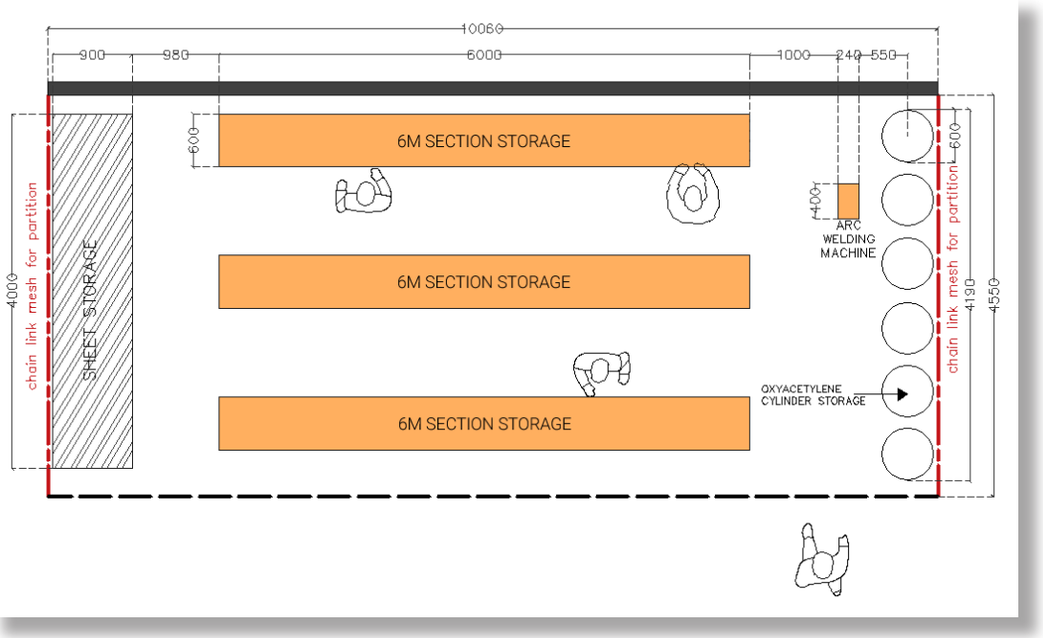
Tyre Section



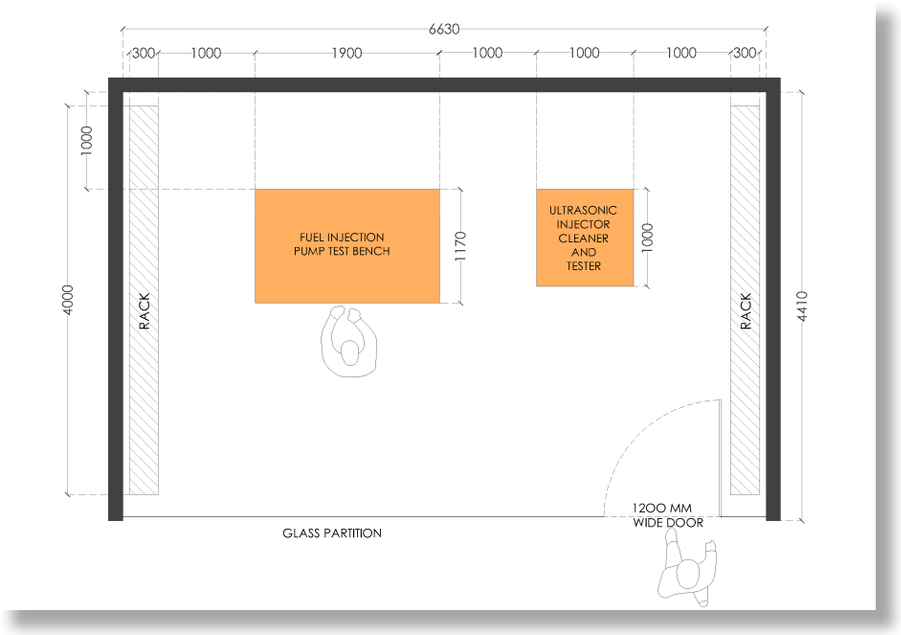
Machine Shop



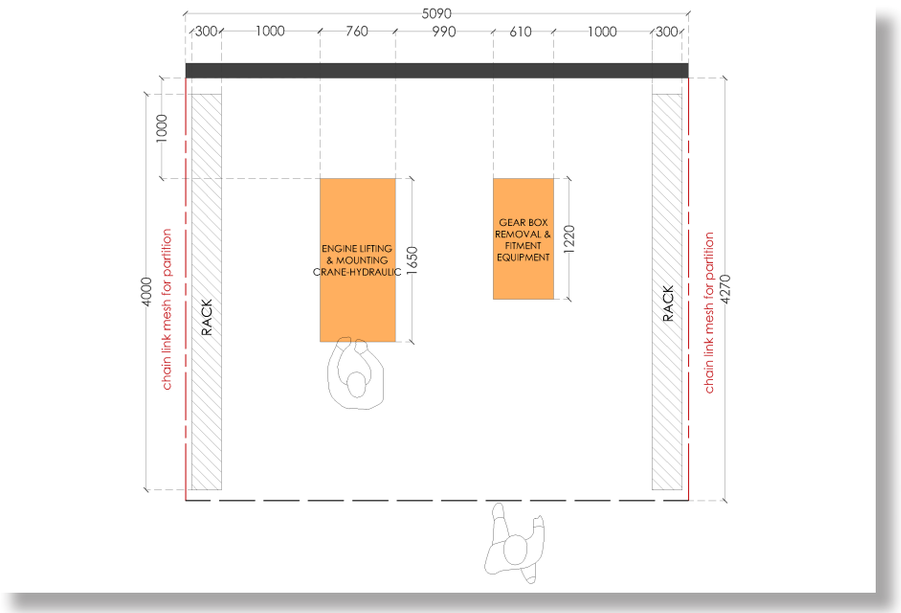
Body Shop



Fuel Injector Section

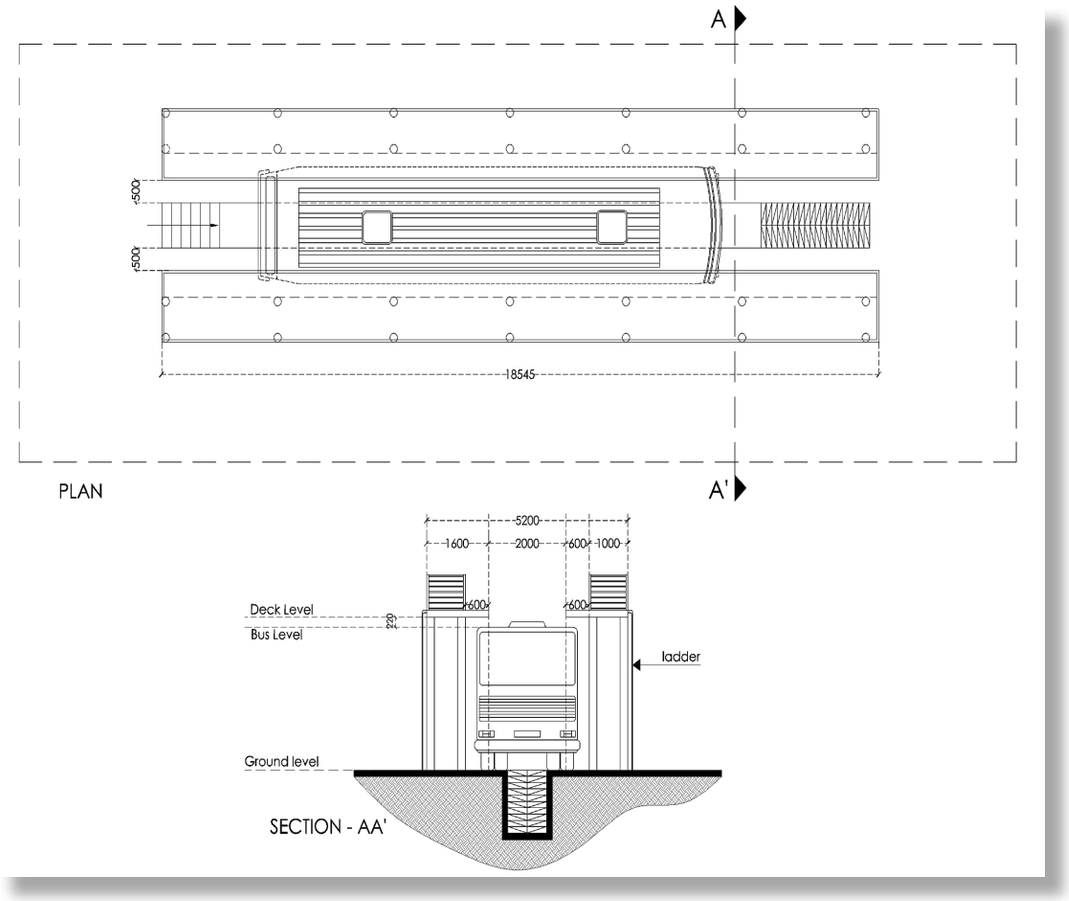


Reconditioning of Major Aggregates Section

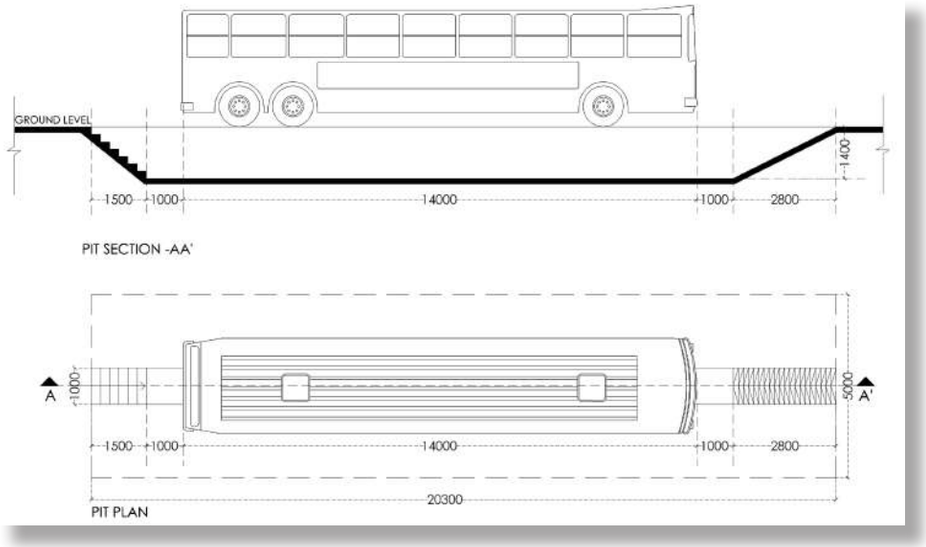


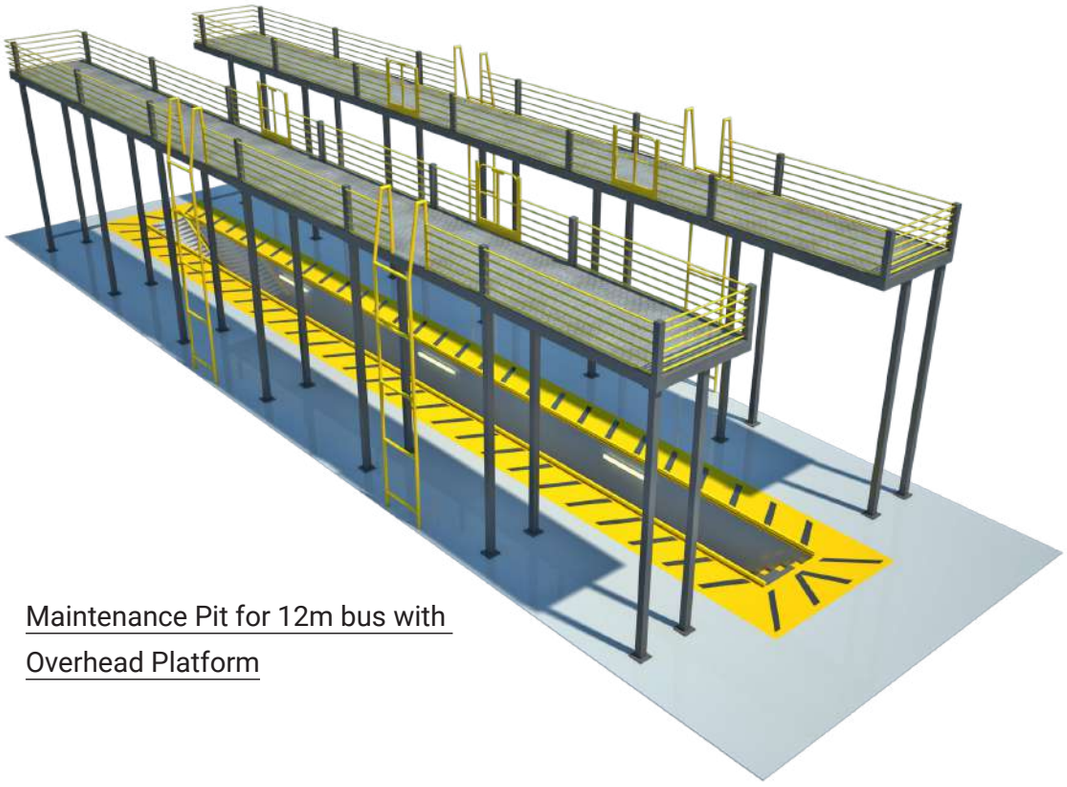
ANNEXURE 4: MAINTENANCE PITS

Maintenance Pit for 12m bus with Overhead Platform

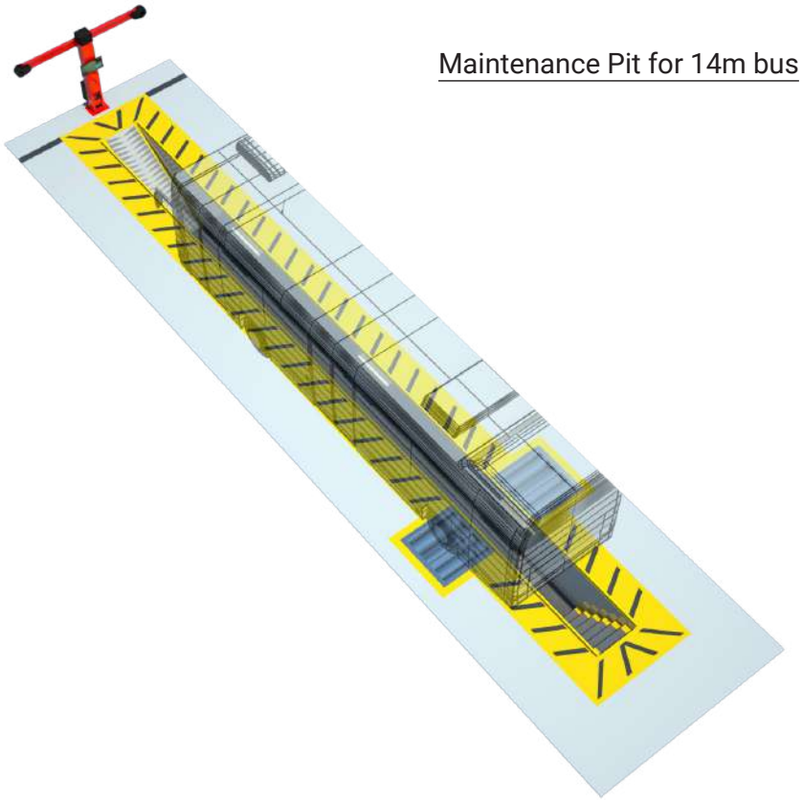


Maintenance Pit for 14m bus



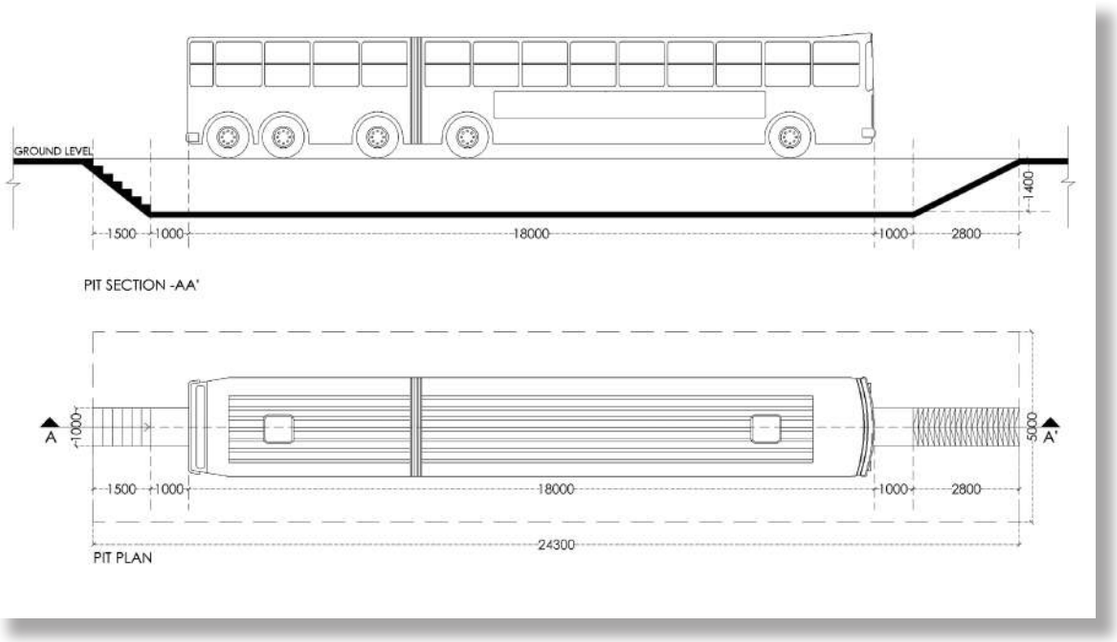


Maintenance Pit for 12m bus with Overhead Platform

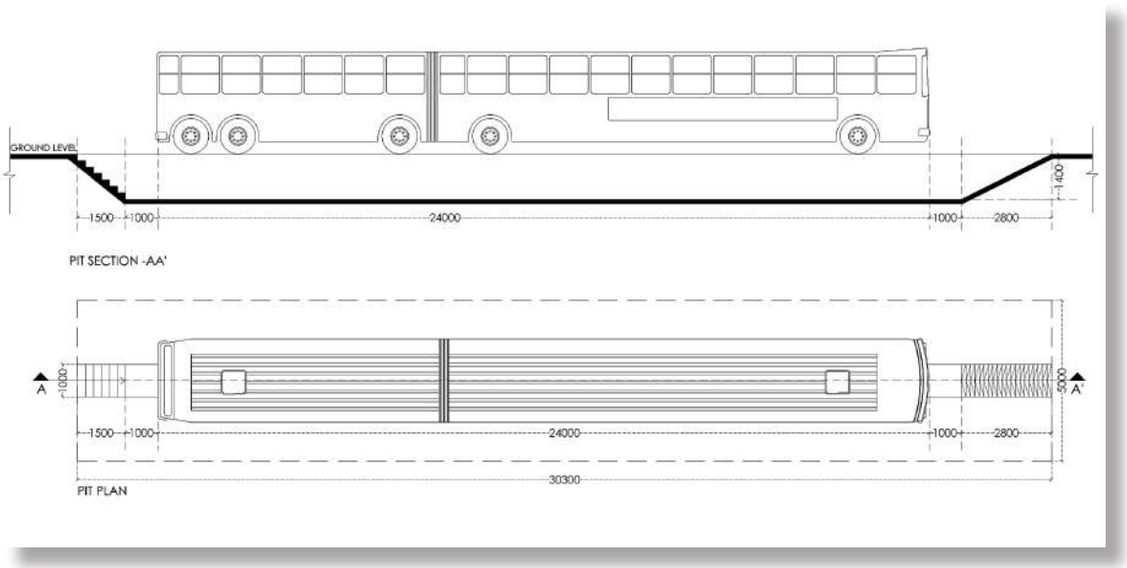


Maintenance Pit for 14m bus

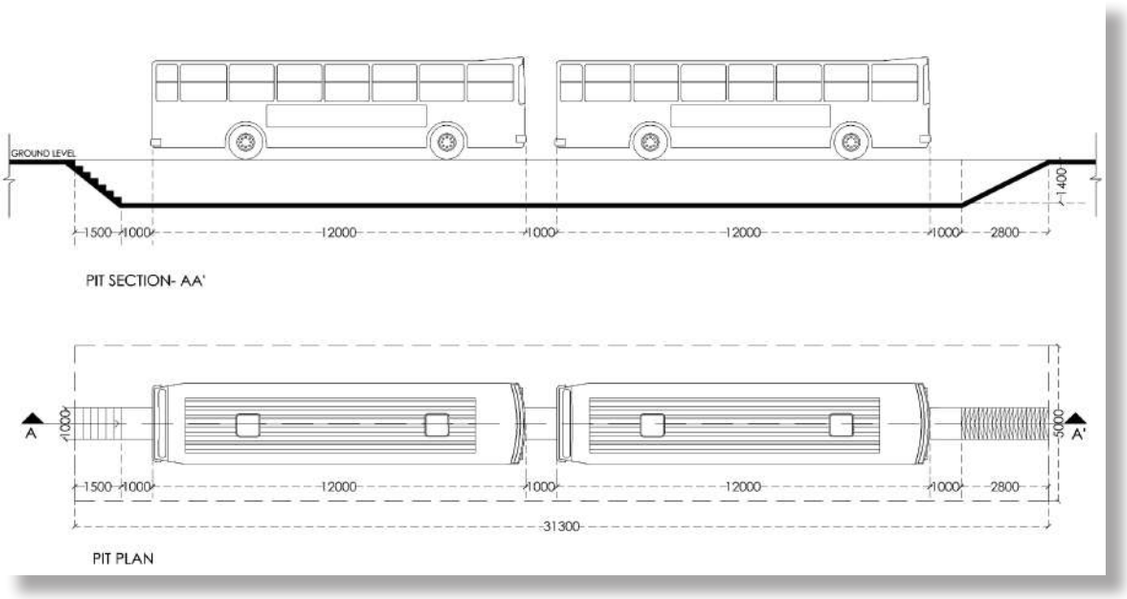
Maintenance Pit for 18m bus

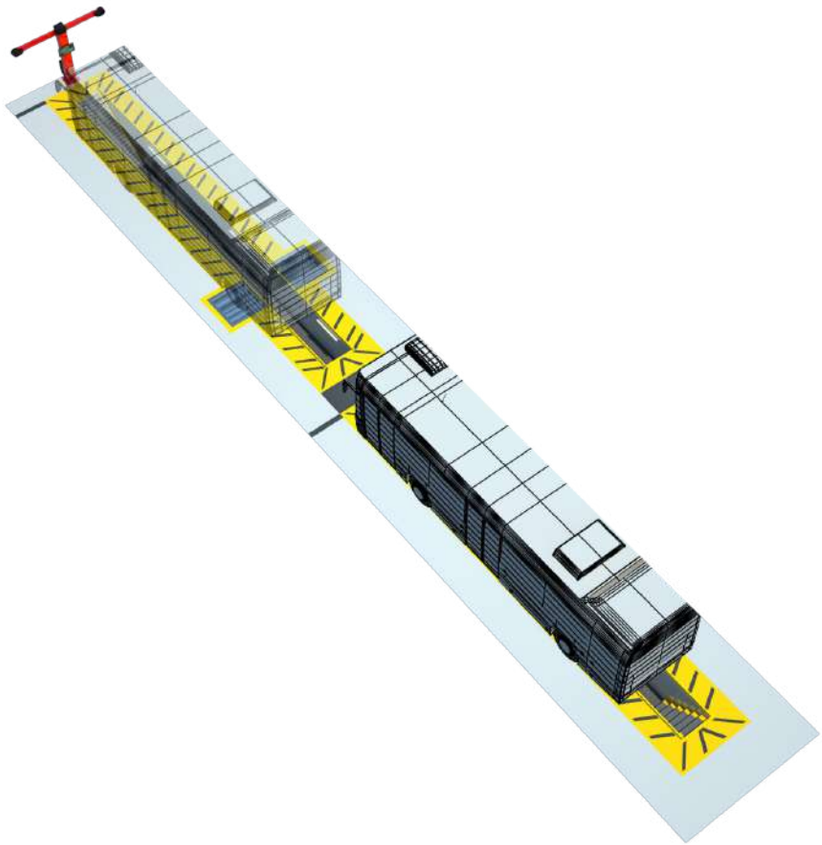


Maintenance Pit for 24m bus

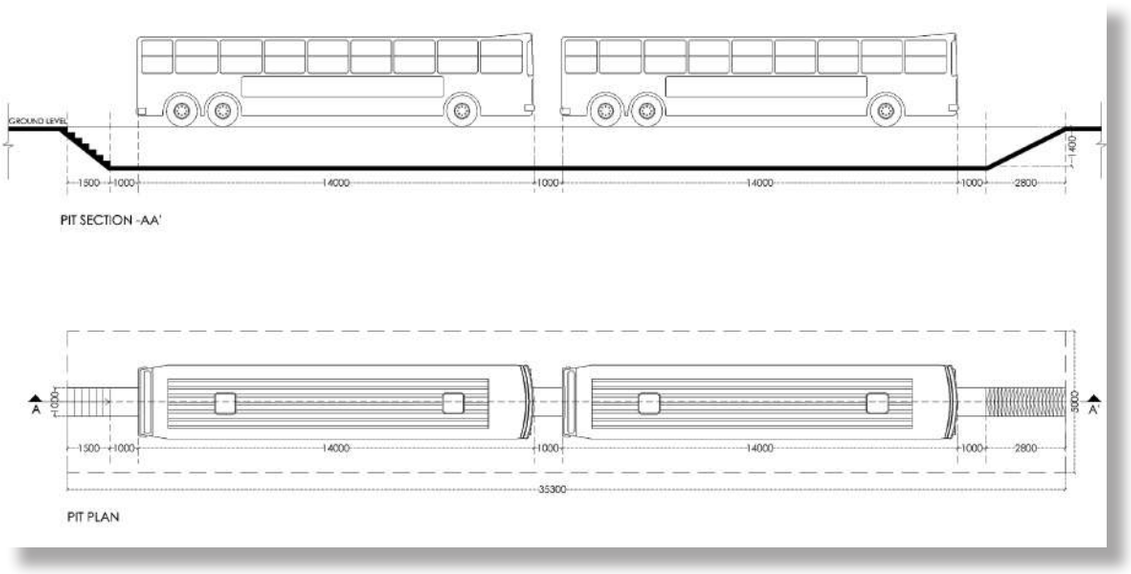


Double Length Maintenance Pit for 12m bus

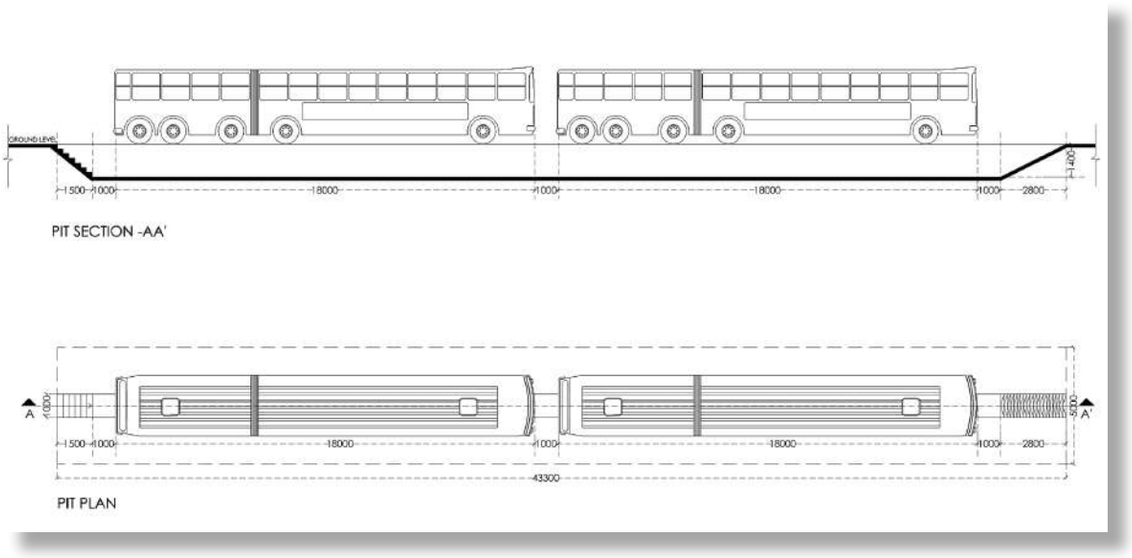




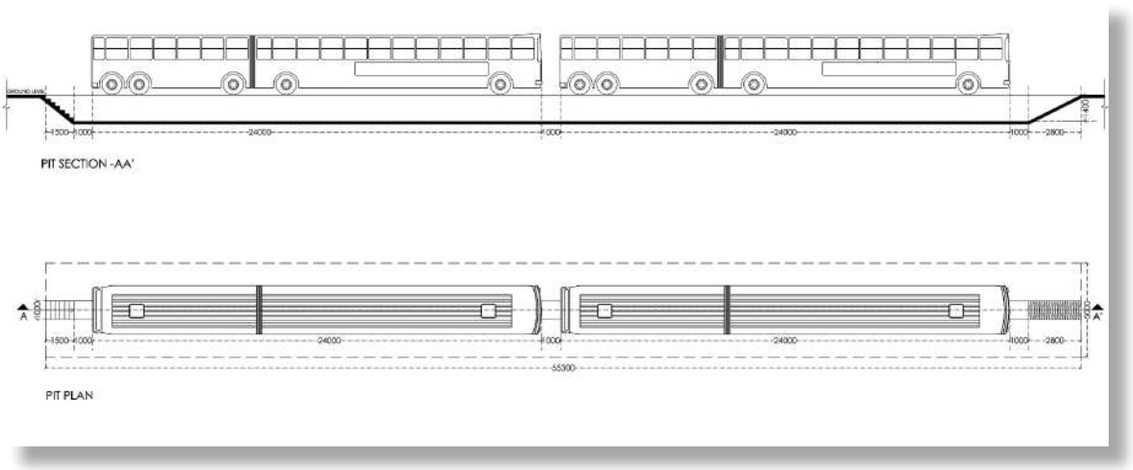
Double Length Maintenance Pit for 14m bus



Double Length Maintenance Pit for 18m bus



Double Length Maintenance Pit for 24m bus



ANNEXURE 5: BS VI DPF REGENERATION

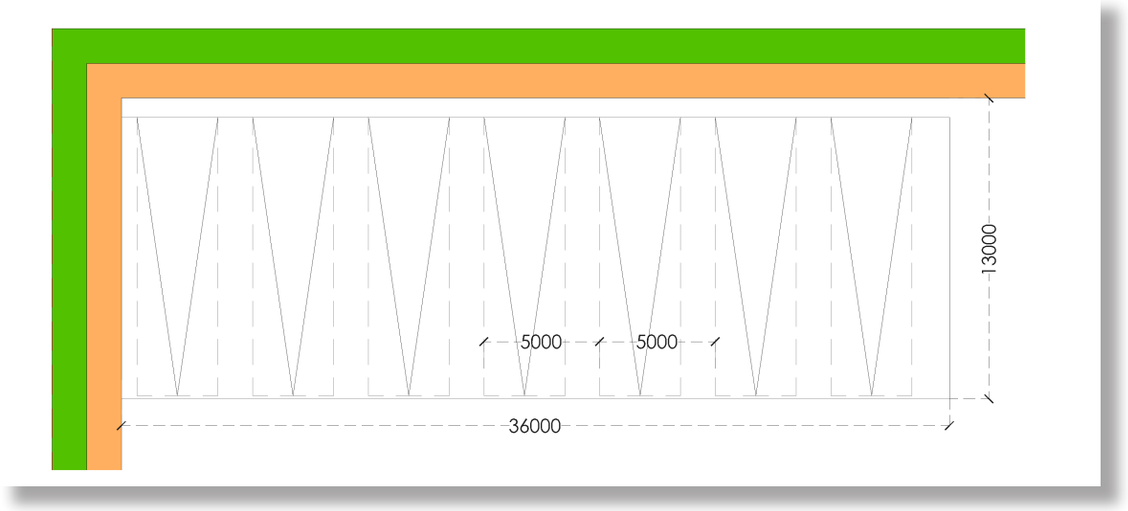
India will move forward to stricter emission norms from BS4 to BS6, which is a big step towards clean air. But it will also require certain modifications in the depot design to accommodate the specific requirements pertaining to the operations and maintenance of the BS6 compliant buses.

