Recommendations for urban and spatial planning regulations and guideline principles

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SUMMARY SHEET

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Abstract	D 53.6 deals with recommendations for urban and spatial planning regulations and guideline principles for electrically driven buses. It focuses on battery buses, plug-in hybrid buses and so-called hybrid trolleybuses. The focus lies on design principles for the installation of charging infrastructure both inside and outside of bus depots, as such installations play a major role in implementation projects. Additionally, legal and regulatory aspects connected to the implementation of electric buses are discussed.
Key words	Electric buses, charging infrastructure, design principles, road space, bus stops
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DOCUMENT CHANGE LOG

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1	26/03/2018	Main structure	Fraunhofer	
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ACRONYMS

DC: direct current

LV: low voltage

MV: medium voltage

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1. EXECUTIVE SUMMARY

This document describes recommendations for urban and spatial planning regulations and guideline principles for electrically driven buses. It is structured as described hereafter.

After a short introduction in chapter 2, which defines the scope of this document, chapter 3 deals with guidelines for both spatial and urban planning. Hereby, the document discusses planning aspects for battery buses, plug-in hybrid buses and so-called hybrid trolley buses.

The guidelines for urban planning focus on design principles for road, bus stop and bus depot infrastructure for the recharging of battery and plug-in hybrid buses. In a first step, available charging technologies are described. The focus of chapter 3 lies on the design and the space requirements of bus stop infrastructure to enable easy recharging processes for battery and plug-in hybrid buses. This includes recommendations regarding the installation of the necessary fast charging infrastructure, as these two aspects play a major role in implementation projects.

Trolleybuses are a mature propulsion technology and the necessary catenary network technologies and installations are widely known. Therefore, the document only describes aspects of trolleybus technologies as far as so-called hybrid trolleybuses are concerned.

Finally, requirements on design for and design examples for bus depots are discussed.

Chapter 4 looks at legal and regulatory aspects and the document is finalised by conclusions in chapter 5.

Company	Sections	Description of the partner contribution
Berends	Chapter 4, revision of all chapters	In-depth analyses of legal and regulatory aspects, text, revision
Fraunhofer	All chapters, chapter 4 only revision	Collection of design principles and examples, texts, revision, language check

Table 1 - Partner's Contribution

2. INTRODUCTION

Electric buses are a relatively new or re-born technology as far as battery und plug-in hybrid buses are concerned. This is not only mirrored by the relatively immature key technologies like batteries, charging devices or electric auxiliaries, but also by a lack of well proven regulations in terms of adapted urban and spatial planning and gaps in the national or local building codes.

The term **Spatial Planning** describes methods, practices and approaches used primarily by the public sector to influence or regulate the distribution of people and activities in different spaces.

Urban Planning comprises all technical and political processes, which deal with the development and design of land use in urban environments. It includes amongst others the transport infrastructure inside or to and from urban areas.

This document describes principles for spatial and urban planning regarding the use and the implementation of electrically driven buses, as far as

- battery buses that are exclusively recharged at bus depots or other parking areas,
- battery buses that are recharged at bus depots and at bus stops, mainly terminal stops
- plug-in hybrid buses, or
- so-called hybrid trolleybuses

are concerned. Requirements on charging infrastructure for plug-in hybrid buses and battery buses are very similar. Therefore, plug-in hybrid buses are not discussed separately.

3. RECOMMENDATIONS AND PLANNING GUIDELINES

Recommendations and planning guidelines are directly connected to the requirements of electric buses in terms of urban structures, bus infrastructure and road space demand.

3.1 Requirements on the general structure of cities – spatial planning

In general, buses are the mode of public transportation which can be adapted to urban structures in the easiest way. The only exception are trolleybuses as their necessary catenary network is sometimes difficult to install, which is one of the reasons why their implementation is often hampered.

3.1.1 Battery Buses

Battery buses will have to be able to be implemented in existing urban structures, with no or only minor changes in bus operation. Otherwise, they would not meet the general expectations on urban buses and would lose their means of existence.

