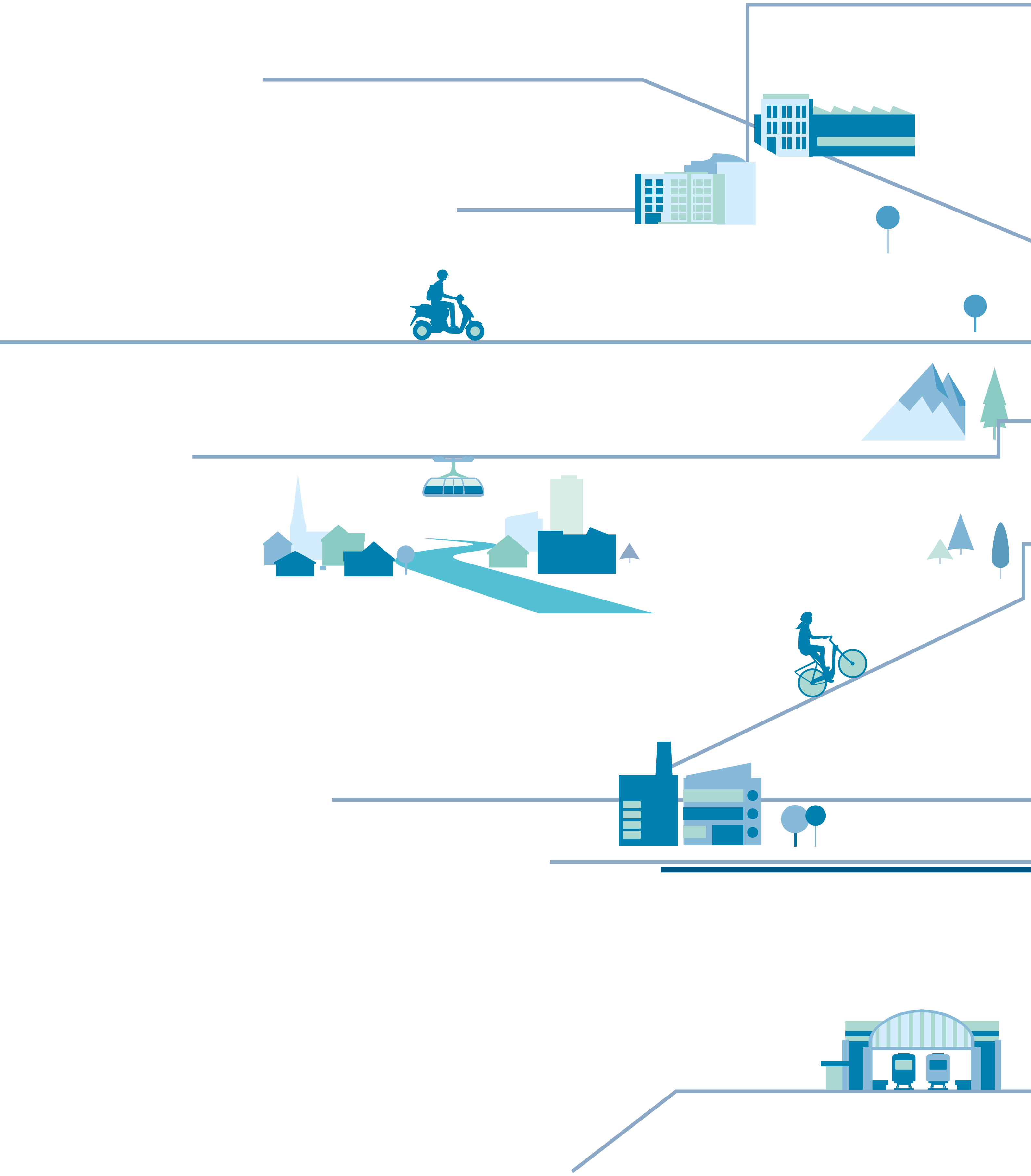
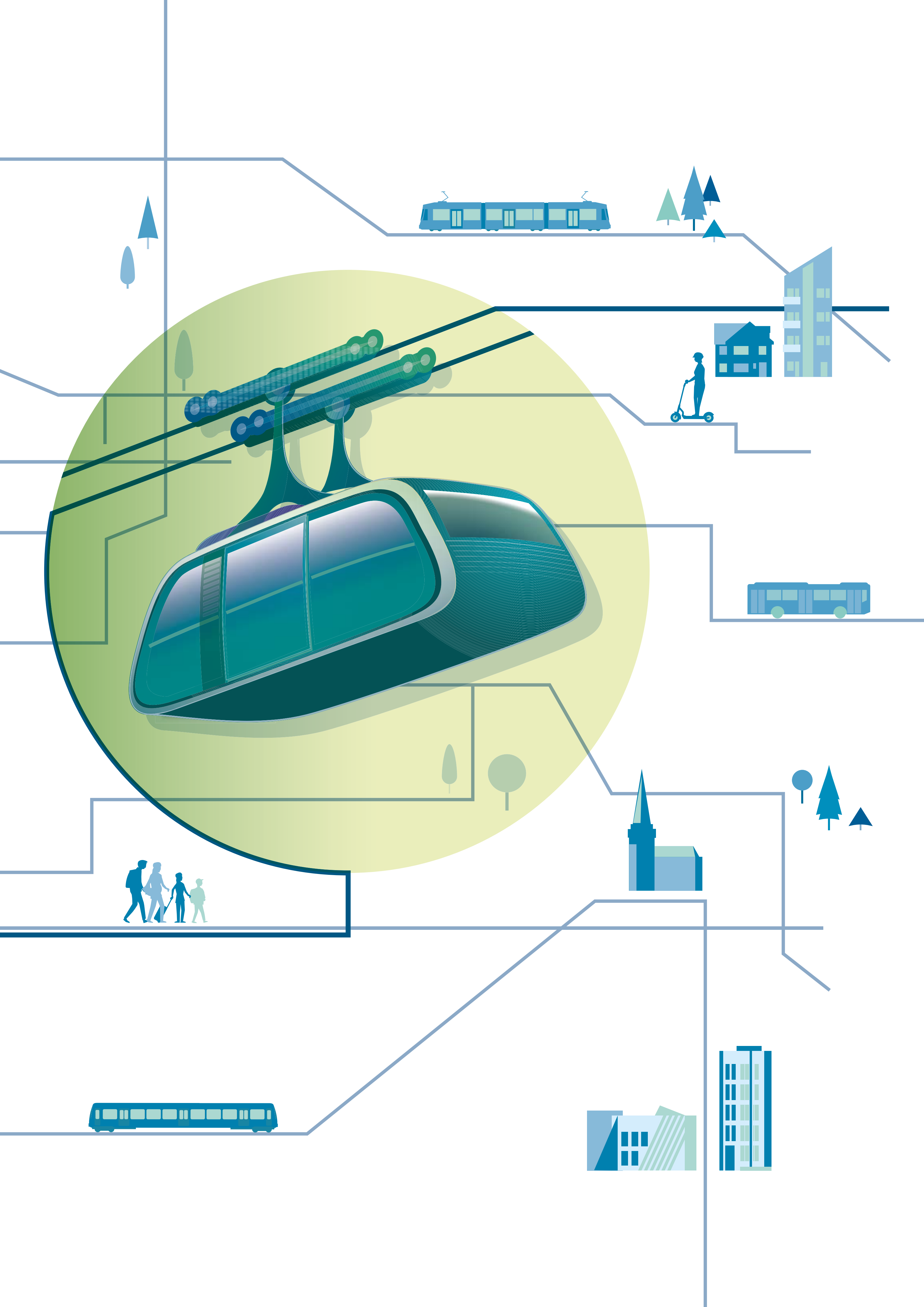
# *Urban Cable Cars in Local Public Transport*

Guidelines for local authorities, transport operators and associations – from proposal to planning, construction to operation

Federal Ministry
for Digital
and Transport





*Dear reader,*

How many times have you been stuck in traffic wishing you could just hover above the masses of cars? It is not impossible. Cable cars can overcome almost any obstacle. It is our goal to make this a part of your experience with local public transport – on your daily commute or when running errands.

Urban cable cars are far more than a simple tourist attraction or technical gadget. They not only provide access to skiing areas, but can also complement public transport services.

Some major urban areas are already using cable cars as a reliable mode of transport that is not affected by traffic jams. La Paz/El Alto in Bolivia, for instance, has ten cable car lines, which makes it the largest urban cable car network in the world. In Europe, cities like Toulouse and London are already successfully operating urban cable cars. In New York, the Roosevelt Island Tramway has been running for over forty years across the East River, providing a spectacular view of Manhattan.

In Germany, apart from the aerial tramways in the mountains, cable cars can only be found in Berlin, Koblenz and Cologne to date. However, they are not integrated in the local public transport network. This is something we want to change. To do so, the Federal Ministry for Digital and Transport has been coordinating closely with the scientific community, the federal states and local authorities for more than three years now. The 'Urban Cable Cars' working group has focused its work on integrating cable cars into urban mobility services.

We are happy to see that numerous cities all over Germany are considering building urban cable cars. However, the local authorities are facing mostly similar challenges and do not have many points of reference for guidance at the moment.

With these "Guidelines on Urban Cable Cars in Local Public Transport", financed through our 'Urban Transport Research Programme' (FoPS), we are now offering support. Local authorities can find concrete guidance and transferable planning bases here. Our aim is to create a national standard for urban cable cars in Germany, which cities and local authorities can consult. All the experience has so far been gained in the tourism sector only. While cable cars may be a reliable transport system, they are still new to local public transport.

There are plenty of reasons to support transport by air. Urban cable cars provide solutions for green mobility and can extend and complement the transport network in a meaningful and sustainable way.

- Since the cabins use airspace, local authorities can save space on the ground and use it for other purposes.

- Cable car cabins can easily and quickly overcome obstacles, such as hills, rivers or railways with low emissions.

- This makes it easy to connect new areas, close gaps in local public transport and significantly reduce road traffic. All this can be done without any major construction work.

- Cities and municipalities can easily promote climate-friendly mobility by deploying aerial tramways.

We would very much like to establish cable cars as a normal mode of transport. This is why the Federal Government is supporting cities and local communities with their cable car projects by providing financial assistance under the German Local Authority Transport Infrastructure Financing Act. We are paving the way and providing incentives for local authorities: The new version of the standard evaluation (2016+), which was published this year, makes it a lot easier to demonstrate the benefits for local public transport projects. This basis for pro rata federal funding serves as proof of the economic efficiency as required by the Local Authority Transport Infrastructure Financing Act (GVFG).

The inhabitants of Koblenz for instance have had positive experience with cable cars.
The cable car was established in 2011 for the Federal Horticultural Show. Initially, it was supposed to be dismantled after the show, but a citizens' action group fought to keep it.

This was a total success. The ride across the Rhine river to the Ehrenbreitstein fortress is spectacular. All this shows that we are providing financial support because we want to get things going. Cable cars can make their way into German cities. We are convinced that they are part of sustainable mobility.

Allow yourselves to be inspired and hover with us into the future!

Dr Volker Wissing,
Member of the German Bundestag
Federal Minister for Digital and Transport

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Mi Teleférico circulating monocable aerial ropeway in La Paz, Bolivia

# 1 Introduction

*These guidelines serve as a source of reference: from project proposal to the planning, construction and operation of cable car systems as part of local public transport services in towns and cities across Germany. They describe which areas require consideration both before and during project execution.*

Expanding local public transport sustainably and integrating services into the urban environment in the best-possible way are important social objectives. All modes of transport must initially be given equal consideration. The urban cable car thus presents one of many potential solutions for addressing urban mobility needs, alongside more conventional public transport systems. In Germany, the funds required for transport infrastructure are furnished by the various state levels. This applies both to roads and to public transport, meaning that future investments in urban cable cars as part of local public transport will also be largely funded by the public authorities.

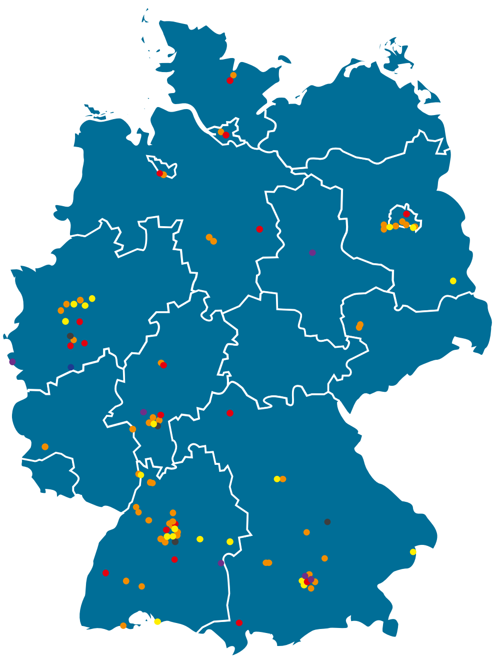
Aerial tramways have for many years provided a popular and reliable means of transport, especially in alpine regions, where they were first used for transporting goods and later also passengers. Aerial tramways offer several clear advantages: not only can they directly overcome obstacles and elevation differences to create a direct point-to-point connection at the +1 level, but their dedicated track means they also remain largely unaffected by external influences. Furthermore, the stations and pylons require only minimal ground space. In fact, in other countries – South America in particular – the extensive benefits of aerial tramways over other transport systems have led to their being integrated into urban public transport infrastructure.

**Info box 1: Defining urban cable cars**

In the context of these guidelines, urban cable cars are defined as aerial tramways which travel through the urban environment and permanently complement the local public transport system. They are principally used for passenger transport and are integrated into local public transport system traffic planning and fare structures.

In Germany, aerial tramways are a familiar sight in alpine regions, but they are also occasionally used in the urban environment to serve visiting tourists as attractions at garden shows and other events. However, in order to be considered an urban cable car, the system must constitute an integral element of the local public transport system and fare structure. This has hitherto not been the case anywhere in Germany. However, the success of urban cable cars in other countries has raised their profile and traffic planners in Germany are now increasingly turning to aerial transport as a potential mobility solution.
A study identified over 100 project proposals in Germany (see Figure 1) from across all parts of the nation. While many of these proposals disappeared after a brief moment in the limelight, others were subject to closer scrutiny in individual studies. Given the dynamic development of the individual cable car projects, specific reference is limited here to the cable car project in Bonn since (as of October 2022) this project is the most advanced following the positive outcome of the standard evaluation. However, other proposals are also being pursued currently.
To date, no urban cable car has been realised in Germany. There are several reasons for this.

*Figure 1:*
*Cable car projects in Germany*



**Key: Cable car projects in Germany**
- Initial proposal/proposal revisited
- Initial proposal with preliminary investigation
- Study commissioned/ongoing
- Study completed
- Positive benefit-cost analysis
- In planning/approval phase
- Project not pursued further

Though there may be no shortage of proposals, when it comes to implementing cable car projects in Germany, information is scarce and progress is slow. For this reason, the Federal Ministry for Digital and Transport commissioned Stuttgart-based planning and consulting firm Drees & Sommer SE together with the Institute of Transportation Research Stuttgart as part of the Urban Transport Research Programme (FoPS) to carry out a study on 'integrating urban cable car projects into urban and traffic planning'. These guidelines for implementing cable cars as an element of local public transport are the outcome of the study. The researchers looked at examples of other urban cable car projects from across the globe, interviewed experts in the cable car field, examined existing planning proposals in Germany, and held workshops with the city administrators and inhabitants of six selected cities (designated 'high-flyer' cities to promote a positive vision). Existing studies and planning frameworks were also reviewed, and include

- guidelines published by the Bavarian State Ministry for Housing, Construction and Transport on cable car developments in urban locations,

- the feasibility study by Karlsruhe Institute of Technology – Institute for Transport Studies on cable cars in Baden-Württemberg,

- guidelines published by the public transport association Verkehrsverband Westfalen on urban cable cars in local public transport, and

- the publication Cable Car Confidential by Creative Urban Projects Inc.

The findings of the study were collated and then incorporated into this document.

These guidelines are designed to offer support with finding meaningful use cases for urban cable cars and bringing cable car projects to successful fruition. They are for local authorities, transport associations and transport operators, as well as anyone else interested in the topic of urban cable cars. The aim is to create general, transferable planning principles for integrating urban cable car projects into urban and transport planning in Germany, and establish a master plan for realising these projects as integral elements of local public transport.

Portland Aerial Tram reversible aerial ropeway
in Portland, United States

# 2 Guideline structure and scope

These guidelines on implementing cable car projects and installations aim to offer information and guidance for cities and local authorities across Germany seeking to initiate and plan their own cable car projects. Key information and topics to consider are presented in detail along with recommendations for action. Figures and info boxes offer further insights into the content provided. The contents of these guidelines reflect the most current information available at the time of publication. Future changes (such as possible amendments or adaptations to the legal bases) and real-world experience gained from implementing cable car projects in Germany cannot be included at present and may deviate from the assumptions made in this document. All aspects of the organisation and implementation of a cable car project must always be assessed and determined on a project-specific basis.

Section 3 'General principles' presents basic information on potential urban cable car applications and systems, opportunities and challenges, and the regulatory framework. Cities and local authorities in Germany should already be familiar with this information at the project identification stage if they are to properly evaluate whether the cable car as a means of transport is fundamentally suited to the project in hand and should be included for further consideration. Section 4 'Cable car project model' runs through a project model including key milestones which can be consulted during implementation of the local project. This section also includes the stages of the approval processes generally applicable to the planning and implementation of all cable car projects. It is important to note here that each project must be evaluated on its own merits and in the specific context. The project flow depicted is not intended to be a complete or accurate representation of the real-world project.