One of such requirement is the provision of segregated space for the purpose of "Regeneration".

The engine exhaust passes through the porous walls of the Diesel Particulate Filter (DPF). The Diesel Particulate Filter (DPF) during the course of engine operations, traps the Particulate Matter (PM) consisting of carbon soot, ash and soluble organic fractions. The PM keeps accumulating in the DPF and is periodically burnt off to remove the PM from the DPF. The process of burning off the PM collected in the Diesel Particulate Filter is called Regeneration.

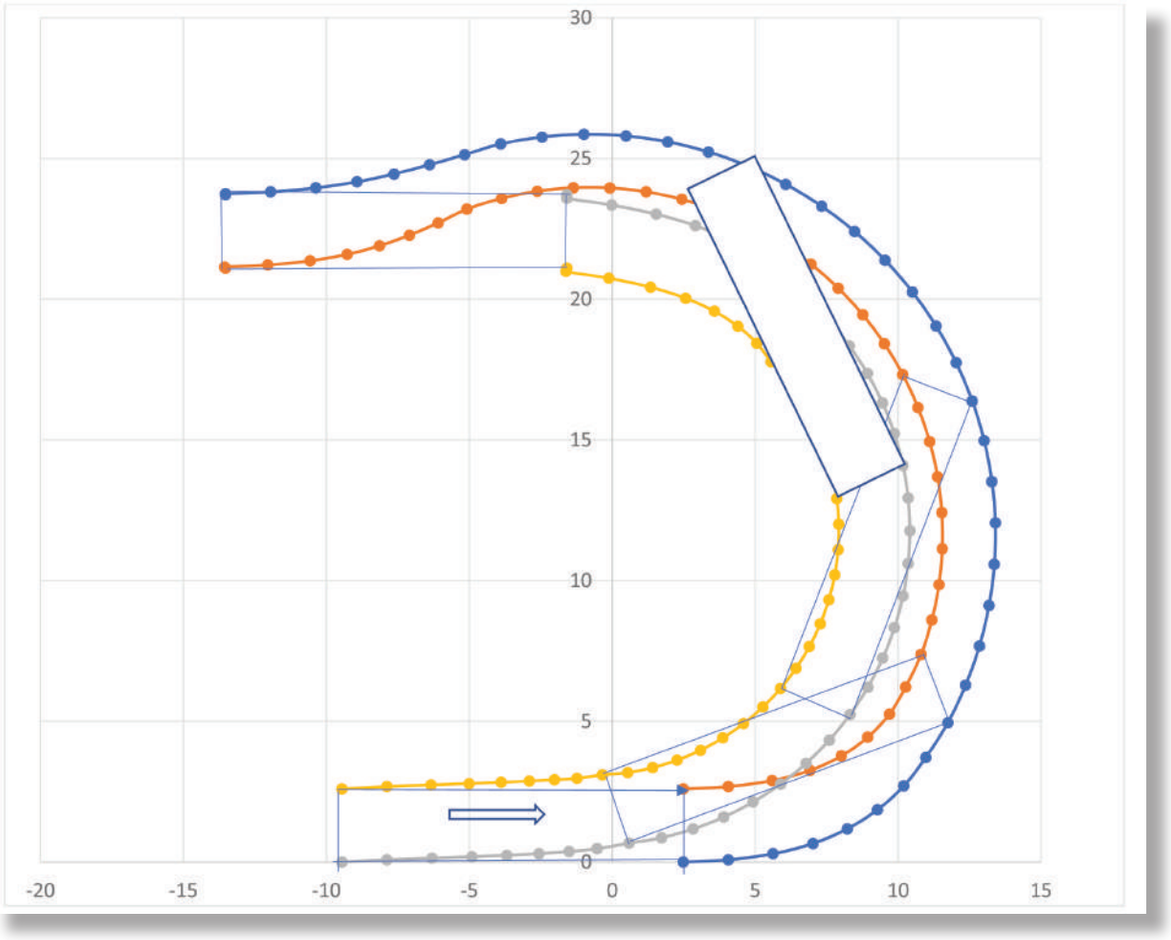
The regeneration as a process hold significance for the city bus operations, especially the depot design. The reason behind such significance is that the temperature of the engine exhaust of the buses running on intercity routes (continuous running at high speed) is in the range of 250° - 500° C which is sufficient to burn off the PM deposited in the DPF. The same cannot be said about the Engine Exhaust of the buses in city bus operations. The Regeneration process for such buses require additional fuel to generate the temperature of nearly 600° C to burn off the deposited PM.

An illustrative layout of a DPF regeneration area in a depot is presented below.



ANNEXURE 6: DETERMINATION OF TURNING PATH

Illustrative guidance relevant to the determination of turning path for 12m low floor bus and articulated vehicles is presented below.



ANNEXURE 7: PARKING CONFIGURATIONS

The space requirement for a 12m low floor bus and ease of usage for different types of parking configurations is tabulated below:

SN	Type of Parking Configurations	Ease of to and fro movement (on scale of 1-5) [11]	Area per bus (in sqm)
1	Angular – 30^0	5	110-120
2	Angular – 45^0	4	90-100
3	Angular – 60^0	4	85-95
4	Row Parking	3	80-90
5	In line Parking	2	80-110

Though the Angular- 30^0 ranks highest in the ease of movement and the row parking is the most space efficient, the Angular – 60^0 provides the best balance between the ease of movement and space usage.

Space Requirement for Bus Parking

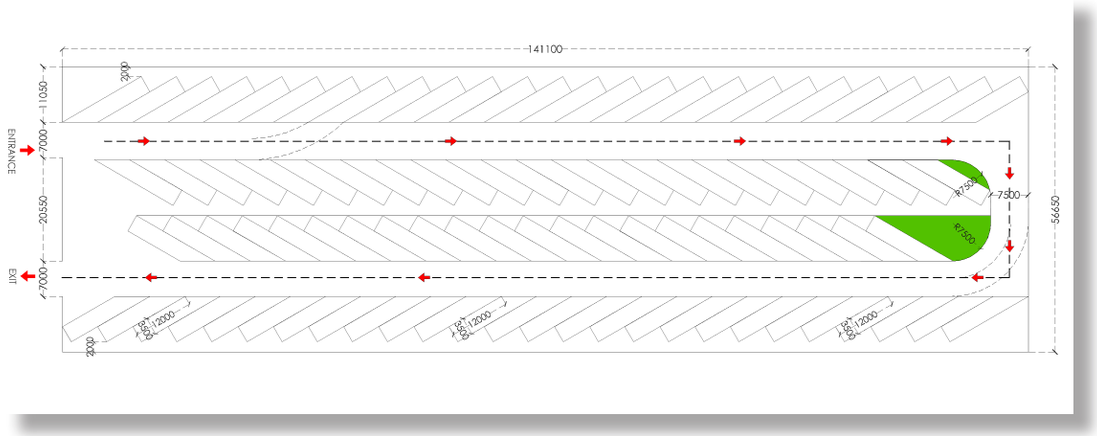
Bus Depot Design Guidelines suggests a minimum parking space requirement of 89 sqm per bus at an angle of 60^0. On the other hand, **VDV Guidelines** suggests the following minimum parking space requirements under different configurations.

- 123.80 sqm per bus (At 45^0 parking in double rows)
- 148.40 sqm per bus (At 45^0 parking in single rows)

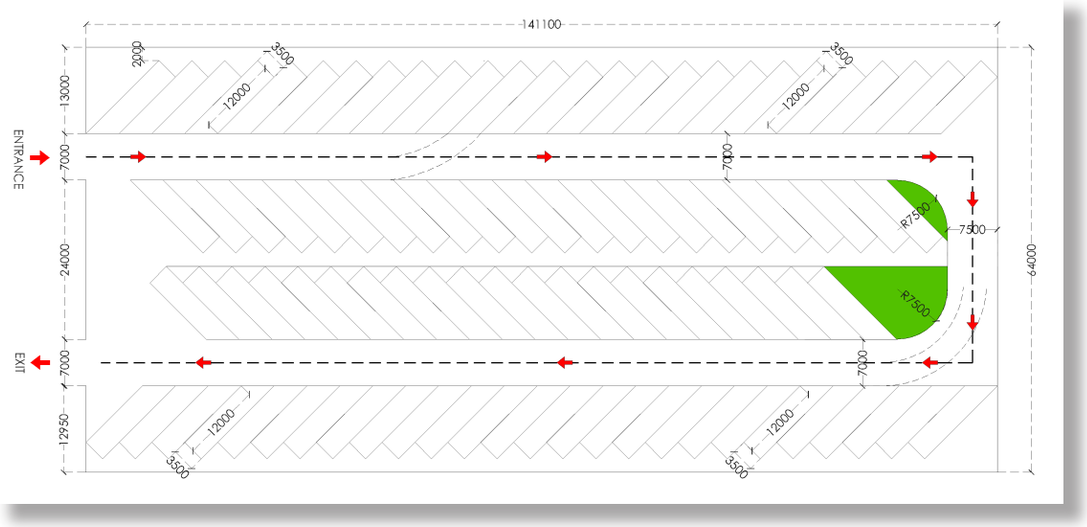
The bus parking space should be kept in the range of 89-148 sqm per bus based on the preferred parking configuration of the operator.

The illustrative layout for different types of parking configurations are provided below.

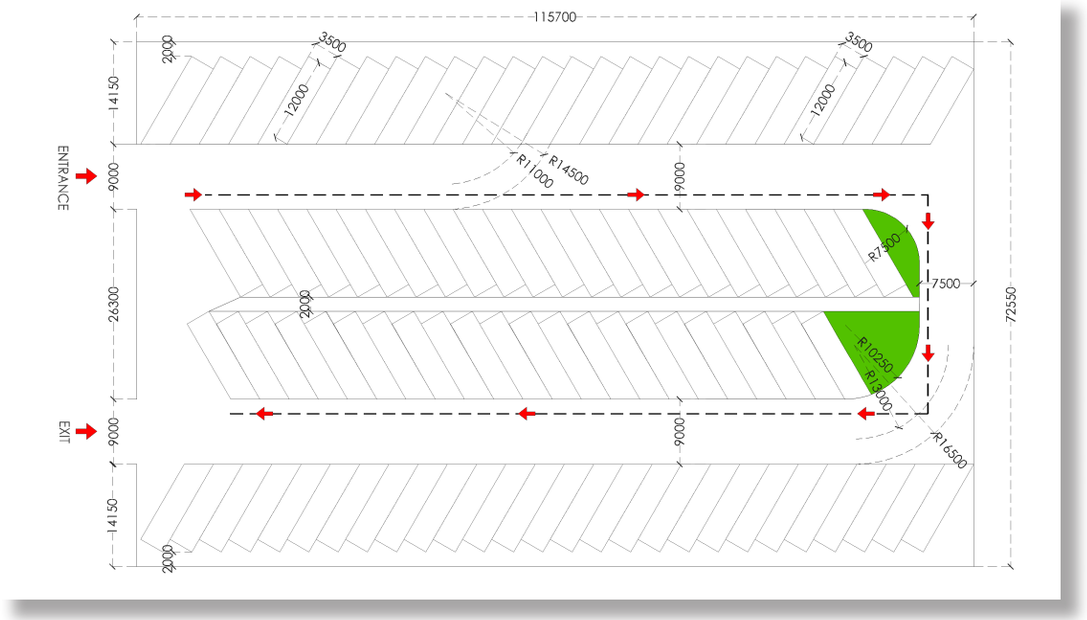
[11] On the scale of 1-5, 5 having the highest ease of to and fro movement.



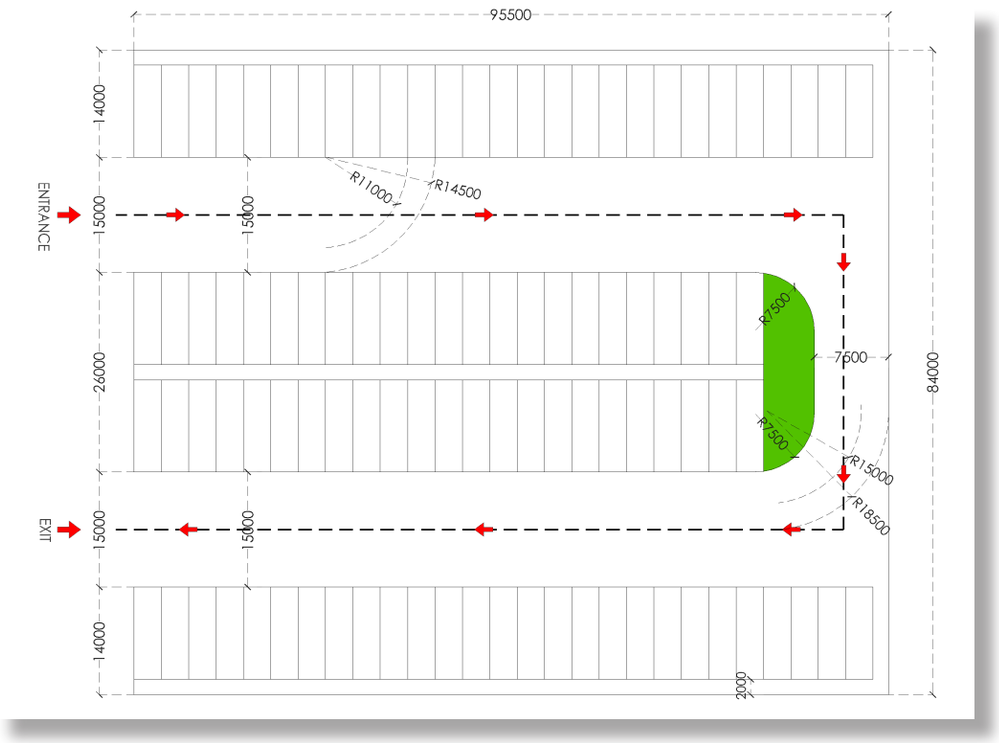
Angular - 30^0



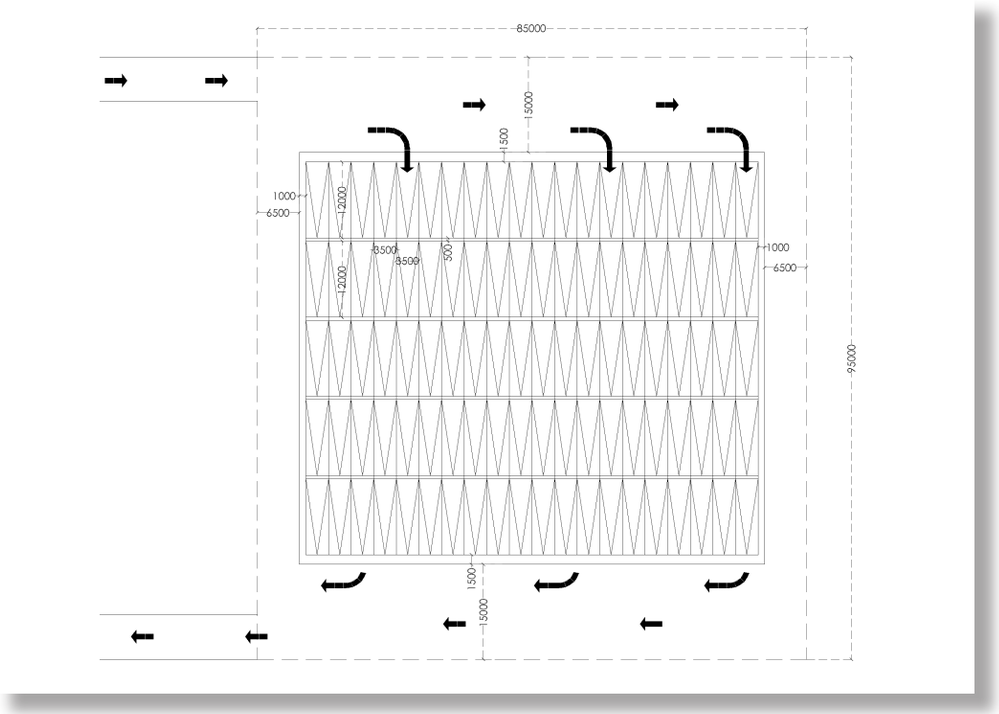
Angular - 45^0



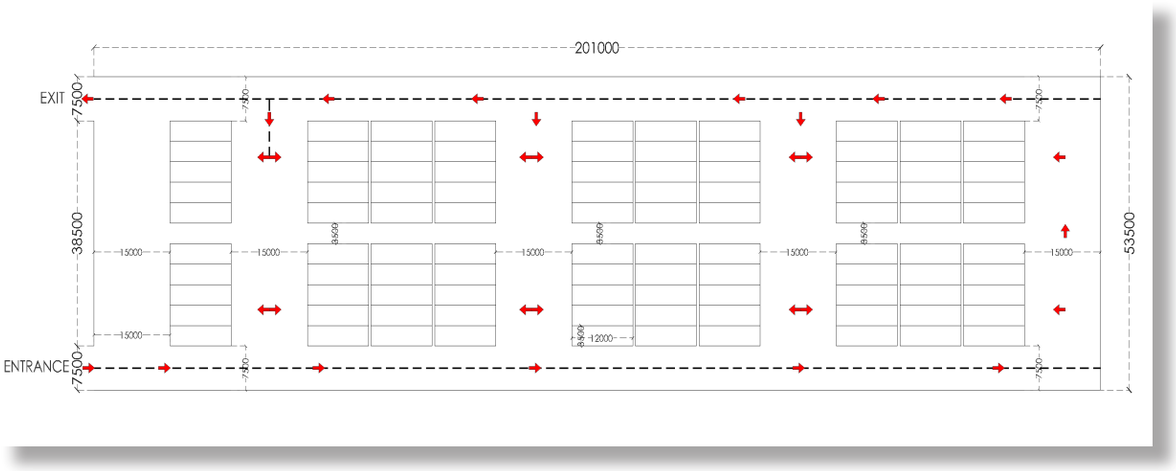
Angular - 60^0



Row Parking



In line Parking – Option 1



In line Parking – Option 2

6 DESIGN CONSIDERATIONS FOR STAFF MOVEMENT AREAS

The process of design and placement of the depot components relating to the personnel movement in the depot should ensure convenience and safety of the staff and must adhere to the following planning principles.

(i) Minimal walking distances.
(ii) Universal access for differently abled.
(iii) Segregated movement area for Bus Drivers, Conductors, Administrative Staff and Bus Maintenance Staff
(iv) Minimum crossflow between bus, personnel and inventory movement.

Universal Access

Bus Depot Design Guidelines state that provision should be made for universal accessibility. Ramps should be provided to accommodate the level changes for the mobility impaired.

The depot components/ facilities can be effectively designed based on the above mentioned work flow of the following types of personnel.

(i) Bus Driver & Conductor
(ii) Bus Maintenance Staff and
(iii) Depot Administrative Staff

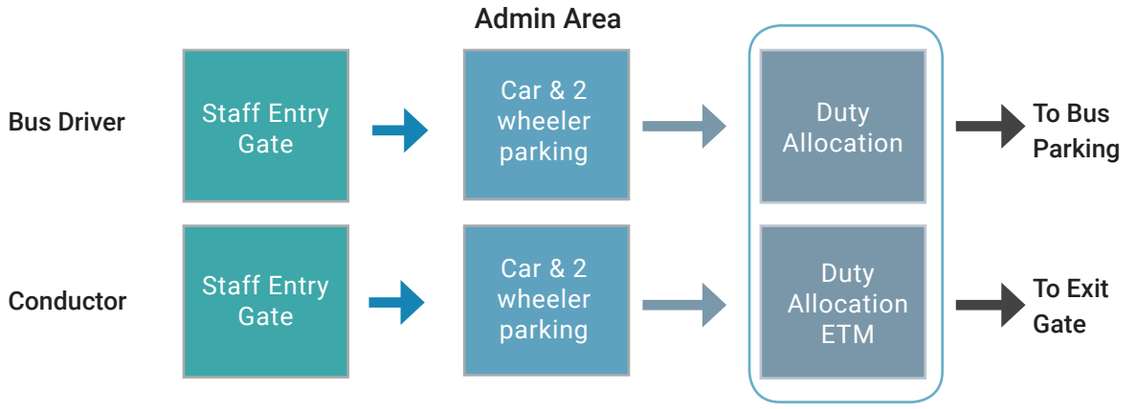
The activities and movement associated with each of the above staff need to be mapped and the relevant facilities should be designed keeping in view the aforesaid planning principles.

The following sections present the planning and design considerations for each of the staff type.

6.1 Bus Driver & Conductor Movement

The bus driver and conductor movement in a depot starts with the vehicle parking area where the driver/ conductor may park their private vehicles (if any). Both the bus driver and conductor follow the same route i.e. through the staff entry gate (separate from bus entry) to the vehicle parking for the parking of their respective private vehicles and then towards the administrative

building for duty allocation and collection of duty kit such as duty slip, way bill, pre-printed tickets, ETM etc. The bus driver then moves to the bus parking for the start of the daily duty and the conductor proceeds towards the bus exit gate and waits for the bus to arrive. The following illustrations presents the movement flow of the bus driver and conductor in the bus depot.



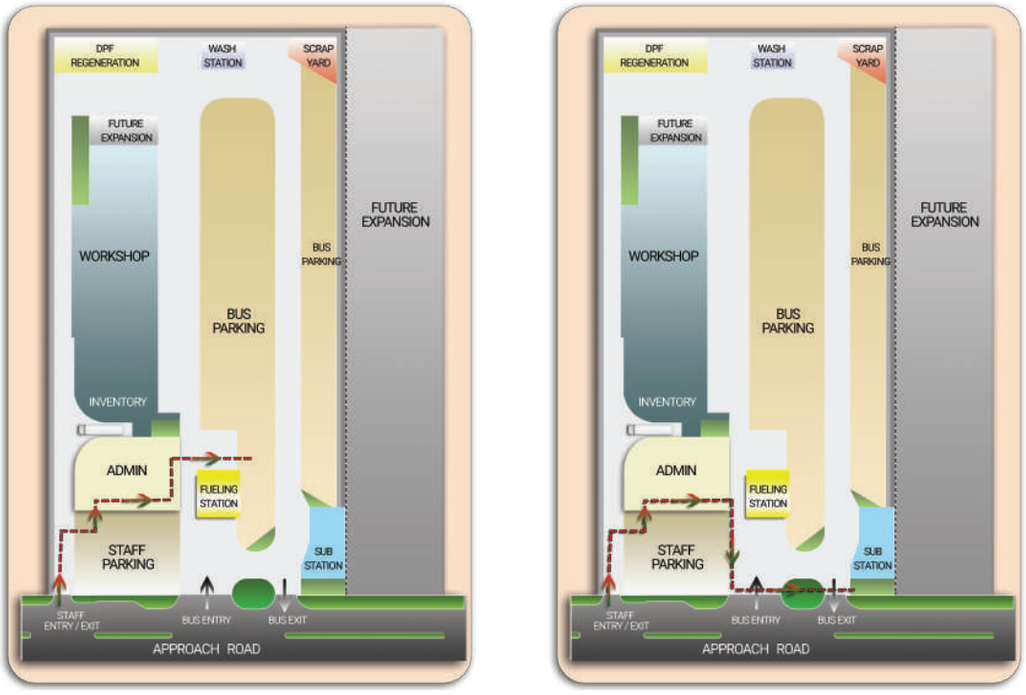


Figure 6-1: Bus Driver Movement (Left) & Conductor Movement (Right) Area

The design of the following elements of the bus depot relevant to the movements of bus driver and conductor are discussed in this section.

(i) Staff Entry and exit Gate
(ii) Car and two wheeler parking
(iii) Duty allocation space

6.1.1 Staff Entry Gate

The staff entry gate should not only be designed to facilitate the movement of staff vehicles but other vehicles also (excluding the buses).

This gate should be separate from the ones used for bus entry and exit to ensure conflict free movement of the buses. The vehicles entering from this gate shall use the same gate for exit as well. The width must be at least 5m to allow access to large commercial vehicles.

An illustrative layout is shown below.

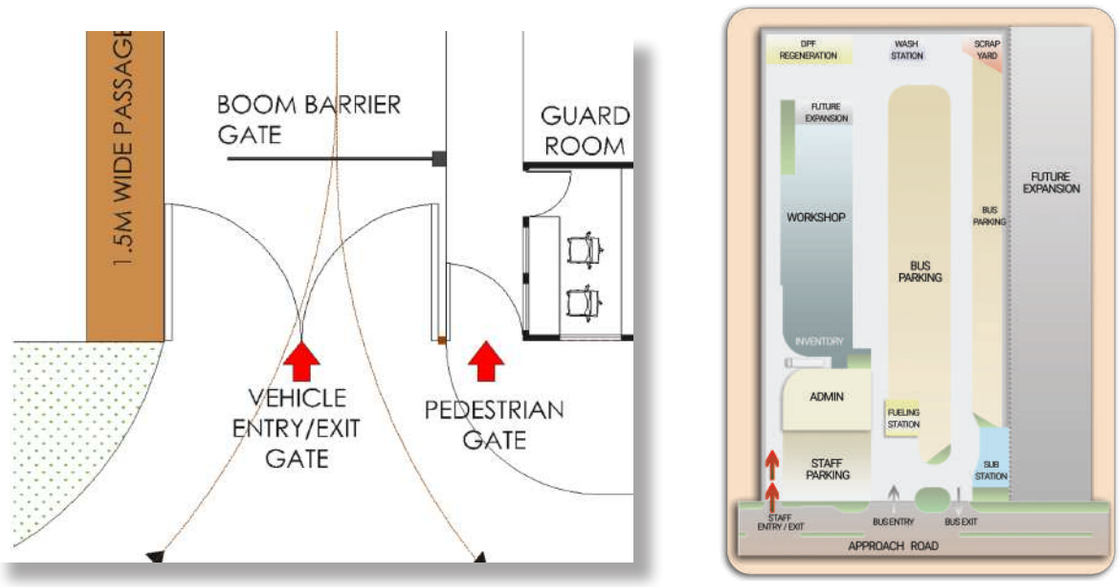


Figure 6-2: Staff Entry/ Exit Gate

The shape and orientation of land parcel vis a vis the access to the main road need to be carefully examined in order to determine the number of entry and exit for the bus depot.