However, certain urban structures would ease their introduction or would reduce the cost of their charging infrastructure outside of bus depots. Cities which feature major bus hubs, e.g. at subway or tram stations, with the possibility to centralise the recharging of buses from as many as possible bus lines would significantly reduce the cost for

- grid connection (provided that a sufficiently powerful electric grid is available),
- maintenance, and
- redundancy (either by means of sharing of charging stations or jointly used extra charging stations).

Furthermore, electric buses with opportunity charging function require more space for bus stops and bus terminals (see 3.2.1).

Additionally, battery buses are still hampered by insufficient operation distance, which in many cases does not meet the requirements set by day-to-day operation. Theoretically, this could be eased by network designs, which lead to shorter daily mileages for buses. However, this would result in higher vehicle and personnel demand and / or less comfort for passengers in most cases.

3.1.2 Conventional Trolleybuses

Trolleybuses need expensive and in many cases difficult to install catenary networks. Apart from the difficulties which quite often arise from the implementation of catenaries on urban roads, especially in historic town centres, their financial feasibility is only given if a higher number of buses use the same catenary sections. This can be facilitated by stretched urban structures instead of more circular cities. However, in the vast majority of cities, this cannot be changed or influenced anymore or only in the long term where new urban districts are developed.

3.1.3 HYBRID TROLLEYBUSES – TROLLEYBUSES WITH PARTIALLY CATENARY FREE OPERATION

So called hybrid trolleybuses which feature energy storages to drive significant parts of a line off-wire are very often regarded as solution to overcome the difficulties which quite often arise from the installation of catenaries in city centres. However, the financial feasibility is also only given, if the catenaries are used by as many as possible buses which again can be partly influenced by the general urban structure.

Additional information on hybrid trolleybuses and their catenaries are given in chapter 3.2.2.

3.2 Urban planning – requirements on bus stops and road space

3.2.1 BATTERY BUSES

3.2.1.1 Charging technologies

The recharging of battery buses outside of bus depots or parking areas (so-called opportunity charging) requires fast charging stations, either with conductive or inductive power transfer technologies.

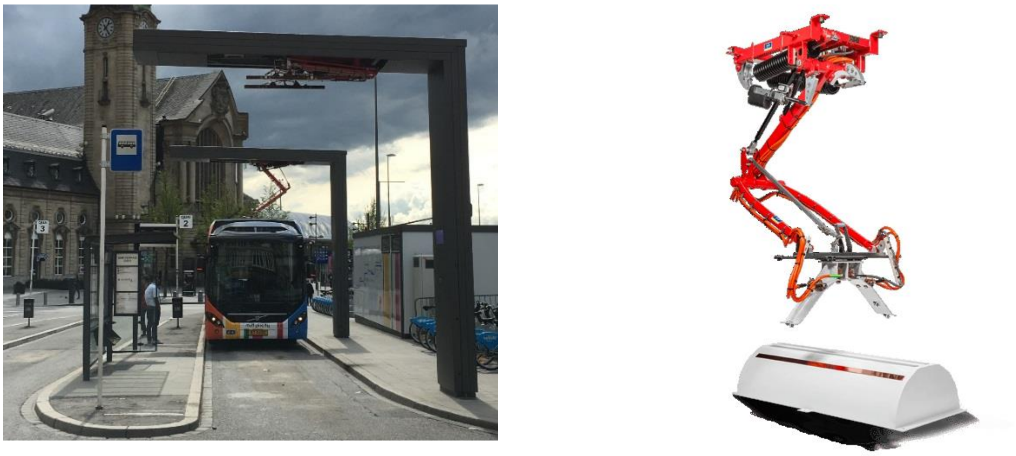
Among a number of solutions, there are four major conductive or contact based power transfer technologies in Europe, which all use pantographs to connect battery buses to fast charging stations. The Schunk Smart Charging systems uses roof mounted pantographs, which contact four poles inside a road side contact hood (see Figure 1). Another roof mounted pantograph like technology is the ABB TOSA system, which is currently operated on line 23 in Geneva.