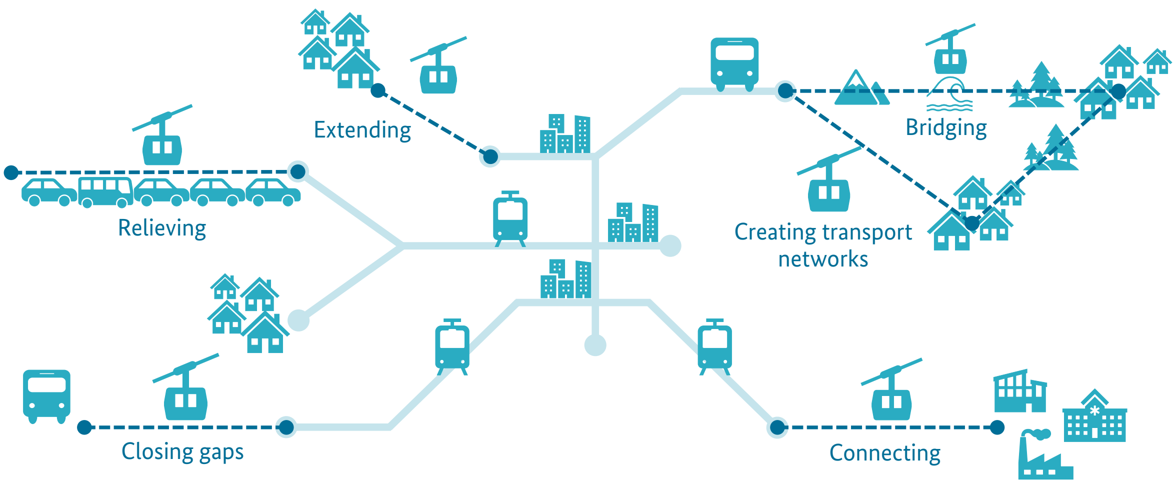
The subsequent sections are provided in no particular chronological order and do not necessarily have to be completed in the sequence in which they appear. However, the order has been chosen to offer a logical project structure; it begins by establishing the framework for a cable car project before moving on to the technical and operational specifications of the system, and then the topics of investment and funding.
In Section 5 'Traffic, environment and urban integration', demand potential and the prevailing circumstances within the study area are identified and analysed. This then provides the basis for selecting the cable car system in Section 6 'Technical infrastructure and operation'. Operational topics to be considered and included in planning are also covered in this section.
Section 7 'Evaluation, investments and funding' outlines the contents of the standard evaluation, which was updated in 2022. The changes now mean that cable car projects, too, can be evaluated adequately. Depending on which project phase or issue is being worked on within the project, the topic areas can be considered separately from each other.

Lastly, Section 8 'Outlook and innovations' presents current research projects and innovations in the cable car industry.

# 3
# General principles

Generally speaking, rope-propelled systems fall into one of two categories: top supported, which are suspended from a rope, and bottom supported, which are supported by tracks underneath. These guidelines focus on approaches to realising aerial tramways (top-supported systems), since their ground space-saving potential and the ability of such systems to overcome topographical and structural obstacles allow them to be optimally integrated into the existing transport network. Bottom-supported, or track-based, systems are not considered beyond this point. Unless otherwise specified, wherever the term ‘cable car’ appears in these guidelines, it refers to aerial tramways.

*Figure 2:*
*Use cases for urban cable cars*




## *3.1 Use cases and applications*

As with all types of transport systems, the characteristics of cable cars make them particularly suited to certain use cases. The key characteristics of cable car systems include

- routing at the +1 level away from all other traffic,
- the option to realise direct point-to-point connections without detours, and
- in the case of circulating ropeways, which convey passengers continuously, there is no need for a fixed timetable since a cabin is always ready for departure provided the gaps between cabins are kept suitably short.

The primary purpose of cable cars is to overcome topographical, structural or traffic-related obstacles.

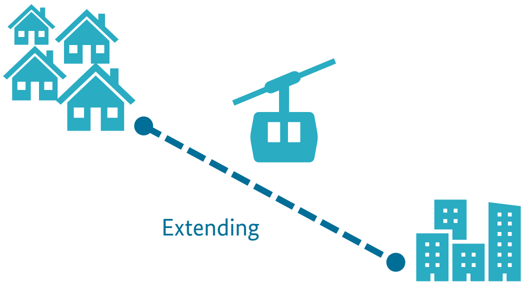
Since cable cars are routed at the +1 level, and the pylon heights can vary significantly, they are able to **bridge** barriers posed by terrain or infrastructure that existing local public transport could not – or, at least, not without significant additional effort and cost. For example, cable cars can directly traverse not only natural features such as rivers, steep slopes and valleys, but also obstacles caused by urban infrastructure, like densely populated areas where ground space for building out the existing transport network is at a premium. This is where the major advantage of urban cable cars comes to bear.

*Figure 3:*
*'Bridging' use case*


Cable cars can provide direct connections between points that would otherwise involve circuitous routes for other forms of transport; the cabins simply float over motorways or other barrier-separated transport corridors, resulting in significantly shorter journey times.

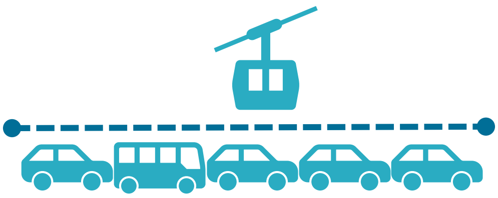
In addition to bridging and closing gaps, the above-mentioned characteristics of urban cable cars also make them suited to further use cases, as follows.

*Figure 4:*
*'Extending' use case*




Cable car constructions offer a comparatively fast and cost-effective solution to **extending** existing local public transport routes. In conjunction with their bridging role, cable cars can also be considered for urban mobility where structural barriers prevent the expansion of the existing system or this would be at great cost. Cable cars can serve as feeders to existing local public transport, thus expanding the services available.

*Figure 5:*
*'Relieving' use case*




In many areas, existing infrastructure is reaching its limits. This applies both to local public transport services, which are extremely busy and often overcrowded, as well as to motorised personal transport, which causes congestion. Since they are routed via the +1 level, cable cars can offer an additional transport system in particularly congested areas, taking up minimal ground space and absorbing some demand to **relieve the pressure** on existing infrastructure. The construction of a cable car system lends itself particularly well in areas where, due to a lack of space, it is impossible to expand existing infrastructure, like adding a bus lane.

Cable cars are a good way of **closing transport gaps**, for instance to major sources of traffic generation, such as industrial parks and residential areas, shopping centres, etc. In radial transport networks, provided there is a corresponding demand, cable cars can also create tangential links that save passengers the need to travel through the city centre and thus help to relieve the often overburdened infrastructure in these areas. This is where circulating ropeways, which convey passengers continuously, are particularly advantageous; since there is always a cabin ready for departure, there is no need to coordinate timetables with existing transport systems.

Cable cars can be used to **connect** the geographically disparate locations of traffic generators with high employee and visitor traffic volumes, for instance universities, exhibition centres and airports. Here, too, circulating ropeways as continuous conveyors present an advantageous solution as they establish a continual connection between the locations. Since these kinds of facilities are often located on the outskirts of cities, a further benefit of cable cars is their suitability as a high-capacity link between these locations and the existing local public transport network.

The option to link different cable car lines together in a single station building allows the creation of urban cable car **transport networks**. However, this is contingent on there being a lack of adequate existing urban transport infrastructure. In Germany, the local public transport networks tend to be very well organised and require only targeted additions. Hence, the creation of transport networks using urban cable cars is of secondary importance in Germany.

*Figure 6:*
*'Closing gaps' use case*


*Figure 7:*
*'Connecting' use case*

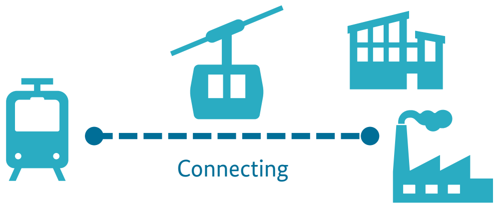
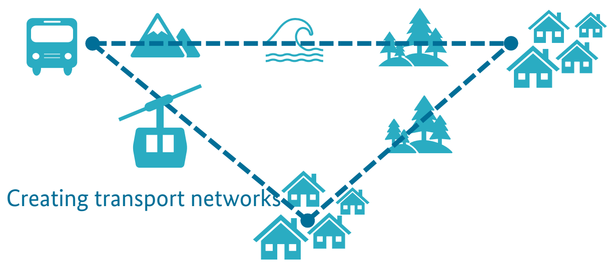


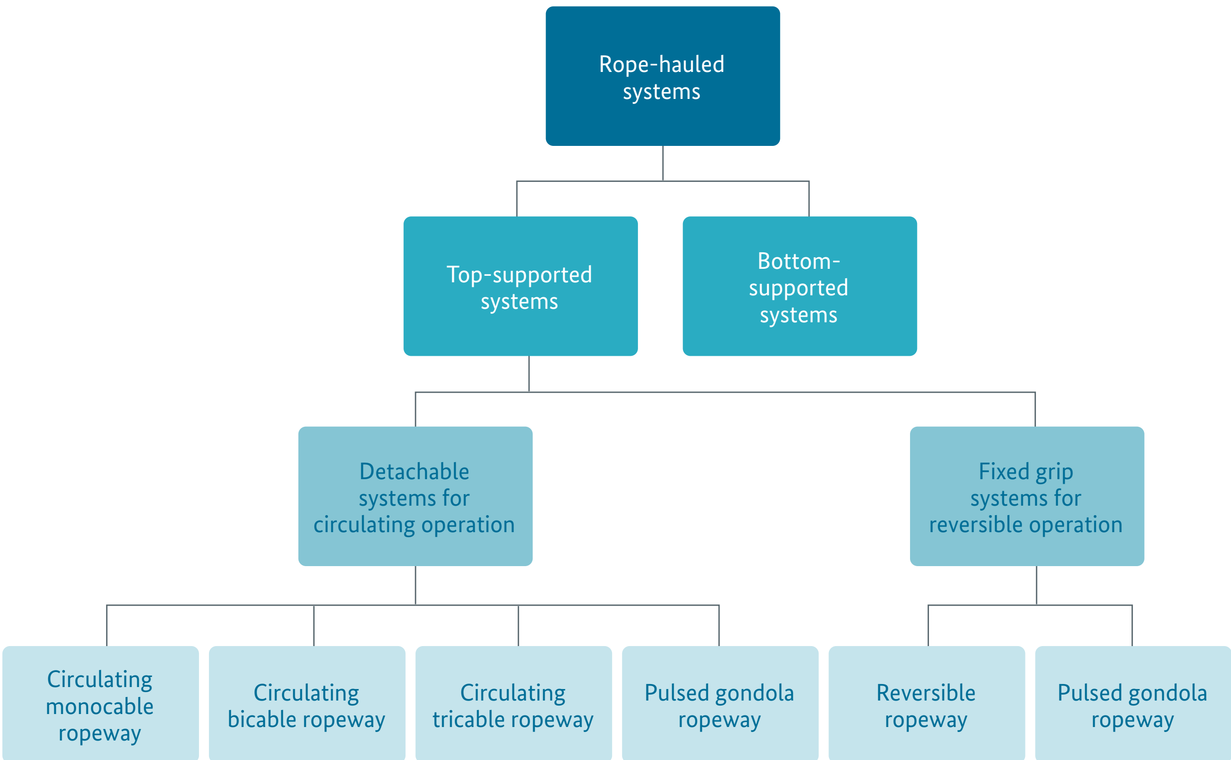

*Figure 8:*
*'Creating transport networks' use case*



### 3.2 Cable car systems

Aerial tramways are systems that provide a linear, point-to-point connection between two stations. A minimum of one rope is tensioned between the stations and driven by a motor, thus propelling the attached cabins. Each system has what is known as a free rope span, meaning the distance that can be straddled without the need for additional pylons. Over longer distances, the required ground-to-rope clearance is achieved by incorporating aerial lift pylons along the ropeway route. Systems classed as aerial tramways include reversible ropeways and circulating ropeways; these systems differ in terms of the number of ropes and their mode of operation. A reversible ropeway has one cabin or a cluster of cabins per direction of travel, while a circulating ropeway propels a larger number of cabins in continuous operation suspended at intervals from the haul rope. The main systems of interest in an urban context are reversible ropeways and detachable circulating ropeways.

*Figure 9:*
*Overview of rope-hauled systems*



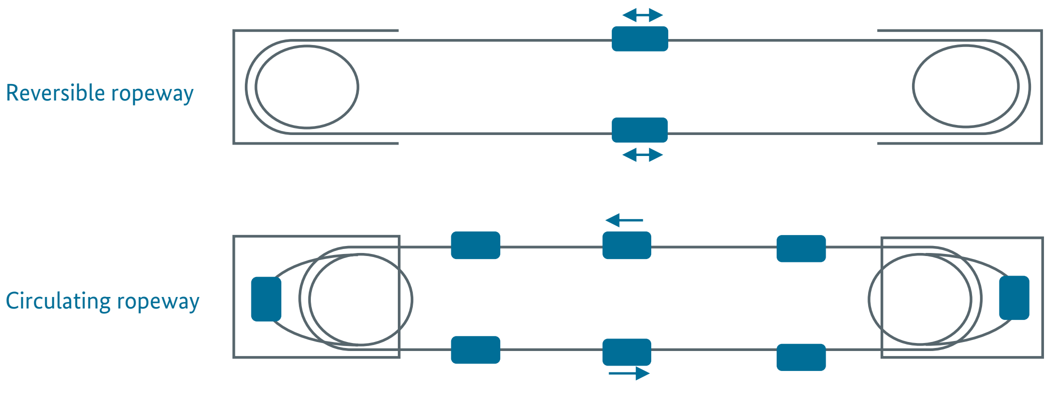
In the case of **reversible systems**, boarding and deboarding in the station is only possible once the cabins have been brought to a complete stop. Where demand is high, it would thus make sense to use large-capacity cabins so as to offer sufficient transport capacity. Since the number of cabins on a reversible aerial ropeway cannot be changed, the system's capacity is determined solely by the cabin size. For most reversible aerial ropeways, a timetable is drawn up with fixed departure times, similar to a bus or train timetable.

Greater potential in an urban setting is offered by **circulating systems**, where cabins spaced equidistantly along the rope are in continual operation to enable frequent departures. The circulating ropeway operates on the basis of a steel rope loop that rotates 180 degrees around two opposing bull wheels. The cabins circulate on the same principle as a paternoster lift. Unlike reversible ropeways, the cabins of circulating ropeways can be detached during operation to allow capacity to be adapted dynamically. This high degree of flexibility makes it theoretically possible to respond directly to peaks and troughs in demand.

However, such adjustments cannot be to the detriment of the service's reliability and should only be carried out at the pre-defined times published on the timetable (see Section 5.1.2).

Moreover, cabins can be detached after entering the station to slow down the travel speed and make boarding and deboarding more comfortable for passengers. Cabins can even be brought to a complete standstill, although this reduces the system's capacity (see info box 'Passenger transfer', Section 6.1.4). Following passenger transfer, the cabins then accelerate back up to running speed and are re-attached to the rope. This does not affect the speed of the remaining cabins in operation, which continue to travel as normal. Circulating ropeways thus offer a greater total carrying capacity and their high departure frequency significantly reduces waiting times compared with timetabled public transport. The use of intermediate stations for further boarding/deboarding options can enhance the catchment effect and unlock greater passenger potential.

*Figure 10:*
*Operating principle of aerial tramways*



### *3.3 How cable cars differ from other public transport systems*

A broad spectrum of systems delivers local public transport services in Germany. The most widely used include buses, trams, rapid transit railways and local trains, but other systems have also established themselves in individual cities, such as the subway, the dual system for light rail, funiculars, ferries, rack-and-pinion railways and other, special types of transit (such as overhead monorails).

These systems can be distinguished from one another and from the urban cable car as a further local public transport system using various criteria and system properties. The final classification of a transport system is based on the sum of its attributes. An initial classification can be made based on the attributes that play a key role in public perception:

- Transport route (road, rail, water, rope)
- Propulsion system (combustion engine or electric motor)
- Speed and range (short, medium, long)
- Locomotion principle (standing, suspended, hovering, floating)
- Carrying capacity (vehicle size, frequency)

One obvious difference to other local public transport systems is the rope on which the cable car travels. The majority of transport systems in widespread use are land-bound, with buses generally using existing road infrastructure while trams, light rail services, etc. travel on dedicated rail networks. Much of this infrastructure is at the 0 level, as well as at the -1 level in many densely populated inner-city areas. This increases the independence of local public transport systems from other traffic. Subway trains run on an entirely separate rail network, generally at the -1 level, but also sometimes at the 0 level (fenced-off outdoor sections) or the +1 level (elevated rails). Since they are routed at the +1 level, cable cars travel entirely separately from other traffic, which minimises the influence of external factors on their operation. In terms of the track itself, the overhead monorail in Dortmund offers the closest comparison to a cable car. The cabins travel between stations at the +1 level, though the stations themselves can be at the 0 level. However, the infrastructure costs for an overhead monorail are higher than those for a cable car due to the number of support pylons required by the monorail and its box-girder construction.

Most buses and a portion of rail traffic (especially regional services) still use internal combustion engine vehicles. This will change in the future as vehicles with batteries or fuel cells become more widespread. Electric propulsion has been used for trams, light rail transit and subway trains for over a century. Local passenger rail services in urban areas also switched to electric propulsion a long time ago. Cable cars, too, are propelled by electricity, but unlike other local public transport systems the drive motor is located in the station rather than in the vehicle/cabin itself. The electric motor drives the rope and therefore also the cabins. Funiculars are the only other 0-level transport system to operate on the same principle.

There is significant variation in the speed and range capabilities of the various local public transport systems. In most cases, it is less about the parameters that are technically and theoretically possible, and more about what is actually possible in real-world use. For instance, while it would be technically possible to build subway trains capable of speeds of 160 kph and extend subway lines to 100 kilometres in length, this would not make sense in the real world. The distances between stops would prevent the train from reaching top speed and the high requirements of subway track infrastructure prevent the construction of correspondingly long connections. Of greater relevance is the speed actually travelled, taking the stops into account. Urban local public transport systems travel between around 20 kph (city buses and conventional trams) and 50 kph (rapid transit railway). The line lengths of local public transport systems are even more varied, ranging from 1- to 2-kilometre-long local bus routes, to light rail transit and subway routes of up to 40 kilometres in length, and rapid transit railway routes that can span up to 100 kilometres.