In view of the above, the following type of vehicles should use the staff entry gate:

(i) Staff Vehicles
(ii) Inventory Vehicles
(iii) Visitors Vehicles
(iv) Utility Vehicles
(v) Emergency Vehicles

The illumination and safety related guidance is tabulated below.

Illumination	The outdoor illumination levels at the staff entry gate should be in the range of 50-150 lux. 200-300 lux is required in the security cabin.
Safety	• Outdoor Day/ Night CCTV cameras with IP 65 protection should be provided at the entry and exit gates. • Boom barriers and steel roller gates should also be provided at the entry and exit gates.

6.1.2 Car & Two Wheeler Parking

Various options should be explored for the entry/exit combination to the parking lots keeping in mind the adjacent site access. The design plans should be developed keeping in view the zoning of different activities in the bus depot development.

The parking requirement of cars, 2 wheelers and cycles should be as per the local development bye-laws of the city.

Primary design considerations for parking lots should include:

i. Parking facilities should be provided for all passenger vehicle categories keeping in view the requirement of parking for differently abled people.

ii. The parking access to and from the bus depot should be designed in a manner that causes least conflicts with the bus flow.

iii. Minimum walking distance from parking lot to the bus depot administrative block.

The indicative layout of car & two wheeler parking is presented hereunder.

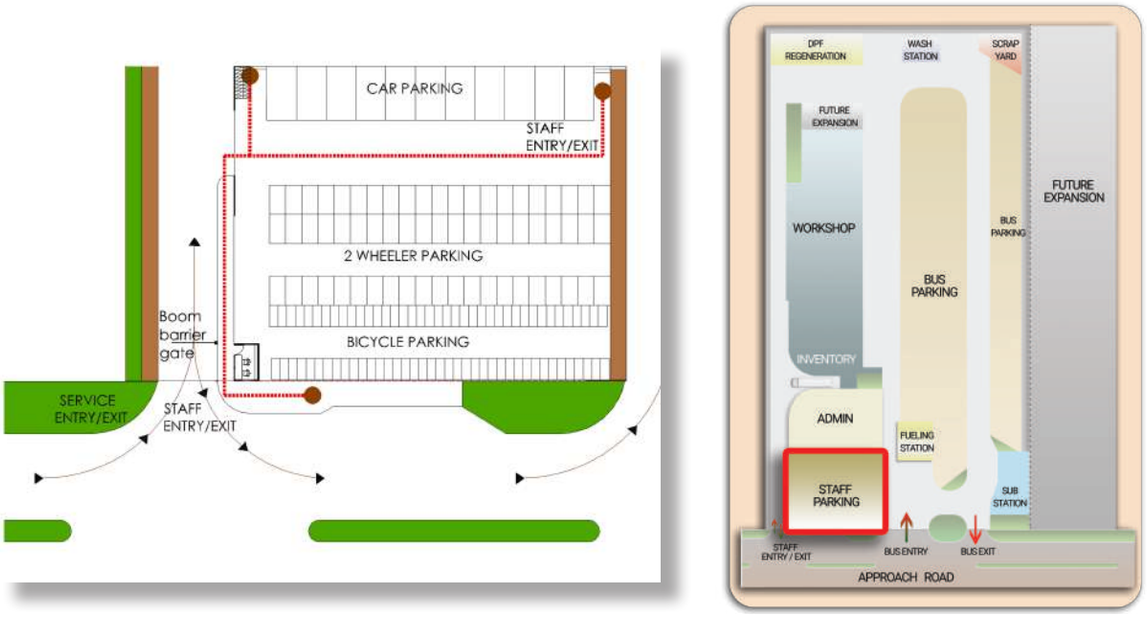


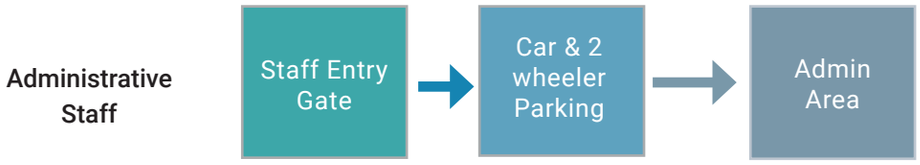
Figure 6-3: Car & Two Wheeler Parking

The illumination level required is presented below.

Illumination	An illumination level of 75 lux should be maintained in the parking area.

6.2 Administrative Staff Movement

The administrative staff movement in a depot, starts at staff entry gate then to the vehicle parking for the parking of their respective private vehicles. The administrative staff then proceed towards the Administrative Building for the commencement of their daily duty.



This section discusses the Administrative Section. The following illustration presents the movement flow of the administrative staff in the bus depot.

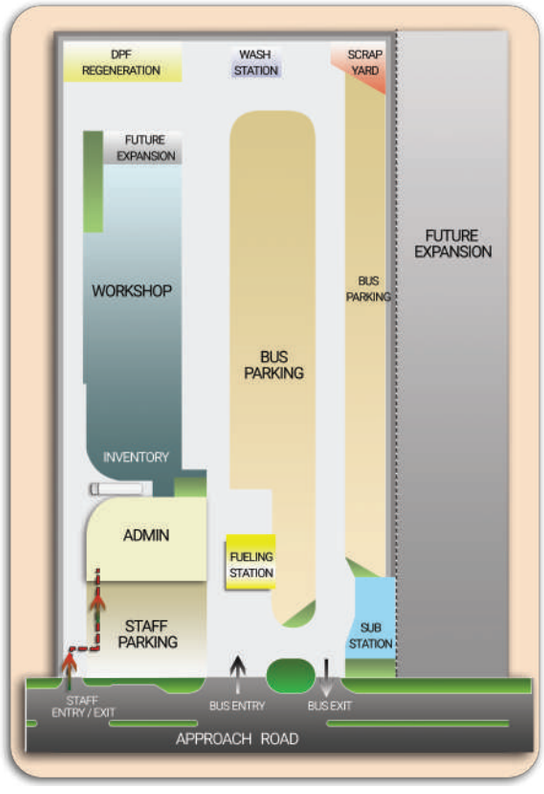


Figure 6-4: Administrative staff movement.

6.2.1 Administrative Section

Administrative block should generally be the first building in the bus depot. The administrative block houses the administration and operations personnel and hence this block is required to be equipped with the following.

SN	Sections	Area
1	Depot Manager's office	19 sqm
2	Administrative section including	
(a)	Accounts and HR section	8-10 workstations depending upon the operational requirement
(b)	Point of service for attendance	As discussed below in this section
(c)	Duty Allocation room for drivers	22 sqm
(d)	Duty Allocation room for conductors with Electronic Ticketing Machine (ETM) charging	29 sqm
(e)	Ticketing and Way bill section	22 sqm
(f)	Conference/ Meeting room	12 sqm
(g)	Ticket checker's office	11 sqm
(h)	Control room	Based on the operational requirement of the operator
(i)	Lost and found section	4-6sqm
3	Training and development section	
(a)	Training room	60 sqm
(b)	Simulator room	50 sqm
4	Cash section	22 sqm
5	Server/ Management Information System (MIS) room	19 sqm
6	Staff Amenities	
(a)	Toilets	As per NBC guidelines annexed as **Annexure 1.**
(b)	Dormitories	Minimum number should be equal to number of buses in-shedding after 10 pm and out-shedding before 5 am.
(c)	Lockers	As per operational requirement
(d)	Recreation	As per operational requirement

In addition to the above, this block generally also have

(i) areas with moveable walls like conference rooms and meeting rooms,
(ii) circulation spaces which include corridors, stairways, lifts and emergency exits, and
(iii) central services responsible for data processing, control room and telecommunications

The design considerations adopted for administrative section are provided in **Annexure 1**. It may be noted that due to change in technology or operational requirements, several of the above-mentioned components such as Cash section, Server/ MIS room etc. may undergo changes in requirements. Therefore, it is suggested that these should be built together, with temporary partitions in order to cater to the future requirements.

POS for Attendance

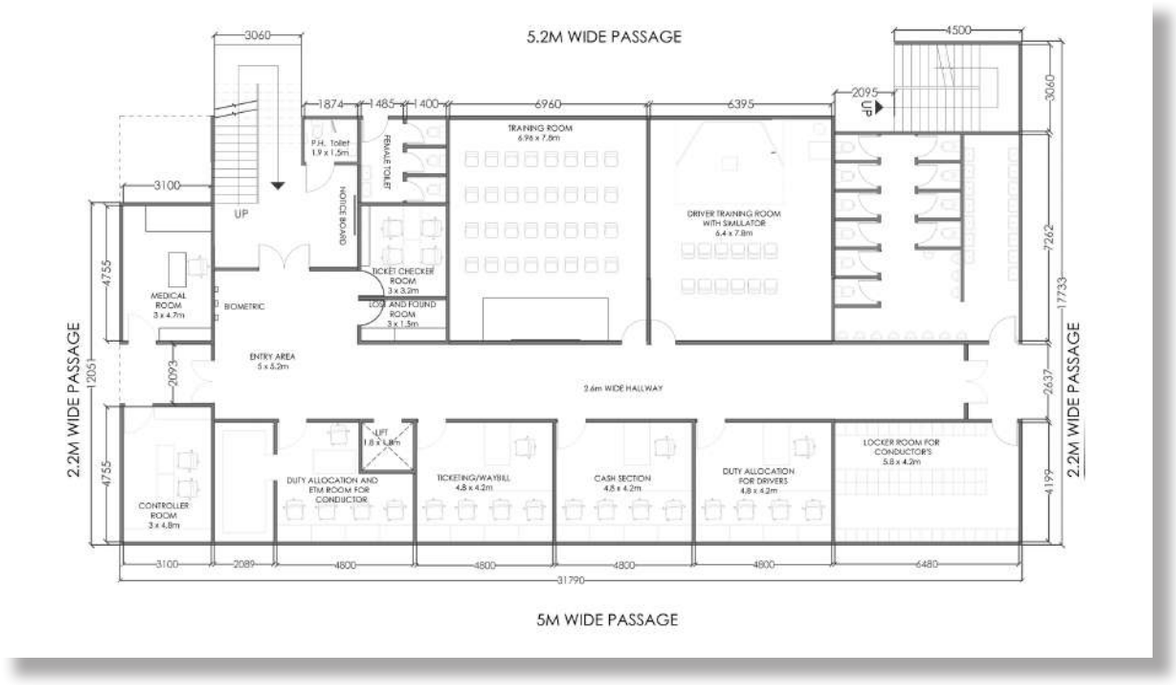
This should be an open area with multiple point of service. The suggested area is 3 m X 1.5 m. The number of points of service could be calculated as follows:

Table 6-1: Calculation of Number of Points of Service for Attendance

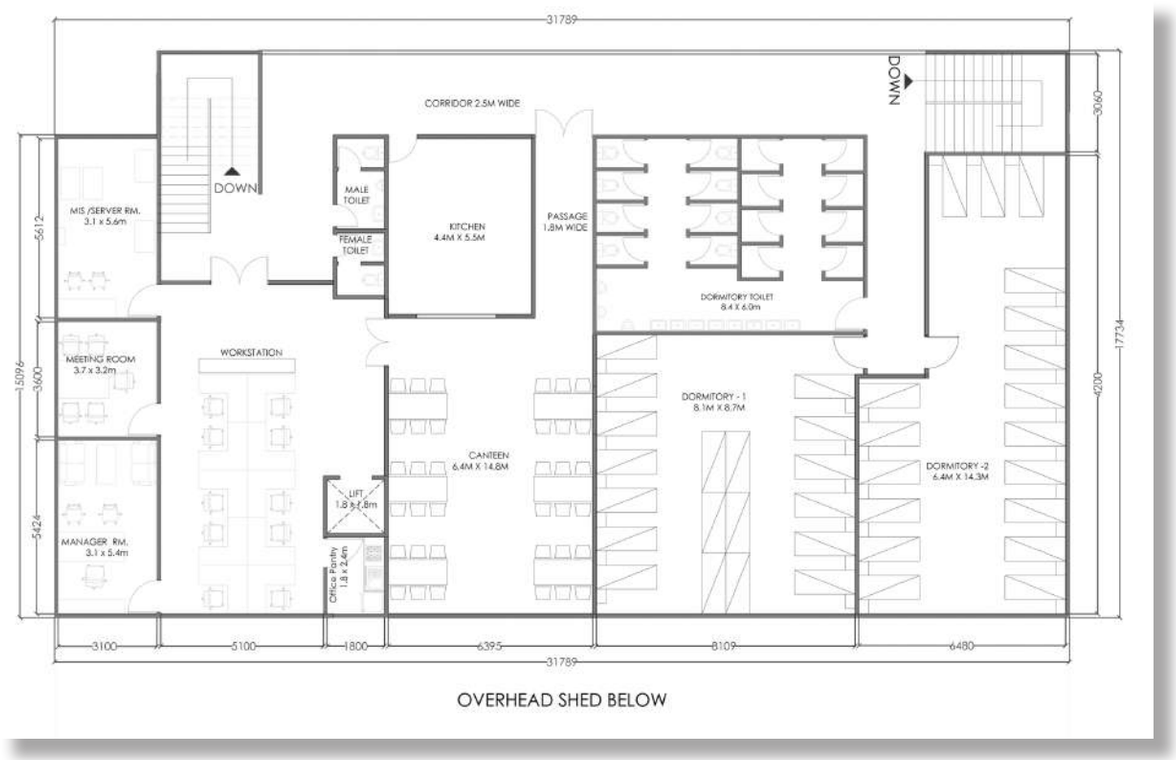
SN	Parameter	Formula	Units
1	Peak Hour Requirement	A	
2	Attendance Time	B	in minutes
3	Attendance completion time	C	in minutes
	Number of POS required	= A x B / C	

However, a minimum of 2 POS for attendance should be provided for the purpose of redundancy.

The illustrative layout of administrative area is shown below.



Ground Floor



First Floor

Figure 6-5: Administrative Area

The illustrative layouts some of the sections of the administrative area are presented in **Annexure 1.**

The following lux levels in various areas of administrative section are recommended.

Table 6-2: Recommended illumination levels for various areas in the Administrative Section

Areas	Recommended lux	Minimum lux
Office Area	1000	500
Corridors, Passageways, Stairs	150	100
Toilets & Washrooms	200	100
Lockers	150	100
Dormitory	150	100
Canteen	300	200

6.3 Maintenance Staff Movement

The Maintenance Staff traverses through the staff entry gate to the vehicle parking for the parking of their respective private vehicles and then towards the maintenance section for the commencement of their duty.

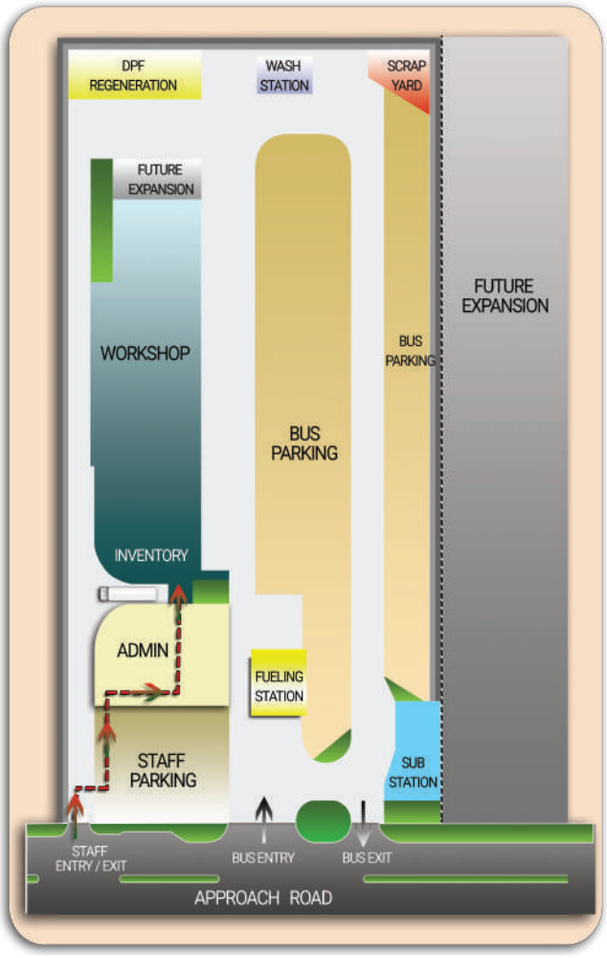


Figure 6-6: Maintenance Staff Movement

ANNEXURE 1: DESIGN CONSIDERATIONS & ILLUSTRATIVE LAYOUTS FOR ADMINISTRATIVE AREA

The designing of components in Administrative area is undertaken by taking into account the space requirement of a person to execute a particular task. The design considerations and illustrative layouts for the following areas in the administrative section have been discussed below.

i. Office Space,
ii. Toilets
iii. Dormitory
iv. Lockers
v. Cafeteria
vi. Training & Development

Office Space

According to Neufert Architects' Data, office buildings can be categorized as

Closed Plan Office

- In this plan, there is full-height walls or partitions for segregation of space into offices with doors.
- Advantages - Controlled environment, Security, Visual privacy and Physical separation
- Disadvantages - Lower efficiency compared to Open Plan office, Lack of flexibility, High cost of relocation and Restricted individual & group interaction

Open Plan Office

- In this plan, there is no ceiling-height divisions or doors and all workstations are located in an open space.
- Advantages - Efficient space utilisation, Greater planning flexibility, Ease of communication and Lower life-cycle costs
- Disadvantages - Higher initial costs, No visual privacy and Less environmental control

Modified Open Plan Office

- This plan is a mix of closed and open plan as certain workstations are positioned in an open plan and others in private offices like closed plan.
- This plan extracts and enhances the advantages of both closed and open plan.

As described above, in modified plan office, all areas are multipurpose for individual or team work except for some areas designed as separate offices like depot manager's office. This plan is used for designing the module for office areas and workstations. The requirement and space allocation for different areas is calculated in two parts.

Individual Space	=	(individual space x number of people) + allowances for immediate ancillary needs + a factor (usually 15%) for primary circulation
Non-individual Space	=	informed estimates based on existing good practice or comparable examples + an additional factor for primary circulation

Where

Individual Space	• This space is for areas where number of personnel is required for calculating the area requirement. e.g. Office area, dormitory etc.
Non- Individual Space	• This space is for areas where fittings and equipment sizes are more important than number of personnel for calculating the area requirement. e.g. workshop area, server / MIS section etc.

The space requirement per person for different areas depends on a number of factors i.e.

(i) number of personnel,
(ii) type of work,
(iii) use of equipment and machinery,
(iv) degree of privacy and
(v) storage needs

The calculated space requirement for different areas is as follows.

Closed Plan Office	=	8-10 m2
Open Plan Office	=	12-15 m2
Workstation	=	Work room (min. 8 m2 floor area) + Free circulation space (min. 1.5 m2 per person and min. 1 m wide)

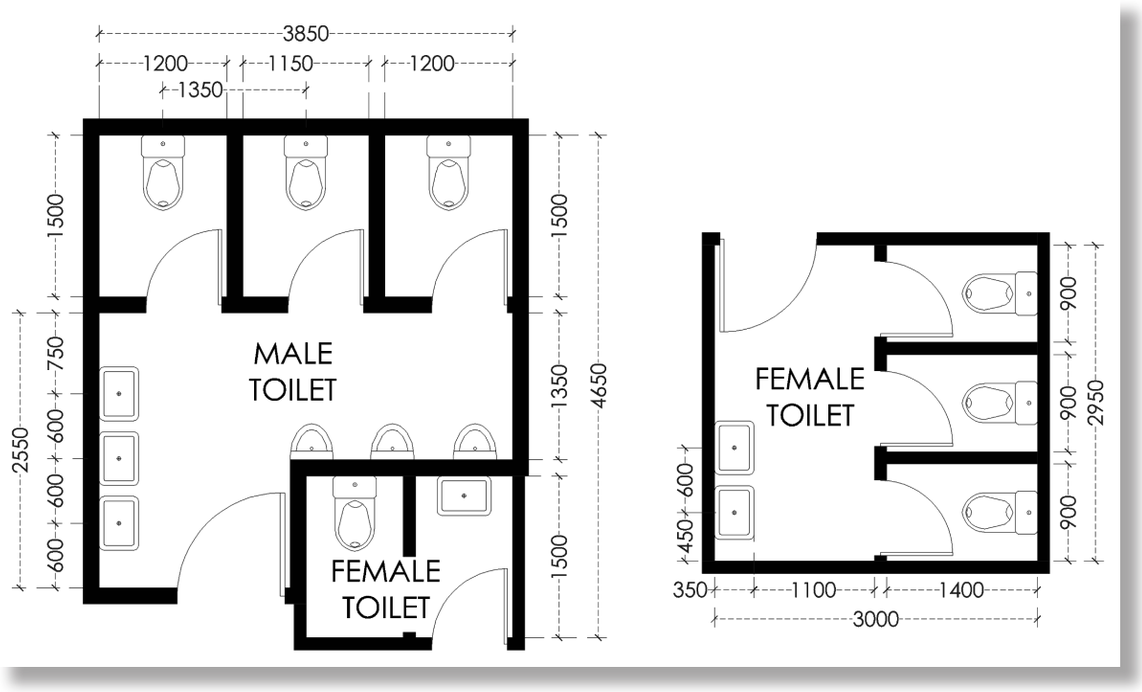
Toilets

The NBC 2016 suggests the following standards for toilets based on the number of users.

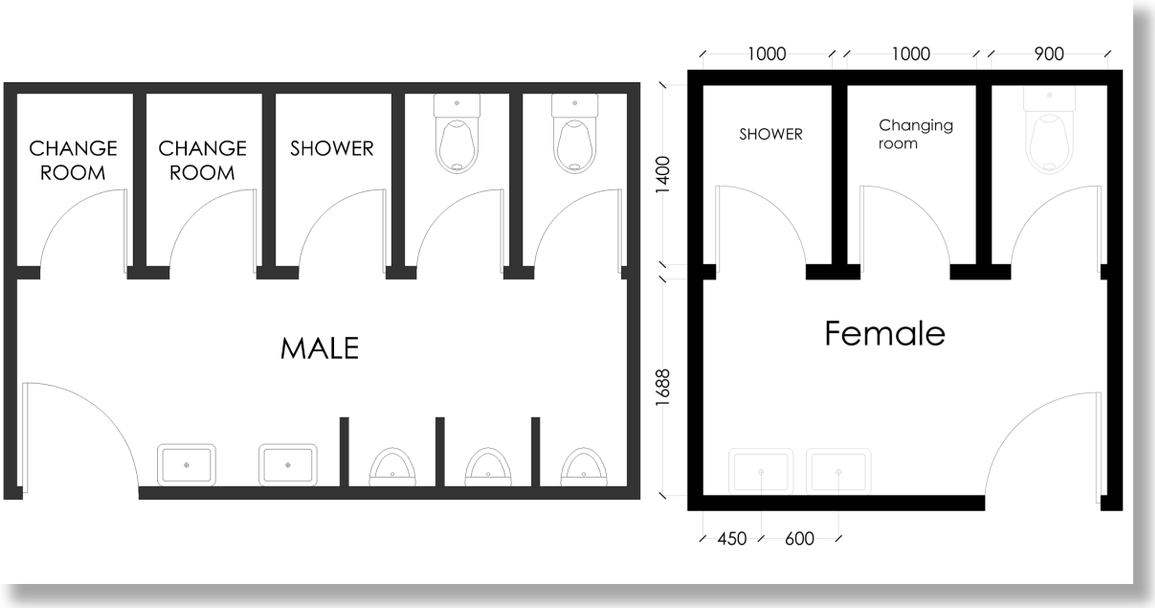
Table: Standards for Toilets

SN	Fixtures	Admin Area / Visitors		Workers	
		Male	Female	Male	Female
1	Water Closets (Workers & Staff)	1 for upto 25	1 for upto 15	1 for upto 25	1 for upto 12
		2 for upto 35	2 for upto 25	2 for upto 35	2 for upto 25
		3 for upto 65	3 for upto 40	3 for upto 65	3 for upto 40
		4 for 66 upto 100	4 for upto 57	4 for 66 upto 100	4 for upto 57
			5 for upto 77		5 for upto 77
			6 for 78 upto 100		6 for 78 upto 100
	For persons 101-200	3%	5%	3%	5%
	For persons above 200	2.5%	4%	2.5%	4%
2	Ablution Tap	1 in each Water Closets	1 in each Water Closets	1 in each Water Closets	1 in each Water Closets
3	Urinals	1 for 7 to 20		1 for 7 to 20	
		2 for 21 to 45		2 for 21 to 45	
		3 for 46 to 70		3 for 46 to 70	
		4 for 71 to 100		4 for 71 to 100	
	For persons 101-200	3%		3%	
	For persons above 200	2.5%		2.5%	
4	Wash Basins Wash Basins in row or troughs and taps spaced 70mm c/c	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof
5	Drinking Water Fountain	1 per 100 or part thereof with minimum of 1 on each floor		1 per 100 or part thereof with minimum of 1 on each floor	
6	Cleaners Sink	1 on each floor	1 on each floor	1 on each floor	1 on each floor
7	Showers/Bathing Room	As per requirements			

The various toilet layouts for different areas in a depot based on the above standards are presented hereunder.