Figure 1 – Schunk Smart Charging pantograph

Inverted pantographs are mounted at mast arms and contact four poles on bus roofs from above. Figure 2 shows two different solutions of inverted pantographs.

Plugs are limited in their electric power and are usually only feasible at bus depots.

Finally, inductive power transfer systems use a primary coil below the road surface, which creates an alternating electromagnetic field. This electromagnetic field is then converted to electric current by a secondary coil attached underneath a vehicle.



a) Stemman-Technik b) Schunk Smart Charging (source: Schunk)

Figure 2 – Inverted pantographs

3.2.1.2 Design principles for the positioning of buses

All listed technologies have in common that buses must be positioned within certain tolerances regarding

- their position in the longitudinal direction,
- their position in lateral direction, and
- the angular deviation from the centre line of the roadside contact system or pantograph, which in most cases is parallel to the kerbstone line.

Although the tolerances vary from technology to technology and have not yet been finally standardised, bus stops or waiting areas need to facility a bus approach which either enables a straightening up of two axle vehicles or a straightening up of the first bus segment of articulated or bi-articulated buses.

Figure 3 – Roadside bus stop with charging mast (Oberhausen, Germany)

Bus stops or waiting areas at the edge of a carriageway with a straight trajectory or generous curves are usually suitable as charging point, as long as the approach of buses is not hampered by parking vehicles or other obstructions (see Figure 3 as an example).

However, opportunity charging requires several minutes of charging times, which means that charging positions on carriageways are only feasible if the general traffic is not obstructed by waiting buses. This also applies to bus boarders which usually offer the best approaching conditions, especially for articulated buses.

Bus bays or lay-bys are only suitable

- if their design allows the straightening up of buses or at least of the first bus segment along the kerbstone, and
- if there is enough road side space for the installation of the charging mast.

This means that generous design parameters, especially for the entry taper and the straightening distance are necessary. Figure 4 may serve as an example for minimum design parameters in the city of London. Similar design recommendations can be found in other countries, e.g. RASt 06 in Germany.

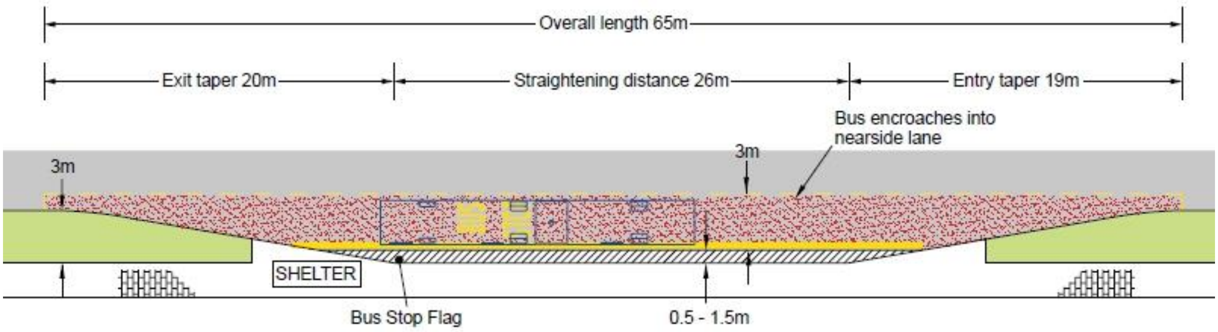


Figure 4 – Bus bay for articulated buses (source: Transport for London)

Normal terminal loops for buses, as they are recommended by design guides (e.g. RASt 06), are usually not suitable for charging points as buses cannot straighten up along a defined kerbstone inside the loop. However, minor adaptations, especially straightened and extended exit tapers, may in many cases help to use terminal loops as charging points.