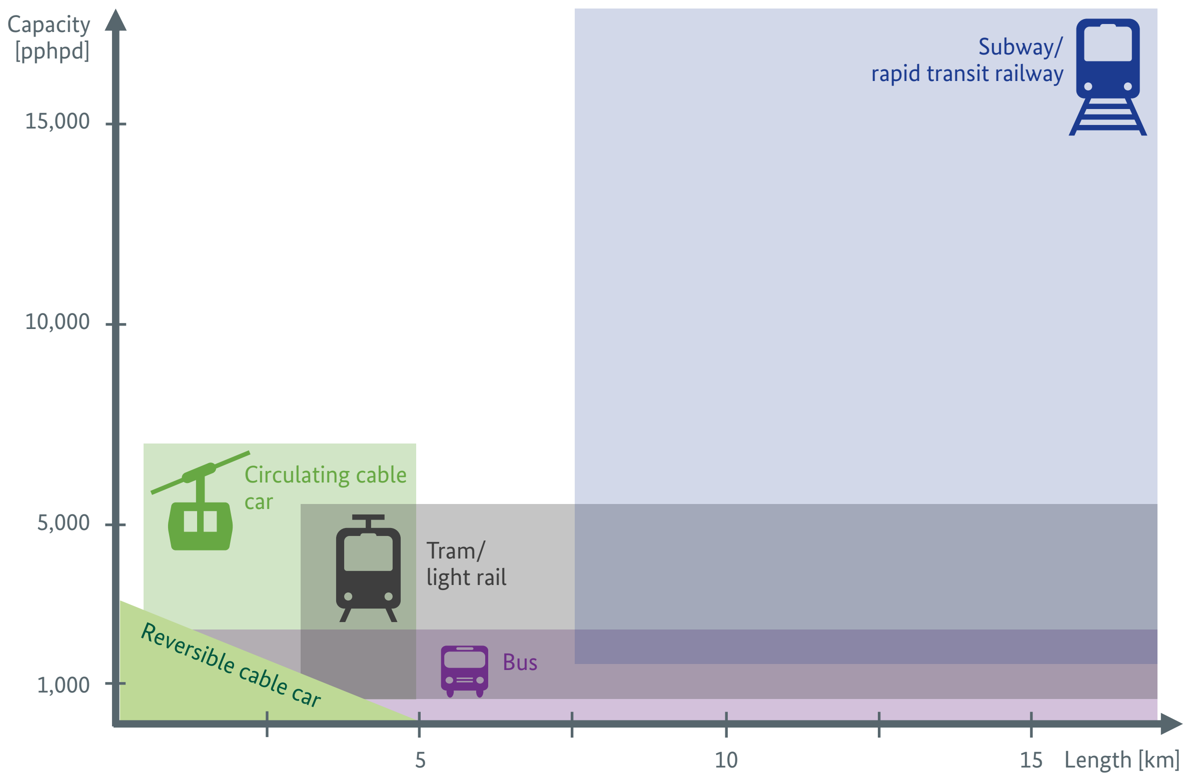
Due to their design, cable cars reach lower speeds of between around 20 to 45 kph. However, it is important to remember that, unlike other systems, cable cars offer a direct connection – meaning the distance from A to B is often shorter by cable car than by, e.g. bus. While most cable car projects have hitherto not exceeded a planned route length of 5 kilometres, longer links are possible in principle. However, it should be noted that as the route length increases the advantages of a direct connection dwindle due to the cable car's comparatively slow speed; the journey time benefits compared with other modes of transport are gradually lost.

The most conspicuous difference of the cable car to most other systems is its locomotion principle. Virtually all other local public transport systems use land-bound vehicles which stand on a road or a rail. By contrast, cable car cabins are suspended from a rope and thus hang beneath their track. However, this is not unique to cable cars; some other special constructions also utilise this principle, including the overhead monorail in Dortmund and the suspension railway in Wuppertal.

The passenger capacity of local public transport systems is calculated based on the vehicle size and service frequency. The size of the vehicles varies greatly, often within the same system. For example, buses can range from 8-seater minibuses to bendy buses capable of carrying up to 180 passengers. The same is true of local passenger rail services, which can carry 150 passengers in compact regional carriages connecting rural areas. By contrast, in metropolitan areas rapid transit railways can carry over 500 passengers, and the triple-carriage services over 1,500 passengers. Similarly, cable car cabin sizes also vary by system, with different conveying capacities offered by circulating monocable aerial ropeways, 3S systems or reversible aerial ropeways. The cabins of a circulating monocable aerial ropeway are generally designed to carry 8 or 10 passengers, while the cabins of a 3S system can convey around 30 passengers.
Reversible aerial ropeways can be configured with yet significantly larger cabins. The continual high-frequency service offered by circulating ropeways means they can handle capacities that are roughly equal to those of a bus or tram departing every five minutes, despite the comparatively small cabin size. The capacities of reversible aerial ropeways are lower and also dependent on the length of the ropeway itself (see Section 6.1.2).

Figure 11 shows a spread of the typical line lengths and capacities across different local public transport systems.

*Figure 11:*
*Comparison of line lengths and passenger capacities of different local public transport systems*



### *3.4 Regulatory framework*

The legal requirements applicable to the introduction on the market and the trade of cable car systems and safety components are founded in European law, specifically 'Regulation (EU) 2016/424 of the European Parliament and of the Council of 9 March 2016 on cableway installations and repealing Directive 2000/9/EG'. As an EU regulation, it is directly applicable in member states and hence also in Germany. The regulation also contains general provisions on the design, manufacture and putting into service of new cable cars, and it is the member states which must ensure compliance with these provisions.

The necessary federal-level implementing regulations on the conformity assessment and market surveillance for cable car sub-systems and safety components were enacted in the law implementing Regulation (EU) 2016/424 of the European Parliament and of the Council of 9 March 2016 on cableway installations and repealing Directive 2000/9/EG (Act on cableway installations, SeilbDG).

Since, within Germany, power is granted exclusively to the federal states to legislate on cable cars, as enshrined in Article 70 (1) of the Basic Law (GG) in conjunction with Article 74 (1) para. 23 GG, it falls to the federal states to enact laws on the manufacture and operation of cable cars. Therefore the approval, operation, monitoring and supervision of cable car installations is regulated in federal state laws, which fulfil the respective framework requirements laid down in European law.

The requirements below are regulated in the wording of the above-mentioned laws as well as in the Eurocodes on structural design and the CENELEC standards on electrotechnical standardisation, and must be documented in the approval process and/or drawn up for each installation. The contents of, inter alia, the federal state law and of Regulation (EU) 2016/424 are definitive in this regard. Article 8 of Regulation (EU) 2016/424 requires a safety analysis and a safety report. These documents must include

- EU declarations of conformity for all safety components and sub-systems of a cable car pursuant to Article 19 Regulation (EU) 2016/424,
- a rescue concept,
- a fire prevention concept,
- an evacuation concept for station structures,
- proof of structural integrity for the station and track structures (pylons), including adequately dimensioned impact protection.

The following aspects must also be covered:

- Determination of space requirements for the entire installation including space for cabin parking and maintenance
- Dimensioning of access structures; optimisation of access and transfer times
- Dimensioning of storage space
- Integration into existing structures (including subway structures, bus stations)
- Interactions with power lines and overhead power cables

The above list is in no way intended to be complete or accurate; if applicable, further technical documents and certifications must be furnished.

The supervisory authorities in the federal states regulate comprehensive inspections of the cable car installations in their entirety; these can include, for instance, checks of all essential technical functions and equipment prior to commissioning, regular checks and servicing work, and the performance of scheduled general inspections of the entire installation as described above.

A cable car committee provides a platform for the federal states to share their experiences with the safety requirements relating to the introduction of cable car systems on the market and their operation. The federal government enjoys guest status at the committee's meetings.

The respective federal state guidelines on planning and approval procedures must be complied with.

### *3.5 Opportunities and challenges presented by urban cable cars*

Urban cable cars enhance the existing spectrum of local public transport systems and open up new options for expanding local public transport infrastructure. Like all local public transport systems, the inherent pros and cons of the urban cable car system make it ideally suited to specific use cases.

Key advantages of urban cable cars over other local public transport systems:

- Circulating ropeways convey passengers continuously with very high departure frequencies. This results in high capacities and short waiting times.
- The ropeway as a transit route makes it possible to traverse various topographical, structural or traffic-based obstacles as well as extreme elevation differences.
- Routing via the +1 level means cable cars do not compete with other traffic.
- Cable cars require comparatively little infrastructure, mostly in the form of stations. Depending on the specific project circumstances, they can generally be built faster and more cost-effectively than other systems with comparable characteristics.
- Cable cars produce very low local emissions due to the separation of the drive from the vehicle itself. The central drive system creates a very energy-efficient means of transport.

On the other hand, the system has a number of limitations and challenges to consider:

- The comparatively low speeds make cable cars unsuited to longer distances.
- Due to the nature of ropeways, additional sections can spur off existing stations but not outside of stations.
  Individual sections are required in order to realise a cable car network.
- Cable cars can only change direction at intermediate stations or turn stations.
- Despite the high departure frequency, the arrival of large numbers of passengers simultaneously may lead to longer waiting times (e.g. event traffic or connecting rail passengers).
- Routing at the +1 level can be a source of contention due to the encroachment of the cable car on the urban and natural landscape or when travelling over properties.
- The area around the pylons and stations is affected by noise emissions. A careful review must be made of each use case in respect of permissible thresholds.

Initially, then, the planning stage must focus on defining which requirements apply to the desired local public transport service, so as to determine which transport systems qualify for further consideration as a potential solution. Subsequent steps work through the process of determining which solution optimally addresses the local transit need. This could – but does not have to – be an urban cable car.

### *3.6 Integration into local public transport networks and fare structures*

As is the case for any other type of transport system, urban cable cars must be planned as **an integral part of the local public transport network**. However, this does necessarily mean there must be a network of several urban cable car lines, similar to the Mi Teleférico network in La Paz, Bolivia. The background to the Bolivian project is not comparable with the situation in German cities; Paz lacked adequate public transport services prior to the cable car being built. While this is not generally the case in German cities, there are, on occasion, gaps in local public transport services which urban cable cars can plug.

Cable cars can thus become part of the urban public transport landscape and must be planned accordingly within the context of existing public transport systems. The goal is to integrate the cable car into the existing network in a way that brings about an overall improvement in public transport services. The success of urban cable cars depends largely on how well they are integrated, both spatially with other transport providers, as well as into the fare structure. Achieving optimal integration into the existing local public transport network is thus an important planning task.

To ensure optimal **transit connections** with other transport systems, **intermodal transit hubs with the shortest possible transfers** are required, where the distance between various transport systems is reduced to a minimum (e.g. cable car – rapid transit railway/cable car – light rail transit/cable car – bus, etc.). This level of integration can optimise the transport benefits not only of a cable car, but also of the other public transport systems, and maximise its potential. Traffic models can be used to identify the ideal feeder points to the existing local public transport network (see Section 5.1.1).

A further key aspect is **fare integration** in the existing public transport fare landscape. This means offering passengers the option to use an urban cable car with the same tickets and on the same terms as other local transport systems. Passengers thus require only one ticket for the end-to-end journey (e.g. rapid transit railway – cable car – bus) and are able to switch freely between all public transport systems. This applies both to single tickets and to commuter tickets (e.g. monthly tickets).

Integration into the local public transport fare landscape is an important step towards increasing acceptance amongst potential regular users (commuters, etc.) of the urban cable car as a 'normal' form of public transport. Studies show that integration into the district ticket systems is essential for passengers and that, conversely, separate standalone fares are seen as a barrier to use.

The integration of urban cable cars in local public transport is also a formal requirement of the funding conditions in the Local Authority Transport Infrastructure Financing Act (GVFG) (see Section 7.3). GVFG requires the project seeking funding to be incorporated into a local transport plan or an equivalent plan for the purposes of evaluation (Article 3 para 1 b) GVFG).

Mi Teleférico circulating monocable aerial ropeway
in La Paz, Bolivia

# 4
# Cable car project model

### *4.1 Project schedule (time line, essential steps, milestones)*

There are many different approaches to implementing cable car projects, but one aspect they all have in common is the need to tailor the schedule to the specific project.

A project model is provided below for use as guidance when implementing cable car projects. Similar to the service phases of the statutory fee schedule for architects and engineers (HOAI), the project is broken down chronologically into the following phases: **demand analysis**, **conceptual planning**, **design, approval, project execution** and **commissioning**. Both the content and timing of the different project phases provided in these guidelines can be adapted if required; there is no fixed order in which they must be completed.

A well-structured project improves the chances of successfully implementing a cable car project. However, a slew of further factors can mean that even the best-planned projects never ultimately come to fruition. The project must at all times comply with the regulations and laws in the respective federal states, some of which are mentioned in this section for illustrative purposes.

#### *Demand analysis phase*

Irrespective of which mode of transport is ultimately chosen for closer examination in the course of an expert opinion, the first step is to determine whether there is a **need to expand or optimise the local public transport system** in the respective study area. Demand is analysed by way of a vulnerability analysis, which is carried out within the scope of the local transport plan. The findings from the vulnerability analysis are used to formulate a set of objectives and to review potential ideas and courses of action. Corresponding measures are then put in order of priority. The goal at this stage is to lay the foundation for the structure of local public transport and establish a coordinated approach with respect to the possible stages of development.

*Figure 12:*
*Project model*

| | Process | Milestones | Third parties | Participation |
|---|---|---|---|---|
| Demand analysis phase | Vulnerability analysis in the local public transport study area ↓ Preparation of a local transport plan and determination of contents | Resolution on local transport plan<br>Planning resolution for firm projects | • If required, external support with preparing local transport plan | • Provision of information on basic principles of the 'cable car' system<br>• Involvement in preparing the local transport plan |
| Conceptual planning phase | Tenders for an expert opinion on possible alternatives for expanding local public transport (if required, including system comparison) ↓ Detailed comparison of alternatives (tenders for a separate expert opinion may be necessary) | Definition of project team and project owners<br>Short list of alternatives (incl. short listing the system)<br>Identification of a preferred alternative | • Experts and planners<br>• Stakeholders<br>• Supervisory authority | • Provision of information on the corridors and transport systems considered in the expert opinion |
| Design phase | Tenders for building planning, structural engineering services and cable car technology ↓ Planning phase (adapted from service phase 3) incl. standard evaluation | Planning resolution<br>Review and selection of award strategy<br>Selection and integration of the operator | • Transport operator, operator<br>• Funding providers<br>• If required, cable car manufacturer (strategy-dependent) | • Provision of information on the specific cable car project<br>• Integration of project initiatives (dialogue events) |
| Approval phase | Approval procedures through the technical supervisory authority (cable car) ↓ Submit GVFG application | Implementation resolution<br>Conclusion of funding agreement | • Experts and planners<br>• Supervisory authority<br>• Funding providers | • Participation in the approval procedure (e.g. planning approval process) |
| Project execution | Tenders for construction work (station building, cable car technology) ↓ Construction work phase | Review and selection of award strategy<br>Acceptance | • Experts and planners<br>• Transport operator (operator)<br>• Construction companies (by trade)<br>• Cable car manufacturer | • Ongoing information on construction |
| Commencement of operation | File application to commence operations with the technical supervisory authority ↓ Test runs and rescue drills | Commencement of operation | • Supervisory authority<br>• Transport operator (operator) | • Opening ceremony |

The regulations and requirements for the preparation, content and implementation of the local transport plan are governed by the Passenger Transportation Act (PBefG). Responsibility in this context lies with the local public transport partner (federal states/local authorities and joint authorities). If required, third parties can be engaged to provide support. The local transport plan is adopted by way of a resolution by the policy committee.

**Recommended civic participation measures:**
Throughout the project, and hence also during this early phase, it is essential to keep the public up to date and informed about the basic principles of urban cable car systems. This could take the form of non-project-related information events or other, transparent communication initiatives. It is important to ascertain at an early stage whether there is any specific requirement, if applicable on the basis of federal state law, to involve citizens in the process of preparing the local transport plan. Irrespective of legal duties, the act of involving the public strengthens understanding and ultimately also acceptance of potential courses of action.

### *Conceptual planning phase*

Once a decision has been made on the planning phase, a call for tenders is put out for an **expert opinion** to examine the options for optimisation and expansion in the study area (e. g. in the form of a feasibility study), followed by commissioning and preparation of the opinion.
A dedicated **project team**, including experts and planners (see Section 4.3), must be set up at this stage. Ensuring the availability of adequate staff capacities is essential to the smooth running of the project.

The study should cover **a potential analysis, infrastructure and operational planning, and the economic feasibility study on the transport system**. If required, a **system comparison** should also be performed in this context to support the selection of the best-suited mode of transport. It makes most sense to include a system comparison if several different modes of transport could potentially address the transit needs at this point. The expert opinion should pinpoint which alternatives are suited to optimising and building out the study area (including determining the mode of transport). For the remainder of the project model, we will work on the assumption that the urban cable car offers the greatest potential in the study area.

The goal of a comprehensive **comparison of alternatives** is to provide the basis for a final decision on a preferred variant. If required, a separate contract for this expert opinion can be awarded.

**Recommended civic participation measures:**
Citizens should be informed about the objectives and content of the expert opinion (including the route corridors and transport systems under consideration). By providing information and keeping the lines of communication open throughout the course of the project, the aim is to provide ample opportunity for interested parties to participate ('the project does not take place behind closed doors').

### *Design phase*

Once the **planning decision** has been made, before the design phase can get under way the first step is to review and determine the **award strategy for the planning services**. This is used as the basis for requesting tenders on and the subsequent commissioning of the building planning and structural engineering services as well as the cable car technology. Analogous to service phases 3 and 5 of HOAI, this is then followed by the planning of the cable car system. The operator of the system must be selected and brought on board the project at the start of the planning phase; if applicable, the cable car manufacturer can also be involved.

The **standard evaluation** must be carried out in parallel to the planning phase with the involvement of the funding providers.

**Recommended civic participation measures:** During this phase, citizens should be kept up to date on the project and involved, e.g. by way of civic dialogue, to clear up unanswered questions and help allay concerns.

*Approval phase*

The legal requirements with respect to the introduction on the market and the trade of cable car systems and safety components are based directly on European law. Federal state laws on cable car installations regulate the approval, operation, monitoring and oversight of cable cars (see Section 3.4).

At all times, projects must comply with the regulations and laws of the respective federal states. Experts and planners must be involved in the approval process.

The application for funding under GVFG must be submitted in parallel to the approval process. The funding agreement is then concluded once a final decision has been made to build and operate the cable car.

**Civic participation measures:** It is a formal requirement to involve and consult the public as part of the approval process.

As a rule, the procedural laws in the federal states include the requirement for a mandatory public consultation for projects requiring planning approval. If federal state laws or other regulations require an environmental impact assessment to be carried out for the project, civic participation is mandatory here, too.

*Project execution phase*

The cable car stations and the installation technologies are configured in accordance with the applicable statutory frameworks and technical standards. Further information is provided in the relevant sections below. The project stakeholders during this phase include, among others, the operators, the experts and planners, the construction companies and the cable car manufacturers.