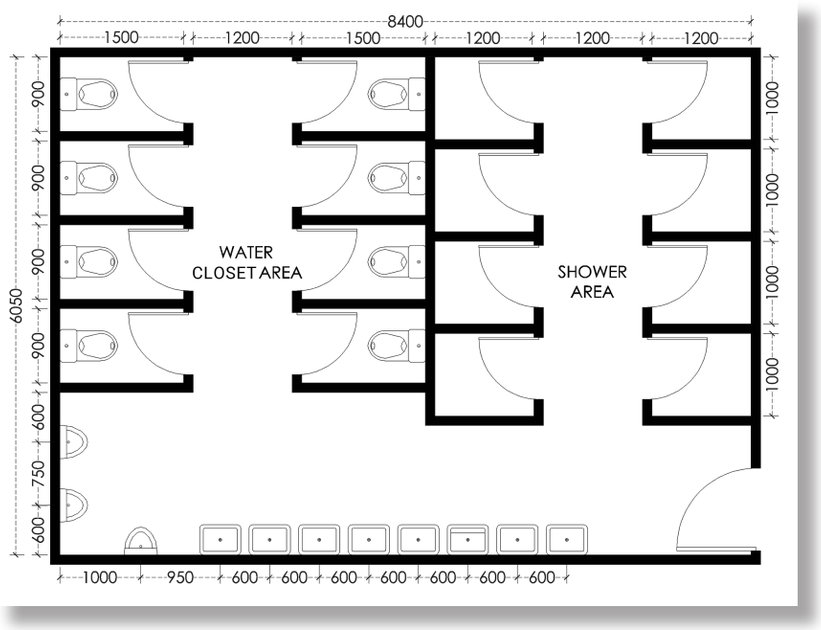


Office Toilets



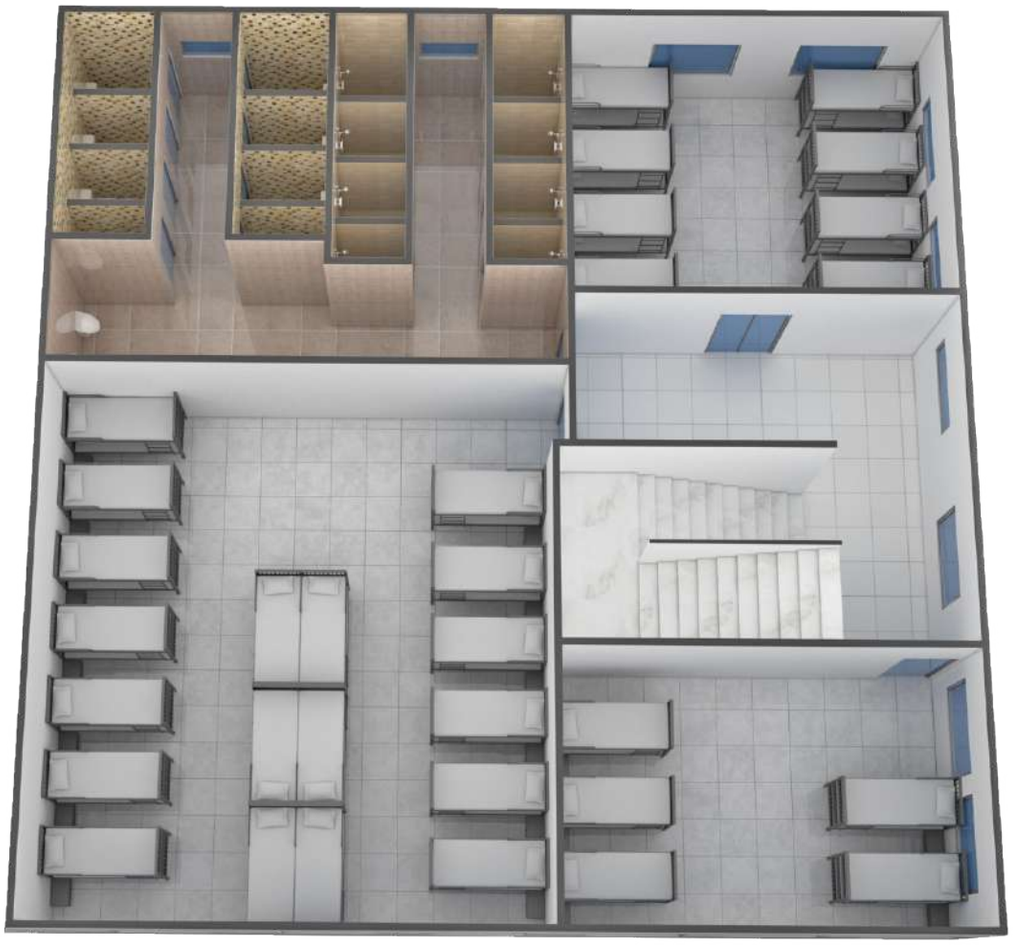
Workshop Toilets

(It may be noted that in case of female workshop personnel, the above layout can be used in the maintenance area)

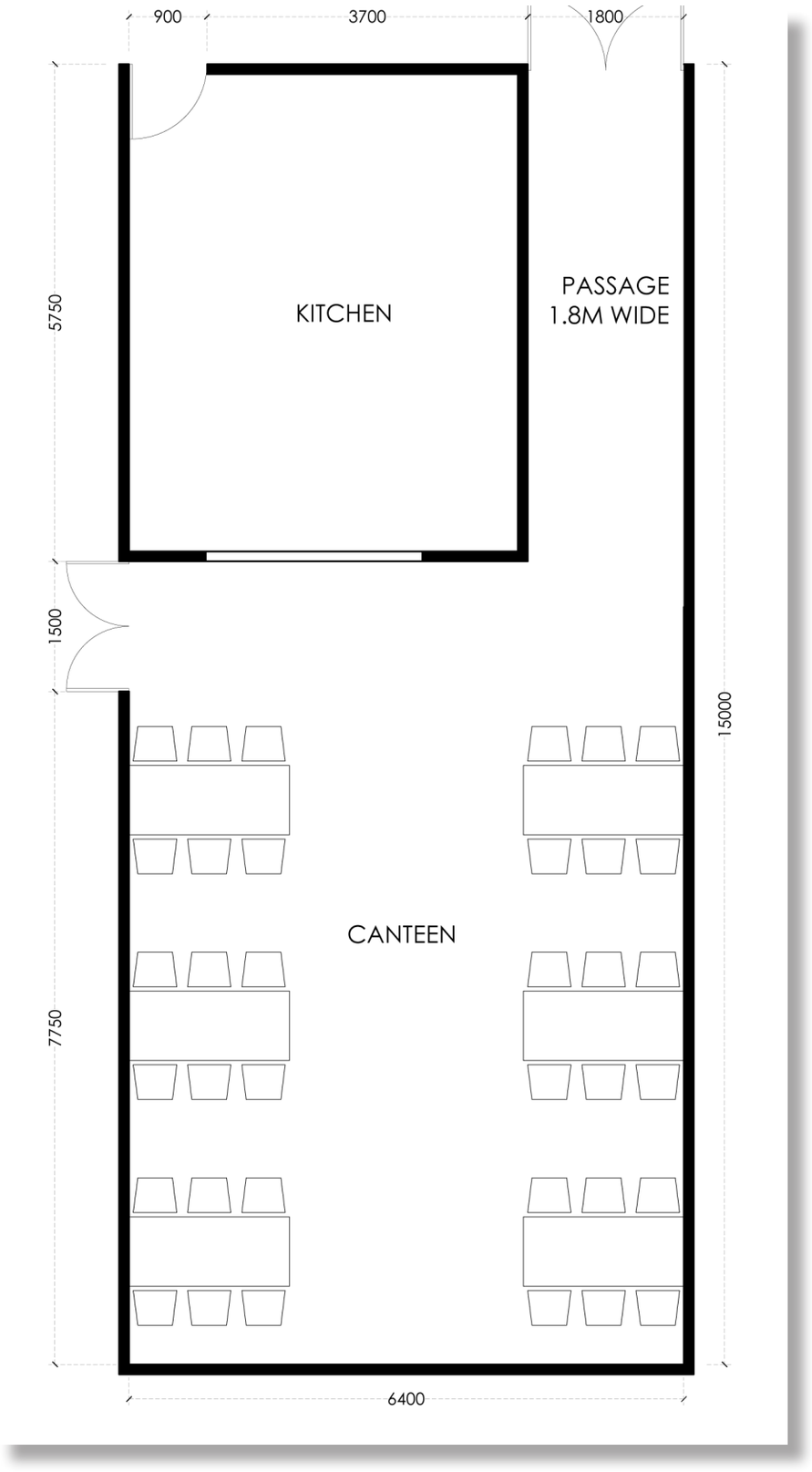


Dormitory Toilets

Dormitory & Toilets - 3d Illustration



Cafeteria



Cafeteria

Training & Development

Capacity building or capacity development is the process of strengthening of the knowledge or skills of individuals required to carry out their respective jobs more effectively. In any depot, three categories of employees determine the efficiency of the depot (1) drivers; (2) conductors; and (3) maintenance staff. Each of them should be provided training on regular basis for the efficient bus depot management. An annual timetable should be fixed for training of each individual.

a. Capacity Building of Drivers & Conductors

Capacity building of drivers & conductors should be done on a regular basis. It is suggested that each depot should have a dynamic motion based simulator for training of drivers and training room for conductors. This may reduce the number of accidents, bus body damages and seems to improve fuel efficiency.

The layout for the training room and simulation room is presented below.

Training Room

Simulation Room

b. Capacity Building of Maintenance Staff

Capacity building of maintenance staff should be undertaken by the bus manufacturer or the equipment manufacturer. This should be followed by periodic refresher courses.

7 DESIGN CONSIDERATIONS FOR INVENTORY AND MATERIAL MOVEMENT AREA

The inventory vehicles shall enter from the staff entry gate to avoid the conflict with the bus movement and further proceed towards the inventory loading/ unloading bays.

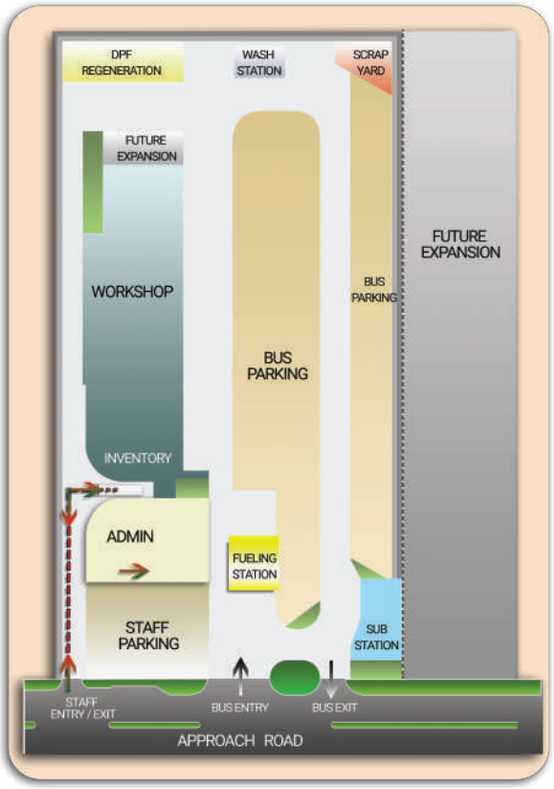


Figure 7-1: Inventory Vehicle movement.

Area requirement for following stores should be provided:

(i) Tyres
(ii) Spares
(iii) Lubricants
(iv) Aggregates and Large Size Parts
(v) Auto Electric
(vi) Old Parts
(vii) Warranty Parts

The space provisioning for the storage of inventory for the above mentioned stores is based on

(i) Number of buses in the depot
(ii) Number of days for which the inventory level is to be maintained as per the availability of

the spares in the local market,

(iii) Lead time for the inventory

Also, loading and unloading of the trucks/ vehicles with inventory supplies and their accessibility/ circulation areas in the depot should be designated.

Docking platform for loading and unloading of material at the inventory storage should be raised to 4 feet to bring it on level with the cargo bed of the truck. The gates for the individual inventory sections should have a minimum width of 3m. A space allocation of at least 2m must be made for the aisles of the individual storage sections for the smooth movement of forklifts (the standard width of forklifts is 4 feet). A space of 1.8m should be provided at the end of the aisles for the turning of the forklifts. The depot design presented in the manual presents the inventory storage on two levels (i.e. ground and basement level).

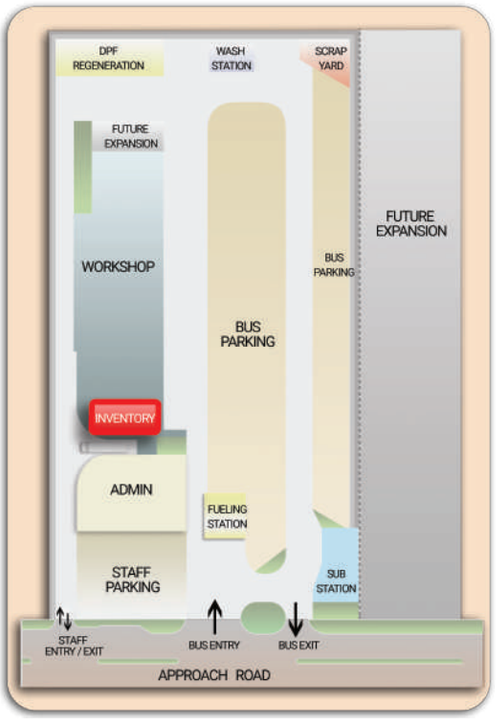


Figure 7-2: Location of Stores in Maintenance Area

The main equipment and illumination requirement are as follows:

Equipment	The storage area should have lockable rolling steel shutters at the gates. Portable ladders should be provided at convenient locations within the storage.
Illumination	The storage area should have illumination levels in the range of 150-200 lux

The location and an illustrative layout of the inventory area for loading and unloading of trucks is shown below.

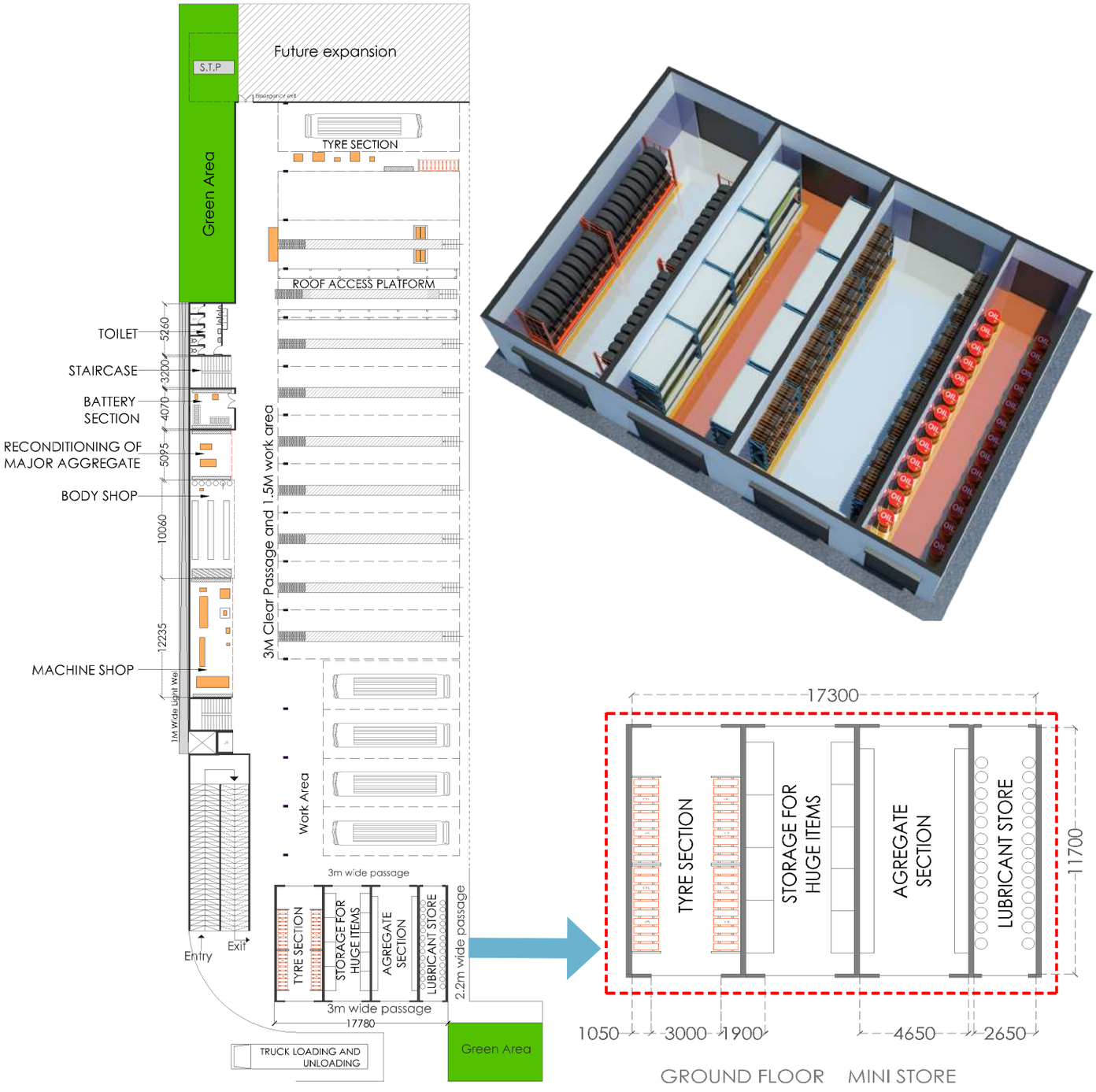


Figure 7-3: Inventory Area Ground Floor

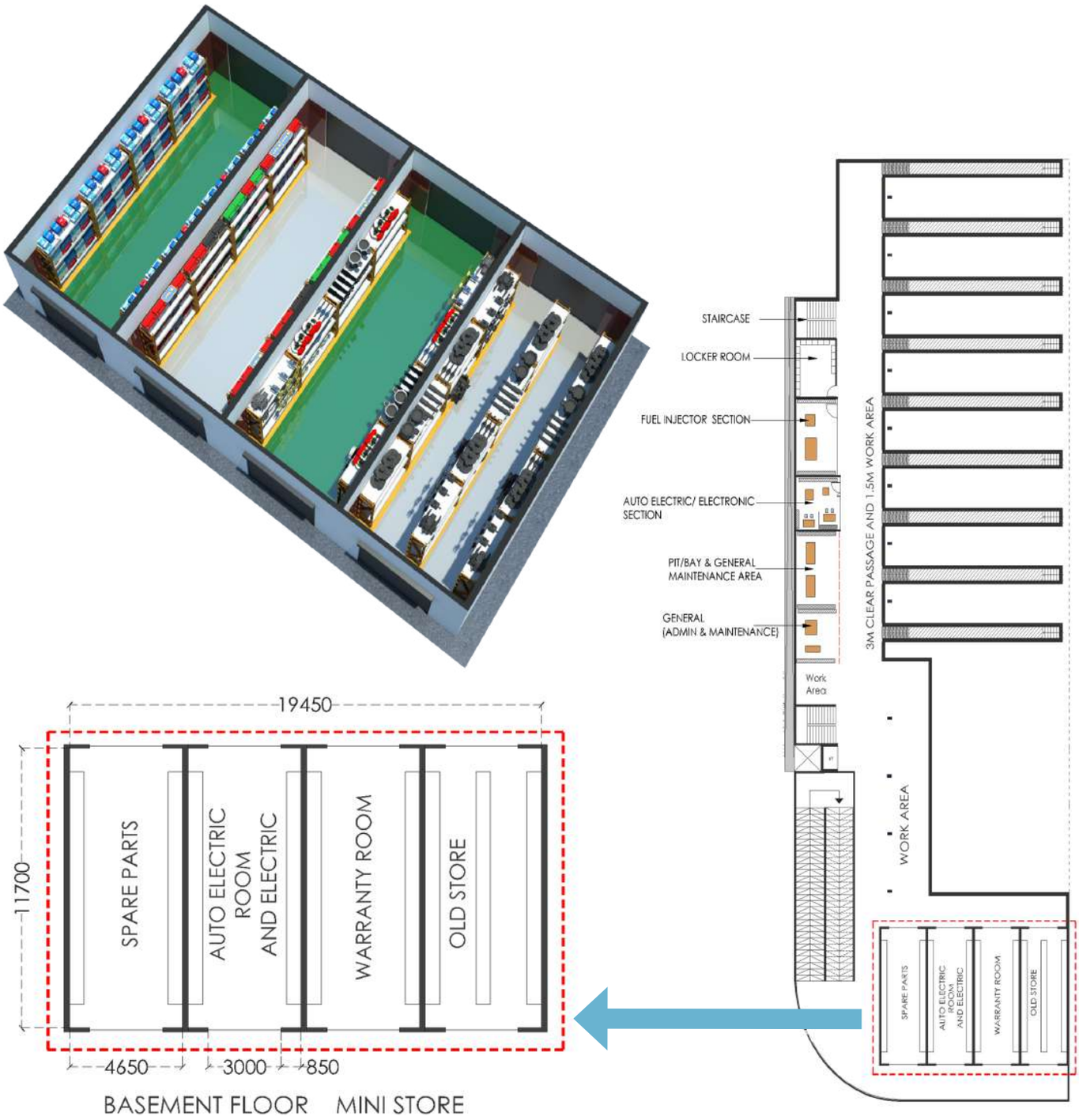


Figure 7-4: Inventory Area Basement Floor

8 SAFETY & SECURITY

To ensure a safe and secure environment in a bus depot, certain measures should be implemented at the planning stage itself. The measures below are only indicative and would be implemented based on site specific needs. Separation of the bus depot building, and the remaining site is necessary to determine security measures and protocols in case of threats/ emergencies.

8.1 Safety Measures

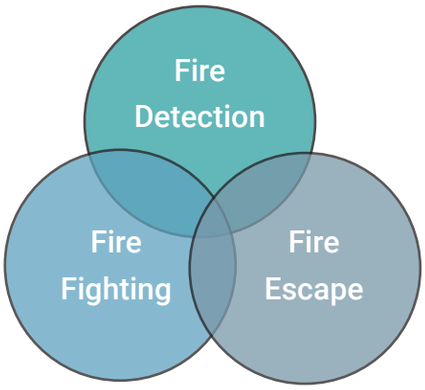
Bus Depots are operational 24 x 7 hours. The depot facility is usually with large open spaces and may be perceived as unattended or unsupervised if adequate countermeasures are not taken. Besides safety in operations, utmost care should be taken in ensuring that personnel and inventory are safeguarded. A health and safety management system based on OHSAS 18001:2007 standards may be implemented to ensure overall health and safety of depot staff.

8.1.1 Minimizing Health Hazards

To reduce accidents and health hazards, each and every design decision should be carefully reviewed. The common prevention strategies would include adequate illumination levels, anti-skid surfaces, careful grading between levels, guards and safety rails at appropriate places etc. In addition, careful management of waste, black & grey water, adequate air changes, avoidance of prolonged noise and vibration exposure, and regular maintenance are important. NBC 2016 and other relevant codes should be adhered to for this purpose.

8.1.2 Minimizing Fire Hazards

A bus depot workshop is highly susceptible to fire hazards due to the nature of work carried out in the premises. Usage and storage of highly volatile material in conjunction with activities of inflammatory nature like welding, grinding, sanding etc. carried out in the workshop premises demand higher level of attention in designing of the fire protection measures to be deployed in a depot. To combat the risk of fire hazards, the following measures should be considered.



The above parameters are discussed in detail in **Annexure 1.**

Specific guidelines mentioned in the fire and life safety codes (NBC and NFPA) should be adhered to while planning and design of Fire Fighting System keeping in view the following guidance:

(i) National Building Code 2016: Part-IV for fire protection and local Bye-Laws.
(ii) Relevant ISI Codes: Specifically IS: 5290 and IS: 5312, IS: 908 and IS: 2190.
(iii) NFPA (For reference and guideline)
(iv) Recommendations of local Chief Fire Officer.

8.2 Security Technology

Safety and security of personnel and material in a bus depot is a significant parameter to be considered in the depot design and security technology has a big part to play in ensuring safety and security at the bus depot. The term 'security technology' is to be understood as covering all devices used for defense against criminal danger to the body, life or valuables.

In reality, all parts of a building can be penetrated, even those made of steel and reinforced concrete. The need for security should be established by an in-depth study of vulnerable areas. The security system with appropriate technology can be put in place considering the systems mentioned in the succeeding paragraphs.

Alarm Systems

In theory, every security system can be bypassed and every premises can be breached. The Alarm Systems come into picture in case of such an eventuality. Burglar and Fire alarm systems help safety of the personnel and property.

The Burglar and Fire alarm systems cannot prevent intruders entering premises nor can they prevent fire hazards, but they can give the earliest possible warning in case of intrusion and fire.

Public Address System

Public Address (PA) systems should also form a part of the security apparatus of the organization. Where the alarm system informs the personnel about the danger from the danger, the PA system allows for the broadcast of specific instructions in relation to the emergency safety procedures.

Access Control on building premises

If the outer perimeter armed with aforesaid outdoor supervision system is breached then the building premises becomes vulnerable to unauthorized entry. To mitigate the threat, the access to the building should be controlled with biometric or RFID card based identification system or any other relevant technology along with robust magnetic contact or mechanical locking device. CCTV cameras should be provisioned at every access.

Outdoor supervision systems

These are the first line of defense against unlawful intrusion and are used to monitor areas around the building. They increase security by monitoring and recording all nearby activity, usually up to and including the property boundary. They consist of mechanical or constructional measures, electronic or other detection devices.

Some of the measures include fencing, wall barriers, gates, manned patrols and electronic measures like outdoor CCTV, motion sensors etc. to deter, delay, detect and give early warning about unauthorized people or vehicles.

Some of the technology interventions briefly discussed above along with other security measures are presented in the following sections in greater detail.

8.3 Security Measures

8.3.1 Access Control

All private vehicles entering the bus depot premises should bear the unique parking stickers

which should be inspected at the security post at depot entrance. The various sections in a depot premises should be compartmentalized and personnel must be allowed conditional access outside their designated work area. The personnel movement in the depot facility may be controlled/tracked by use of RFID cards or biometric systems at various access points.

Restricted and Segregated access for pedestrians

Bus Depot Design Guidelines states that a provision should be made to restrict the unauthorized entry to bus operation and maintenance area. It also suggests segregated access for crew and staff members.

i) Pedestrian Access

All pedestrian access should be designed so as to reduce vehicular pedestrian conflict with the use of bollards (preferably retractable/removable). The bollards act as a physical separation between the pedestrian and bus movement.

Bollards of at least 1m height should be designed to resist at least 6 kg force travelling at 64 kmph. The bollards may also be illuminated at the top so that they can be easily seen.

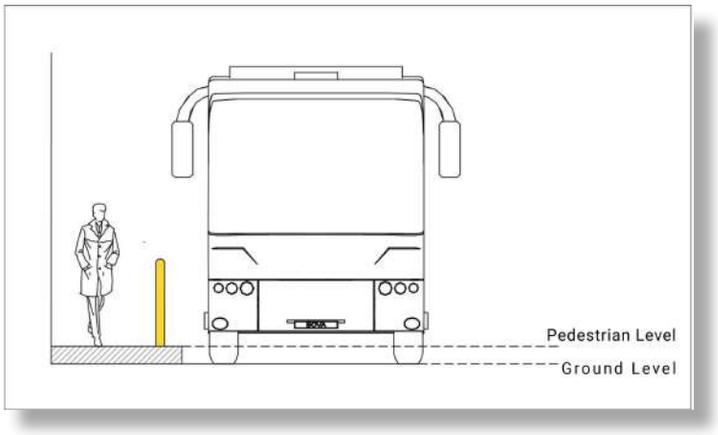


Figure 8-1: Segregated Pedestrian movement (Bollard shown in yellow)

The pedestrian movement should be clearly marked on the floor across the bus depot and should be encumbrance free at all times.

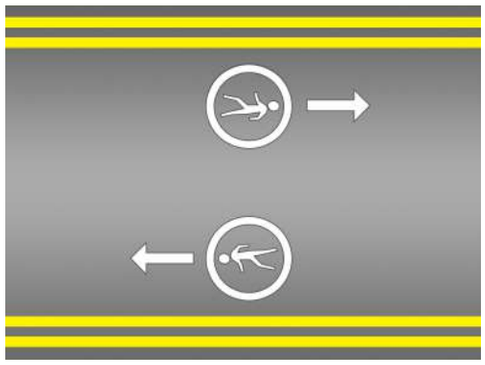


Figure 8-2: Designated Pedestrian Movement

Marked Bus/ Pedestrian Movement Corridor

VDV guidelines recommends paved, drained and marked parking for bus and pedestrian movement inside the bus depot.

ii) Vehicular Access

All vehicular access points into the bus depot (buses, staff/ private vehicles, supplies and pedestrian) should be equipped with night/day and all weather CCTV surveillance equipment. Additionally, automatic vehicle scanner and under car scanning should be set into pavements in weatherproof and easily maintainable enclosures for screening of private vehicles entering the bus depot. The depot operation area should be physically segregated and no private vehicle should have access to the depot operations area.

iii) Parking Access

Staff and private vehicle should have a segregated parking space and no vehicle in the parking space should have access to the bus depot operations areas. If required, conditional access may be provided for emergency situations, by way of boom barriers or retractable bollards.

iv) Other Built Structures

All built structures sharing wall with bus depot operations area should be so designed so as to not have direct access into the bus depot operations area or have adequate access control measures akin to those employed at access points of the building itself.

8.3.2 Site Lighting

Lighting design provides an appropriate transition from street into and throughout the bus depot premises. It is vital to provide adequate lighting to promote a sense of real and perceived security. Key considerations while designing an illumination plan would be Safety, Economy, Durability, Energy Efficiency and Easy Maintenance. Lighting should be in tune with other architectural elements of the bus depot.

i) Site Lighting

Adequate lighting levels should be provided in the various areas of the bus depot especially at the entrances the depot to ensure adequate identification of access and egress points to the facility.

There should be provision for external emergency lighting with uninterruptible power supply system within site premises in case of power failure to assist in safe and orderly evacuation.

ii) Illumination Levels

Lighting should be designed to meet minimum illumination levels and quality standards for both indoor and outdoor application. Natural lighting elements such as sky lights, sawtooth roofs, site reflectors and light tubes etc. should be used to enhance lighting level without increasing the energy load of the bus depot. Lighting levels should be uniformly distributed and abrupt changes in illumination levels should be avoided.

The following general principles in relation to the indoor illumination must be considered while planning and designing of the lighting.

- The spacing between light fittings and the walls depends on the height of the room
- The desirable incidence angle at which light strikes objects and wall areas should be 30° (optimum) and 40°
- Direct glare, reflected glare and reflections from monitor screens should be limited
- Ideally, light should fall on a working position from the sides
- For office areas, light sources in the warm white or neutral white ranges should be used

The power requirement towards lighting load should be calculated to meet the minimum illumination levels as required for operations in both indoor and outdoor operations. Further, the table below presents the desirable lux levels in the various sections of the bus depot.