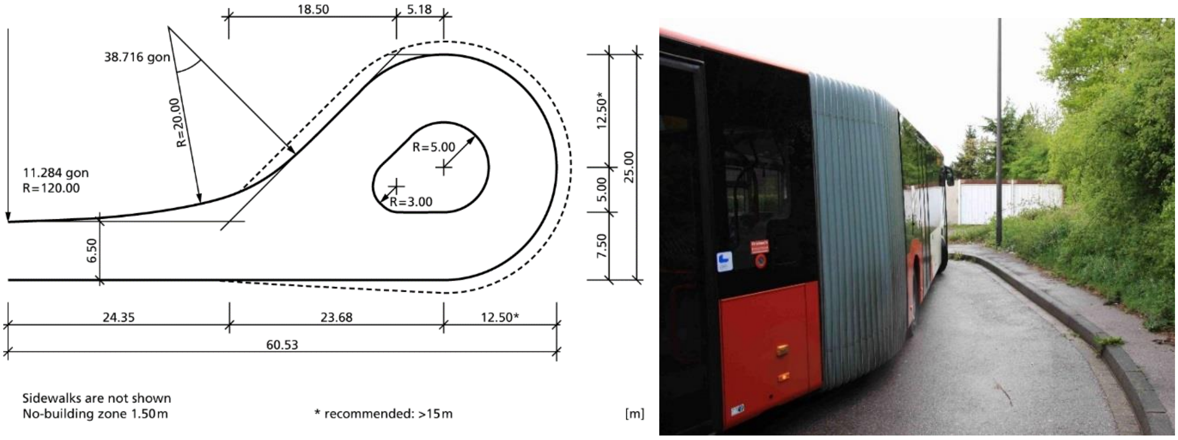


Figure 5 – Terminal loop design and the resulting lack of non-straightened up buses

Figure 6 – Kassel kerb

Special kerbs (e.g. Kassel kerb, see

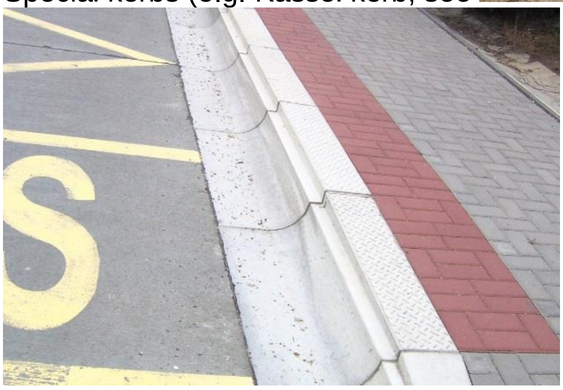


Figure 6) ease the lateral and angular positioning of buses and should at least be provided in bus bays or where a straight approach is not possible.

The number of charging points at for instance a terminal stop is determined by

- the number of bus lines,
- their average headways, and
- their scheduled turn-around times less average delays.

Opportunity charging at terminal stops usually requires charging times which are more or less equal to the so-called turn-around time of buses (time between arrival and departure) less average delays. In many use cases, the turn-around times are longer than the scheduled headways, which results in two or even more buses to be recharged at once, with constant and shifted arrivals and departures.

Solutions which require the advancement of buses during their turn-around times, e.g. with charging points in a simple row and charging masts at minimum distance inevitably lead to a loss of charging time. Furthermore, the charging time or at least the time for advancement cannot be regarded as non-working time. If the advancement of buses is to be avoided, long distances between charging masts in a simple row are necessary to ensure the straighten-up of buses which have to stop in front of other buses.

Figure 7 – Angled boarders at bus terminal Sonneberg, Germany

Alternatives are shown in Figure 7 to Figure 9 as examples. Angled boarders require more lateral space than simple kerbside bus stops but need substantially less space in the longitudinal direction if the approach and straightening of buses is considered with a bus parked in the rear charging position. The lateral space requirements can be at least partially compensated by the placement of the charging station at the jutted end of the boarders.