**Recommended civic participation measures:** Citizens should continue to be given transparent information about the project.

*Commissioning phase*

In preparation for commissioning, the application to commence operations must be filed with the technical supervisory authority. Test runs and any necessary rescue drills must be carried out in parallel to ensure all relevant procedures are reviewed and fully functional. The project stakeholders during this phase include, among others, the operators, the experts and planners, the construction companies and the cable car manufacturers.

### *4.2 Structure of the project developer*

To date, little experience has been gained in Germany with urban cable car projects that have moved beyond the feasibility study stage. However, talks with the six 'high-flyer' cities have provided revealing insights into important aspects worthy of consideration when designing and developing projects of this nature.

Generally speaking, the project developer can treat the cable car in the same way as other modes of transport. However, an urban cable car is also classed as a **major infrastructure project**. To ensure a successful project outcome, a corresponding organisation that is proportional to the scope of the project must be set up in the city administration. A project owner must also be named.

Accompanying project groups or task forces can also contribute to the successful advancement of the project. It is a major ongoing challenge to coordinate the various stakeholders, their views and demands. However, by involving interdisciplinary stakeholders early on, this can promote mutual understanding for the various interests being represented and ensure the necessary expertise is incorporated into planning. The group of participants can be broadened and varied continually. If the potential cable car operator has already been identified, they can also be involved from the outset. First, this approach ensures existing know-how can be utilised. Second, since, generally speaking, an urban cable car will be a **new transport system** within the company, especially for municipal transport operators, early involvement gets the transport operator on board with the project from the start and helps to reduce any opposition. Especially in view of the respective risk receptors, it is also essential to involve representatives from other agencies. Further stakeholders can be involved (including temporarily) as necessary to address specific questions as they may arise.

Given that the urban cable car has only begun to gain traction in traffic planning in recent years and many planners completed their training before its introduction, in some areas there is a shortage of information on the cable car as a mode of transport. This will diminish going forward, and these guidelines will also serve to improve understanding. For all projects, the involvement of external service providers and/or engineering firms must be reviewed on a case-by-case basis. Selecting the right firm, taking their expertise and background into account, can often be the first step of the project.

### *4.3 Stakeholders/contractors*

During the project initiation phase and at the latest from the start of the planning phase, an interdisciplinary **project team** must be put together of members with the necessary expertise. Due to the various aspects that require consideration during project initiation, it is advisable to involve experts in the following fields: cable car planning, traffic planning, urban planning and/or architecture, public consultation and civic participation, and project management and coordination. If applicable, it is also advisable to bring on board an environmental expert and a legal expert. Significant influence can be exerted on the contents of a project, especially in the initial phase. It is therefore essential to identify affected stakeholders early on and involve them in the planning process.

### *4.4 Client and operator*

Cable car projects can be realised by the public authorities, by the private sector, or by a partnership of the two. It is important to **distinguish between the cable car client and the eventual operator**. These could be one and the same company or different companies.

Where there is a general need for public transport in a city, in most cases the public authorities or public enterprises (utility companies, etc.) will act as the client for an urban cable car. This is standard practice. Since cable cars are a suitable method of establishing a connection to a traffic generator on the city outskirts, it is also possible for the owner of the traffic generator to act as the client for the purpose of improving its own transit links. However, it is unusual to see private investors taking on the role of client for an urban cable car. As a rule, the investor model is limited to special cable car projects (catering to specific events). Another potential client model would be a cooperation between a private investor and the public authorities in the form of a public-private partnership.

Similarly, **operation can be taken on** either by the public authorities – in the form of a **municipal transport operator** – or by a **private transport operator**. When selecting the operator, it is important to take into account their suitability and their expertise in cable car operation. Where the cable car is operated by the municipal transport operator, in most cases the cable car will constitute a new transport system in addition to the existing buses, trams, subways and rapid transit railways, etc. The company must first establish the necessary expertise internally by way of staff training or by hiring and training new team members (see Sections 6.2.3 and 6.2.5 for information on staff requirements). If the municipal transport operator is unable to demonstrate the necessary suitability and expertise, or this would prove too time-consuming and costly, a private transport operator with experience in operating cable cars may be considered as an alternative.

Irrespective of who is the client and who the operator, it is essential to ensure cooperation and coordination between all project stakeholders.

**Info box 2: Autonomous operation**

Self-driving cable cars are attracting growing attention with their promise of efficiency gains and cost savings. The first unstaffed installations are already up and running (e.g. the Gondelbahn Kumme in Zermatt, Switzerland). Autonomous systems enable staff savings to be made since, at the basic level, they operate without the need for human intervention. However, this does not mean that the cable cars operate entirely without staff. First, autonomous systems require a control centre from where they are monitored. In the event of a service disruption, for instance if a passenger becomes trapped in a door, the system automatically shuts off and must be switched back on from the control centre. This requires a team of trained staff in the control centre. Where several cable cars operate in close proximity to one another, they can be monitored from a joint control centre with the attendant positive effects on staff costs.

A number of technical safety measures are required to maintain the safety of autonomous operation. These include, first and foremost, platform doors that separate the waiting area from the track and only open when a cabin is ready for boarding. The station must also be monitored via CCTV and sensors installed to ensure, for instance if someone or something becomes trapped in the door area, that this is recognised immediately and the system shuts down.

Second, the service and maintenance works required for self-driving cable car systems are the same as for staffed systems. Hence, the personnel required to perform these tasks must be kept available at all times – irrespective of how the cable car operates. These costs must be considered when calculating the operating costs.

### *4.5 Participation measures:*

In general, the public wishes to be informed about – and involved in – local projects, particularly infrastructure projects, whether cable car-related or not. This stems in part from the way society is organised in Germany. Decision-making in a pluralist system, respecting democratic principles, as a rule involves a large number of stakeholders, each representing different views. The result is a high willingness to speak out in support of, but also against, a project. Consequently, it is not unusual to encounter opposition and scepticism when introducing new matters.

Whether an urban cable car is fully **accepted** as an integral element of the local public transport system and ultimately then used is dependent on the public's personal perception of user-friendliness, safety and possible encroachments on their personal space.

To ensure a targeted and preferably unimpeded implementation of an urban cable car, comprehensive action to provide and promote **information and participation** (informing and involving citizens) must be taken throughout the course of the project. Project teams must work with experts in civic participation to define beforehand which specific communication and participation measures are prudent at which point in the project. Further guidelines can be used for orientation, such as the 2014 Manual for Good Public Participation in the Planning of Major Transport Projects in the Transport Sector published by the Federal Ministry of Transport and Digital Infrastructure. Unlike with other infrastructure projects, the focus initially should be on providing information and clarification. Many members of the public still associate cable cars with the Alps as a mode of transport used for recreational sports, and may be unaware of the benefits they can offer in urban settings. Providing basic information on this topic (without reference to a specific project) can improve people's knowledge of and attitudes towards urban cable cars.

Conversations with the public in Germany have shown that information on and participation in the specific project are desirable **at the earliest stage possible**. At the same time, it is important to note that involving the public (too) early on makes it impossible to provide any firm – and certainly no final – project details and parameters, in particular on the ropeway route or the projected costs. These details can only be confirmed and presented definitively at a later point in the project (following in-depth examination and planning). The risk is that the public will refer back to and rely on these initial forecasts, which can cast a shadow on public perception should things change as the project progresses. It is therefore essential to include explanatory notes to this effect in early-phase communication on potential ropeway routes and initial cost estimates.

In many cases, the prospect of building an urban cable car is communicated publicly before its suitability for the corresponding use case has been investigated in detail. Where ideas prove untenable or are not pursued further, this has a negative effect on the public's perception of cable cars as an urban transport method. This approach should be avoided.

Furthermore, external communication must be clear that the idea is not to realise an urban cable car at any cost, but rather that preliminary investigations and feasibility studies will be carried out to consider all potential modes of transport of which the urban cable car is one possible contender. It is essential to offer informed explanations of the benefits of urban cable cars, for instance in respect of climate protection, the building and operating costs, and the impact on the surrounding area. Compared to just a few years ago, the public is now far more aware of the fundamental need to utilise transport methods with a small carbon footprint. In view of climate change, this awareness will only intensify going forward.

Objections or opposition from those who are directly affected can cause infrastructure projects to be delayed or to fail entirely. Experience shows that opponents of a project are likely to rally faster and with greater tenacity than its proponents. Project proponents or those neutrally disposed usually tend to forgo their right to visibly adopt a position. This should be taken into consideration in order to ideally involve all groups actively in communication and dialogue throughout the process. In all cases, dialogue and educational work should take place with proponents and opponents of the project to give a platform for both groups to have their voices heard and, if applicable, help to foster a balanced viewpoint.

It is usually very difficult to win over groups who are generally opposed to urban cable cars. However, it is important not to allow individual interests to overshadow the overall benefit to society.

Generally speaking, routing the cable cars so they do not pass directly over private residential properties helps to minimise opposition to such projects. For example, in new residential developments it is important to communicate as early as possible whether and which path a cable car connection could be realised, in order to enhance acceptance among property owners and/or residents. Developers should thus be involved from the very beginning.

**Info box 3: Best practice example (civic participation in the 'high-flyer' cities)**

The choice of participation method(s) depends largely on the individual project and will be selected and implemented ideally together with experts in civic participation. One possible approach is described below; this was successfully applied and implemented during the preparation of these guidelines:

Together with the Federal Ministry for Digital and Transport, six German cities were selected following an analysis of local cable car projects or project proposals. The cities were chosen partly on the basis of geographical criteria, i.e. a best-possible spread across the entire country, and partly based on the progress made by each with respect to realising an urban cable car. The final selection comprised Bonn, Kiel, Leipzig, Frankfurt, Stuttgart and Munich. In describing the vision for these cities, they were designated 'high-flyer' cities – in reference not only to their pioneering role as regards the pursuit/realisation of innovative mobility forms, but also to the means of locomotion utilised by an urban cable car. A workshop was held, at which city administrators discussed planning details and experiences, and dialogue events were organised for citizens of the respective city. For the latter, in cooperation with the local authorities, between 300 and 600 inhabitants were selected at random and letters sent to enquire about their interest in taking part in the dialogue event. Data privacy regulations, including, inter alia, Article 6 (1) e) of the General Data Protection Regulation (GDPR), must be strictly complied with in this context. Those who were interested in attending could register voluntarily by providing their email address.

At the events themselves, the focus was on sharing and discussing basic information about urban cable cars. City-specific projects and considerations were not addressed. This was openly communicated throughout the preparatory phase. The goal was to inform and educate interested participants and to provide a platform for open dialogue between the initiators and the public on selected topics.

Due to the situation with coronavirus at the time, the event was held using a hybrid format. Questions and comments were collected and answered in a live stream using a chat box, a questionnaire tool and an option for interactive participation. Small groups discussed the topics of urban design, transport, civic participation and the environment. Opinions were requested, and concerns and barriers discussed. The outcomes were then presented with the involvement of all participants.

The feedback from citizens was very positive. They appreciated the opportunity to participate and actively express their personal opinions. It became clear that, in addition to interest in local projects and considerations, the provision of transparent information and education – on how urban cable cars work and their pros and cons – is an extremely important tool for fostering public acceptance. This can be achieved via information and communication channels, events and civic dialogue. Citizens desire a platform where they can find information and actively ask questions and express their concerns. A preference was expressed for visualisations and simulations of a cable car in the cityscape, e.g. using a virtual reality headset. Such tools can help to make an urban cable car tangible for everyone.

# 5 Traffic, environment and urban integration

Urban cable cars constitute new, linear infrastructure within a city with a multitude of resultant interactions. These relate not only to the effects of the cable car on traffic, which require planning and evaluation in the context of existing local public transport services, but also the cable car's effects on its surroundings and the numerous related risk receptors on which the installation acts. Not only that, but the cable car also has an impact on the cityscape, since pylons and ropes – depending on their location and height – can be visible from afar.

All of these interactions must be considered in cable car planning in relation to the requirements arising from the cable car system specifications. Cable cars offer many opportunities to positively influence these interactions and thus lay the foundation for bringing an urban cable car to successful fruition, starting in the planning phase.

## 5.1 Traffic

Prior to planning the ropeway route, the key question to ask is: What is actually needed from a transport perspective, i.e. does a **traffic bottleneck or transport need** exist that can be optimally served by a cable car?

Local public transport services in Germany are already well developed, offering attractive connections between heavily frequented destinations. In such cases, the addition of urban cable cars is generally not expedient since this would result in unnecessary parallel services. Nevertheless, service **gaps** remain in which existing demand cannot be adequately served. The goal then here is to find solutions to which urban cable cars can also contribute.

Cable cars must not be given special status in these efforts to find a solution. They must be treated the same as other transport methods to ensure the best solution is found to the unique transport problem based on the **merits and system limitations of each mode of transport**. It is therefore extremely important to approach the search for a solution to a transport problem without any fixed expectations. The cable car and its effects on transport should not be considered in isolation. Other transport systems must also be included in the comparison. Due to their attributes, there are inherent advantages and challenges associated with cable cars that lend them to solving transport problems in certain use cases. In other cases, it may be another transport system that proves to be the better option. In this case, efforts must focus on the best-suited transport system rather than moving ahead with the cable car project at all costs.

### *5.1.1 Traffic models*

Traffic models provide insight into the level of **demand** for a connection and how a cable car or other **transport system** could contribute to **solving** a transport problem. Cable cars should never be considered in isolation when working with traffic models, but rather analysed in combination with other, existing transport systems to gain a realistic idea of the effects on the network and the interactions between the systems. It is also advisable to develop multiple route options and to compare and contrast their effects on the transport situation to identify the most suitable path for the cable car.

The effects predicted by the traffic model influence several areas, including project dimensioning (see Section 5.1.2). Generally speaking, in traffic models cable cars can be treated like any other transport system. Their special characteristics can be replicated in the model, where the comparatively low travelling speed of circulating ropeways with short departure intervals is offset by the high frequency of services with correspondingly low waiting times. Both aspects flow into the calculation of perceived journey time, which describes resistance to using local public transport, and thus are an expression of the attractiveness of an urban cable car compared to other transport systems.

A particular feature of the cable car – especially in the case of circulating ropeways – is the comparatively small cabin size and corresponding cap on staff requirements. Under certain circumstances, this can result in a build-up of crowds of waiting passengers, since not everyone can board one cabin. However, the high cabin frequency of circulating ropeways means crowds quickly disperse. Modern traffic modelling software can replicate these effects by incorporating access barriers that prevent boarding where cabins are already full, and calculate the corresponding prolongation of journey times.

Another special characteristic of urban cable cars is their tourist appeal. Whereas conventional transport methods are used to travel from A to B, i.e. the journey is a means to an end, their +1-level routing enables cable cars to offer a new perspective of a city and turn the journey itself into the purpose of an activity. Trips taken other than purely for conveyance reasons have not been considered in traffic models thus far. Neither are there any insights into the effect of urban cable cars on tourism, nor has this effect been replicated in traffic models.

**Info box 4: Transport system 'bonus' in traffic modelling**

For passengers, the perceived attractiveness of the various transport systems can vary enormously. Reliability, subjective ride comfort, even the memorability of the route can be contributing factors. Transport systems which are considered to be more attractive have an edge in terms of acceptance and tend to be passengers' first choice. Revealed preference analyses are often used to rank the attractiveness of one transport system over others. These analyses are based on observations of passenger behaviour. Where revealed preference analyses cannot be conducted, stated preference analyses can offer an alternative. These use questionnaires to investigate the usage behaviour of transport users by asking them, for example, to choose their preferred means of transport from a list of services available.

Traffic modelling can replicate the perceived attractiveness of a transport system by incorporating a system-specific 'bonus' into the journey time. There is plenty of research on the positive perception of rail-based transit, which is referred to as a 'rail bonus', over bus systems. It has not been possible to investigate the **attractiveness of urban cable cars** against other transport systems to the same extent due to the small number of projects that have been implemented. Only a small number of the stated preference surveys conducted so far on passengers' transport preferences have included urban aerial tramways. These found that, while urban cable cars were perceived as more attractive than buses, they tended to be ranked slightly lower than rail-bound modes of transport. This perception is also taken into account in the newest version of the standard evaluation (see Section 7).
Here, a 'transport system bonus' is granted to urban cable cars over buses, similar to the 'rail bonus' for rail-bound transport systems. This approach provides a good benchmark for traffic modelling.

### *5.1.2 Supply and demand*

Over the course of a day it is normal to experience certain fluctuations in demand for local public transport services. Peak times are usually mornings and mid-afternoons. Demand is highest during the morning rush hour, and lowest outside of peak hours. Conventional transport systems respond to these fluctuations by deploying vehicles of varying sizes and increasing or decreasing departure frequencies.

Cable cars also offer the ability to respond to **fluctuations in demand**. This works differently according to whether the system is a reversible or a circulating ropeway. With the former, the speed or departure frequency can be adapted provided this is technically feasible for the system in question. For the latter, there are three possibilities:

- Adjusting the rope speed over **the course of the day** to respond to fluctuating demand. Where the speed is reduced during periods of low demand, the number of cabins remains the same, as does the distance between cabins on the rope, while the time between departures increases. This reduces capacity and increases journey times. On the other hand, lowering speeds can reduce energy consumption and wear and tear (see info box 'Adapting services throughout the day to optimise operating costs', Section 5.1.2). The positive effects of a lower speed must thus in each case be weighed against the increase in journey time. A traffic model can be used to predict the impact of longer journey times on the attractiveness of the service.
  In theory, special tracks could also be used to add or remove cabins according to demand without interrupting running operation.
  The advantage: capacity adjustments have only a minimal effect on journey time due to the shorter interval between departures. However, this process remains a purely theoretical one for the time being. For existing systems, the removal or addition of cabins brings the system to a standstill, which is to be avoided unless absolutely necessary.

- **Over the course of the week**, the number of cabins in operation can be adjusted on different days depending on anticipated demand. For example – system configuration permitting – fewer cabins can be used on weekends, or more on days where events are expected to generate high traffic. However, the number of cabins must be set prior to commencing operation for the day, since subsequent adjustments result in downtimes and are therefore to be avoided.

- More cabins can be made available at a later point in the installation's **life cycle**, provided this option was incorporated in the planning phase and the system is designed to cope with additional cabins. Without this, subsequent adjustments to capacity are no longer possible. Provided the installation has been dimensioned accordingly, one option is to align the service with current demand initially, and then respond as demand rises over time.