Table 8-1: Recommended illumination levels for various areas in the bus depots

Areas	Recommended Lux	Minimum Lux
Bus Management Facility		
Entry/Exits	150	50
Security Cabin	300	200
Parking	75	75
Fuelling	500	300
Washing	500	300
Bus Maintenance Facility		
Machine Shop	1000	750
General Admin & Maintenance Section	750	500
Auto Electric Section	1000	750
Fuel Injector Section	1000	750
Paint Booth	1000	500
Body Shop	750	500
Pit & General Maintenance Section	750	500
Suspension Section	750	500
Tyre and Wheel Section	750	500
Battery Room	500	200
Inventory Storage Area and Loading Bays	200	150
Recon and Major Aggregate Section	750	500
Administrative Facility		
Office Area	1000	500
Corridors, Passageways, Stairs	150	100
Toilets & Washrooms	200	100
Lockers	150	100
Dormitory	150	100
Kitchen	750	500
Canteen	300	200

Only energy efficient luminaires should be used as per the overall lighting plan. They should be "cool white light" types of lamps.

iii) Lighting System Fixture Parameters

The lighting system includes Normal lighting (powered via normal and reserve circuits) and Emergency lighting (designated lights on emergency circuit) besides illuminated signage.

As an energy-efficient strategy, choice of luminaires should be monitored and intelligent systems should be introduced where lighting is activated by occupancy sensors and light sensors for external lighting. Of critical importance is increasing the dependence on natural light through careful fenestration design and material choice, resulting in potential energy savings.

8.3.3 Security and Electronic Surveillance

i) Site Boundary

The design of the site perimeter shall create a physical separation of a minimum of 1.5m height. The delineation could be in the form of built structures including shops, non-permeable installations etc. Concertina cable loops may be erected for protection against trespassing and intrusion. Floodlights, preferably photocell based perimeter illumination of minimum 30 lux may be deployed to prevent any dark areas on the site periphery.

ii) Electronic Surveillance

CCTV systems provide surveillance capabilities used in the protection of people, assets, and systems. A CCTV system serves mainly as a security force multiplier, providing surveillance covering a larger area, and for longer duration, than would be feasible with security personnel alone.

CCTV systems have many components with a variety of functions, features, and specifications which are needed to be understood in order to design an appropriate CCTV system.

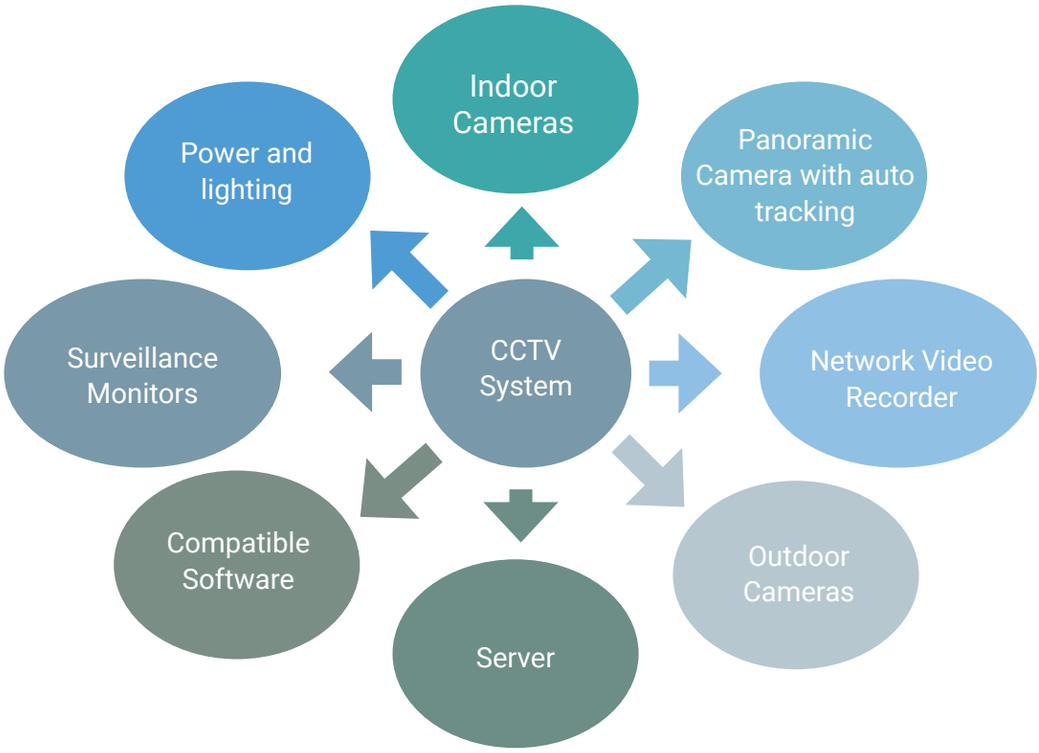


Figure 8-3: Components of a CCTV System

The CCTV system design and requirements are provided in detail in **Annexure 2.**

8.4 Signage

Signage is a critical design element for the proper functioning of a bus depot facility. It is a key element assisting users in the depot environment. It is closely linked with the ease of use of the facility by its occupants and visitors. Signage becomes increasingly important in the case of depot workshop operations by aiding in

(i) Ease of operations
(ii) Safe and segregated circulation of vehicles and personnel
(iii) Warning signage at hazardous areas

Institute of Urban Transport (IUT)-Code of Practices (Part 4) should be adhered to for proper placement and design of signage.

8.4.1 Signage Functions

A perfect signage design is legible, easy for all to comprehend and totally self-explanatory. The following are the primary function of a signage in a depot.

i. **Wayfinding** : Guiding personnel and visitors to and from various parts of the bus depot building.

ii. **Information Dissemination** : Provides essential information to the user to facilitate navigation of the facility components.

iii. **Security** : Contributes to an enabling, user friendly, safe and reassuring user experience. Signage are vital in guiding people to safety in case of an emergency.

Also, coordination would be of utmost importance between lighting and signage designs. Signage surfaces may either be lit with supplemental external luminaires or preferably, be trans-illuminated by locating light sources within signage. Lighting should be designed so that people with low vision can easily read the text of accessible signs without glare.

While designing and placing signage the following considerations need to be accommodated.

8.4.2 Signage Design

The viewing distance decides the letter size used for signage design so that the signage will be legible from distance. The following table shows the height of letter for varying viewing distance as provided in the IUT-Code of Practices (Part 4).

Table 8-2: Alphabet Size & Viewing Distance

Viewing Distance (in meter)	Alphabet Height (in mm)
2	6
3	12
6	20
8	25
12	40
15	50
25	80
35	100
40	130
50	150

8.4.3 Signage Border

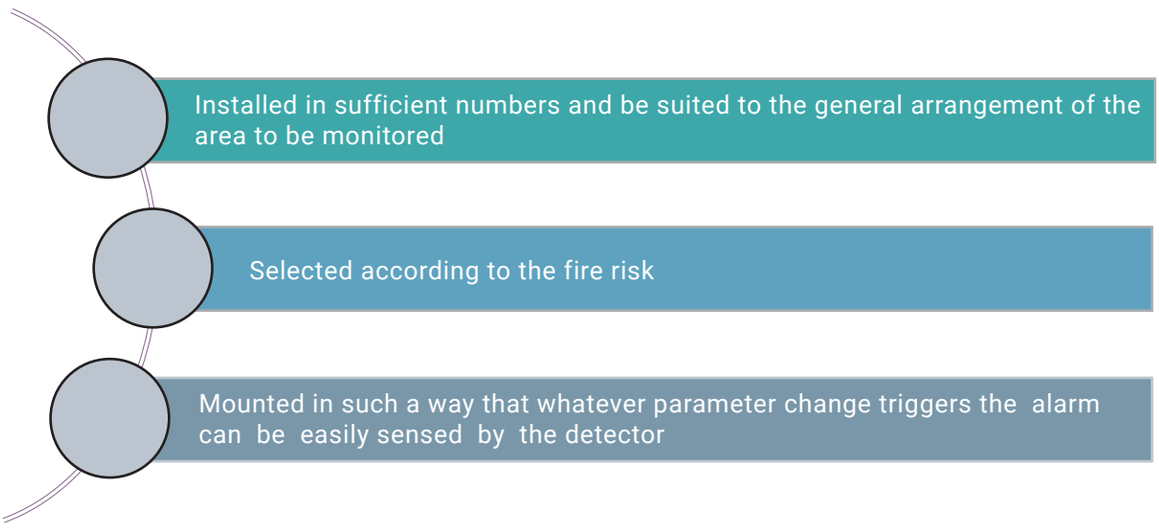
All signage shall have a border of the same colour as the legend, at or just inside the edge, unless otherwise specified in the IUT-Code of Practices (Part 4). Moreover, the corners of all the sign borders shall be rounded.

ANNEXURE 1: FIRE FIGHTING

Fire Detection

The earlier the detection of a fire, the easier is it to put out. With every passing minute (or even, second), its severity and spread increase. This makes fire detection a significant parameter in the design of a fire protection system.

The fire detection involves use of fire detectors which are a part of the fire alarm system and can trigger a transmitting device that raises the alarm in a remote control centre. There are automatic and non-automatic fire detectors. The latter are those which can be activated manually. Automatic fire detectors are part of the overall fire alarm system that sense changes in specific physical and/or chemical parameters (either continuously or sequentially in set time intervals) to detect a fire within the monitored area. They must be:



The following types of detectors can be deployed :

Smoke Detectors	• Ideal for rooms containing material that give off large volume of smoke • Types: Optical Smoke Detector, Ionisation Smoke Detector
Flame Detectors	• Ideal for rooms containing materials that burn without smoke, or produce very little. • Activated by radiation emanating from flames
Heat Detectors	• Ideal for rooms in which smoke that could wrongly set off other early warning systems is generated under normal working conditions (e.g. in workshops where welding work is carried out) • Maximum detectors: triggered when a maximum temperature is exceeded (e.g. 70°C) • Differential detectors: triggered by a specified rise in temperature within a fixed period of time (e.g. a rise of 5°C in 1 minute).

Firefighting

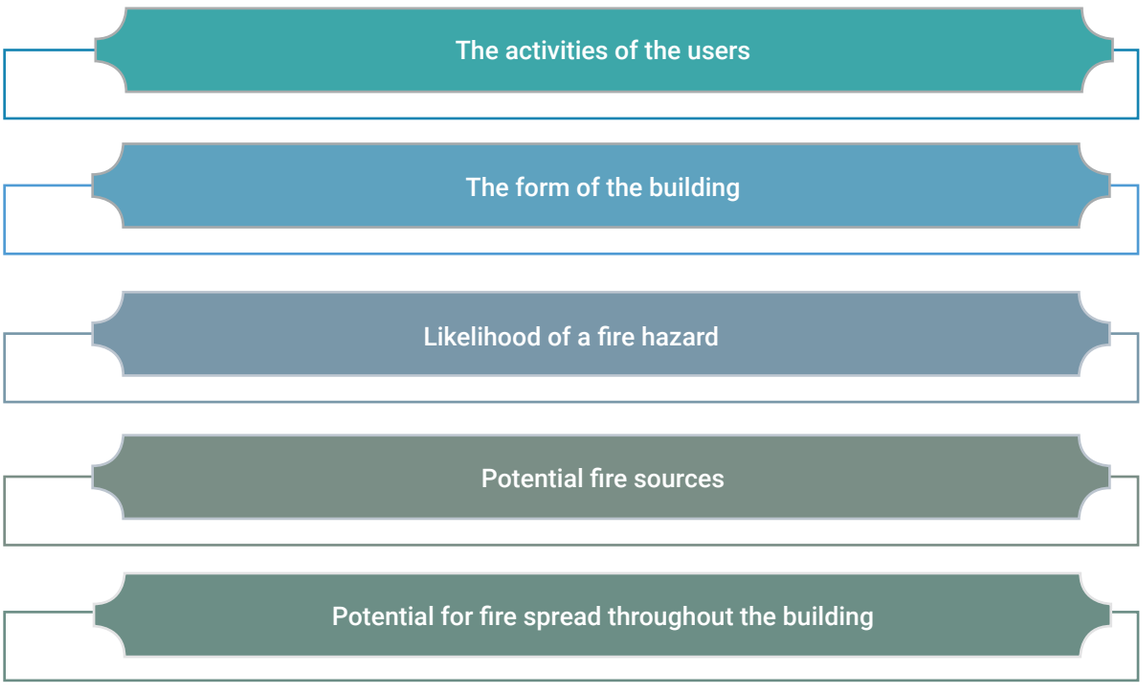
The firefighting system comes into picture once the fire is detected. A robust firefighting system should be designed based on the nature of the operation of the section of the bus depot i.e. a different firefighting system may be adopted for administrative areas and workshop area. The following are the firefighting systems appropriate for a bus depot facility.

Two prominent types of sprinkler system can be deployed in the depot premises:

- **Wet sprinkler systems** are systems in which the pipeline network behind the wet alarm valve station is permanently filled with water. When a sprinkler responds, water emerges from it immediately.
- **Dry sprinkler systems** are meant for facilities in cold regions where there is a possibility of frost formation in pipes. The pipeline network behind the dry sprinkler valve station is filled with compressed air, which prevents water from flowing into the sprinkler network. When the sprinkler system is triggered, the retaining air pressure is released and water flows to the sprinkler heads.

Fire Escape

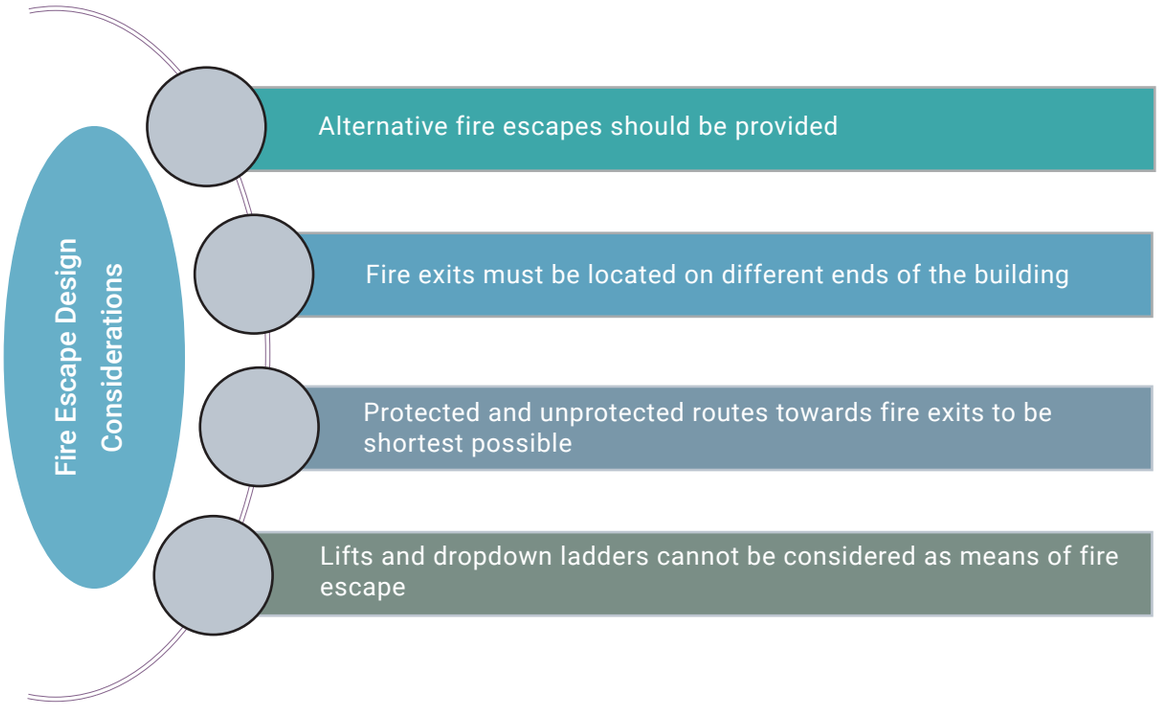
Evacuation of the personnel from the depot facility in the event of a fire is of primary significance. Every minute lapsed poses incremental risk to the life and material. Factors to be taken into account when designing means of escape from buildings are presented below.



The following assumptions are made to achieve a safe and economic design of a fire escape:

- Occupants should be able to escape safely without outside help.
- Fire normally breaks out in one part of the building.
- Fires are most likely to break out in the furnishings and fittings rather than in the parts of the building covered by the building regulations.
- Fires are least likely to break out in the structure of the building and in the circulation areas due to non-use of combustible materials.
- Fires are initially a local occurrence, with a restricted area exposed to the hazard. The fire hazard can then spread with time, usually along circulation spaces.
- Smoke and noxious gases are the greatest danger during early stages of the fire, obscuring escape routes. Smoke and fume control is therefore an important design consideration.

The general principles to be applied in relation to the planning and design of a fire escape are presented below.



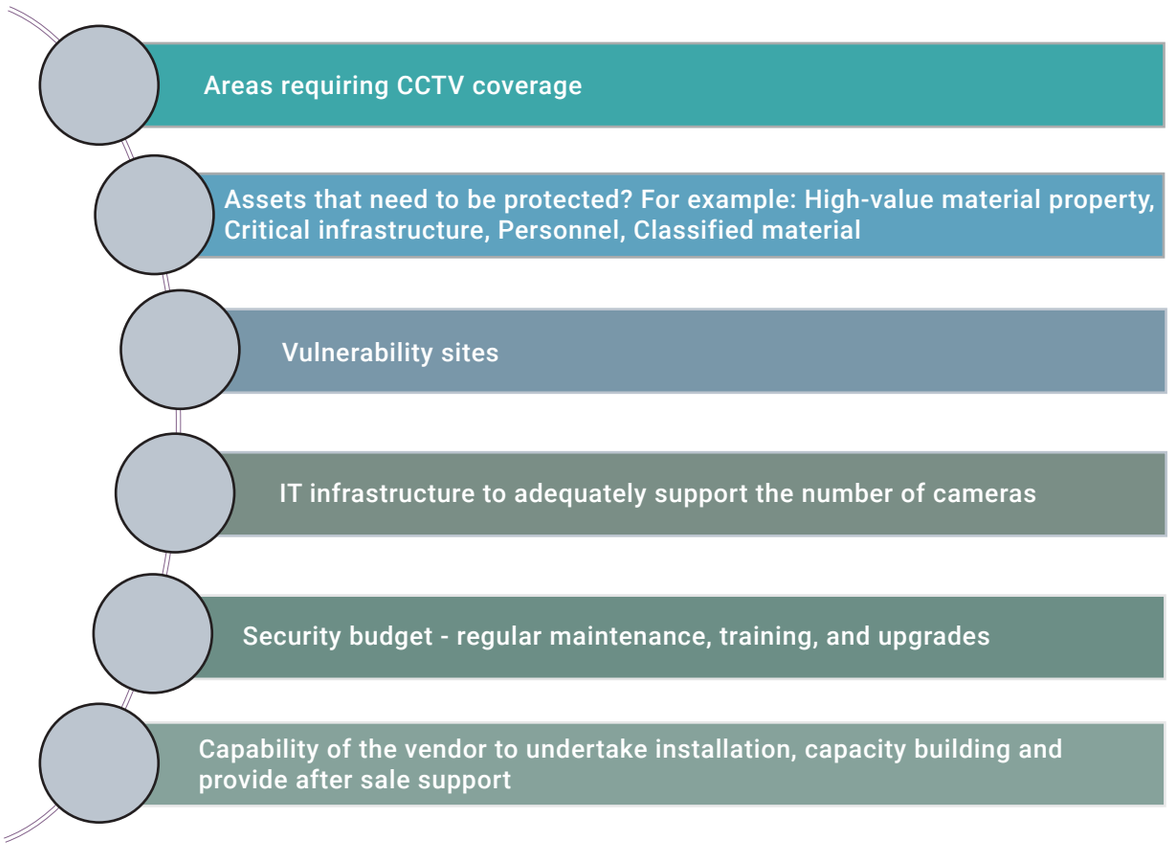
The NBC 2016 also suggests that the following firefighting measures may be applicable to the bus depot buildings based on the building height.

SN	Type of Building Occupancy	Office Building	Workshop Building	Storage Building	Hazardous Building
1	Fire Extinguisher	R	R	R	R
2	First Aid Hose Reel	R	R	R	R
3	Wet Riser	NR	R	R	R
4	Down Comer	NR	NR	NR	NR
5	Yard Hydrant	NR	R	R	R
6	Automatic sprinkler	NR	R	R	R
7	Alarm system	R	R	R	R
8	UG Tank	NR	1,50,000	75,000	Min 240 minutes
9	Terrace Tank	1000	20,000	10,000	50,000
10	Pump capacity at UG Tanks (Lts/min)	NR	2280 (Diesel) 180 (Electric)	1620 (Diesel) 180 (Electric)	Based on covered area
11	Pump capacity at Terrace Tanks (Lts/min)	450	NR	900	900

Note: R = Required, NR = Not Required

ANNEXURE 2: CCTV SYSTEM DESIGN

A list of questions to determine the overall CCTV system requirements is presented below:



Following a sound design process enables organizations to make decisions that result in the deployment of a CCTV system that meets functional and operational requirements. As CCTV is part of a multi-layered security approach, a system design should begin with a comprehensive needs assessment to ensure security risks and mitigation plans are identified. Clear requirements, a comprehensive site survey, and proper equipment selection and installation must all be considered when designing a CCTV system. An efficient CCTV design must incorporate a clear definition of system requirements and system design considerations.

CCTV system, like any other security infrastructure, comes with its own inherent strengths and limitations. It is important to clearly define the CCTV system requirements to fulfill the expected security needs of a bus depot.

The CCTV system design takes shape based on the defined system requirements. CCTV design considerations such as lighting, power, transmission, cost, camera types, lenses, monitors,

multiplexers, and other components are important in the design and layout of a CCTV system and should be incorporated in the CCTV system design.

Defining CCTV System Requirements

- Need Assessment
  - Functional requirements
  - Operational requirements
  - Infrastructure requirements
  - Data storage requirements
- Multidisciplinary system design team.
- Site Analysis
- System layout considerations

Defining CCTV System Design Considerations

- Lighting
- Robust and reliable power supply
- Video transmission
- Scalability
- Cost
- Reliability and Maintainability

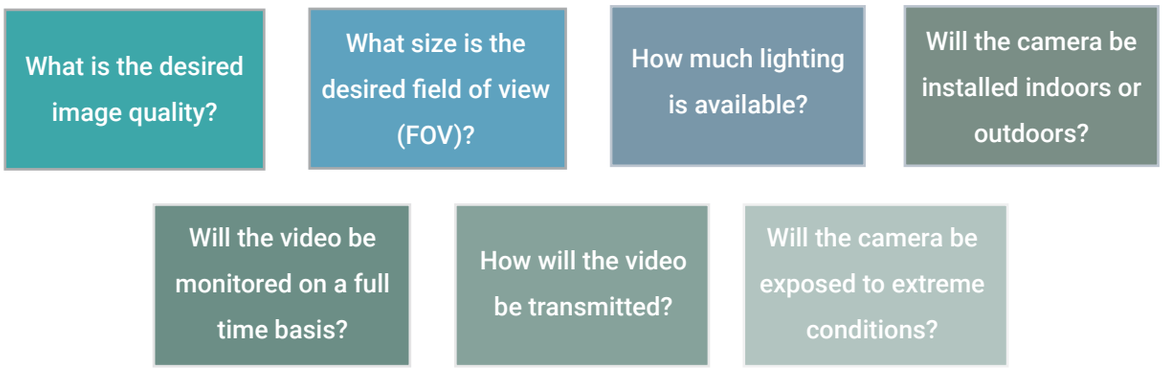
The process CCTV system design must include personnel from varied internal disciplines such as security, facility maintenance, management, operations etc. to integrate their individual perspective towards security based on their operational experience in the overall CCTV system requirement.

A needs assessment gathers and analyses four sets of requirements:

Need Assessment	
Functional requirements	Define camera coverage needs such as surveillance of perimeters, parking area, and storage areas; surveillance of approaches to, and spaces within, buildings or other structures.
Operational requirements	Define the capabilities of the CCTV system components that will enable it to provide the expected information under all operating conditions. Conditions to consider in the operational environments include day and night operations, lighting, weather conditions, and temperature changes
Infrastructure requirements	Define needs for installing or accessing fiber or hard-wire cables, wireless networks, and power sources, to name a few, necessary to successfully implement an integrated CCTV system
Data storage requirements	Define the organization's video retention and storage

Cameras

Choosing a correct camera for particular operational environment is critical to a successful CCTV system design. The answers to the following questions may help determine the best camera type for the operational requirement:



Based on the answers to the above questions, cameras can be chosen from the following types based on the operational requirement.

Fixed Cameras	Fixed cameras are mounted in a stationary position and are focused on a single FOV, typically one particular area of interest.
Pan Tilt and Zoom (PTZ) Cameras	PTZ cameras come in a variety of sizes and shapes for interior and exterior uses. Typically, a PTZ camera can be turned and tilted on two axes to provide pan and tilt capabilities and the focal length of the lens can be varied to change the FOV. This enables PTZ cameras to offer more flexibility for viewing and capturing images in real time than fixed cameras.
Connectivity Type	CCTV cameras may employ one of two types of data transmission: • Network Cameras– Network cameras connect to IP-based networks, including the Internet, and provide remote viewing and recording. Network cameras are also available in high definition (HD) which can provide greater image detail. • Analog Cameras– Despite increasing use of digital network cameras, a market for analog cameras still exists. Analog cameras have options for high resolution, making them applicable for various surveillance needs. These cameras also have some cyber security advantages because the coaxial cable they are connected with would require physical access to breach. In present scenario, wired / fiber-connected CCTV systems would be preferred against Wi-Fi connected. In case Wi-Fi connectivity is considered, arrangements should be made to ensure continuous Wi-Fi connectivity.
Day/Night Cameras	Day/night cameras offer flexibility by automatically adjusting to current lighting conditions.
Low-Light or Night Vision Cameras	Low-light cameras are designed to perform in some level of ambient lighting, such as indoor restaurant lighting, street lamps, or a full moon; they are not intended for use in complete darkness. Night vision cameras used in CCTV systems typically consist of near-infrared (NIR) and IR cameras with built-in IR illuminators. They are designed to allow the operator to view night scenes. The distance from which a CCTV camera can detect objects at night depends on the capability of the camera components, such as the lens and sensor, as well as on the intensity of the IR illuminator used.
Thermal Imaging Camera	These cameras detect infrared and heat radiations. These cameras can capture imagery in fog or smoky conditions.

CCTV Monitors

The selection of monitors is as important to the quality of the image as the selection of cameras, lenses, and other components in the imaging chain. The video monitor market offers a number of choices, such as liquid crystal displays (LCDs) and LED displays, various sizes, and other features which should be selected based on the need and cost implications.

Digital Video Recorders (DVRs)

DVRs perform the complex task of digitizing, compressing the video feed from the CCTV cameras and storing the data for retrieval during the storage period.

DVRs can include a variety of features and capabilities such as

- On-board software, such as video analytics;
- Image protection/authentication techniques;
- Internal hard drive for video storage;
- Ability to easily search for and locate events;
- Ability to record one or more camera inputs while performing video analytics;
- Removable hard drive for archiving purposes; and
- Ability to transfer data to expandable storage systems called Redundant Array of Independent Disks (RAID) to free up recording space

DVRs may be classified as simplex, duplex, or triplex. Simplex DVRs cannot record while searching and viewing recorded images. Duplex systems can record while searching. Triplex DVR systems allow the operator to view recorded and live video while recording continues.

Communications System

Bus depots should be provided with a central communications system consisting of

i. **Personal Branch Exchange (PBX) System:** This system is meant to provide a captive intra-organization voice connectivity network building.

ii. **Help Point Intercoms (HPI):** These provide assistance at the push of a button, allowing immediate contact with the security or information desk from specific locations within the site.

iii. **Public Address (PA) System:** The system should provide for a public address system which shall broadcast information, emergency notifications, music etc. at the bus depot. Speakers shall be installed at appropriate distances to provide for adequate sound intensity (dB) at all locations around the bus depot.

9 UTILITIES

The planning of a bus depot should be undertaken with the demand forecast for the utilities so as to identify the reliable, cost effective and environment friendly technology for the estimated demand and its supply.

9.1 Water

The planning of the plumbing system should adhere to the following.

(i) Water source and its reliability.
(ii) Adequate storage of raw and treated domestic water.
(iii) Reuse of the treated water to reduce or eliminate waste water discharge.
(iv) Water supply for bus depot building through gravity by using overhead water storage tanks.
(v) Connection of roof rainwater and run-off rainwater to collection pits.
(vi) Recycling of waste water and reusing for washing of buses, flushing and landscaping.
(vii) Designing of sanitary, waste & vent system with a view to make them water tight and gas tight to prevent escape of foul gas and odour.
(viii) Water treatment system as per SP:35(S&T) 1987.

9.1.1 Water Requirement

Water requirement should be calculated based on the provisions of IS: 1172, NBC and prevalent practice in the industry. An illustrative example for calculating water requirement for a bus depot is as follows.