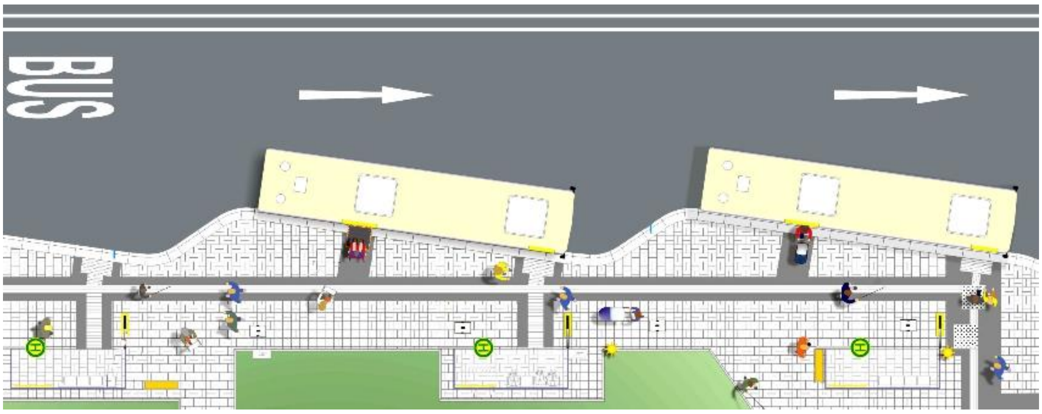


Figure 8 – Angled boarders (source: barrierefreie-mobilitaet.de)

Figure 9 shows an example of an adapted terminal loop at Haste Ost in the city of Osnabrück. The depicted terminal loop provides two charging positions in parallel and one additional take-over lane, e.g. for buses which will immediately return to the bus depot.

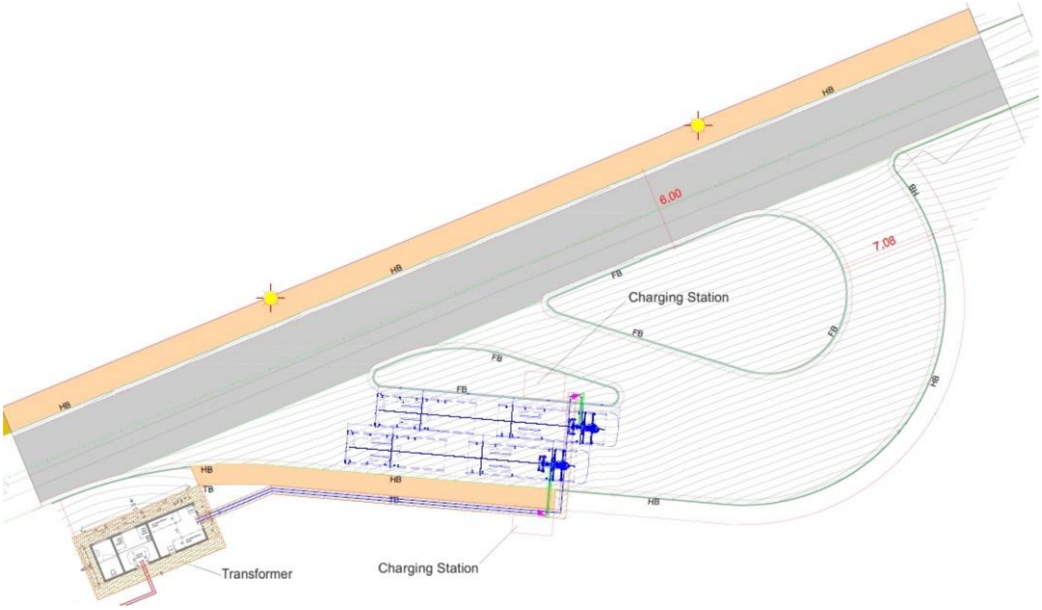


Figure 9 – Terminal loop design with two charging points (source: SW Osnabrück)

3.2.1.3 Design principles for the roadside contact systems

The position of the charging mast or pole is determined by several considerations. The longitudinal position must facilitate the placement of the vehicle pantograph or contacts on the vehicle roof above the first axle, as this is the part of buses which drivers can control best. Additionally, this will be most likely the position of the contact system on bus roofs prescribed by the standards pending.