The **reliability** of the timetable must at all times be the primary criterion for an attractive local public transport system. Ad hoc adjustments to address intra-day fluctuations in passenger volumes are to be avoided. Adhering to predefined speeds and the departure intervals communicated in the timetables is therefore essential for two reasons: it gives passengers certainty when planning their connections, and helps maintain the attractiveness of the system. There are, however, other ways to adapt capacity, such as by varying the speeds at predetermined times of day, or by varying the departure frequencies on different days of the week.

**Info box 5: Adapting services throughout the day to optimise operating costs**

Since energy consumption rises proportionally to the rope speed, and wear and tear on moving parts increases quadratically, adapting the speed has a direct effect on the operating costs. As the speed declines, so does the number of coupling operations required for detachable circulating ropeways, thus potentially lengthening the service intervals. (Note: the grips of detachable circulating ropeways must be inspected after every 5,000 coupling operations.) Setting an appropriate speed can thus have a positive effect on the operating costs.

The service can also be adapted and operating costs reduced by feeding an appropriate number of cabins onto the line. Deploying fewer cabins on off-peak days also reduces energy consumption, albeit to a lesser extent than reducing the speed would. The fewer empty runs that take place, the less wear and tear occurs, especially on the grips.

Service adjustments which could have a detrimental effect on passengers' end-to-end journeys must not be carried out during the day in response to current demand, but must instead be limited to fixed times or days communicated in the timetable on the basis of anticipated demand.

### *5.1.3 Capacity*

Appropriate dimensioning is a crucial part of any transport project. If the service is on too small a scale, capacity bottlenecks will ensue and comfort and attractiveness will suffer. Too large, and this will generate avoidable construction and operation costs. To predict anticipated demand for the cable car and to scale the service appropriately, the project should be calculated using a traffic model. This is particularly important for urban cable cars, since once the installation is complete it is no longer possible to swap out the technology, nor is it possible to increase maximum capacity later on due to the constraints imposed by the construction and/or the choice of cable car system. It is thus essential to consider an appropriate forecast horizon, so as to ensure that the installation continues to meet the prevailing demand. Project dimensioning is based on the outputs generated by the traffic model.

The capacity of a cable car is measured by how many people it can convey per hour and direction. Generally speaking, there are several parameters which can be adjusted to influence the capacity. These include:

- the cable car system
- the cabin size
- the speed
- the frequency

As continuous conveyors by design, circulating ropeways are capable of conveying more passengers than reversible ropeways. On the other hand, reversible ropeways can handle much larger cabins, but only one cabin or group of cabins can be used per direction of travel. The capacity of reversible ropeways declines as the length of the ropeway increases, whereas for circulating ropeways the length has no effect on the capacity.

When it comes to **dimensioning**, the decisive factor is the level of rush-hour demand in the load direction. The standard evaluation provides concrete figures for dimensioning purposes:

- Where journeys take no longer than 30 minutes on average, which is generally the case for urban cable cars, planning should be based on a maximum utilisation of 65 % of the seats and standing places, the latter based on four people per square metre.

- Where journeys take longer than 30 minutes on average, planning should be based on a capacity limit of 100 % of seats.

Adequate consideration must also be given to special areas for parking wheelchairs, pushchairs, bicycles, etc. In the case of circulating monocable aerial ropeways, which tend to have comparatively small cabins and no standing room, it is important to consider that wheelchairs or pushchairs will take up several seats that cannot be otherwise occupied. The capacities in these smaller cabins tend to be limited to one wheelchair plus one additional person or one bike plus one additional person. If special usage requirements are expected to be high on a connection, this must be given appropriate consideration during dimensioning.

Increasing the speed above standard can achieve only limited increases in capacity. As a rule, the greatest potential for increasing capacity is achieved by shortening the intervals between cabins. However, same as with the speeds, this has an impact on station sizes.

Urban cable cars do not have to be restricted to passenger transport. A conceivable alternative is to combine a passenger service with goods transport, either by incorporating mixed-use cabins capable of transporting both simultaneously, or passenger-only/goods-only cars. This unlocks new potential in particular for courier, express and parcel services, where incoming goods can be transported by cable car to a centrally located terminal for last-mile distribution.

## *5.2 Environment*

Like conventional local public transport, the cable car also has a certain environmental and economic impact on its surroundings. The entire life cycle of the urban cable car must first be evaluated if it is to be considered a sustainable means of transport.

### *5.2.1 Sustainability*

Sustainability and sustainable development mean fulfilling the needs of the present in a way that does not have negative consequences for future generations. Importantly, the three dimensions of sustainability – economic efficiency, social equality, ecological soundness – must be seen as equally significant. Planning must give balanced consideration to and weigh the three pillars of ecology, economy and society.

To ensure a complete overall picture and evaluation of urban transport systems taking these aspects into account, the accounting framework must cover the entire life cycle. All factors, influences and measures must be included and evaluated with respect to the available sustainability criteria, e.g. the United Nations' Sustainable Development Goals (SDGs), formed before, during and after system operation or the construction of infrastructure and buildings:

- Raw material extraction phase: the supply of all materials, upstream processing by suppliers, and transport from the supplier to the manufacturer's production facility or the construction companies

- Manufacturing phase: the resources required for production and the energy consumed

- Transport phase including assembly: the transport emissions generated between the plant gates of the manufacturer, building materials supplier or construction company to the usage location, including the emissions generated by assembly and installation

- Use phase including servicing: the energy consumption required to operate and service the technical installations and all infrastructure

- Disposal phase: decommissioning of the installation and associated transport and waste management

The technical system, infrastructure and the building must all be evaluated in respect of their ecological, economic and social footprint. Standard tools used in this context include the life cycle assessment, which offers a transparent way of measuring and evaluating $CO_2$ emissions, as well as life cycle costing, which looks at the entire life cycle of the installation. The social aspects are measured and/or evaluated on the basis of human-centric impacts.

### *Ecology*

In normal operation, cable cars are 100 % powered by electricity and produce **zero harmful local emissions**. A diesel back-up generator is used solely in emergencies (e.g. power outage) for passenger recovery. Cable cars travel high through the air and leave no discernible fine particle residues at ground level.

Since circulating ropeways do not operate on elevated track structure, merely requiring ground space for the construction of stations and pylons, they take up very **little ground space** overall, which in turn leads to **minimal soil sealing**. Generally speaking, the space required for stations and pylons is determined predominantly by the cable car technology used. However, the stations can swell to sizeable proportions due to the significant space needed for the stationary drive and brake mechanisms. By contrast, the pylons take up minimal ground space. The separation effect seen with road or rail infrastructure is virtually non-existent for cable cars. Most urban cable car ropeways are at a considerable height to ensure maximum flexibility for future construction projects along the path beneath. In urban spaces, the station building is often elevated (+1 level) in consideration of existing infrastructure so as to reduce impediments to existing private transport. By moving to a second transport level, the cable car preserves the building land beneath its path and enables the space to be used multi-functionally. Nevertheless, land usage beneath the ropeway route must not impact on the cable car operations. A further advantage is that cable cars are quick and simple to dismantle.

### *Economy*

In addition to the positive environmental effects of reduced soil sealing, cable cars, even systems with a high transport capacity, are **low energy users**. This is down both to their technical construction (mass ratios and wind resistances cancel each other out) and to the use of incredibly energy-efficient direct drives which transfer over 95 % of the power produced. The maximum performance of the cable car’s drive system is designed to withstand worst-case loading conditions. These must be determined taking all system-related and operational characteristics of the cable car into account (pursuant to EN 12930 ‘Safety requirements for cableway installations designed to carry persons – Calculations’). While the cable car must be able to continue running safely under such conditions, this performance is not necessary in daily operation. Given this, energy consumption cannot be determined merely as a product of the maximum drive power and operating time. Rather, energy requirements are a result of actual drive power multiplied by operating time. This is also affected above all by the type of system in question (monocable, 2S or 3S), since various different sources generate the frictional forces which have a major bearing on the amount of drive power required. On a monocable system, friction stems mainly from the movement of the carrying/haul rope over the support rollers, whereas on 2S and 3S systems friction is mainly generated by the running gear on the carrying rope. The gradient must also be considered when calculating the friction, since only the weight component of the roller load is relevant. The steeper the rope's incline, the lower the weight components.

Energy requirements must be calculated precisely for each individual cable car system. However, the standard evaluation (see Section 7.2.2) offers an approach to calculating energy requirements based on simplifying assumptions which take the special characteristics of urban settings into account. Since this is a generalised approach, it cannot achieve the same accuracy as an individual calculation of energy requirements would. Nevertheless, it is accurate enough to offer evidence of the economic efficiency of a project and can thus be used in the early stages of planning to provide a rough overview of the expected operating costs.

### *Society*

Urban cable cars can be deployed as a non-discriminatory means of transport. Equality and **participation** for all potential passengers is of utmost importance. These aspects are addressed in the previous sections in relation to the cabins and station design.

The topic of subjective safety was tackled in the workshops held with inhabitants of the 'high-flyer' cities. For citizens, guarantees of subjective safety (e.g. fear of heights, health issues) are paramount, for instance through the implementation of technical safeguards. Cable car cabins can be designed to accommodate this (see Section 6.1.1). The topic of height was also broached. For the workshop participants, the notion of travelling at the +1 level was unfamiliar and led to the general assumption that the height could be problematic. This, too, must be incorporated into planning and considered both during implementation and ongoing operation.

**Info box 6: Health and well-being**

The development of an enjoyable and comfortable infrastructure and transport system is an essential step towards reducing the stress factors we encounter daily such as noise, traffic jams and pollution. Health and well-being is becoming an increasingly prominent topic, and must be addressed if a new mode of transport is to be made attractive for inhabitants.

In a world that is constantly in flux, it is hard to imagine life today without this trend: it is already commonplace in many areas and industries. With a focus on health and well-being, the goal is to create infrastructure that people identify with and feel happy using. Support begins from the very first planning phase in order to prevent the need for modifications later on. The end goal should be happy, healthy users and employees, as well as an economically efficient system.

A variety of methodologies can be used to achieve this goal, including interviews and workshops to evaluate the needs of users and employees at close range. Others include stress tests, as well as monitoring and gleaning best practices from similar infrastructure systems, to identify potential and challenges, before condensing all insights into perfectly tailored recommendations for action. The health and well-being scorecard, which provides a tangible measurement of well-being, also forms part of the methodology. It is scored on the basis of the following questions:

- What is the visual appearance? Does it blend into the cityscape functionally and design-wise?

- What is the atmosphere in the stations or cabins? Is a colour and lighting concept in place? Are a variety of materials, furnishings, etc. used?

- How is the new system explained? Are there enough employees available to help users?

- Are steps taken to ensure a comfortable working environment for employees, e.g. by offering quiet space? Does the 'S' of environmental, social and governance play a central role, with factors such as occupational safety, wage parity and equal opportunities?

In conclusion, action to safeguard health and well-being is becoming an increasingly relevant part of our daily lives due to the positive effects on our welfare. Fostering the well-being of each individual in order to strengthen the community as a whole is more important than ever. Unrelenting progress in all areas of daily life brings with it rising pressure, for example, to balance life and work, while stress levels climb ever higher. In order to be seen as an attractive employer, it is necessary to win over not only potential users but also employees. The health and well-being concept should aim to structure the journey as comfortably as possible. The goal is to develop a mode of transport that addresses the needs of the surrounding area and the community. If a more comfortable and relaxed mobility solution is to be created for future users, it is essential not only to generate enthusiasm for the new project early on, but also to capitalise on this enthusiasm and leave a lasting positive impression. This can be achieved by taking steps to ensure that, rather than feeling overwhelmed by the new transport system, the public feels well informed, up to date and able to identify with it. The design of the cabins and stations, and consideration for the surrounding area, play a decisive role in achieving this.

### *5.2.2 How the cable car influences the environment (risk receptors)*

*Flyover privacy*

The cable car's path must **wherever possible pass over publicly owned land or agricultural/ commercial spaces**. Planning should aim to avoid using private land designated for residential use to the maximum extent possible.

The route corridor to be used when assessing the land that will be passed over is calculated by adding together the track gauge, the maximum lateral swing of the cabins, and the maximum oscillation of the ropes (based on the static rope line calculation). This equals the maximum track width, or 'installation threshold', which represents the horizontal clearance envelope required by the cable car (as per the site plan) excluding the necessary protective zones to other objects pursuant to EN 12929-1 'Safety requirements for cableway installations designed to carry persons – General requirements – Part 1: Requirements for all installations'.

Where the route passes over private property, permission must be obtained from the land owner irrespective of the cable car's suspension height (Article 903 German Civil Code [BGB]). The wording on the restriction of owners' rights in Article 905 BGB is vague: "The right of the owner of a plot of land extends to the space above the surface and to the subsoil under the surface. However, the owner may not prohibit influences that are exercised at such a height or depth that he has no interest in excluding them." For standard cable car suspension heights up to 60 metres above ground level, it can be assumed that the owner will be afforded the right of consent. Where it is not possible to find a route for the cable car that does not pass over private property, the right of veto granted to landowners in Germany could lead to the need for prolonged litigation. This is due to an extensive approval process which can vary from project to project, the duration of which cannot be foreseen (minimum process duration: one year).

From a technical and legal perspective, buildings, company premises (e.g. railway installations) and power lines may be crossed in compliance with the statutory provisions. As is the case when crossing other linear infrastructure, it is advisable to enter into corresponding **crossing arrangements** to clarify the technical details in particular. Irrespective of the question of easement when crossing private property, the focus in this context is on matters of fire prevention and rescue. Generally speaking, pursuant to EN 12929-1 'Safety requirements for cableway installations designed to carry persons – General requirements – Part 1: Requirements for all installations', circulating monocable aerial ropeways may operate at a maximum aerial height of 60 metres (exceptions are permissible with a special rescue concept); there are no height restrictions on cable cars with carrying ropes (reversible ropeways, circulating 2S systems, circulating 3S systems). In accordance with the technical provisions of EN 12929-1, in most cases vertical clearances of 2.5 metres between structures and the cable car clearance envelope and of 1.0 metre between the clearance envelope of roads and the cable car are sufficient, taking dynamic effects and risks as defined in EN 17064 'Safety requirements for cableway installations designed to carry persons – Prevention and fight against fire' as well as other dangers in accordance with the safety report into account.

*Shadows/reflections*

It is not generally possible to avoid a **shadow being cast** by a moving cabin over the course of the day. The intensity and size of the shadow cast by a cabin on the facilities and buildings below varies with the cable car's height. The higher the cabin, the smaller the effects of the shadow.

Detailed shadow predictions can be made using a 3D simulation taking all of the local characteristics into account. It will be periodically necessary to engage a corresponding expert to determine and evaluate the effects of the shadows cast with respect to their impact on people and animals for the project in question.

**Info box 7: Privacy when passing over residential property – smart glass**

**Smart glass** – also known as switchable glass – can be installed in cabins to safeguard privacy for residents who live in the vicinity of the cable car. Smart glass is a type of glazing that can alter its level of transparency. The energy this requires is powered either by electricity or by the sunlight shining on the glass.
Smart glass blocks passengers' view over sensitive route sections. At the same time, windows can be configured to obstruct a view down but to also prevent a sense of confinement, even where the glazing is non-transparent.

*Noise/vibration*

Compared to other transport systems, cable cars generate the **lowest noise emissions**. Emissions reduction is a planning task that falls to engineers or architects. It is also necessary to engage a corresponding expert to determine and evaluate the impact of the specific project.

Various technical and operational measures which can contribute to reducing noise emissions are provided below. These are taken from the Swiss Federal Office of Transport's directive on noise prevention in cable car installations. This list is not exhaustive.

*Technical*

**Optimise the installation locations**

- Maximise distance and use shielding (terrain, building sections, other buildings)

- Conduct sources of noise generated by the cable car operation (mechanical vibration) through the station foundations and into the earth. Depending on the distance to the ground and its composition, these sound waves can also be transmitted to neighbouring buildings. Where this is the case, the cable car foundation must be designed in such a way as to prevent transmission to neighbouring buildings, e.g. using special sheathing plates to isolate the vibrations

**Building planning**

- When planning a potentially integrated cable car station, it is important to ensure the station is structurally decoupled from the rest of the building to prevent the transmission of vibrations. However, if the design does include connection points (e.g. connection mounts for false floors on the station upright), these must include bearings designed to isolate the vibrations

**Façades: openings and shields**

- Avoid openings from high-noise spaces or ensure they are soundproofed

- Extend buildings/walls as far as possible over station structures to act as shields; integrate hold-down supports if possible

**Reduce echoes in halls**

- Soundproofing material used on the ceiling and walls reduces noise exposure for staff, customers and the environment

**Pylons**

- Solidly built pylon towers (thicker steel, fill steel tubing with gravel or concrete, concrete pillars)

**Drive type and positioning**

- A direct drive is quieter than a drive with gears

- Positioning of the drive in a suitable station or, e.g. in the lower ground floor

**Enclosure, undercover**

- Stable, soundproofed station cladding or stable undercover to combat the emission of station noise through the cladding

- As the technology currently stands, high-noise components including undercover are generally enclosed

**Optimise the rope type**

- A compact rope reduces vibrations

- Eight-strand ropes and ropes with special synthetic fillers can contribute to improving the vibrations generated by circulating ropes. These tend to run more smoothly than six-strand ropes

**Roller batteries (type)**

- Use a low-emission construction

**Roller batteries (roller spacing)**

- Align the roller spacing with the spacing of the cable strands to reduce vibrations

- **Pedestals, ladders, etc.**
  - Prevent loose parts from vibrating and striking each other

*Operational*

**Reduce speeds**
**(day and/or night)**

- Where viable, minimise rope speed (on standard, larger detachable cable car installations, the noise level drops by around 2.5 dB(A) per 1 m/s reduction in speed)

**Shunting speed**

- Where viable, minimise rope speed during shunting manoeuvres (most effective in off-peak times)

**Optimise the number of cabins on the rope**

- Reducing the number of cabins on the rope minimises the frequency of relatively loud and disturbing spurious noises

**Convoy operation**

- During periods of low passenger volumes, operate cabins in convoy formation, possibly bring to a stop in between

**Optimise operating hours**

- Limiting the operating hours has a direct effect on the noise rating level

**Info box 8: Environmental impact**

A key aspect of cable car considerations is the biogeographic analysis, which must be carried out periodically as part of transport, cable car and urban planning. As an investigation of environmental considerations, it looks at the **ecological and urban planning compatibility** of the project. **Constraints during the construction phase** must also be identified and evaluated as part of the environmental considerations for infrastructure projects.