Table 9-1: Water Requirement

Description		Water Consumption per unit (LPCD)	Water Consumption (in litres)
Number of drivers and Conductors	A	15	A1 = A X 15
Number of workshop staff at the bus depot	B	45	B1 = B X 45
Number of office staff at the bus depot	C	45	C1 = C X 45
Dormitories	D = Number of beds X Occupancy factor of dormitories	135	D1 = D X 135
Bus Washing	E = Number of buses to be washed	Per Bus Water Requirement = As per the water requirement of washing plant per bus	E1 = E X Per Bus Water Requirement
Horticulture Activities	F = Horticulture area in square meter	1	F1 = F X 1
Workshop	G = Number of buses to be washed	5	G1 = G X 5
Total Water Requirement			**A1+B1+C1+D1+E1+ F1+G1**

9.1.2 Treatment Facilities

The provisions of following minimum facilities should be considered while designing the bus depot:

1	Water Recycling Plant (WRP)	To recycle water and for potential reduction in the fresh water requirement.
2	Sewage Treatment Plant (STP)	To treat waste water/sewage for reuse in flushing and landscape.
3	Effluent Treatment Plant (ETP)	To treat waste water generated from washing of buses for reuse in washing of buses.
4	Oil Separator	To separate grease and oil from waste water generated from workshop area.

Waste water treatment

Effluent Treatment Plant (ETP) must be mandatorily installed in the depot.

The capacity calculation of the above mentioned facilities is provided below.

Table 9-2: Capacity of Treatment Facilities

Flushing requirement	=	24% X (Total Water Requirement – E1 – F1 – G1)
STP capacity	=	90% X Flushing Requirement
Flushing Water Tank capacity	=	Flushing Requirement X 2
Fresh water requirement	=	Total Water Requirement – Flushing Requirement – E1 – F1 – G1
Water Treatment Plant Capacity	=	Fresh water requirement
Raw Water Tank capacity	=	Fresh water requirement X 2 X 1.1
Treated Water Tank capacity	=	Fresh water requirement X 2
Fire Tank Capacity	=	As per NBC 2016
Overhead Water Tank capacity for flushing	=	Flushing requirement X 60%
Overhead Water Tank capacity for all other activities except flushing	=	Fresh water requirement X 60%
ETP capacity	=	90% X (Total Water Requirement – F1 – Flushing Requirement)
Treated Water Tank capacity for ETP	=	(E1+ F1 + G1) X 2

9.1.3 Water Storage and Distribution

i. The incoming water supply line shall be fed into underground fire water reserve tanks. Water from underground fire water reserve tank should overflow into underground raw water storage tank.

ii. Water from the underground water tanks should flow to overhead tanks for gravity flow system.

iii. For drinking water, localized RO at usage points should be provided.

9.1.4 Rainwater Harvesting

(i) Rain water drainage system should be provided to transfer rain water from terrace, paved area and horticulture areas to rainwater collection pits through catch basins.

(ii) Capacity of rainwater collection pits should be a minimum of 50% of average annual rainfall or the yearly fresh water requirement of the bus depot.

Rain water harvesting

Bus Depot Design Guidelines recommends rain water harvesting to reduce the strain on the municipal water supply and ground water.

Table 9-3: Rainwater Harvesting

SN	Type of Structure/ Surface	Catchment Area (in Hectare)	Run off Coefficient	Discharge (m^3/hr)
1	Terrace/Hard Paved Area	A	0.9	A1 =A X 0.9 X I
2	Paved Surface (Road)	B	0.8	B1 =B X 0.8 X I
3	Horticulture Area	C	0.2	C1 =C X 0.2 X I
			Rainwater collected	**A1 + B1 + C1**

Note: I is intensity of rainfall in the region in mm per hour

9.2 Power

A bus depot has 24/7 operations. Infrastructures of such key significance demand a robust and reliable power supply to support their operations. The system planning should adhere to the following.

(i) Reliability of power supply in the bus depot from two different discoms or DG.
(ii) Ease in maintenance of equipment.
(iii) Safety of personnel and equipment.
(iv) Protection against lightning in accordance with the requirements of IS 2309.

(v) Provision of Earthing system for substation equipment like HT panel, transformers, DG sets & LT panel.
(vi) Carrying out Distribution earthing all along the LT distribution system.
(vii) Installation of suitable transformer with appropriate adjustments towards Power factor and loading.
(viii) Generation and usage of solar energy to enhance sustainability.

9.2.1 Demand Analysis

Power requirement in a bus depot is typically towards lighting (Internal and Outdoor), HVAC and operations of plant and equipment.

The calculation of lighting load and power load should be calculated based on Energy Conservation Building Code (ECBC) 2017 whereas equipment load shall be as per individual equipment specifications.

Lighting Load	=	Area (in sqm) X Basis of Lighting Load (in W/sqm) X Demand Factor
Power Load	=	Area (in sqm) X Basis of Power Load (in W/sqm) X Demand Factor
Equipment Load	=	Load as per individual equipment specifications
Total Load	=	Lighting Load + Power Load + Equipment Load
The Demand Factor calculation for the individual connected loads should be as per ECBC 2017.		

The equipment sizing for transmission and distribution of power in a bus depot should be calculated based on the evaluated total load of the bus depot.

9.2.2 Rooftop Solar Power

The rooftop of bus depots shall be used for generation of solar power. In addition to the obvious benefits of reducing power expenses and aiding in sustainability, it helps in reducing HVAC expenses by reducing temperature of the building.

Use of Solar energy

Bus Depot Design Guidelines recommends the use of solar energy on the built up areas of the depot.

The space requirement for a rooftop solar power plant is based on the following factors:

(i) Orientation of roof in relation to the movement of the sun.
(ii) Shape of the roof.
(iii) Generation Capacity of the solar panels.

Average space required for installing a solar power plant in India is approximately 14m^2 per KW. The Ministry of New and Renewable Energy (MNRE) guidelines, Solar Energy Corporation of India (SECI) guidelines and the guidance issued by state nodal agencies for renewable energy may be referred to for installation of rooftop solar power plant. [12]

9.3 Heating, Ventilation and Air Conditioning (HVAC)

A human being produces about 1.5 kcal/h per kg of body weight. An adult weighing 70 kg therefore generates 2520 kcal of heat energy per day, although the quantity produced varies according to the circumstances. For instance, it increases with a drop in room temperature just as it does with physical movement.

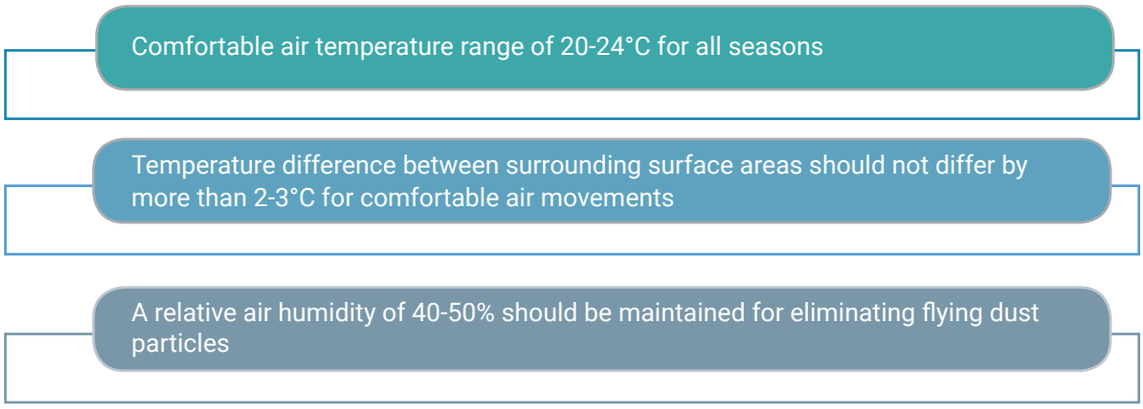
An air temperature of 20-24°C is comfortable both in summer and in winter. The surrounding surface areas should not differ by more than 2-3°C from the air temperature. A change in the air temperature can be adjusted by changing the surface temperature (e.g. with decreasing air temperature, increase the surface temperature). If there is too great a difference between the air and surface temperatures, excessive movement of air takes place. The main critical surfaces are those of the windows.

The air conditioning in the bus depot is proposed for the administrative block, ITS and Electronic Equipment section, Fuel Injector section and wherever dust free environment is required.

[12] The Bus parking can have a cover designed to bear the load of a rooftop solar plant. It will provide an excellent opportunity to generate electricity which can be used to charge Electric Buses. The cover will help in keeping low the battery temperature of the Electric Buses

When heating a closed space, care must be taken to ensure that low temperature heat is used to warm the room air on the cold side of the room. With surface temperatures above 70-80°C decomposition can take place, which may irritate the mucous membrane, mouth and pharynx and make the air feel too dry.

It is important to control air movement and humidity as far as possible. A relative air humidity of 40-50% is comfortable. With a lower humidity (e.g. 30%) dust particles are liable to fly around and pose a risk of inhalation.



HVAC installation aims at controlling and optimizing the following factors for the comfort of users of that area in the building.

(i) Air quality
(ii) Air movement
(iii) Dry-bulb temperature
(iv) Relative humidity
(v) Noise and vibration
(vi) Energy efficiency
(vii) Fire safety

Design Considerations

(i) Recommended indoor temperature, relative humidity, air velocity, mean radiant temperature
(ii) Outside design conditions
(iii) Construction material and orientation of exposures of building components
(iv) Fenestration area, thermal properties and shading factors
(v) Internal load of equipment, computer/server and lighting

9.3.1 Air Conditioning System

For calculating the heat loads, the following parameters should be considered:

Outdoor Conditions	Outdoor Design Conditions (as per location of site) which shall be based on Weather data compiled and published jointly by ISHRAE and ASHRAE India Chapter (AIC) corresponding to 0.4% annual cumulative frequency of occurrence.
Inside Conditions	1. For the semi enclosed area such as Entrance area, Security etc., inside conditions could be as follows: (i) Summer & Monsoon seasons • Temperature - 25 +/- 1 deg C, • Relative Humidity (RH) less than 60%. (ii) For Winter Seasons • Temperature - 20 +/- 1 deg C, • Relative Humidity (RH) less than 60%. 2. For the enclosed areas such as Office, Dormitory etc., inside conditions could be as follows: (i) Summer & Monsoon seasons • Temperature - 24 +/- 1 deg C, • Relative Humidity (RH) less than 60%. (ii) For Winter Seasons • Temperature - 21 +/- 1 deg C, • Relative Humidity (RH) less than 60%.

Generally the area requiring air conditioning in a bus depot would be limited to administrative block and ITS and Electronic Equipment section, therefore AC load in a bus depot shall not exceed 200 TR and hence, Variable Refrigerant Flow system (Air Cooled) system shall be used or individual air conditioning units could be used which may be more economical.

9.3.2 Ventilation

A human being breathes in oxygen with the air and expels carbon dioxide and water vapour when he exhales. These vary in quantity depending on the individual's weight, food intake, activity and surrounding environment.

It has been calculated that on an average human beings produce 0.020 m^3/hr of carbon dioxide and 40 g/hr of water vapour.

Where air quality is likely to deteriorate because of naked lights, vapours and other pollutants as in case of a bus depot or workshop, rate of exchange of air must be artificially boosted in order to provide the lacking oxygen and remove the harmful substances.

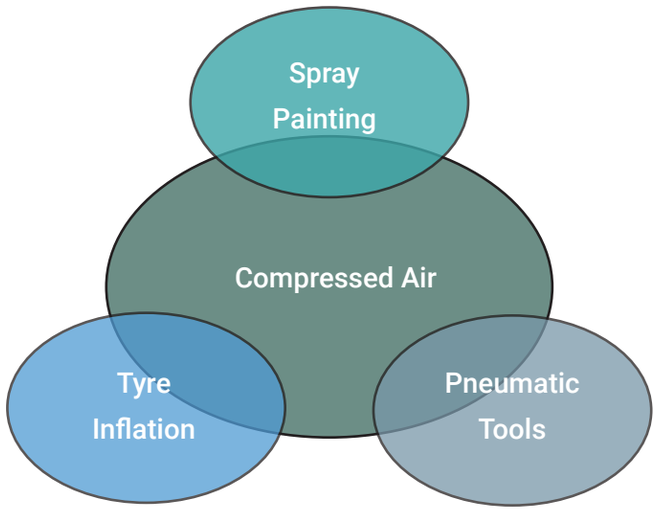
Proper air changes should be provided for Toilets, Kitchens and Workshop area. Air Change required for various areas are as follows:

Table 9-4: Area wise Air Changes Requirement

1	Toilets	6-10 Air Change Per Hour
2	Kitchens	• Minimum of 45-50 air change per hour • Both filtered fresh air supply and exhaust air system to be provided • Filtered fresh air should be 85% of exhaust air • Exhaust air shall be passed through scrubbers before releasing to the atmosphere. • Grease removal system to be provided.
3	Fresh Air for Air-conditioned Areas	As per ASHRAE 62.1
4	Basement	• Minimum 12 air changes per hour • In large basements, each compartment to be independently ventilated at this rate.
5	Workshop area	8-10 Air Change Per Hour
6	High fume area such as Battery room	15-30 Air Change Per Hour

9.4 Compressed Air

Compressed air is of high significance inside a bus depot for the purpose of maintenance and repair of rolling stock in a depot workshop. The following are the application of compressed air in the depot workshop.



The following type of air compressors are preferably deployed in a bus depot workshop.

- Reciprocating type compressor
- Rotary Screw type compressor

Both the compressor types have their inherent benefits suited for specific type of operation in a bus depot. Some of the prominent characteristics of each compressor type are discussed below.

Reciprocating Compressor	Rotary Compressor
Good for Tyre Inflation	No need for an Air reservoir
Low power Consumption	100% duty cycle (no pulsating air supply)
Proven Longevity	Higher Cubic Feet per minute rate with Clean and cool air
Low Cost	Suitable for operating Pneumatic tools

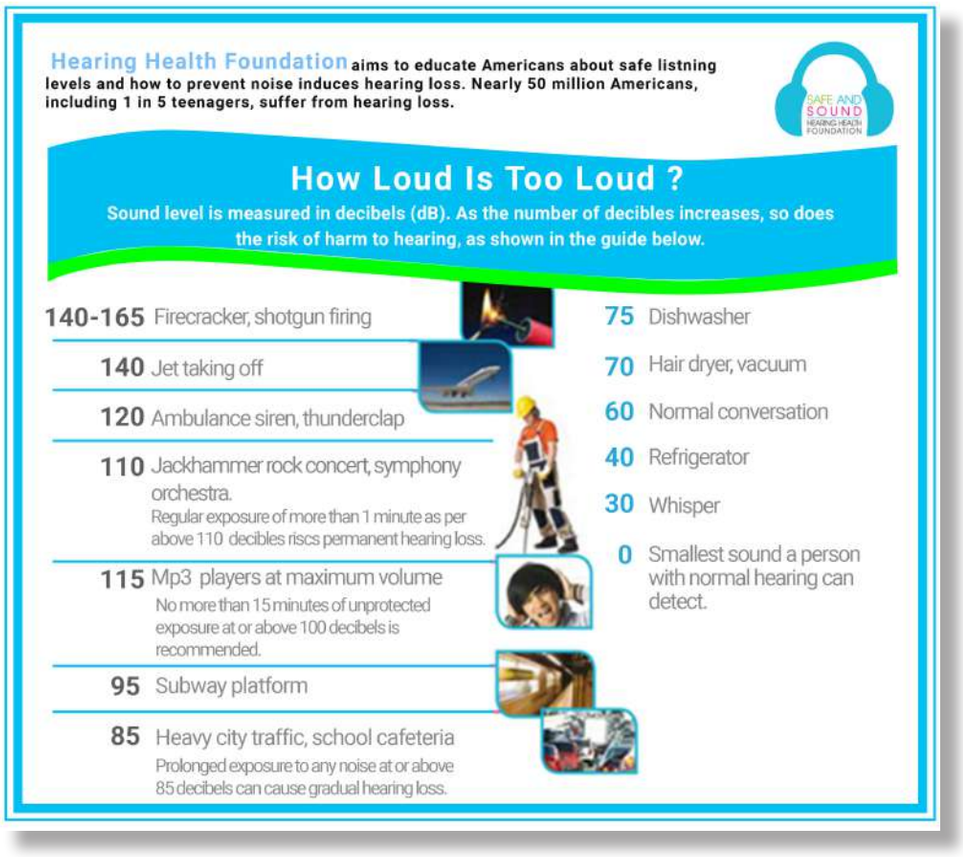
As a guiding principle, for a bus depot for 100 buses, a reciprocating compressor of 15 HP and a screw type rotary compressor of 20 HP with centralized piping would meet the compressed air requirement. However, a detailed analysis should be undertaken based on the type of usage and volume/ pressure of compressed air requirement which changes substantially with technology.

10 ENVIRONMENT

Depot operations involve a set of activities which can cause pollution or adversely affect the environment. Therefore, the following mitigation measures should be adopted :

10.1 Noise Abatement

Depot Management is responsible for monitoring and controlling noise levels created by the depot activities. Continuously high and excessive noise levels can cause permanent hearing impairment to staff, disturb the neighbours and have an adverse effect on the community and environment.

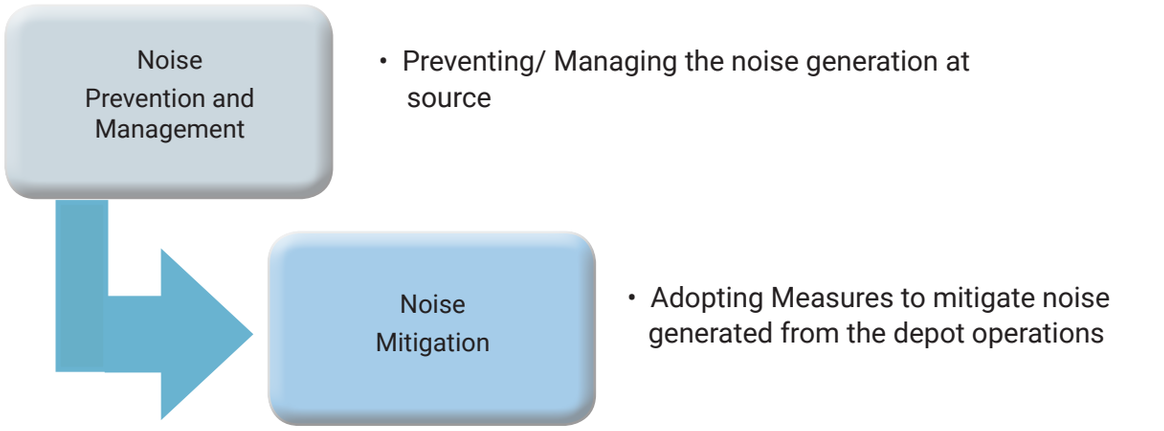


Source: https://hearinghealthfoundation.org/decibel-levels accessed on October 2, 2019

Figure 10-1: Noise Levels

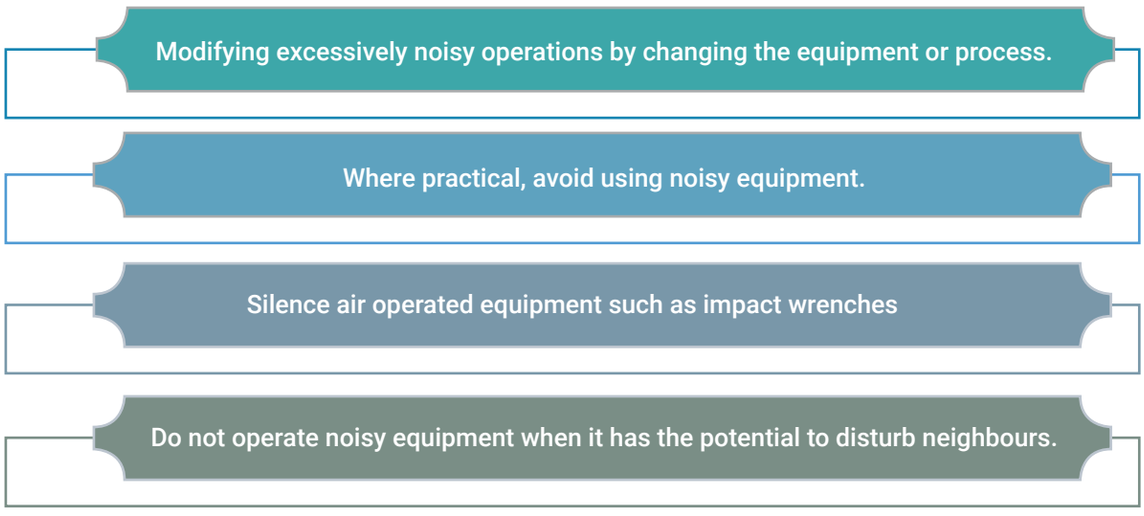
Noise levels are cumulative and increase with each extra sound. Conversely, noise can be reduced by eliminating sounds. Excessive noise levels always have an adverse effect on your staff and neighbours.

The menace of noise pollution in a bus depot can be tackled in the following two ways.



10.1.1 Noise Prevention and Management

Prevention of noise generation can be achieved to a reasonable extent by the adoption of the following measures.



With the adoption of the aforementioned noise prevention practices, it is possible to reduce the noise generation arising from the bus depot operations to a large degree. However, noise mitigation measures are required to further reduce the noise levels.

10.1.2 Noise Mitigation

Noise mitigation in the context of bus depot design is a set of strategies or measures put in place to reduce noise pollution or to reduce the impact of noise both indoors and outdoors. The CPCB Guidelines 2015 present the following standards for ambient noise.

Table 10-1: Noise Standards (CPCB - 2015)

Category of Area/ Zone	Day time Leq dB(A)	Night time Leq dB(A)
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	50	40

The noise mitigation measures may include

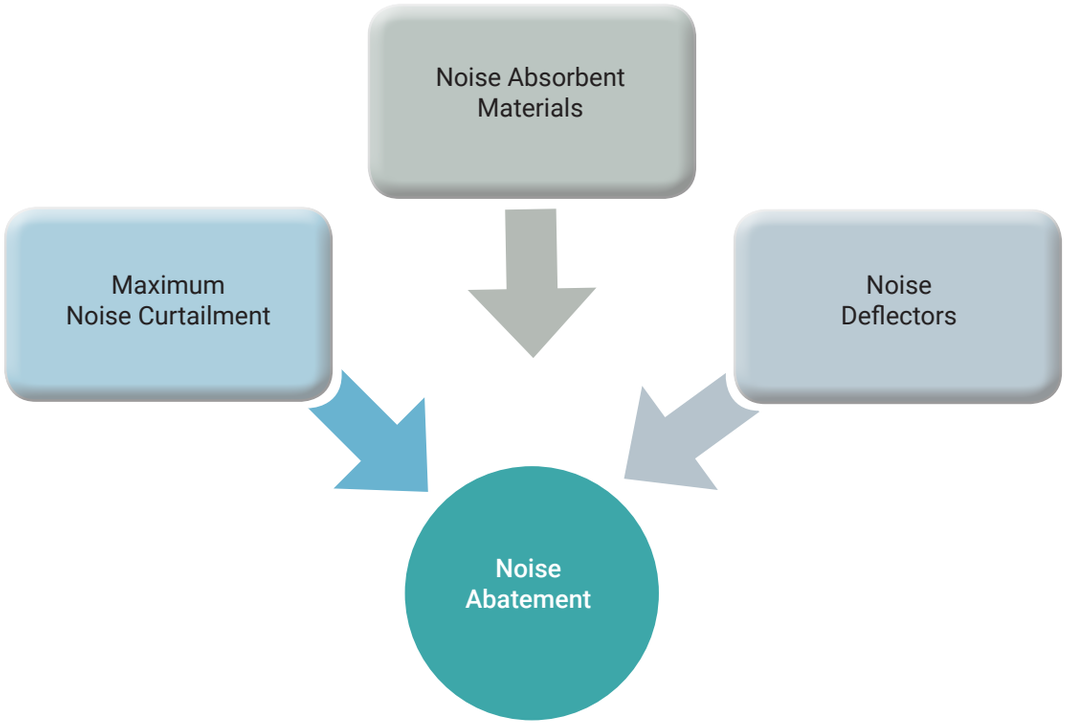


Figure 10-2: Noise Mitigation Measures

One of the natural measures for noise mitigation is a green belt of 1.5m width along with an additional 1.5m pedestrian walkway all along the periphery of the site.

The following equipment and interventions may be deployed for effective noise mitigation at the bus depot.

Figure 10-3: Noise Mitigation Equipment

Amongst the above presented noise mitigation measures, the noise barriers erected around the periphery of the bus depot compound will be the most effective countermeasure to the noise generated by the bus depot. A polycarbonate noise barrier is a better choice in terms of durability and cost in comparison to a metallic noise barrier.

In addition to the noise prevention and mitigation measures prescribed above, certain steps towards personnel protection from noise pollution at the bus depot should be implemented including:

Use warning signs to remind people to wear hearing protection.

(i) Noise level tests must be conducted by a competent person and work must be undertaken periodically.
(ii) Have staff that work in noisy environments undergo a hearing check every two years.
(iii) Have operators and other affected personnel wear earplugs, or similar devices, when carrying out noisy activities.

Amongst others, the Guidelines for community noise (WHO, 1995, 95 p.) and CPCB Guidelines for Noise should be referred for planning the noise abatement measures in a depot.

10.2 Air pollution: Indoor Air Quality, Dust, Fumes and Exhaust

The bus depot comprises open washing area, inspection bays, automatic washing bays, fuelling bays, workshop stores, tyre shop, administration block, canteen & recreation area and dormitories.

The fresh air in the areas which are covered and closed shall be supplied with filtered fresh air free from any objectionable odour. The paint shop shall be provided with ventilation system of 15-30 air change per hour. The paint shop shall be at positive pressure.

The basement area should be provided with ventilation rate of minimum 12 air changes per hour for smoke exhaust in the eventuality of fire. Mechanical fresh air and exhaust system shall be provided in the basement areas.

Administration block, canteen and dormitories may be air-conditioned with variable refrigerant system. These areas shall be provided with filtered fresh air as per ASHRAE 62.1 standard.

The toilets should be provided with ventilation system of 6-10 air changes per hour. Utilities rooms and welding rooms shall have ventilation rate of 15-30 air change per hour.

10.3 Wastewater and Effluent Management

Wastewater arises from workshop or administrative areas in a bus depot. More focus is required in dealing with workshop wastewater generated from washing of buses and surface runoffs. As effluent could have presence of detergents, solid suspended matter, oil and diesel, an environment management plan has to be in place for treating such waste before discharge.

An ETP system is capable of producing high quality water with highest possible bacterial reduction without adding chemicals. The functioning of ETP system is described below.

(i) The effluent from main line is collected through gravity pipes into a screen chamber. The manually cleanable screen shall be provided to remove floating & big size particles.
(ii) The waste water passes through oil and grease trap. Clear effluent shall then pass under baffle wall to the next unit. The oil and grease will have to be removed manually from time to time.
(iii) Screened and degreased water then passes into equalization tank to homogenize the waste water quality. Air mixing is provided to mix contents of equalization tank. A coarse bubble aeration system is provided to mix the contents of equalization tank and also to avoid septic condition in the tank.
(iv) The raw effluent will be fed to Aeration Tank. The treated effluent from this tank is transferred to treated water storage tank. This treated water from the storage tank will pass through pressure filters, activated carbon filters to make it clean and odourless.
(v) This water is to be stored in the tank for usage in flushing/horticulture.