The safety distance from the edge of carriageway is regulated in each European country (e.g. 50 cm in Germany). However, the overhang of buses may require greater distances, especially in terminal loops, bus bays and at angled boarders, subject to the turning radius and the bus dimensions. Furthermore, greater distances are recommendable at bus stops where passengers board and alight to ease the passenger flow along stopping buses.

The clearance between the roadside contact system and the surface of the carriageway is also regulated by national legislation. If normal road traffic is not restricted from entering the charging point area, at least 4.5 m clearance is required. Many cities require even higher clearances, e.g. 4.7 m.

Furthermore, the contacting emits short high frequency sounds as metal hits metal, which may hamper the installation of masts in the immediate vicinity of residential houses. Such short sounds are inherently connected to the use of such contact systems, which needs to be considered by including exemptions for noise emissions at e.g. specification sheets.

3.2.1.4 Space requirements for charging infrastructure

A fast charging station consists of

- a transformer (MV to LV) if no sufficient low voltage grid connection is available,
- the actual charging station with a DC-output,
- the charging mast or pole, and
- the road side contact system.

The floor space requirements directly depend on the electric output power. Compact transformers with a nominal power of up to 630 kVA have overall dimensions of about 1.4 x 3.0 x 1.6 m (W x L x H) with an additional base depth of approx. 0.8 m. Accessible transformer stations have significantly higher dimensions and are usually used for higher nominal powers, e.g. when several charging stations are to be connected.

Compact charging stations which are connected to the LV-side of transformers have overall dimensions of about 0.8 x 2.4 x 1.8 m (W x L x H) for 350 kW DC output power.

Figure 10 – Compact transformer (source: uesa GmbH)

Other overall dimensions may apply where charging stations are connected to the tram or subway DC-grid.

Neither the transformer, the actual charging station nor the charging mast have to be placed next to each other. Distances of up to 150 m between the charging station and the mast are possible, which offers a certain degree of flexibility in the arrangement of charging infrastructure at bus stops.

3.2.2 HYBRID TROLLEYBUSES

Catenaries or overhead lines for trolleybuses are state of the art and the requirements for their installation and legal aspects must not be explained here again. Normally, they are installed in both directions but hybrid trolleybuses facilitate the installation of overhead lines in only one direction (e.g. on longer uphill sections), either to save investment cost or in cases of limited road space.

However, whereas the de-wiring of the poles does not need any special installations, the contacting of overhead wires still requires wiring devices (refer to Figure 11). They need to be installed at bus stops or any other places where the buses always stop. The only requirement is that drivers must be able to position the buses in parallel to the centre line of the wiring devices. Furthermore, the contacting also emits short high frequency sounds which again hampers their installation in the immediate vicinity of residential houses.

Figure 11 – Wiring device (source: Alexander Schmitz)

The necessary length of overhead wires along a given line depends on

- its topology,
- the passenger demand,
- the operational speed on sections with catenaries, and of course on
- vehicle characteristics such as charging power, storage size and energy consumption.

As a general rule, about 40 – 50 % of a bus line need to be equipped with overhead lines. Under ideal conditions, this may be reduced down to about 30 %, if the overhead lines are especially installed on roads with low operational speed, which often contradicts the wish to install them on major trunk roads and not in city centres.

3.3 Requirements at bus depots

Bus depots need to be adapted to house the necessary charging infrastructure for the energy supply to whole bus fleets. The general layout of a bus depot charging infrastructure is explained in Figure 12. Additional MV/LV-transformers will have to be installed in almost all cases if a higher number of buses must be recharged in parallel.