Generally speaking, the analysis must begin very early on in the project and run in parallel to the ropeway evaluation. This allows rough statements to be obtained during evaluation on the likelihood of realisation, as well as on potential ecological or urban planning conflicts for the different alternatives, so they can be correspondingly incorporated into the examination of alternatives and any exclusion criteria defined. The investigation and evaluation of the project's impact on the environment and in particular the ropeway alternatives under consideration are central and mandatory elements of the examination of alternatives.

For a necessary environmental impact assessment, an analysis must be carried out on the environmental impact according to potential undesirable ecological effects. Environmental risk receptors can be examined based on the categories population – in particular human health – fauna, flora, biodiversity, land, soil, water, air, climate, landscape, cultural heritage and other risk receptors besides. The analysis determines and evaluates the impact of the project versus the status quo, and also takes interactions between the individual risk receptors into account. A quantitative or qualitative evaluation method and a benchmark for an environmental footprint can be used to evaluate the materiality of the impacts presented. The law in the respective federal state defines the legal bases and specific provisions applicable to an environmental impact assessment on the construction of cable cars.

For the purposes of the spatial vulnerability assessment, the study areas are examined and broken down according to the potential for conflict to arise. The potential for conflict arises in areas where the overlap of several risk receptors or a single risk receptor gives rise to a particularly high spatial vulnerability.

As a rule, it is expedient to use the environmental impact assessment risk receptors defined in the respective federal state regulations or, if referred to, those in the Environmental Impact Assessment Act (UVPG) as the basis for the evaluation, and to classify and evaluate these risk receptors for the individual project. Major planning conflicts resulting from particularly high spatial vulnerabilities can be bypassed or minimised by, for instance, making structural adjustments or modifying the ropeway route. This is followed by a discussion of the influence quantities for humans – in terms of urban design and the environment.

The spatial vulnerability assessment gives rise to the need to additionally examine alternative ropeway route options, thus making it possible to pursue the alternatives that achieve the project goals while taking best account of spatial vulnerabilities. From a nature conservation perspective, it may also be necessary to review alternatives if the project encroaches on certain protected areas. The examination of alternatives is therefore one of the essential preconditions for a derogation procedure in accordance with the Habitats Directive (FFH).

## *5.3 Urban integration*

Needs-based transport infrastructure is essential for cable cars as a mode of transport and urban mobility solution. Not only must this **transport infrastructure, as a new component of the urban environment,** be integrated into the cityscape with respect to its technical dimensioning, but also into existing and emerging urban spaces. This is due to the spatial impact of the elements of the cable car system. Elements requiring integration are the stations, including the station building, and the ropeway route, consisting of pylons, ropes and carriers (cabins), each of which has a different spatial effect. These guidelines pertain both to the potential and limitations of the cable car system, and to the architectural, visual and design aspects of urban planning along the ropeway route.

### *5.3.1 Cable car stations and their significance for the urban environment*

The station and station building constitute a major component of the cable car system. In addition to their **technical significance** as the housing for the drive, return and other essential systems, the stations are also used for **boarding and deboarding**. Cable car stations can take virtually any shape and size provided they fulfil the overall purpose and their function within the system. Stations generally fall into the following categories:

- Drive stations and return stations: these house the main technical components of the drive system and are used for boarding and deboarding.

- Intermediate stations: the option to incorporate intermediate stations allows passengers to board and deboard at key transit hubs.

- Turn stations: due to the limited ability of cable cars to go around corners (see info box 'How cable cars navigate corners', Section 5.3.2), certain ropeway routes will require the construction of a technical turn station to allow a change of direction. Intermediate stations can be combined with turn stations to synergistically leverage the technical and transport benefits.

Cable car station design is extremely flexible, which offers a clear advantage. Minimum sizes are determined by the technical configuration. The minimum station sizes vary according to the system and speed. In addition to the technical side are the other demands and requirements applicable to the station's transport infrastructure hubs, as well as further functions in the station context. These are described below.

*Urban development*

The spatial impact of the cable car on the urban surroundings arises essentially from its direct effects on traffic. The choice of station location has an attendant effect on the area's **reachability**. The area around the station experiences a positive benefit from this improved reachability. At the same time, the additional traffic generates undesirable and disruptive effects.
**Urban integration** must aim to minimise these negative effects and leverage the improved reachability and ensuing traffic as a means of promoting development for the area/quarter. Cable car projects can thus have a **positive effect on urban development**.

The choice of station location can, provided it forms part of a holistic urban planning concept, elevate the project to that of urban generator. As a result of the higher traffic volume, the location can reap advantages from its improved reachability with strengthened services in the surrounding area and attract further functions, such as social services, cultural facilities or service companies to the district. The goal is to best unlock potential synergies to conscientiously reshape and further develop the area along the planning horizon, without causing lasting damage.

Similar to railway stations, cable car stations are seen as entry portals to parts of the city. Appealing station design can shape the identity of the city quarter and strengthen the cable car's urban generator effect. Consequently, in an urban context the appearance of the station in terms of its architectural quality plays a crucial role.

**Urban cable cars must be integrated into local public transport and ecomobility.** This results in the need to facilitate **passenger transfers**. The routes between transit connections must be short and accessible, and stations on the +1 level must offer lifts and, if necessary, also escalators. It is expedient to create a structural **link between cable car stations and mobility hubs or mobility stations** (see Section 3.6). In view of the potential for connecting passengers, particular consideration should be given to linking local last-mile mobility services. The possible integration of logistics activities is yet another area worthy of further investigation. This could take the form of structurally connected collection-only points or consideration of the site's suitability as a small logistics and distribution centre.

Since the creation of a cable car station necessarily involves encroaching on the existing city structure, whether new or old buildings, individual project-specific planning is essential. In view of the need to accommodate both technical and urban planning imperatives, studies and expert opinions should be obtained on the key planning aspects. An urban planning study – in the form of an outline plan or urban planning concept – which analyses demand according to the respective situation taking use, coverage and potential space into account appears to be an expedient approach to urban integration.

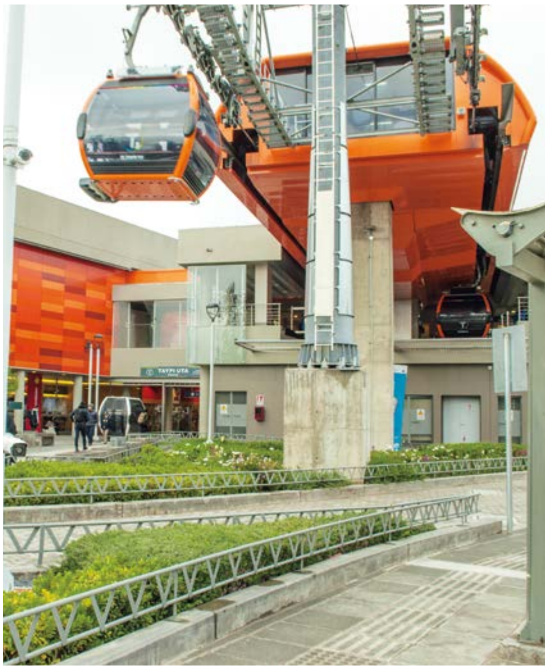
**Info box 9: Station design in Portland**

The Portland Aerial Tram stations in Portland, United States, are a showcase for the flexibility of station architecture. The lower terminal is a successful example of intermodality (with connections to a streetcar, bicycle parking and other mobility options) housed in an airy pavilion-style building. Due to space constraints, the upper terminal features a structurally separate adjacent projecting deck for tickets and boarding, supported on concrete pillars.

*Station architecture*

International examples of urban projects demonstrate the versatility of cable car station architecture. Whereas the stations of the Roosevelt Island Tramway in New York City, United States, are relatively compact, many of the Mi Teleférico station buildings in La Paz, Bolivia, are much larger and incorporate additional facilities such as shopping amenities.

The architecture of a station is dependent on the limitations of its environment. A key factor is the availability of space. Given this, the first step is to determine the elevation of the cable car station. This will usually be either at-grade (0 level) or grade-separated (+1 level). The station can also be either a solitary (detached) structure or integrated into an existing building structure.



Examples of different station constructions
(La Paz, Koblenz and London)

Space permitting, in most cases the standard solution is to build a solitary structure at the 0 level. Technical infrastructure can be complemented by accommodating additional functions for the building. Furthermore, the station can also be integrated into the structure (open/enclosed construction) of groups of buildings. The station shell and the cable car infrastructure can be built independently of one another. This allows the stations to vary considerably in terms of style, shape and size without the need to make any major adjustments to the technical infrastructure installations.

Special constructions include elevated stations or bridge designs. Grade-separated stations must include ramps, lifts or similar to safeguard full accessibility. It is also important to note that elevated station designs involve higher costs. The space created beneath the elevated structure can be marketed or built over with the station in the context of existing transport infrastructure. When it comes to integration into buildings, examples show a diverse range of technical possibilities. Stations can be found atop buildings, in high rises and in lower ground floors.

*Design*
With regard to the acceptance of the cable car system and its potential to serve as an identifying feature of the area, it is clear that great weight should be attached to the station design from the outset. The design of the cable car elements can be coordinated with the surrounding area to create a **harmonious overall appearance**. A conservative design can allow cable car installations to be integrated discreetly into the cityscape; by contrast, eye-catching architecture can be used to create an **attraction and distinguishing feature** of the city. The requisite ground space and structural integration will vary accordingly.

A number of international examples showcase a variety of station designs. In La Paz, the station buildings are the same colour as the lines they serve, which improves the recognition factor and helps with passenger orientation. In Lisbon, Portugal, home to the Teleférico do Parque das Nações, a blue-and-white colour scheme was chosen for the stations built on the water. The London Cable Car in the United Kingdom uses a contemporary station design that also blends in well with its surroundings. From a technical perspective, the sky is the limit when it comes to designs for this promising mode of transport. An appealing design is to be weighed against the investment costs and location requirements.

An urban planning competition can offer a suitable method for finding a solution that meets the various user interests in the urban context combined with an appealing design.

### *5.3.2 The route and its impact on the surrounding area*

Not only the station buildings, but also the ropeway route – including cabins, grips, pylons and the rope itself (see Section 6.1.1) – must be integrated into the cityscape. Since the grip and the rope are essential, unalterable components of the system, they are of lesser importance for urban planning. The focus instead is on the ropeway route as a linear structure including the spatial impact of the route corridor, the pylons as the highest points of the construction, and the cabins as a moving element within the urban landscape.

*Route corridor*
Ropeway routes pose particular challenges for the city and road space. The large clearance envelope required by the pylons and ropeway means the cable car system takes up a substantially sized corridor of urban space. A **carefully considered route** is thus crucial to the acceptance of the cable car system and its urban integration. In particular, the benefits and potential offered by the cable car should be leveraged and weighed against the other modes of transport in terms of spatial encroachment.

**Info box 10: The technical design of the ropeway route depends on the cable car technology**

The choice of cable car technology determines the width of the ropeway route. The following parameters are decisive:

- **Track gauge:** This is largely dependent on the lateral displacement of the rope and the lateral movement of hangers and cabins in maximum crosswinds on the longest rope span. The standard track gauge depends on the manufacturer and is 6.0 to 6.5 metres for monocable aerial ropeways; around 10 to 11 metres for 3S systems; and around 9 metres for 2S systems.

- **Cabin width and lateral movement:** Although smaller, the cabins of circulating monocable aerial ropeways experience greater lateral movement, partly due to their 'singular fixed point in space'. A zone of around 3.0 metres on all sides must therefore be incorporated for all technologies.

- **Lateral cable oscillation:** The calculation must also include the space taken up by the oscillations of the rope itself, which can vary depending on the pylon span. This is also determined by the maximum operating wind speeds; depending on the length of the free rope span, values can be from 0.5 to 3.0 metres in each direction.

- **Distance to buildings:** EN 12929-1 'Safety requirements for cableway installations designed to carry persons – General requirements – Part 1: Requirements for all installations' requires an additional horizontal protective zone of at least 2.5 metres to be incorporated for accessible buildings passed by the cable car. However, in practice EN 17064 'Safety requirements for cableway installations designed to carry persons – Prevention and fight against fire' has proved the more influential standard in this regard.

Excluding the oscillations of the rope, planning should be based on a lane width of around 13 metres for a circulating monocable aerial ropeway, around 16 metres for a 2S system, and around 18 metres for a 3S system. Where ropes are subject to extensive lateral oscillations (on systems with large free rope spans), nominal lane widths of 21 and 24 metres respectively should be used.
The lane width of a reversible ropeway is around the same as that of a 3S system.
The technical term for this maximum lane width is 'installation threshold', which represents the horizontal clearance envelope required by the cable car excluding the necessary protective zones to other objects as defined in EN 12929-1.

A distinguishing feature of cable cars is their **minimal ground space requirements**. As a linear civil engineering structure, the cable car does not cause the dissection effect typically experienced when a flat route corridor is designed for one-dimensional use. Flying overhead at the +1 level has the advantage of creating, or at least retaining, usable urban space at the 0 level. This **multi-dimensional use of urban space** unlocks potential solutions for a very current problem faced by cities in Germany. There is often a great deal of contention in public spaces between the various claims on use: waiting areas, green space, open space, as well as the allocation of space to local public transport, private motorised transport, non-motorised private transport and stationary traffic. The cable car **resolves contention by travelling at the +1 level**. In Germany, cable car installations for national and state garden shows have shown that the space beneath the cable car route remains available for other use and can be freely utilised to offer a high quality of life. This potential to **freely design** the urban environment due to the minimal space requirements is an important argument in the cable car's favour.

Compared to alternative rail-bound projects at the 0 level, the cable car route is a linear engineering structure that requires virtually no additional separation or barriers with the concomitant effects these have on urban spaces. Urban planning benefits from the added space unlocked by moving transportation to another level and room is left for urban life.

The multi-dimensional use of urban road space must also be weighed when considering ropeway routes. While it is technically possible to continue using road space in parallel to use as a cable car route, steps must be taken to ensure that this does not jeopardise the cable car's safe operation. Routing cable cars over roads requires alterations to be made to the road cross-sections at targeted points to create space for pylons and stations. Cross-sectional alterations are already being planned in a large number of cities to redistribute the space allotted to cycle paths, footpaths, bus lanes, etc. In all of these cases, road space is being reduced; the number and/or width of traffic lanes is shrinking. France shows us how integrated planning can work for new tram tracks: space is always incorporated for pedestrians, bicycle traffic and street greening, as well as for urban regeneration to take place in parallel. In Germany, a project of this nature would require the involvement of experts in cable car/route planning at an early stage to help draw up a master plan and to support the subsequent route selection and detailed planning.

Given the negative and disruptive effects caused by the cable car (see Section 5.2.2), a carefully considered route is essential. Cable cars are not automatically the right solution for all urban spaces. Since they are particularly well suited to **public spaces**, this should be given special consideration in planning. The advantages of transport that flies overhead can also be leveraged in urban industrial and business parks, which likewise appear to be an unproblematic option. Where the route passes over private property, the 'not in my backyard' effect is to be anticipated.

**Info box 11: How cable cars navigate corners**

Horizontal changes in direction are challenging for cable cars. Cabins must be decoupled from the rope in order to navigate horizontal curves. Since this is generally only possible in stations or station-like structures, route flexibility is correspondingly limited.

Changes in direction require the installation of intermediate or turn stations. These intermediate stations can be turn-only with no passenger transfer, or turn stations with passenger transfers and platforms. It is often expedient to build intermediate stations at points in the track where changes of direction are necessary, so as to keep the number of buildings to a minimum. Where minor horizontal changes of direction are required along the ropeway (e. g. to avoid passing over private property), the maximum permissible thresholds (around 8 degrees) will be analysed and defined as part of the static rope line calculation.

Some cable car projects were thwarted very early on due to the rapid emergence of concerns relating to the preservation of monuments or the effects on the cityscape. It is thus essential to consider cable cars from an end-to-end perspective from the outset and to suitably integrate potential projects into local urban development planning. The goal is to seek coordination with the responsible authority and **weigh the disruptive effects** early on. This should involve a study of the effects on listed buildings, installations or ground monuments in close proximity to the cable car system's building structures, as well as the effect of sight lines and any negative impact on historical significance.

In historic cities in particular, protective zones must be incorporated. Here, it is very likely that potential ropeway routes will pass through confined spaces; this is where the transport benefits of the cable car system come to bear due to its minimal ground-space requirements (pylons and stations). Compared to, e. g. bus rapid transit systems, cable cars take up less space. Where the routes of bus rapid transit systems and ropeways pass through historic parts of the city, a detailed examination is required.

An international comparison of use cases reveals large variations in the routing of ropeways. Whereas the Roosevelt Island Tramway in New York City, United States, the Portland Aerial Tram in Portland, United States, the Teleférico do Parque das Nações in Lisbon, Portugal, the London Cable Car in London, United Kingdom, and the Téléphérique de Brest in Brest, France, exclusively operate above undeveloped or commercially used land or public roads, the Metro de Medellín in Medellín, Colombia, the Mi Teleférico in La Paz, Bolivia, the cable cars in Algiers, Algeria, and the Keçiören Teleferik in Ankara, Turkey, pass over entire residential areas. The Rittner Seilbahn in Bolzano, Italy, also passes over residential buildings along parts of its route. The option to pass over privately owned spaces adds flexibility when identifying potential ropeway routes and enables optimal links to be created to existing local public transport installations, including in densely populated areas. However, it should be assumed that, in Germany, it will be easier to realise ropeway routes which pass over public spaces. The applicable legal bases, as well as acceptance among the public of a cable car in their direct living environment, are decisive factors when identifying a route. In addition to technical design and planning, **civic participation** and **legal counsel** are two further key elements of route planning.

### *Pylons*

Pylons add new high points to the urban landscape and become elements that shape the cityscape. This requires a **great degree of sensitivity when dealing with the positioning and design** of the pylons. In urban spaces, planning must thus focus not only on technical dimensioning, but also on the design aspect.

The number, position and shape of the pylons all have a major impact on the cityscape. Their size is determined first and foremost by the technical dimensioning requirements. The height, the ground space required for the foundations, and the circumference/width of the pylon are determined by the system type, system capacity and the distance between pylons/free rope span. The local topography also influences the number of pylons required.