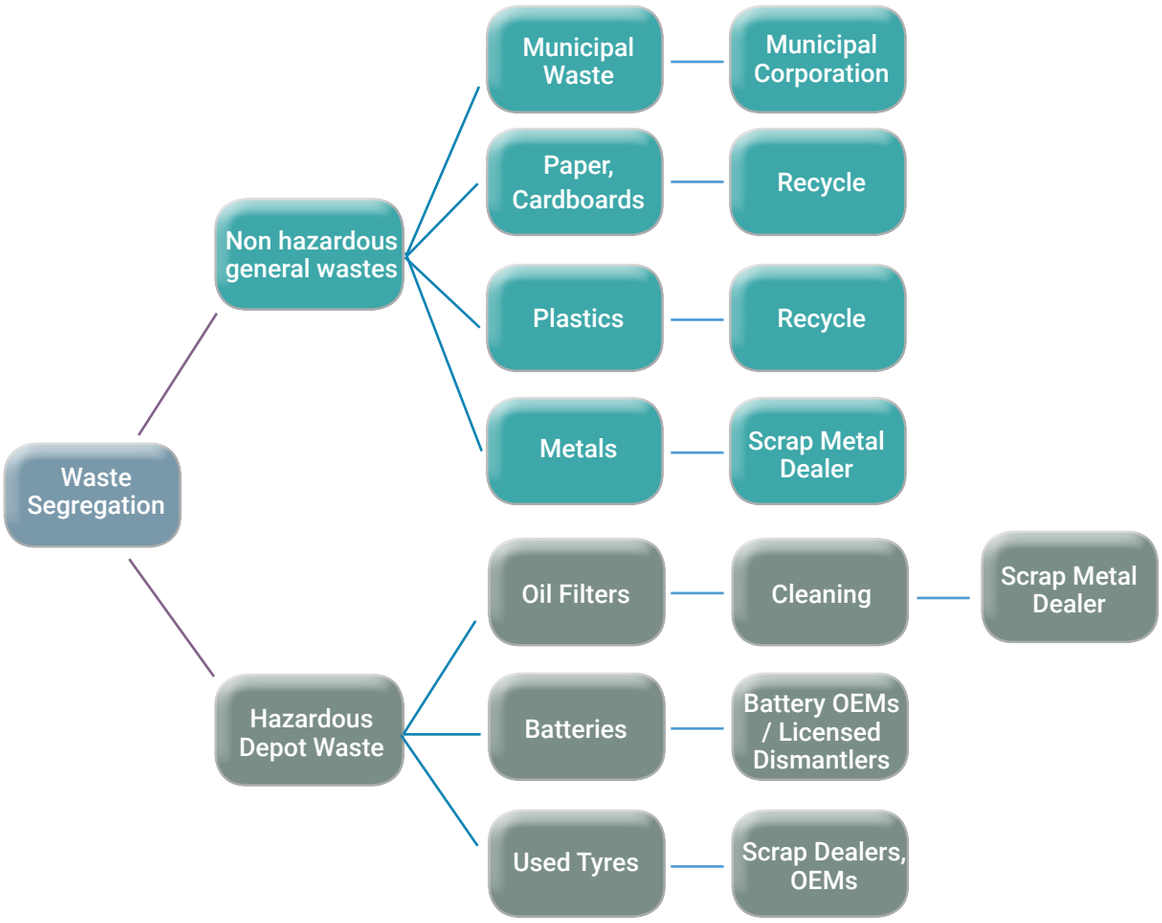
10.4 Waste Oil Disposal

All used oils i.e. engine oil, machine oil, hydraulic oil, coolant oil, quenching oil etc. are classified as Prescribed Industrial Waste and are required to be managed in an environmentally responsible way and as per specified regulations. Prevention and mitigation strategies including proper storage and disposal are discussed hereunder.

Waste Oil	Collect all waste oils in secure, clearly labelled drums or tanks that are stored in an undercover and bunded area. Appoint registered recyclers to off-take waste oil for recycling Keep records detailing the amount of waste oil disposed.
Oil Filters	Separate the oil filters according to type and size Arrange pick-up for recycling.
Solvents	Solvents are usually volatile and pose a fire hazard No solvent must enter the storm water or sewerage system. Appoint registered recyclers to remove and dispose of used solvents
Coolants	Presence of heavy metals, must not be allowed in the waterbodies Must be disposed of to registered recyclers.

10.5 Solid Waste Disposal

The major sources of solid wastes in a bus depot are used tyres, metal scraps, batteries and municipal waste. Proper space allocation would be made till the time it is disposed of. Solid waste should be segregated and properly stored before disposal. The segregation and disposal of different solid wastes generated in a depot is shown below.



Waste bins should be provided along with trash containers in all areas of the bus depot to encourage collection of recyclables. The waste bins deployed in the depot should be compatible with the waste collection vehicles operated by the local authority.

Ministry of Housing and Urban Affairs
Government of India

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MODULE D

IMPLEMENTATION PROCESS FOR BUS DEPOTS

11 IMPLEMENTATION PROCESS FOR BUS DEPOTS

During the Implementation stage, the transition from design to implementation takes place as the detailing of internal functional layout of all the facilities in the depot are finalized which include

(i) Fuelling,
(ii) Washing,
(iii) Bus parking,
(iv) Maintenance,
(v) Inventory strategy,
(vi) Security system,
(vii) Adherence to developmental control norms and statutory obligations,
(viii) At-grade or multilevel depot,
(ix) Broad environmental mitigations measures etc.

As the capital and operational cost for the aforementioned facilities are estimated, the next step is the preparation of bid documents, selection of developer and start the construction process.

11.1 Bid Process Management

Based on the management requirement, type of bidding process should be finalized from the bouquet of available options. Some of the major bidding processes are as follows:
(**Refer Table 11-1 on next page**)

Table 11-1: Bid Processes

SN	Procurement Type	Remarks
1	Unit Rate Contract	• Traditionally adopted in public sector contracts • Gives flexibility to the project owner • Detailed design is undertaken by project proponent • Leads to time and cost escalations, if project management is not done properly
2	Design Build or Engineering, Procurement, Construction (EPC) Contract	• Detailed design is undertaken by contractor • Fixed implementation time and cost as these are fixed upfront
3	Build Operate Transfer (BOT)	• Detailed design is undertaken by contractor • Output based specifications are provided by project proponent • Building material is also defined by contractor as he undertakes maintenance during the concession period. • Time and cost escalations are liability of the contractor

Based on the estimated cost, tender documents for selected bidding process will be developed. Bid evaluation will be undertaken, contractor will be selected and negotiations will be undertaken with the selected contractor before signing of agreement.

11.2 Construction & Implementation

11.2.1 Construction Planning

Construction planning is a fundamental and challenging activity in the management and execution of the depot. Construction planning activity involves deciding upon the choice of technology, the definition of work tasks, estimation of required resources, duration of individual tasks, and identification of any interactions/ conflicts among different tasks prior to mobilization by contractor. A good construction plan forms the basis for developing budget and schedule for work. Developing the construction plan is a critical task in construction management.

In developing a construction plan, it is common to emphasize primarily on either cost control or on schedule control as illustrated below.

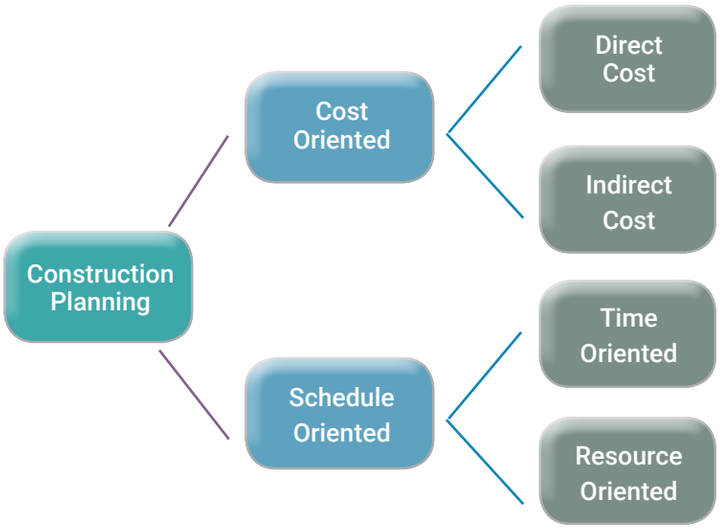


Figure 11-1: Construction Planning

Some depots are primarily divided into expense categories with associated costs. In these cases, construction planning is cost or expense oriented. Within the categories of expenditure, a distinction is made between costs incurred directly in the performance of an activity and indirectly for the accomplishment of the depot. A fine balance between the two differing objectives of saving time or money is required for optimizing depot economics.

Successful implementation of a depot is governed with an efficient scheduling since it can eliminate problems due to production bottlenecks, facilitate the timely procurement of necessary materials, and otherwise ensure the completion of a depot as per the stipulated timeline. In contrast, poor scheduling can result in considerable wastage of labour and equipment.

Civil Construction process is a linear activity where certain activities succeed others. Seasonal changes, mainly rainfall impact the activities like foundation work, concrete pouring etc. resulting in delays. The logistics of materials to be made available at site may also get impacted in cases of severely adverse weather conditions.

Coordinated and integrated construction planning and scheduling, involving all parties concerned in the initial stages will not only bring significant efficiency in cost and time control but also enable structuring of a rigorous monitoring and review framework for successful implementation of the depot.

Building Material

Traditional Masonry construction projects are constructed largely on-site. This is popular among all projects and has an extensive history of use.

It has inherent advantages as the materials are readily available, offers excellent heat and sound insulation, flexibility of design in consideration to health and well-being and durable to last several decades.

The use of locally available materials should be given preference in construction.

Technological Intervention in Building Material

Pre Engineered Buildings (PEB) are the buildings which are engineered at a factory and assembled at site. Usually PEBs are steel structures. Built-up sections are fabricated at the factory to exact size, transported to site and assembled at site with bolted connections.

There are many advantages of Pre Engineered Buildings which are as follows:

i. **Quality control** is the main advantage as all the structural member are engineered before hand, standards of different codes also taken into consideration & these components are made in factory under the supervision of Quality Control Engineer.
ii. **Lower cost** due to the saving in design, manufacturing and on site erection cost.
iii. **Minimizing time of construction** due to the use of software for designing the structural components.
iv. **Low Maintenance** due to use of standard quality of paints over steel members, which increases the ability to withstand & durability thus lowering the maintenance cost significantly as compared to conventional steel building.
v. **Quick Erection**, as all the members are Pre Manufactured & skilled labor is used for connections of different components.
vi. **Warranty on PEB**, mostly warranty period of 20 years is given by manufactures for PEB. But this can be negotiated with the suppliers depending upon the requirements and technology.

The building materials and design provided by Building Materials and Technology Promotion Council (http://www.bmtpc.org) may be considered.

PEB should be considered wherever feasible to save on construction time (~4-8 months) and flexibility in future expansion.

11.2.2 Construction Supervision

A continuous and seamless monitoring and review framework should be developed and established throughout the contract period for managing construction, design, quality, safety, environment, non-conformances, payment, reporting etc. The documents submitted by the contractor will be reviewed. The construction supervision will include

(i) Approval of working methodology
(ii) Day – to– day field inspection
(iii) Issuance of Good for Construction (GFC) drawings
(iv) Compliance with environmental and resettlement safeguards
(v) Finalization of "As- built" drawings
(vi) Commissioning and post commissioning monitoring
(vii) Performance evaluation

The overall construction strategy is shown below.

Construction Strategy

Project Management
- Review of contractors work programme and monitoring
- Implementation of construction management system
- Establish contract tracking system, implementation schedule, delays, milestone achieved
- Budgeting and forecasting - physical and financial progress
- Settlement of extra claims due to variation and escalation
- Dispute redressal and mitigation
- Periodic interaction with stakeholders
- Capacity building and training programmes

Quality Control and Assurance
- Establish Quality Control and Assurance system
- Examination of materials and workmanship at site
- Periodical testing and inspection at site
- Factory testing of materials (3rd party inspection)
- Approval of lab results for release of RA Bills and other payments to contractors
- Commissioning and post commissioning quality checks
- Quality certification

Construction Supervision
- Approval of working methodology Day - to - day field inspection
- Recording measurement of works and certification of works
- Compliance with environmental and resettlement safeguards
- Finalization of "As - built" drawings
- Commissioning and post commissioning monitoring
- Performance evaluation

Reporting / Submittals
- Progress report
- Third party inspection report
- Project performance Monitoring updates
- Commissioning report
- Completion report

Figure 11-2: Construction Strategy

11.3 Approvals and Clearances

At every step in the depot development process i.e. Planning Stage, Design Stage and Construction Stage, certain approvals and clearances are required as discussed hereunder subject to the specific requirements.

PROJECT FEASIBILITY / PRE-SANCTION STAGE

- **Land use plan** -The land use plan for land area is to be notified and approved.
- **Approval for change in land use** – Required when land use shown in master plan is different from bus depot use
- **Relaxation in respect of density/ ground coverage/FAR/ setbacks** (if required)
- **Approval from L&DO** - required from L&DO, when the land is lease-hold.
- **NOC from Coastal Zone Management** - when the land is near the coast as construction is not allowed up to 500 meters from the high tide line.

SANCTION STAGE

- **Local Body Approvals** - required from the local authority and Local body under the provisions of Local Building Byelaws, Master plan and Local Body Acts.
- **NOC from National Monument Authority** - required from the National Monument Authority (NMA)/ Archeological Survey of India (ASI), when the entire project site or part/s of it is within 300-meter radius from the declared boundary of any monument protected under Ancient Monument Act and is under the control of ASI.
- **Approval from Tree Authority Committee** - required from the Tree Authority Committee of Municipal Corporation when there is a proposal for tree cutting.
- **NOC from Airport Authority**
- **Approval from Chief Controller of Explosives** - required from the Chief Controller of Explosives (municipal), for storing of hazardous materials in the building.
- **Approval from The Chief Inspector Of Factories**
- **Environment Clearance from Ministry Of Environment And Forests (MEF)**: for all building/ construction projects having built up area more than 20000 square meters/ and area development projects/ townships covering an area more than 50 hectare or built up area more than 1, 50,000 square meters.
- **Approval from State Pollution Control Board** - Approval for Consent to Establish (CoE)
- **Approval from Chief Fire Officer** - Approval /Fire Safety Certificate is required from Chief Fire

Officer (CFO) (municipal) for the proposals at layout plan stage.

- **Approval from Road Owning Agency** - required from the Road Owning Agency (PWD, NHAI,) when cutting of footpath or road or service lane or Right of way (ROW).
- **Approval from Metro Rail Corporation** - required from the Metro Rail Corporation when the project site is along or on the metro alignment or lies within 20 meters on either side of the metro alignment.
- **Approval from Railway Authority/Port Trust/ Defense** - required when the project site is along the railway corridor / within the jurisdiction of Port Trust respectively.
- **Approval from Traffic & Coordination Dept. (Municipal)** - required) when the proposal involves disruption of general traffic movement/ circulation pattern.
- **Approval is required from the power distributing / supply agency**
- **Approval/ NOC/ Assurance is required from the water supply agency**
- **Approval/ NOC is required from the storm water & drain department/sewerage department**

CONSTRUCTION STAGE

- **Permission from The Central Ground Water Authority (CGWA)**
- **Intimation to the Local Authority** - intimation to the local Authority in writing before 7 days of starting of construction work at site
- **Plinth Level Notice** - Information of completion of work up to plinth level

COMPLETION CUM OCCUPANCY CERTIFICATE

- Completion certificate from local authority
- Approval from the Lift Inspector- Required for installing lift in the building
- Consent to operate from State Pollution Control Board
- NOC from Weight and measurement Department as per Legal Metrology Laws
- NOC from explosive department
- NOC from Industry department
- NOC from labour department

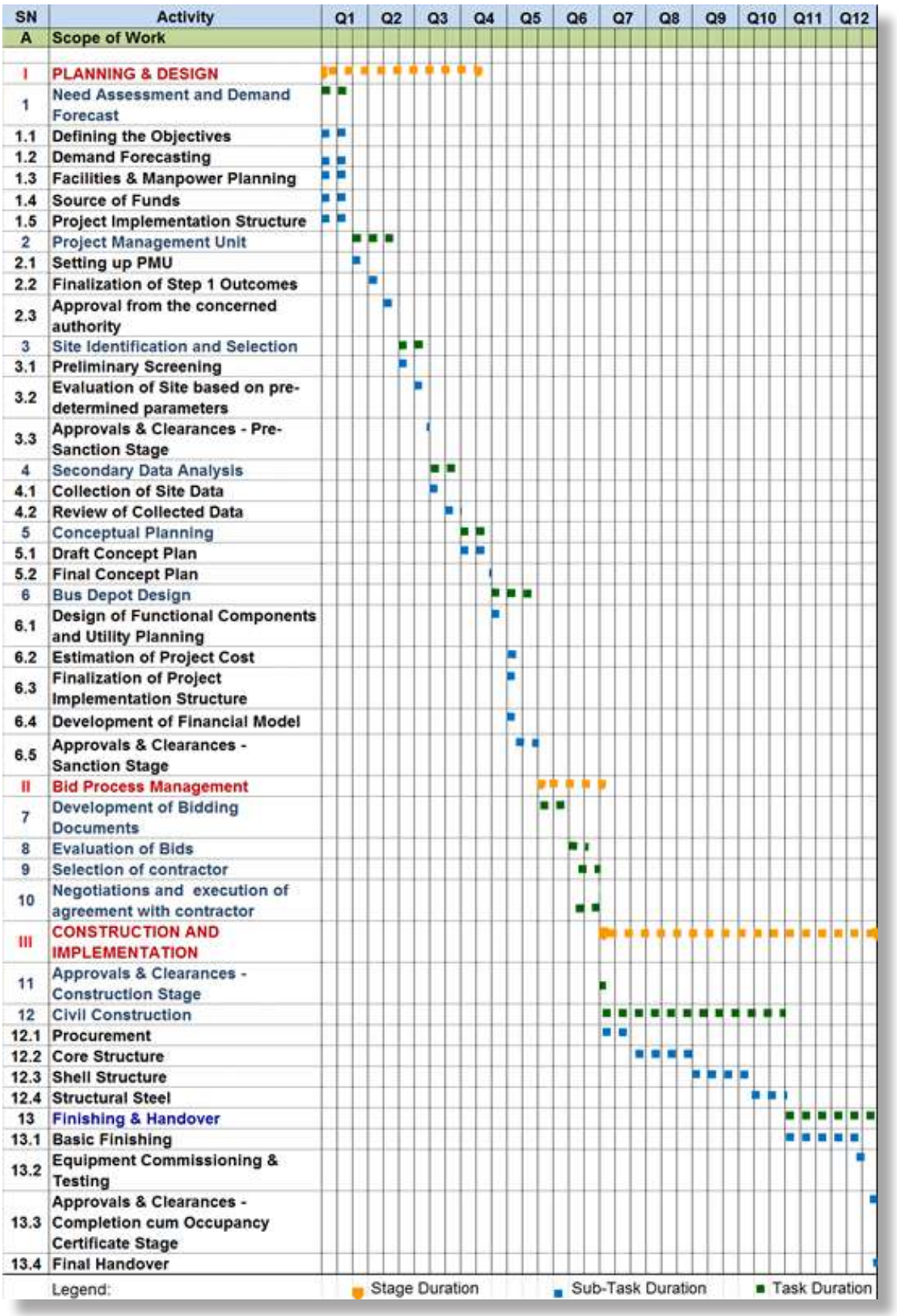
11.4 Depot Implementation Schedule

Some of the plant & machinery required in a depot usually have long lead time. The list is presented below.

Plant & Machinery	Lead Time
1. Washing Area	
Automatic Bus Wash System with 3 brush	12 Weeks
Car Washing Machines, Wet and Dry Vacuum Cleaner	Off the shelf
2. Pit & General Maintenance Area	
Screw compressor for pneumatic equipment 15-20 HP 1.5, Pit Sump Pumps, Brake and clutch liner riveting machine, Electric Chain Pulley block	4 Weeks
Greasing Machines (Portable Greasing System with Trolleys with pneumatic pump), Hydro pneumatic Jacks, Puller for gears (Gear Box)	Off the shelf
3. Auto Electric Section	
Alternator Testing Machine, Auto Electric Bench	4 Weeks
Head light Aligner	Off the shelf
4. Wheel and Tyre Section	
Micro-Processor based Wheel Aligner, Computerized Wheel Balancer, Electro Hydra Tyre changer, Nitrogen Generator and Inflation, Reciprocating compressor pump - 15 HP, Tyre Safety Stand, Tyre Spreaders, Tyre Racks (12 Tyres Cap)	4 Weeks
Tyre Pressure Master Gauge, Pneumatic wheel nut runner (impact Wrench), Master pressure gauge (Tyre Shop Space at Gate)	Off the shelf
5. Battery Section	
Battery Charger table top	4 Weeks
6. Fuel Injector Section	
Fuel Injection pump Test Bench	8 Weeks
Ultrasonic Injector cleaner and tester	4 Weeks
Diesel Smoke meter	Off the shelf
7. Utility Vehicles	
Recovery van 10 Tons	8 Weeks
Battery Operated Brush Truck	4 Weeks

Plant & Machinery	Lead Time
8. Machine Shop	
Brake Disc facing/Brake Drum Turning lathe machine, Engine lifting & mounting crane-Hydraulic 1.5, Lathe machine, Hydraulic press 1.5	8 Weeks
Gear box removal & fitment equipment, Pedestal Drill Machine (6mm to 20mm drill size), Brake shoe riveting Machine	4 Weeks
Bench Grinder, Buffing machine, Straight hand Grinder	Off the shelf
9. Body Shop	
Arc Welding Machine, Electric hand Drilling Machine, Buffing Machine, Oxy Acetylene Gas Welding machine, Spray painting machine, Paint Booth	Off the shelf
10. Suspension Area	
Air Bellow testing equipment	4 Weeks
Spring Removing Trolley, Spring Carrying Trolley	Off the shelf
11. General (Admin & Maintenance)	
Generator Set of capacity 125 KVA	8 Weeks
Multistage Pump, Floor Scrubbing Machine	4 Weeks
Fogging Machine, Portable Ladders (SD)	Off the shelf

The procurement of different machinery depends on the operational and maintenance philosophy of the operator and is undertaken so that it will not affect the implementation schedule as shown on the following page.



SN	Activity	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
A	Scope of Work												
I	PLANNING & DESIGN												
1	Need Assessment and Demand Forecast												
1.1	Defining the Objectives												
1.2	Demand Forecasting												
1.3	Facilities & Manpower Planning												
1.4	Source of Funds												
1.5	Project Implementation Structure												
2	Project Management Unit												
2.1	Setting up PMU												
2.2	Finalization of Step 1 Outcomes												
2.3	Approval from the concerned authority												
3	Site Identification and Selection												
3.1	Preliminary Screening												
3.2	Evaluation of Site based on pre-determined parameters												
3.3	Approvals & Clearances - Pre-Sanction Stage												
4	Secondary Data Analysis												
4.1	Collection of Site Data												
4.2	Review of Collected Data												
5	Conceptual Planning												
5.1	Draft Concept Plan												
5.2	Final Concept Plan												
6	Bus Depot Design												
6.1	Design of Functional Components and Utility Planning												
6.2	Estimation of Project Cost												
6.3	Finalization of Project Implementation Structure												
6.4	Development of Financial Model												
6.5	Approvals & Clearances - Sanction Stage												
II	Bid Process Management												
7	Development of Bidding Documents												
8	Evaluation of Bids												
9	Selection of contractor												
10	Negotiations and execution of agreement with contractor												
III	CONSTRUCTION AND IMPLEMENTATION												
11	Approvals & Clearances - Construction Stage												
12	Civil Construction												
12.1	Procurement												
12.2	Core Structure												
12.3	Shell Structure												
12.4	Structural Steel												
13	Finishing & Handover												
13.1	Basic Finishing												
13.2	Equipment Commissioning & Testing												
13.3	Approvals & Clearances - Completion cum Occupancy Certificate Stage												
13.4	Final Handover												
	Legend:	Stage Duration					Sub-Task Duration					Task Duration	

11.5 Conclusion

A development of bus depot is a long term investment and is critical for efficient city bus service. Therefore, a bus depot should be well planned and the following critical parameters should be addressed at the conception stage itself and refined during the development period.

1 Need of Depot
2 Identification of and engagement with the Stakeholders
3 Site Selection
4 Number and types of buses
5 Type of Fuel
6 Horizon period
7 Maintenance Philosophy
8 Funding Source

ANNEXURE 1: SCHEDULE OF FINISHES

Interior Design Considerations

Interior environment should be so designed to enhance safety, security, personnel comfort and productivity. The interior scheme should help in orientation and way finding, efficient circulation, reflect architectural vision and facilitate depot operational functions appropriately.

Finishes – Administrative Block

The specifications for surface finishes should be made considering durability, cost-efficiency, easy maintenance, personnel security, fire resistance and low embodied energy & environmental threat upon disposal.

i) Floor Finishes

Anti-Skid materials are recommended with strategic contrast colour and texture application to indicate level differences like steps, stairs and specifically designed guiding blocks along main movement corridors for the visually impaired. Depending of expected degree of usage, the materials could be concrete with appropriate non-slip finish, natural or manufactured granite, precast Terrazzo with slip resistant texture, quarry tile, paver brick, unglazed ceramic tile etc.

ii) Wall Finishes

Recommended wall finishes include vinyl wall coverings, ceramic tile, paint, and textured paints. Acoustical wall coverings are to be used in certain areas to create better acoustic environment. In restrooms, for ease of maintenance, ceramic wall tiles are to be used till dado levels.

iii) Ceiling Finishes

Acoustic ceiling panels shall be put throughout the major areas of the bus depot administrative block. In restrooms, water-resistant gypsum boards or plaster with water resistant paint finishes may be used.

The schedule of finishes for individual areas in the bus depot administrative block are presented in the table below:

Area	Finishes
Entry	a. Floor – Granite Stone Floor made of 750 x 750 mm panels. b. Walls – Skirting 300 mm height of Granite Stone, 1200 mm height above skirting the wall shall have granite stone cladding. Rest of the height of the wall shall be plastered & painted with water resistant wall paint. c. Ceiling- shall be plastered & painted with water resistant ceiling paint.
Entrance Lobby with Security Check	i. Floor – Granite Stone Floor made of 750 x 750 mm panels. ii. Walls – Skirting 300 mm height of Granite Stone, 1500 mm height above skirting the wall shall have granite stone cladding. Rest of the height of the wall shall be plastered & painted with water resistant wall paint. iii. Ceiling- shall be plastered & painted with water resistant ceiling paint.
Lockers	a. Floor- Vitrified Tiles b. Walls - Plastered & Painted c. Ceiling-Plastered & Painted
Kitchen	Flooring, Walls and Ceiling - The finished of flooring, wall and ceiling shall be as per kitchen design.
Cafeteria	1. Floor- Vitrified Tiles 2. Walls - Plastered & Painted 3. Ceiling-Calcium Silicate Tiles False Ceiling
Staff Dormitory	a) Floor –Marble floor made out of 1000 x 1000 size panels b) Walls & Ceiling - Plastered & Painted c) Mostly governed by interiors
Offices	a) Floor - Carpet tiles over IPS flooring. b) Walls & Ceiling - Plastered & Painted

Area	Finishes
File Archival Room	a) Floor- Vitrified Tiles b) Walls - Plastered & Painted c) Ceiling-Plastered & Painted
Staircase	a) Steps, Risers and Landings– Granite Stone b) Walls- Glazed Tiles up to 1200 height from steps – Rest of the height of wall shall be plastered & painted. c) Ceiling-Plastered & Painted
Ramps	a) Floor- Flame burnt Granite Stone Floor made of 750 x 750 mm panels. b) Side Walls-Vitrified Tiles
Toilets	a) Floor – Anti skid tiles flooring b) Walls-Glazed Tiles up to height of 2400 mm. Rest of the wall height shall be plastered and painted. c) Ceiling - Plastered & Painted

Finishes – Workshop Area

Area	Finishes
Workshop	a) Floor – Epoxy (As per IS 9197 – 1979) b) Walls – Epoxy (As per IS 9197 – 1979)
Pit	a) Floor – Epoxy (As per IS 9197 – 1979) b) Walls – Epoxy (As per IS 9197 – 1979)
Stores	a) Floor- Trimix
Workshop Toilets	a) Floor- Anti Skid Tiles b) Walls – Vitrified Tiles till Dado level
Section Partitions	GI Chain Linked Mesh Partitions
Racks	MS Powder coated
Parking	Interlocking Pavers 100mm thick M-50 Grade Perforated preferred

Acoustics

The bus depot administrative block faces a unique problem of being in close proximity to high noise generating source i.e. bus depot workshop. The bus depot administrative block design should aim for optimum sound levels to ensure a comfortable environment for the personnel. Prolonged exposure to excessive ambient noise may lead to poor speech intelligibility, lack of concentration along with other health hazards. The acoustic design should ensure that people can communicate clearly and work in an efficient fashion.

While designing, the dominant noise source could be considered to be emanating from the repair and maintenance activity being carried out in the depot workshop.

Appropriate sound absorptive and deflective panels and finishes can contain reverberation and provide a comfortable acoustic environment. For the above, there should be strategic application of sound-absorptive materials and finishes which are environmentally safe.

ANNEXURE 2: SIZE OF LAND PARCEL

The size of land parcel for various size of bus depots i.e. number of buses housed in a bus depot is tabulated hereunder.

Area	50 Bus Depot		100 Bus Depot		150 Bus Depot		200 Bus Depot	
	No	Area (in sqm)	No	Area (in sqm)	No	Area (in sqm)	No	Area (in sqm)
Fuelling Bays	2	200	2	200	3	300	4	400
Washing Area	1	170	2	275	2	275	3	380
Maintenance Bays	8		15		23		30	
Stores (ground coverage)		1750		2650		4000		6000
Workshop Area								
DPF Regeneration Area	4	300	7	500	11	800	14	1000
Bus Parking	50	2500	100	5000	150	7500	200	10000
Administrative Area (Ground coverage)		750		900		1350		1700
Staff Parking		1000		1250		1500		1750
Scrap Yard		250		350		450		600
Sub Station		250		350		450		600
Green Area		600		950		1250		1500
Circulation, queuing		5200	100	7712	150	10000	200	12000
TOTAL AREA		12970		20137		27875		35930
Land Area (in acre)		3.21		4.98		6.89		8.88
Area per bus (in sqm)		260		202		186		180

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MODULE E

ADAPTABILITY

12 ADAPTABILITY OF DEVELOPED BUS DEPOT DESIGNS

Bus depot is generally built with long term timeframe. But Bus technology, urban bus service operations, maintenance and management practices are ever changing and we may see even more rapid changes, in future. During the lifetime of a bus depot it may see several changes in terms of technology or operations or maintenance and management practices. Therefore, the bus depot design should be adaptable to accommodate future changes and possibly the unforeseen ones. This Manual is helpful in planning, design and construction of a depot for buses incorporates the envisaged changes in the immediate, foreseeable future.