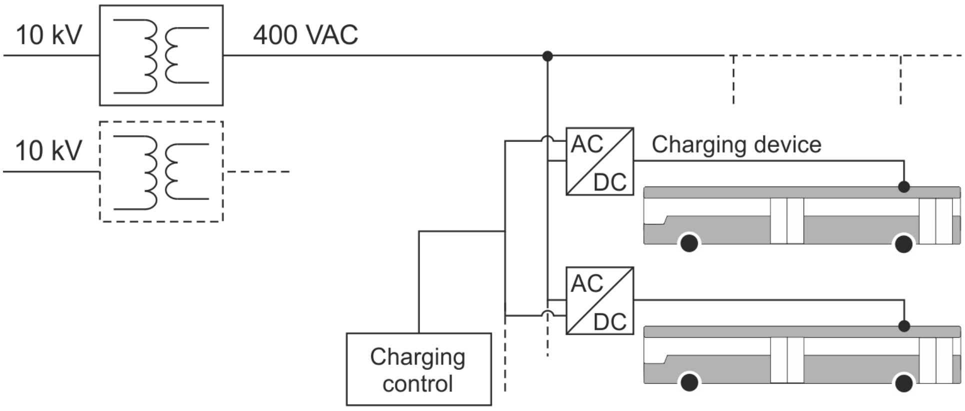


Figure 12 – General layout of bus depot charging infrastructure

The major challenge, however, will be the placement of the charging devices and the setting-up of installations for the connection of the buses to the charging devices. Irrespective of the connecting technology, i.e. plugs or automated contact systems, additional space for its installation will be necessary in most cases. This may lead to the enlargement of bus depots or even to the construction of new ones. Figure 13 shows the principal layout of the parking area for buses and the available space for the installation of charging infrastructure at an existing bus depot. The bus depot provides parking space for 37 articulated buses and 63 solo buses (12 m).

Figure 13 – Parking area on an existing bus depot (sketch taken from the original layout plan)

In this case, the available floor space for setting-up the charging devices including transformers would be sufficient. However, necessary installations for the connection of the buses to the charging devices are extremely difficult to install and will most likely result in the loss of at least two parking rows, as underfloor contact systems are not (yet) available.

Principle design solutions for automated contact systems are shown in Figure 14 and Figure 15.

Figure 14 – Contact systems on single poles (source: Schunk)

Alternatively, a connection of buses with charging devices can also be realised using plugs with cables from above, from the floor or from sidewalls.

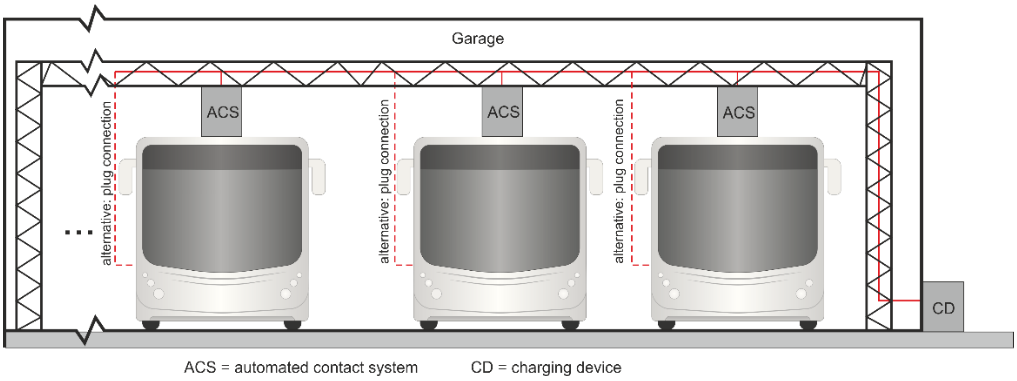


Figure 15 – Installations inside a bus garage – principle design

The installation of poles or even charging devices between buses and the use of cables must take into consideration that the space between buses serves as protected footways and emergency ways, which hampers possible installations even further.

4. LEGAL ASPECTS

The growing importance of the electrification of bus systems and the associated implementation of the necessary charging infrastructure are posing new challenges with regard to legal principles as well as planning regulations and guidelines.

In order to get a comprehensive overview of existing legal frameworks and corresponding planning recommendations, an in-depth research and analysis was carried out by internet and consultation of PT related associations (e.g. VDV, UTP) and ZeEUS partners in various EU member states.