Examples of different pylon constructions (Brest, Toulouse)

Like with the stations, in an urban context it may be necessary to move away from conventional pylons designed purely for function (tubular or lattice steel pylons). A more appealing design that harmonises with the local surroundings can be used to enrich rather than disrupt the cityscape. Technical advancements in the industry now mean that pylons can be designed to meet individual requirements. Best practice examples show that pylons are no longer purely functional, but that their form can help shape the cityscape. The manufacturers make it possible to come up with multiple draft designs. Given a carefully and considerately chosen ropeway route, the clever positioning and design of slimline pylons can minimise intrusion and integrate the structures into the city skyline. On the other hand, it is also possible to design architecturally striking pylons and stations that enhance the cityscape with their unique form. Having said that, the additional costs involved must also be taken into account. The architectural design of the pylons could be included as part of an urban planning competition. It is advisable to have a rough design concept in place in addition to the urban planning study and in parallel to the station building.

Planning must also consider the proximity to other building structures that shape the cityscape. The aim is to prevent an unintended situation of conflict with existing structures of significance. **Lines of sight** to high cable car pylons and the attendant impact must be depicted early on in the planning phase. A large-scale study is required on where the pylons intrude on sight lines and where they can serve as a new element and landmark of the cityscape. In addition to 2D plan views, a suitable method could be to use a 3D representation of critical sight lines and high points. A 3D representation can be a particularly useful tool in political decision-making and for civic participation.

### *Cabins*

Cabins are the vehicles of the cable car system and, as such, constitute a new, moving planning element in the urban space. Cabins can be built and designed in all different shapes and sizes. The standard dimensions vary by system and can be enhanced with a variety of configuration options.

The impact on the cityscape depends on the number, size and design of the cabins. Cabin **design** thus plays a major role in the overall process, but especially in terms of improving acceptance of the system. Importantly, the design can be entirely unique and should be incorporated into the end-to-end communication design concept.

Public transport systems across the globe tend to look and feel very similar. This suggests that branding should be designed in line with other public transport systems. People expect certain aspects of public transport to be confidence-inspiring and easy to understand. The cable car's branding can help it to appear as an integrated element of the public transport system/network and thus foster acceptance.

The cabins offer further potential for incorporating identity-enhancing design that doubles up as advertising space. 'Identity enhancing' here refers to the effect that a particularly attractive design can have on acceptance by society as a whole. Sponsorship in particular offers added financing potential. Advertising income can help to offset the implementation costs for the system in certain areas. The suitability of advertising appears to make most sense where there is a regional link to companies, and potentially also for the specific part of the route in question.

While cable cars offer a certain tourist appeal and the prospect of an exciting experience, the flying cabins can pose challenges in an urban setting due to the resulting sight lines.

Cable car planning must include an initial **compatibility review** in respect of the impact of the cabins on the surrounding area. For example, cabins must not cause a distraction that can pose a safety hazard for other modes of transport. Where a ropeway passes over a motorway, unsafe distractions can be avoided by ensuring there is no view into the interior of the cabins.

The sight line from the cabin is also cause for concern. When building cable car installations, care should be taken to avoid, wherever possible, passing over sensitive areas of land such as residential areas. However, smart glass technology can be used where this is not possible (see info box 'Privacy when passing over residential property – smart glass', Section 5.2.2).

Examples of different cabin constructions (La Paz, Portland and Koblenz)

# 6 Technical infrastructure and operation

Choosing a suitable cable car system and ensuring it operates reliably are key to the success of an urban cable car. Knowledge of the technical characteristics is an essential part of selecting a suitable system with appropriate dimensioning. Concepts must be created to safeguard the smooth operation of the system and staff must be given the necessary training.

The following section takes a closer look at the technical and operational components of a cable car system as known at October 2022.

## 6.1 Technical infrastructure

Cable cars are closed systems in which all components are designed to work together seamlessly. The selection of a suitable system and the dimensioning of the individual components are dependent on the project circumstances and the requirements regarding the individual system itself. In principle, a cable car can offer a suitable solution for various use cases in local public transport.

### *6.1.1 Components*

The points below cover the primary components of an (urban) cable car which must be considered in planning and designed in line with the prevailing requirements and circumstances.

#### *Stations*

The **space required** for stations and pylons is determined primarily by the cable car technology used. It should be noted here that the ground space required by an elevated arrangement of the passenger platforms on an upper floor is limited to the cross-sections of the support framework.

The station length required for circulating ropeways – both terminal stations and intermediate stations – is determined chiefly by the length of the braking/acceleration paths. These paths are necessary in order to slow the cabins to crawl speed or to a complete standstill, and then accelerate them back up to running speed. Their length therefore depends on the maximum rope speed. Reversible ropeways do not require braking/acceleration paths in the stations, meaning the stations can be shorter.

The width of the stations is determined by the track gauge of the respective cable car technology, the cabin widths and the station equipment of the different manufacturers.

Space must be included in the stations for the necessary signalling and control technology, power supply systems, communal areas for staff, workshops and storage space for cabins not in use. The cabin storage system can be adapted flexibly in line with the local conditions and can be chosen independently of the specific cable car system. Space requirements are also determined by the expected visitor traffic to and from the stations and hence also by the dimensioning of the waiting/queuing areas and access routes. Due to their largely modular construction, cable car stations offer diverse options for a customised design that can be incorporated into existing structures.

In the case of elevated stations, vertical access is provided by staircases. Lifts must also be incorporated in order to meet the **accessibility requirements** applicable to publicly accessible installations (see Section 6.1.4). Full architectural freedom can be exercised when designing the exterior shells of the stations, which can be adapted individually to the local surroundings (see Section 5.3.1). However, the design must take into account the positions of the supports as determined by the support structure.

#### *Drive*

Depending on the requirements of the project, the drive will be configured as an overhead or underground drive/drive-tension station. The drive consists of a drive motor, a service brake, a safety brake and the gearbox. Alternatively, a direct drive can also be used as a suitable drive system for cable car constructions.

*Pylons*

Tubular steel pylons have become the established standard for circulating monocable aerial ropeways, while lattice steel pylons are generally used for 2S and 3S systems. Tubular pylons require a central concrete base, and lattice pylons stand on four separate concrete bases. The individual pylons are constructed from tubular steel in a combination of lengths, diameters and wall thicknesses. While special pylons are possible in principle, this will affect the costs and should be reviewed on a case-by-case basis.

Depending on the local topography, the pylons can be disassembled for transport to the site and reassembled on location. Special pylons are pylons of more than 30 metres in height and are constructed as tubular pylons with multiple legs or as lattice pylons.

*Roller battery*

The roller batteries guide the carrying/haul rope along the track. Each roller battery is constructed from multiple rollers. The number of rollers depends on how much load the rope is required to carry. Every roller is made up of a base body, a roller ring and a side board.

*Rope*

Steel ropes are constructed from multiple strands that are twisted around the rope core. The ropes are manufactured by specialist companies and spliced on site.

*Control system and drive electronics*

The cable car control system monitors the safety of the installation, displaying real-time data and all necessary information on a system dashboard. The functions necessary for operation can be activated via the control system. The drive electronics control the travel speed and how the installation responds when cabins enter and stop.

*Cabins*

Several manufacturers build standard 10- or 15-passenger cabins with a modular construction. Seat widths vary by manufacturer, from 425 to 450 millimetres (standard for local public transport). The cabins can be designed to accommodate the needs of individual user groups (e.g. incorporating folding seats to enable the transport of bicycles and wheelchairs). Modern cabins can also be upgraded to include the following elements:

- Heated seats, ventilation
- LED interior lighting
- CCTV
- Wi-Fi, audio/video link
- Swing/pivoting windows
  *(anti-litter design: this is a special type of window opening that prevents items from being thrown out)*
- Further technical features as required

Additional underfloor and baseboard ventilation channels can deliver passive ventilation into the cabins. Fresh air can also be introduced via swing/pivoting windows. Active ventilation or air conditioning can also be installed. However, the lack of power supply along the route and the limited battery capacity means such systems involve additional costs and make little sense from an energy perspective given the amount of time the cabins spend in the station with their doors open.

*Grips*

There are two types of grips that can be adapted to the requirements of the respective systems: fixed grips and detachable grips.

Detachable grips have only one moving part: the grip jaw. The grip opens and closes directly without cams, joints or lever systems. In its normal position it remains closed.

Fixed grips have been used for many years and are constructed from two drop-forged main parts that are affixed to the rope.

### *6.1.2 Cable car systems compared*

The cable car systems found most commonly in urban settings are detachable circulating gondola ropeways configured either as monocable, bicable (2S), or tricable (3S) systems. Fixed grip systems, such as reversible aerial ropeways, can also be considered as a more cost-effective solution, provided they meet the requirements profile. However, they are only suitable for end-to-end connections without intermediate stations.

The different cable car systems are contrasted below. The metrics provided are based on experience gained in real-world operation (including from international examples of urban systems) and have been adapted to local public transport operation and requirements. Plausible values were determined in particular for the cabin capacity and thus overall passenger capacity taking the requisite standing room and special areas for parking into account. As is the case for other conventional local public transport, the number of standing places is thus derived not from the technically permissible maximum threshold but instead is calculated at 0.25 $m^2$ per person. It should be pointed out that these metrics are guide values and may differ depending on the particular design and prevailing circumstances and requirements of the specific project. The technically permissible maximum thresholds for these parameters may be higher.

### *Detachable systems*

The key difference between circulating monocable aerial ropeways and 2S and 3S systems is the function of the rope. Circulating monocable aerial ropeways work using a rope called the carrying/haul rope, which at once both carries and pulls the cabins. On 2S and 3S systems, the cabins are carried (carrying rope) and moved (haul rope) by two separate track ropes or rope clusters. The 3S system is a 2S system but with two track ropes.

*Figure 13:*
*Circulating monocable aerial ropeway*

The cabins are clamped to the endless carrying/haul rope via detachable grips. The cabins travel at a different speed when in the stations as opposed to on the open track. Upon leaving the station, while still on the rails, mechanisms accelerate the cabins from the station crawl speed (< 1.8 kph) up to running speed (max. 22 kph) and the grip closes, attaching the cabin to the rope. The same procedure in reverse takes place upon arrival at the station.

| | |
|---|---|
| **Number of ropes** [units] | One rope as carrying and haul rope |
| **Total capacity** [persons/hour/direction] at 30s intervals | 960 – 1,200 |
| **Cabin capacity** [persons] | 8 – 10 |
| **Track gauge** [metres] | 6 – 6.5 |
| **Speed** [kilometres/hour] | 22 |
| **Section length** [metres] | 5,000 |
| **Pylon span** [metres] | 200 – 300 |
| **Track width** [metres] | 16 – 20 |

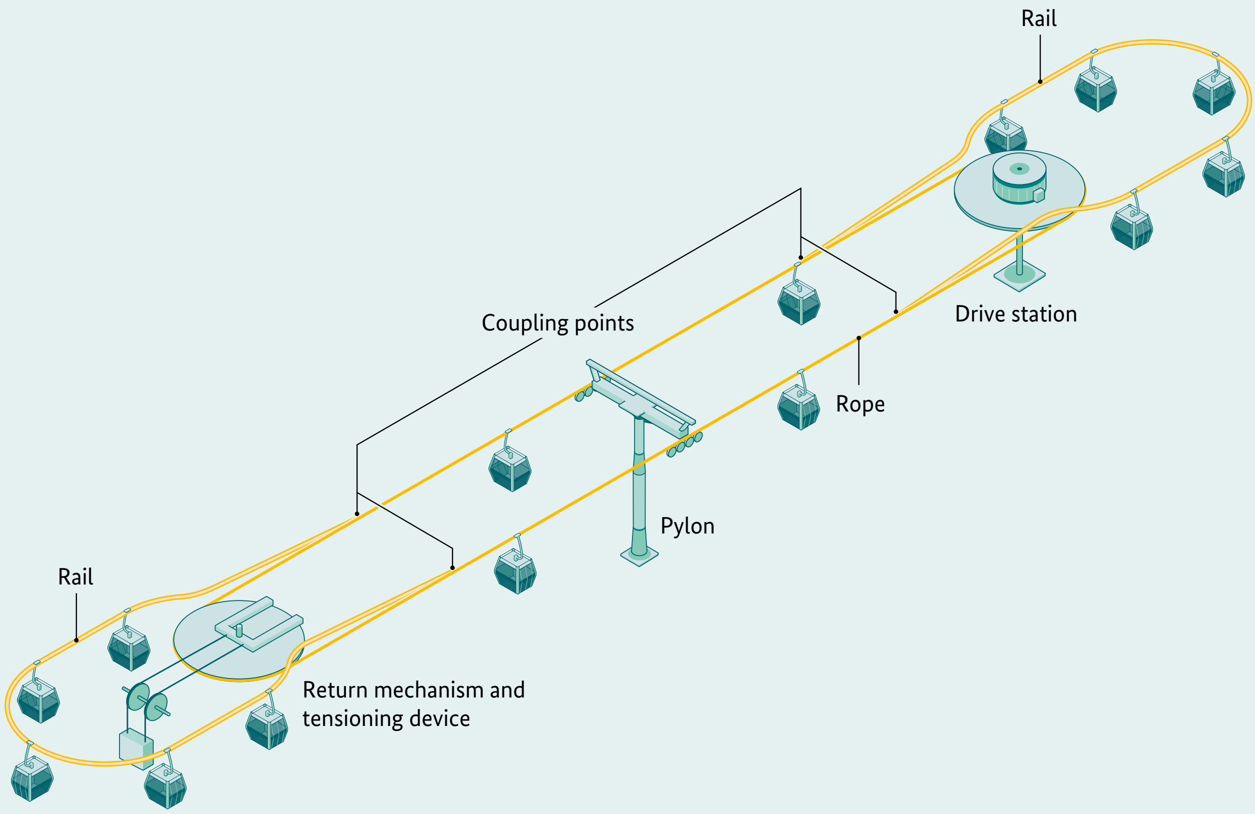

Rail
Coupling points
Drive station
Rope
Pylon
Rail
Return mechanism and
tensioning device

*Figure 14:*
*2S system*

Circulating bicable ropeways use two different types of rope: one for carrying and one for hauling. Each lane has a haul rope that is anchored in a station and kept under constant tension in the partner station with weights or hydraulic tensioning devices. The cable car cabins are equipped with running gear which runs on the carrying rope. The cabins are propelled via the haul rope. This is an endlessly spliced rope that moves continually in the same direction at a constant speed. Detachable grips clamp the cabins to the haul rope.

Cabins arriving at the stations leave the carrying rope and transfer onto a running rail installed in the station. The grips release from the haul rope. Tyre conveyors slow down the cabins to enable passenger transfer at a significantly reduced speed or at a complete standstill. Following passenger transfer, the cabins are accelerated back up to the same speed as the haul rope and re-coupled to the haul rope.

In contrast to circulating monocable aerial ropeways, 2S systems are capable of realising longer free rope spans between the pylons and longer track distances (section lengths), since the cabins are carried and hauled by different ropes. 2S systems can also be configured with larger cabins (up to 15 people).

| | |
|---|---|
| **Number of ropes** [units] | Two: one haul rope, one carrying rope |
| **Total capacity** [persons/hour/direction] at 30s intervals | 1,200 – 1,800 |
| **Cabin capacity** [persons] | 10 – 15 |
| **Track gauge** [metres] | 9 |
| **Speed** [kilometres/hour] | 25 |
| **Section length** [metres] | 6,000 |
| **Pylon span** [metres] | 500 – 750 |
| **Track width** [metres] | 19 – 22 |

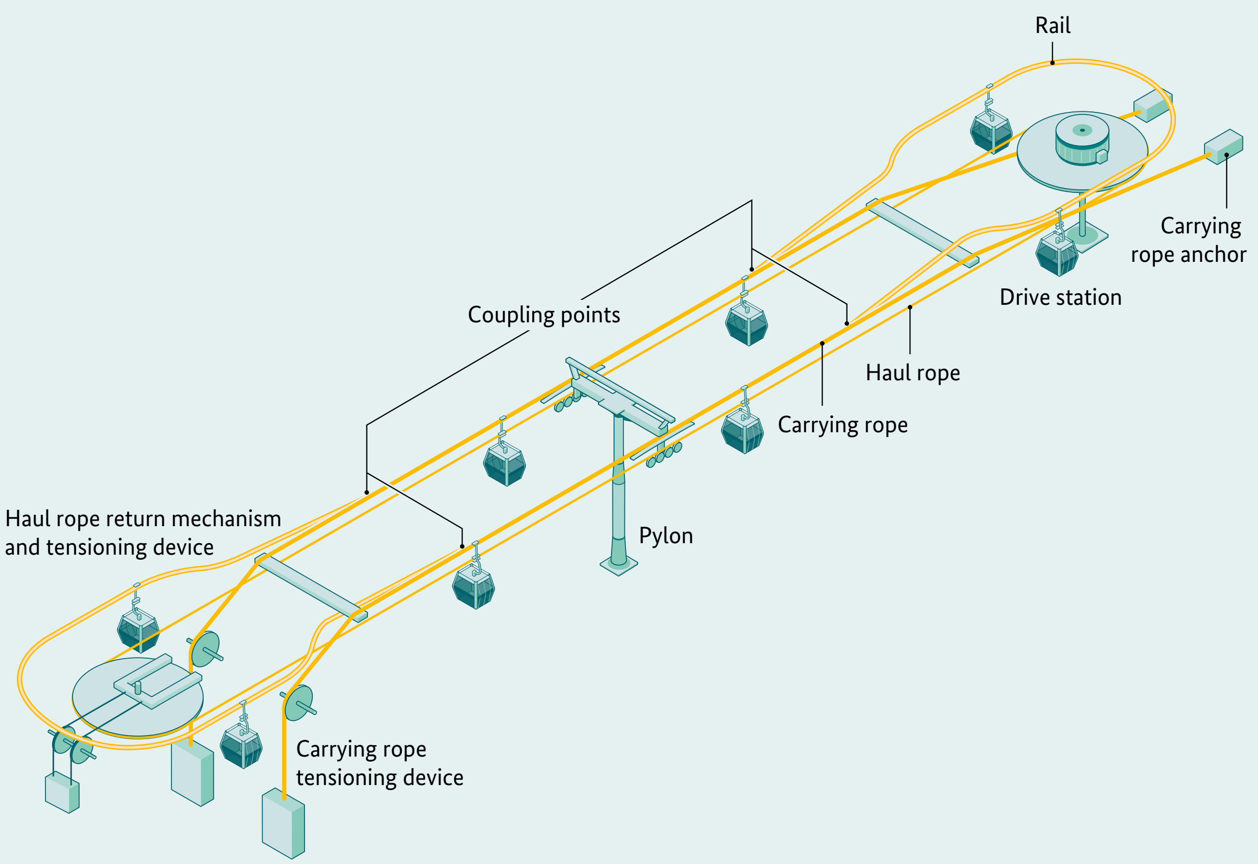

Rail
Carrying
rope anchor
Drive station
Coupling points
Haul rope
Carrying rope
Pylon
Haul rope return mechanism
and tensioning device
Carrying rope
tensioning device