As can be predicted today, the changes that will occur during the lifetime of a depot can be in following areas:

- Bus technology – Introduction of BS VI buses, increased dependence of buses on electronic items and electric buses, autonomous buses, better/ robust built requiring substantially less maintenance.
- Operations & Maintenance – Increase in number of buses, use of digital technology for planning bus service, operations, robotics/ automation in maintenance and parking technology.
- Bus Dimensions/ Type – Change in length, rear axle configuration, fuel, floor height and deck

Wherever possible, depot design should try to accommodate adaptability to the afore mentioned changes in the planning, design and implementation. E.g. While planning, the length of the bus must be freeze beforehand as it is a crucial parameter in planning as mentioned in Module B. Moreover, planning a depot for larger bus which is going to come in say 20 to 30 years will led to wastage of present space. Therefore, a delicate balance is required. While designing the depot, the modifications required in depot design due to envisaged changes in each facility are provided in Module C. While implementation or construction of depot, the use of Pre-Engineered Building as the building material is recommended for faster implementation.

This chapter captures a set of pointers for a depot constructed now to be as flexible as possible to adapt to processes whose adoption will become necessary on account of aforementioned changes in bus technology, operations & maintenance and bus type at a time beyond the immediate, foreseeable future.

12.1 Emerging Technology

a. Stricter emission norms are applicable upon transition from BS IV to BS VI. For BS VI buses, space for Diesel Particulate Filter Regeneration is to be provided within the depot. In the depot design provided in the Manual, space is provisioned so that the depot will be adaptable to this change.

b. Electronics will occupy increasing importance in internal combustion engine (ICE) buses. For this, adequate space will need to be assigned. The sections in maintenance area are proposed to be partitioned using chain linked mesh partitions so that space can be easily increased or decreased.

c. Battery-powered Electric Buses (BEB) are expected to be the rolling stock of choice in city bus service. This will mean major realignments in operations execution and use of depot space for parking, charging infrastructure, battery-handling etc. Range-limitation of BEB will be influenced by the operating condition in specific routes, age of battery/ battery degradation etc. Range will, in turn, determine the number of BEB needed to replace on Internal Combustion Engines (ICE) bus. In case the replacement ratio is greater than 1:1, the space for parking will need to increase. In the parking area, a minimum of 2m space is provisioned for the placement of the charging infrastructure. In the maintenance area, chain linked mesh partitions are proposed as space for maintenance of ICE can be used for storage and handling of batteries.

12.2 Operations

a. Use of digital technology for fare collection, MIS, duty allocation and use of app for booking of bus will impact bus operations. Therefore, the administrative area should be designed using PEBs to incorporate these changes with minimal investment and changes in civil works.

b. Robotics/ automation may change the way, buses are maintained today. This will require changes in the entry/ exit areas, inventory areas, maintenance staff facilities and levels of floor in the depot. Whenever these changes arise in future, relevant changes will be undertaken in depot facilities.

c. Parking technology may change resulting in reduction of bus circulation space in the depot as machines/ cranes/ robots may place the bus at its designated spot. This will lead to

increase in depot capacity and hence, more buses may be accommodated in the depot.

12.3 Bus Dimension /Type

a. With the change in the length and rear axle configuration of the bus, the following facilities/ areas of a bus depot will be impacted:

- Fuelling Area
- Washing Area
- Maintenance bays/ pits
- Parking Area
- Ramps gradients
- Circulation Area
- Queuing Area

This is due to the fact that increased length of bus and change in rear axle configuration, require more circulation area as turning radius and swept path vary. For larger bus say 14m or 18m or 24m bus, more circulation area is required which may be accommodated by using the buffer space allocated for future expansion or parking area may have to be reconfigured. Bus length may even force reconfiguration of the maintenance area.

b. With change in fuel used by buses i.e. Diesel, CNG/ HCNG and Electric, depot design need to be changed accordingly. For Diesel buses, diesel fuelling station is required which is substituted by CNG fuelling station, compressor and HCNG reformer plant in case of CNG/ HCNG and in case of electric buses, no fuelling station is required as requisite charging infrastructure will be installed in the bus parking. In case of change in fuel of the bus fleet, illustrative layout provided in the Manual for CNG/ electric depot may be used for reference.

c. Due to change in floor height of the bus, the pit depth and ramp gradients will be affected. The depot is designed for low floor bus so that the change in floor height will not impact the depot design as for semi low floor and standard bus, the 1400mm pit depth is sufficient as well as ramp gradients. In case of BRT buses, podium is to be provisioned for maintenance.

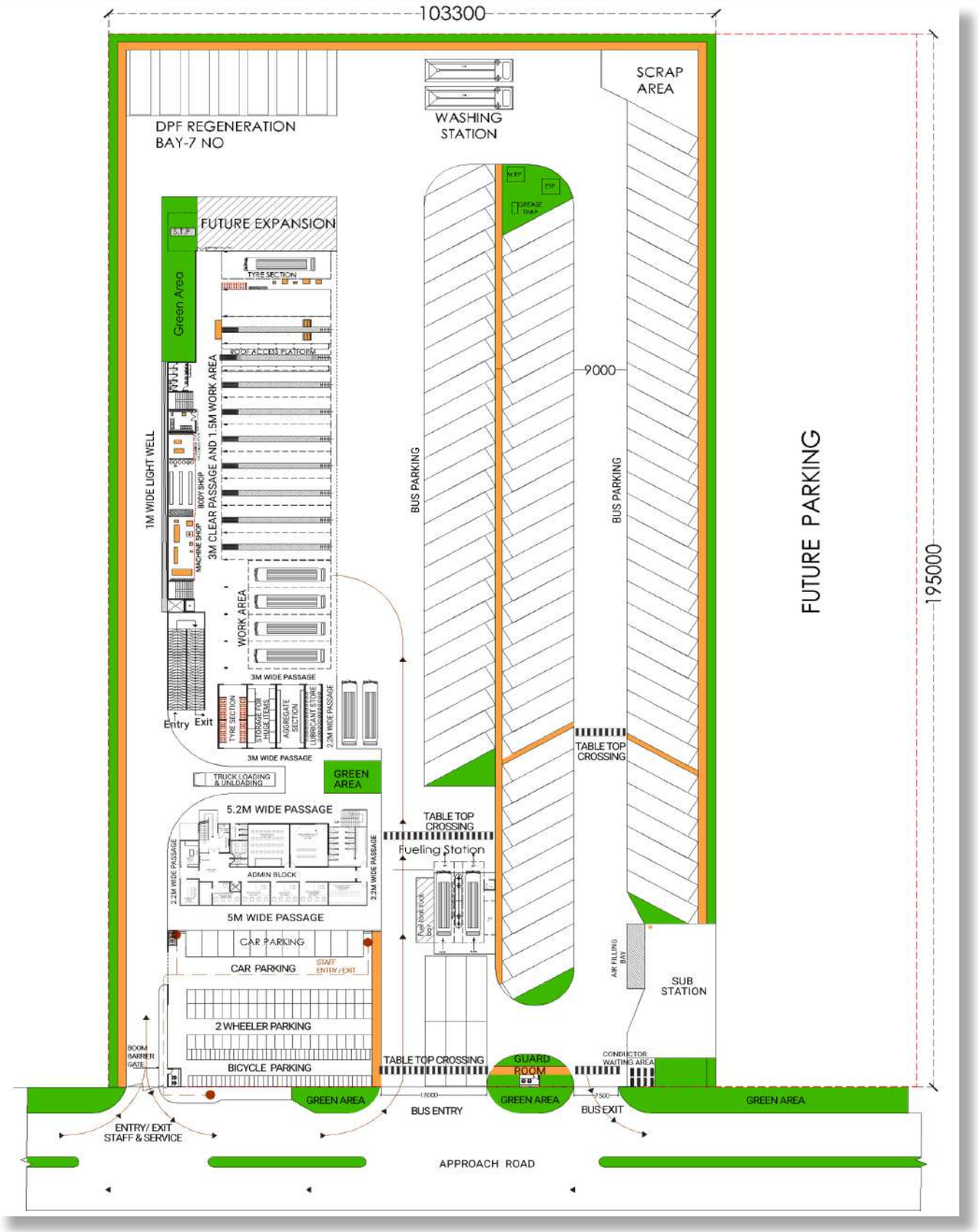
d. Due to change in the deck of the bus i.e. if a depot house a double decker bus as well, then depot design must cater to the additional height. The facilities that will be impacted are the

maintenance and washing area. In washing area, bus washing plant has to be customized to accommodate the additional height of a double-decker bus.

Alignment of depot space to new technology, operation & maintenance and bus type will have to be by way of re-appropriation and re-allocation of what is available. It is for this reason it is important to modularise depot design and use pre-engineered building technology to the extent possible this will improve flexibility and reduce costs & time for future modifications.

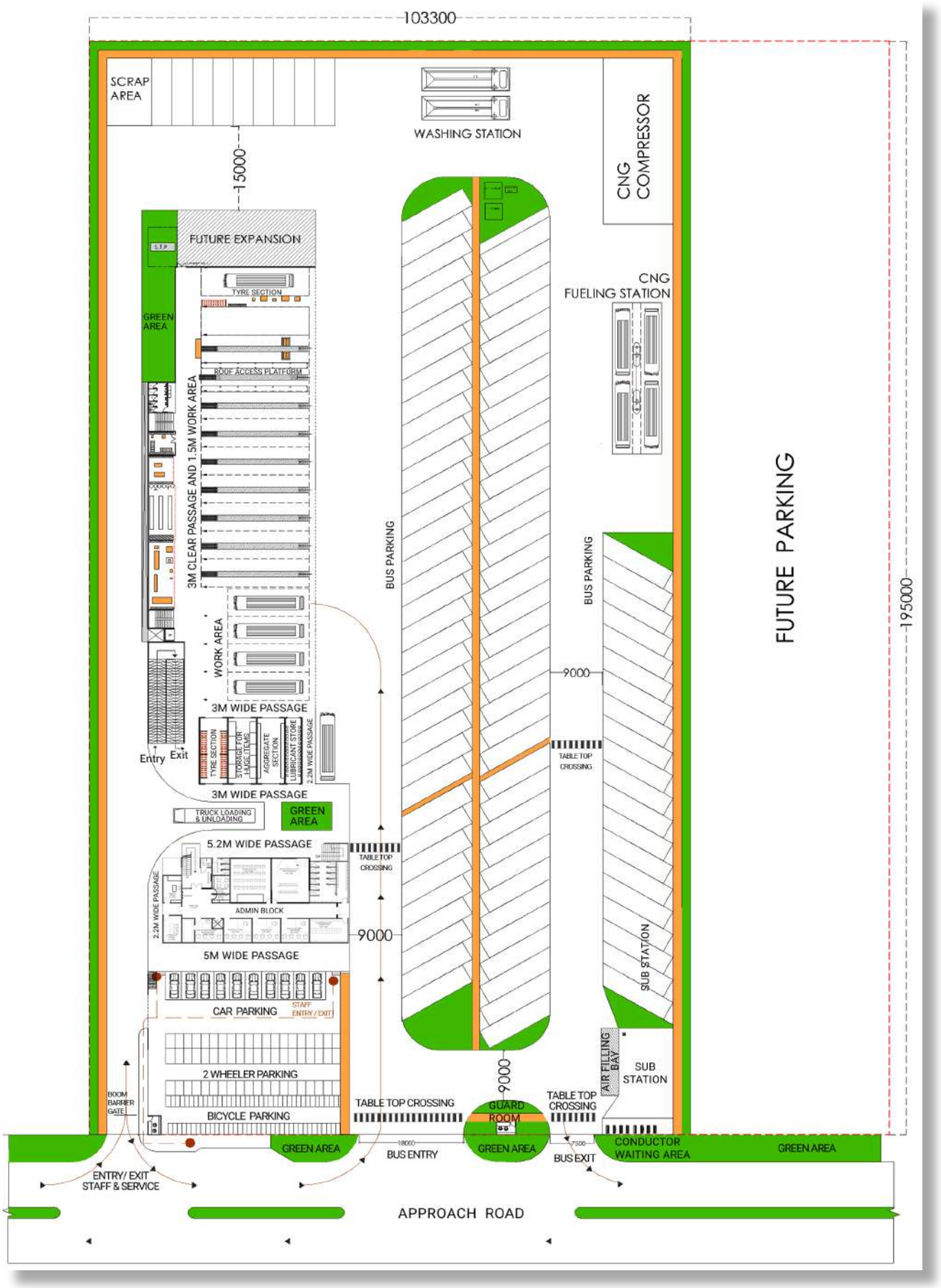
While adaptability is essential to strengthen the resilience of the infrastructure for city bus operations, there are limits to adaptability. Some bridges are to be left to be crossed after sighting.

ANNEXURE 1: BUS DEPOT LAYOUTS



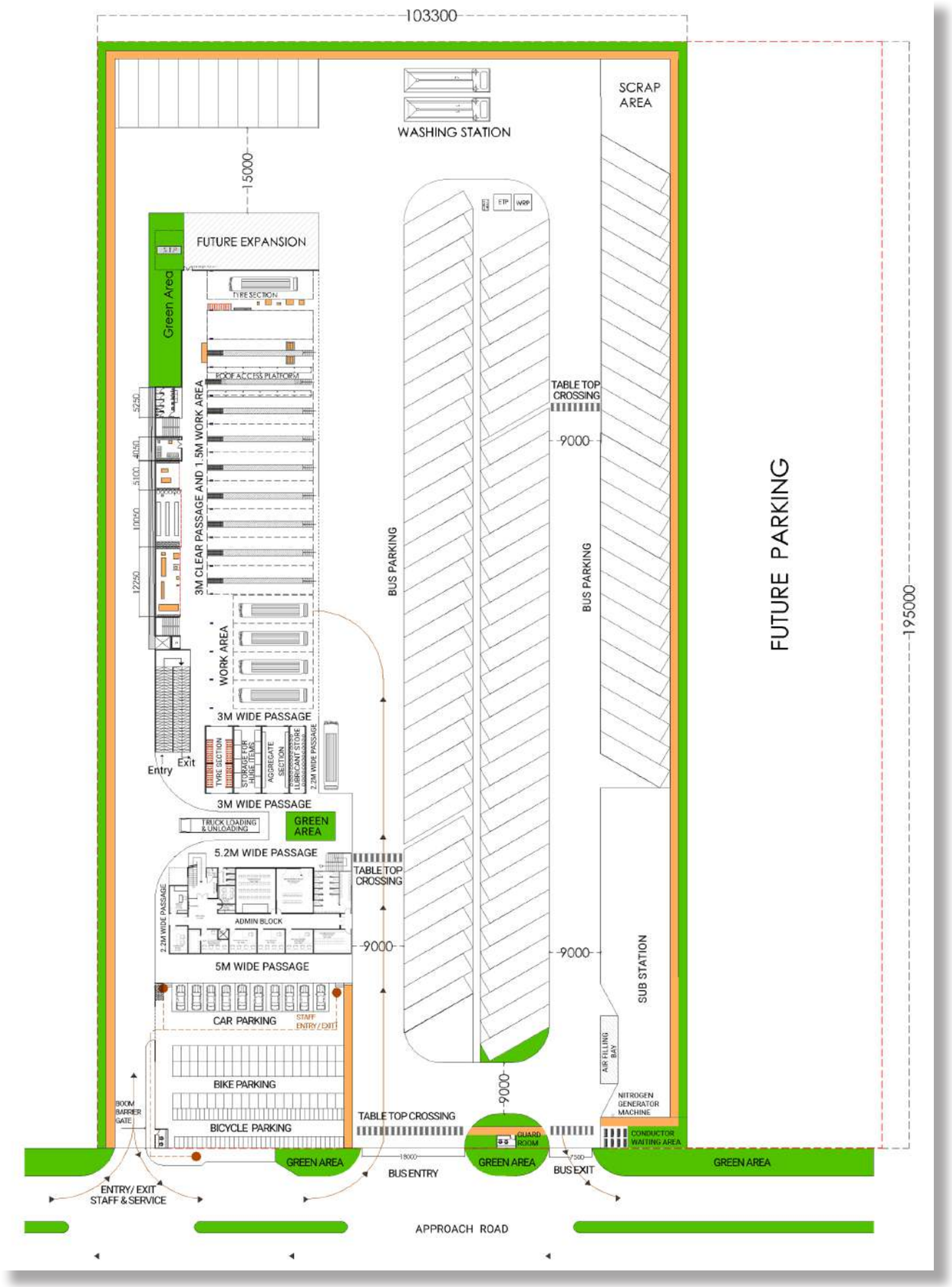
100 Bus (Diesel) Depot Layout

100 Bus (Diesel) Depot Layout - 3d Illustration



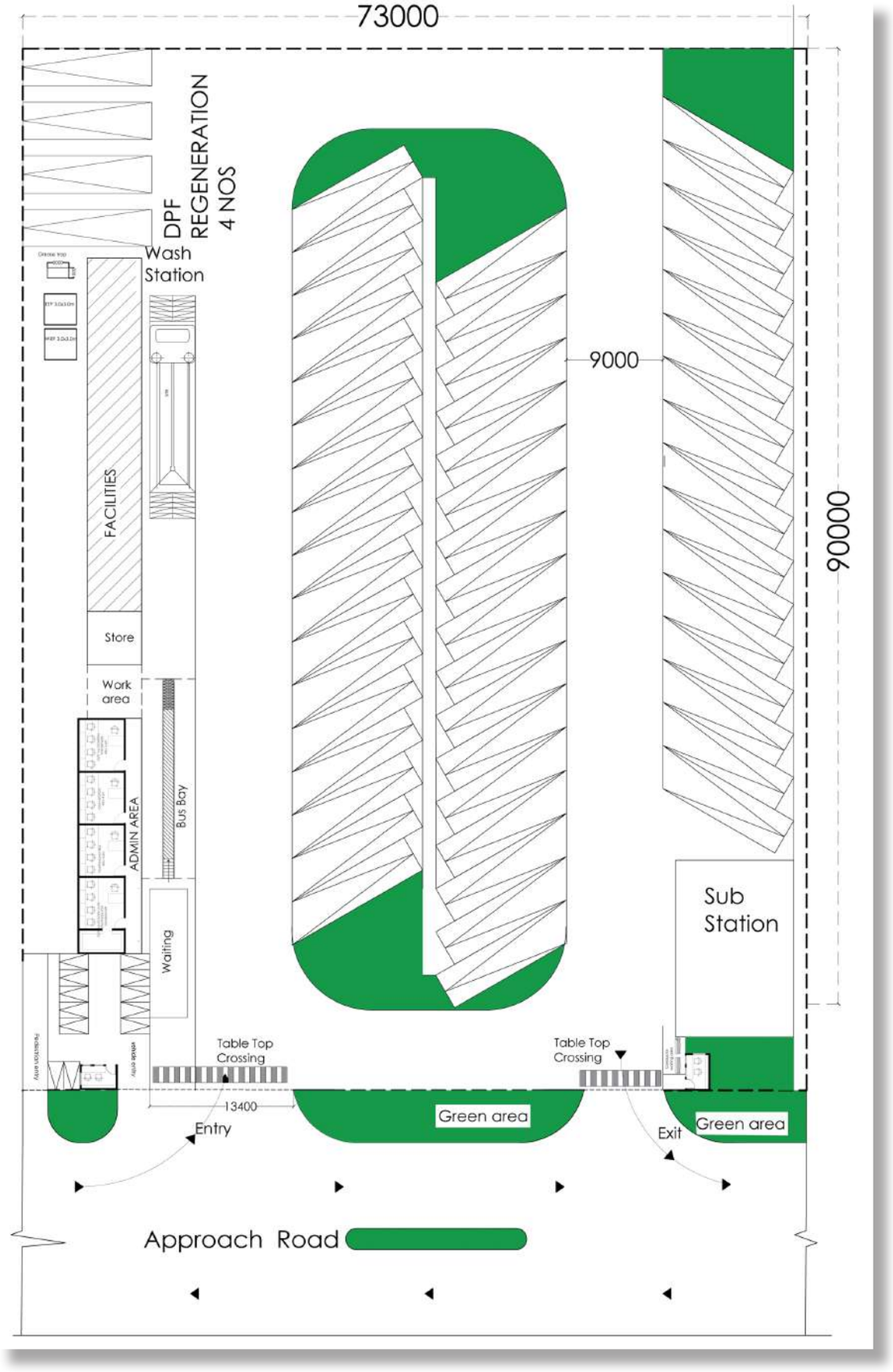
100 Bus (CNG) Depot Layout

100 Bus (CNG) Depot Layout - 3d Illustration



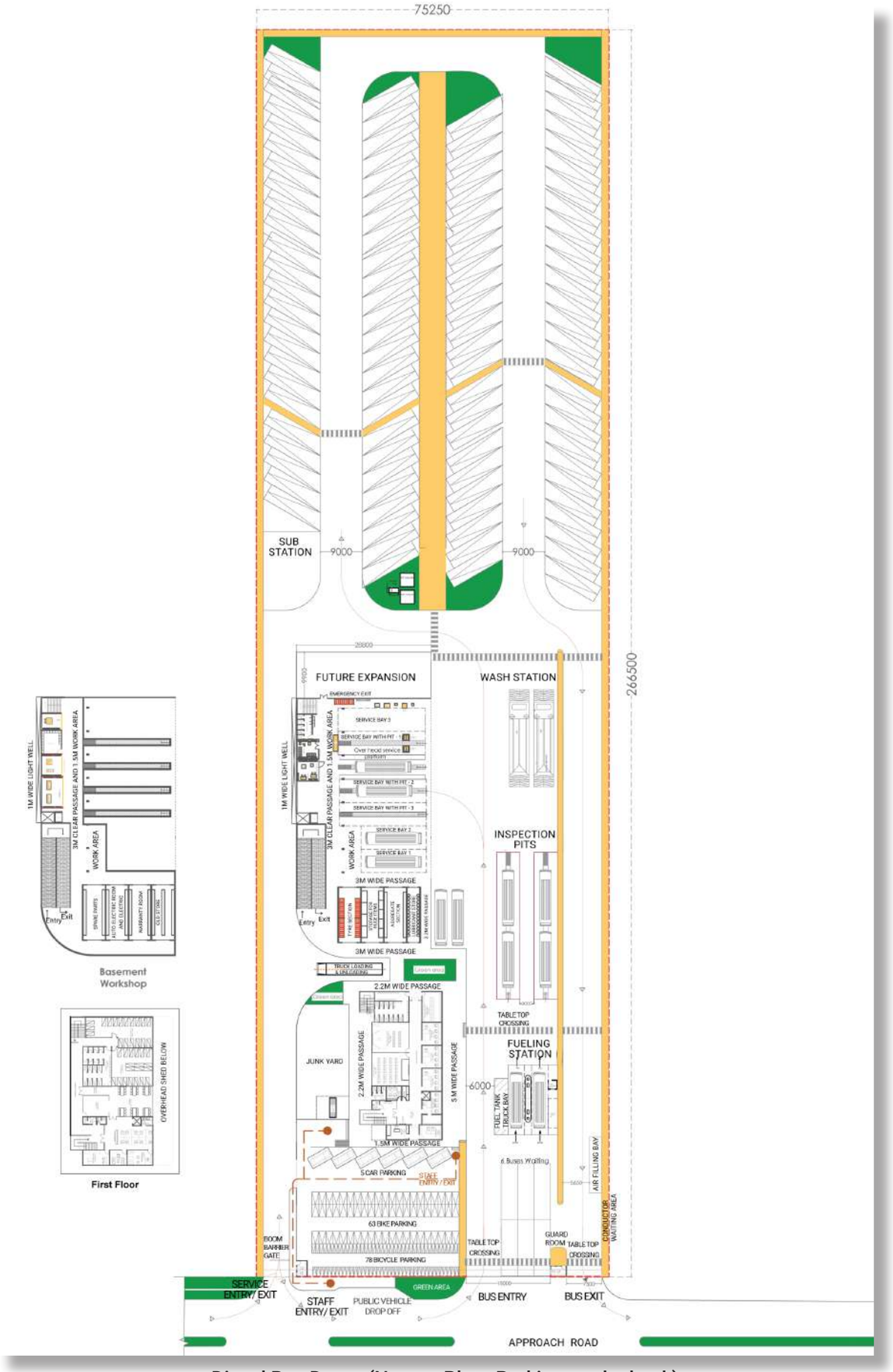
100 Bus (Electric) Depot Layout

100 Bus (Electric) Depot Layout - 3d Illustration



Parking Depot Layout (50 Buses)

Parking Depot Layout (50 Buses) - 3d Illustration



Diesel Bus Depot (Narrow Plot - Parking at the back)

Diesel Depot Layout (Narrow Plot) - 3d Illustration

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Chapters in which items are extensively covered are shown in heavy type with the relevant **section** or annexure (italicized) immediately following :

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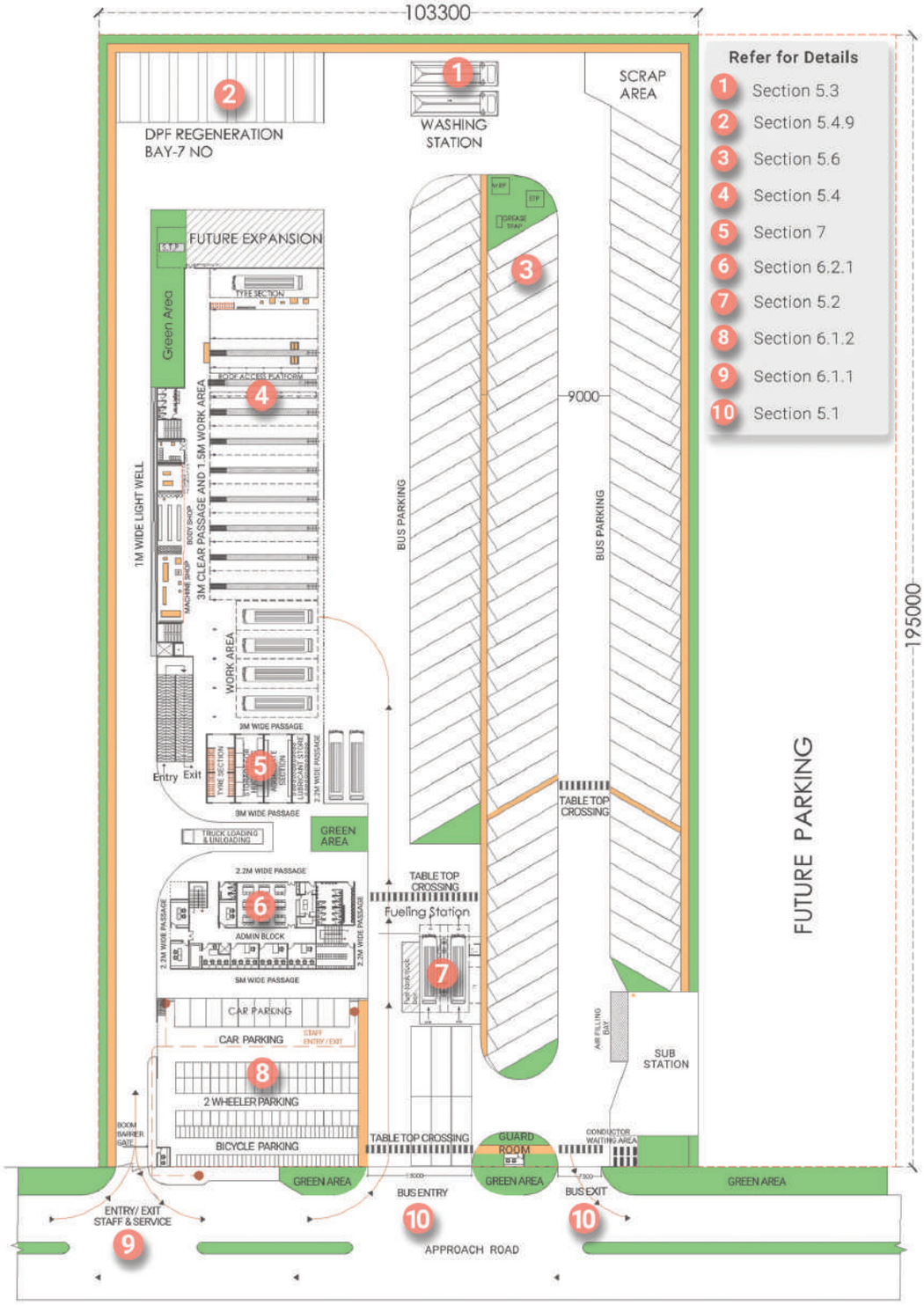

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