The installation of charging stations is subject to several laws, regulations, codes and standards. Municipal bylaws, including those on land use and development, must be taken into account in the installation of charging stations. Depending on the nature of the work, other documents such as the Building Code and other regulatory acts may also apply.

The results showed that only very few national acts and principles are in force and used by the public transport operators, local planning and authorising authorities and power supply companies. As the situation is still very dynamic, due to the fact that several cities recently having introduced or announced to introduce urban electric bus systems, it is very difficult to get a complete picture.

Furthermore the investigation has shown that the basis for planning processes may differ from city to city within one EU member state but in any case are different for the different charging solutions namely overnight charging at the depot and opportunity charging in public spaces as well as charging concepts (slow and fast charging). However the charging infrastructure is easier to manage when it is located at the depot as there are less legal regulations and statutory provisions need to be considered.

When implementing the charging infrastructure (incl. transformer station) in public spaces – at terminal stops, bus stops or interchange stations – the following fields of applications need to be considered:

- acquisition of land
- precipitation / clearing of shrubbery and replacement plantations if required
- cable routing in the public road / sidewalks area
- road markings for the bus stop
- compliance with limit values according to noise guidelines
- approval for installation on public space areas
- bus stop design
- design of the charging equipment / building and its immediate surroundings, e.g. greening

As it comes to the bus stop design the following requirement should be taken into account:

- The design and positioning of the contact system must take into account the necessary clearance profile and safety distances to other electrical conductors.
- Building permit including proof of stability of the charging equipment / building
- For fast-charge stations, electromagnetic compatibility parameters like immunity to interference in accordance to existing standards.
- If the contact system to be installed is top-down solution in the public road space then
  a) the clearance gauge including safety zones in accordance with the Urban

Roads Directive need to be observed, and

b) the mast should enable to turn the charging contact system away from the road space for heavy goods transports.

- The protective distances against contact of live components need to be observed; if these are within these distances, special precautions must be taken against contact.

5. CONCLUSION

Battery and hybrid trolleybuses as well as their electric infrastructure must adapt to the general urban structures and bus operation schemes – not vice versa.

Battery buses will finally need to offer the same flexibility and availability like conventional diesel or other IC buses. However, for the time being, the available range between recharging will not meet the daily operating distances which are required by cost efficient bus operation schemes and which are today covered by e.g. diesel buses. A widely theoretical solution would be the adaptation of bus operations schemes, i.e. the limitation of bus service schedules to approx. 200 km. The drawback of insufficient operational ranges can be counter measured by so-called opportunity charging. Depending on the schedules, bus specifications and available charging power, approx. 70 – 75 % of all bus service schedules can already today be covered using regular recharging at terminal stops during operation.

Suitable charging technologies are available for opportunity charging and by the end of 2019, there will be according European wide standards to offer high flexibilities for their utilisation. However, the charging infrastructure and especially the need for exact positioning of battery buses at the roadside contact systems have direct implications on the design of terminal bus stops, waiting or parking areas and terminal loops. Generally speaking, there will be an increased floor space demand for such facilities of about 15 to 30 %. This may complicate the installation of charging infrastructure, especially in downtown areas. However, numerous field studies in German cities such as Aachen, Bonn, Göttingen, Cologne etc., carried out by Fraunhofer have shown that the possibilities for the installation of charging infrastructure are widely underestimated.

Hybrid trolleybuses offer the unique possibility to combine the mature propulsion technology of trolleybuses with cutting edge battery solutions to reduce the efforts for the installation of catenaries. The implications of catenaries and their installation requirements are widely known and have not been repeated in this document. Although hybrid trolleybuses can significantly reduce the demand for overhead lines down to 30 % under ideal conditions, a sufficiently high number of vehicles is still necessary to counterbalance the cost for overhead lines.

The conversion of whole bus fleet to e.g. battery buses will have significant implications on bus depots. Non trolleybus depots are normally not equipped with a sufficient grid connection to recharge whole fleets of battery buses. The installation of the needed charging infrastructure at bus depots will require additional floor space and may lead to the necessity of new bus depots or their enlargement.

6. ATTACHMENT

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