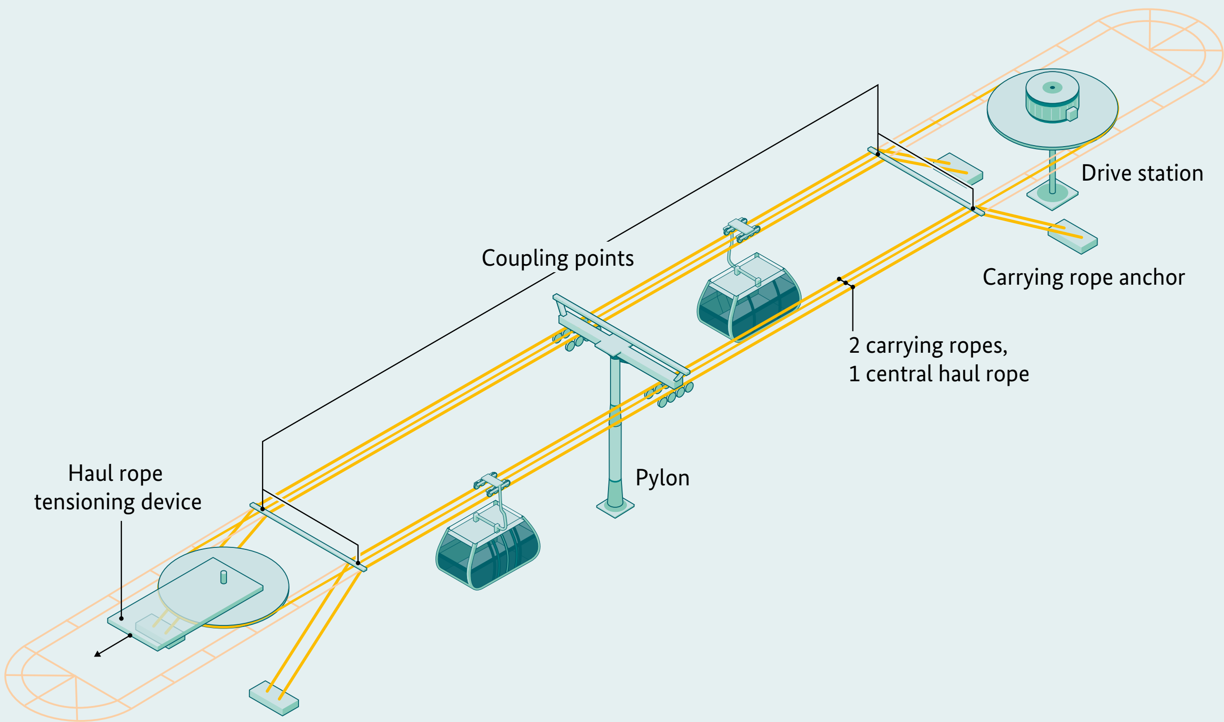
*Figure 15:*
*3S system*

A 3S system is essentially a detachable circulating 2S system with two anchored carrying ropes and an endlessly spliced haul rope. There are three ropes for each lane of travel.
A major advantage of this system is the long free span of the haul rope using rope supports mounted to both of the carrying ropes (intermediate supports). This rope arrangement not only supports the haul rope but also helps to stabilise the carrying ropes. The use of two carrying ropes makes the 3S system very stable in windy conditions.

In contrast to the 2S system, the use of rope supports on the haul rope reduces the prestressing force path of the haul rope loop. Mainly, however, the 3S system enables very long free rope spans to be realised between two pylons.

All 3S systems have detachable running gear with eight rollers, four per carrying rope. The cabins travel through the stations at walking speed propelled by tyre conveyors. The cabins of 3S systems can carry up to 35 passengers.

| | |
|---|---|
| **Number of ropes** [units] | Three: one haul rope, two carrying ropes |
| **Total capacity** [persons/hour/direction] at 60s intervals | 1,800 – 2,100 |
| **Cabin capacity** [persons] | 30 – 35 |
| **Track gauge** [metres] | 10 – 11 |
| **Speed** [kilometres/hour] | 29 |
| **Section length** [metres] | 7,000 |
| **Pylon span** [metres] | 800 – 1,000 |
| **Track width** [metres] | 21 – 24 |


Coupling points
Drive station
Carrying rope anchor
2 carrying ropes,
1 central haul rope
Haul rope
tensioning device
Pylon
Carrying rope anchor

*Fixed grip systems*

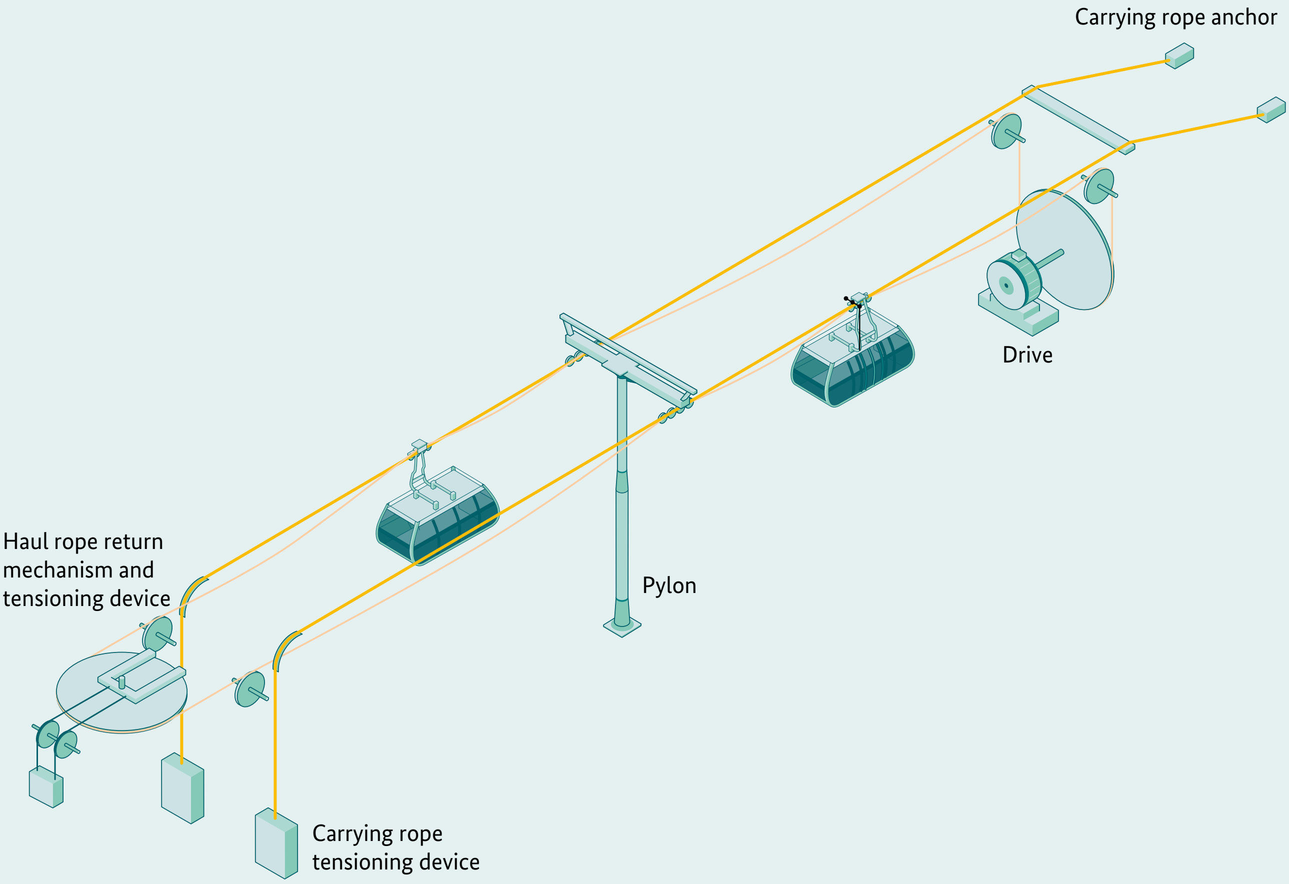
On fixed grip systems, the cabins are permanently clamped to the carrying rope and cannot be detached automatically during operation. The rope power train brings the cabins to a standstill when they arrive in the station.

*Figure 16:*
*Reversible aerial ropeway*

Reversible aerial ropeways travel back and forth between two stations always on the same lane. This means that only one cable car cabin can be suspended from the rope in each direction. Most reversible aerial ropeways are configured with two lanes with each of the cabins travelling in the opposite direction. However, it is possible in principle to configure reversible aerial ropeways with just one lane. The cabins travel on one or two carrying ropes and permanently grip a haul rope. The haul rope is connected to the counter rope via a returning bull wheel and together these ropes form a closed rope loop. This is necessary in order to tension the haul rope and offset the wandering loads on the rope.

Because there is only one cabin per direction of travel, they tend to offer higher capacities than the cabins of circulating ropeways. The maximum system capacity depends on the track length, the system speed and the cabin size.

| | |
|---|---|
| **Number of ropes** [units] | Three: one haul rope, two carrying ropes |
| **Total capacity** [persons/hour/direction] on a section length of 7 km | 300 – 660 |
| **Cabin capacity** [persons] | 50 – 110 |
| **Track gauge** [metres] | 10 – 16 |
| **Speed** [kilometres/hour] | 43 |
| **Section length** [metres] | 7,000 |
| **Pylon span** [metres] | 800 – 1,000 |
| **Track width** [metres] | 24 – 30 |


Carrying rope anchor
Drive
Pylon
Haul rope return mechanism and tensioning device
Carrying rope tensioning device

*Special constructions*
Pulsed gondola ropeways can be configured as detachable or fix grip systems.

## *Pulsed gondola ropeway*

Pulsed gondola ropeways consist of one or more groups of cabins which permanently grip a carrying/haul rope. Most pulsed systems are configured with two to six cabins per group. Pulsed gondola ropeways can be operated as circulating systems or reversible systems. Pulsed reversible systems differ from standard reversible systems only by the number of cabins on the rope in each direction. By contrast, pulsed circulating systems combine the circulating principle with fixed rope grips. These are more similar to reversible ropeways in the way they operate, since the carrying/haul rope is repeatedly brought to a halt.

The maximum system capacity is relatively small and, like reversible aerial ropeways, depends on the track length, the system speed and the cabin size. In circulating operation, it is thus preferable to use detachable systems rather than pulsed gondola ropeways.

| | |
|---|---|
| **Number of ropes** [units] | Depends on the system |
| **Total capacity** [persons/hour/direction] on a section length of 7 km with 5 cabins per group | 150 – 250 |
| **Cabin capacity** [persons] | 6 – 10 |
| **Track gauge** [metres] | 6 – 6.5 |
| **Speed** [kilometres/hour] | 25 |
| **Section length** [metres] | 5,000 |
| **Pylon span** [metres] | 200 – 700 |
| **Track width** [metres] | 16 – 20 |

**Info box 12: Technical standard vs. implementation**

The safety requirements applicable to cable car installations are defined in a range of standards (see 'List of EN standards on safety requirements for cable cars used for passenger transport'). Having said that, the standards do not always correspond to the limits of feasibility from a technical and a safety perspective. For example, EN 12929-1 'Safety requirements for cableway installations designed to carry persons – General requirements – Part 1: Requirements for all installations' defines the following maximum speeds:

- 12.0 m/s or 43 kph for reversible aerial ropeways
- 6.0 m/s or 22 kph for circulating monocable aerial ropeways
- 7.0 m/s or 25 kph for 2S systems
- 8.0 m/s or 29 kph for 3S systems

However, these speeds are not necessarily the maximum possible. Worldwide, there are examples of cable cars with higher speeds as well as other deviations from standard parameters (e.g. longer free rope spans, larger cabins, taller pylons). These installations have undergone the necessary technical inspections and meet the stringent safety standards that apply to all cable cars designed to transport passengers. However, such deviations involve significantly higher costs. While this factor could be incorporated into a viable concept for recreational installations (such as the Cat Ba Cable Car in Vietnam, which has the world's tallest pylon) that market these extremes as records and can offset the additional costs, there are no such benefits for urban cable cars. Not only that, but there is no guarantee that such deviations would enhance the appeal of the cable car in an urban context. Hence, projects should not be planned with parameters that exceed standard thresholds. International examples of urban cable cars show that permissible standard limits are not exhausted in daily operation.

### *6.1.3 International real-world examples*

The examples below demonstrate how essential it is to select and implement the technology and design of the system based on the individual use case. For all projects, the prevailing circumstances (e.g. structural conditions, transport needs, etc.) must be taken into account so as to find the optimal solution. Further to Section 3.1, it is also evident that urban cable cars are suited to potential applications that extend far beyond deployment in mountainous regions. In addition to closing transport gaps and extending/expanding the existing local public transport system, a major advantage of cable cars is their ability to overcome topographical and structural obstacles. These mostly tend to be elevation differences and bodies of water, but also densely populated areas where limited ground space makes it difficult to build out the existing transport network. Cable cars can directly link points that would otherwise involve circuitous routes for other modes of transport, resulting in significantly shorter journey times.

*Téléphérique de Brest in Brest, France*

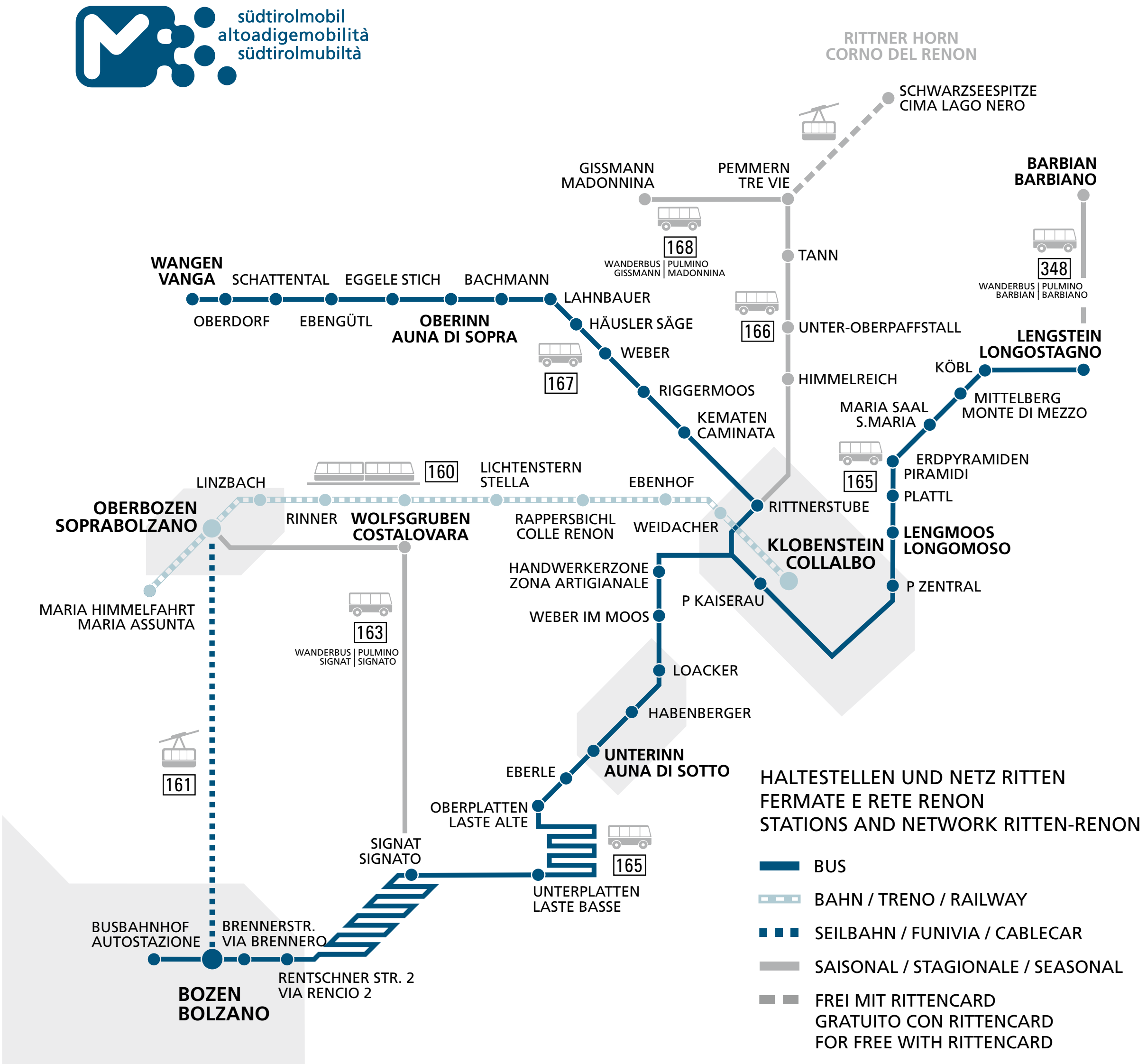
Background: Brest, a harbour city located in northern France, is home to some 140,000 inhabitants. The city lies in a sheltered bay that heads deep inland. At the mouth of the Penfeld river is situated one of France's most important ports. Local public transport consists of one tram line connecting the east and west parts of the city, with bus transit providing the bulk of all services. The cable car crosses the Penfeld river and connects the two halves of the city centre from the Quartier des Capucins to Station Jean Moulin.

The technology of this reversible aerial ropeway allows the cabins to travel above and below rather than adjacent to one another. This required two carrying ropes and two haul ropes each. The different track widths of the two cabins enable them to pass above and below one another. Only one entryway is needed per station thanks to the use of this technology, resulting in significant cost savings (including on station design).

Téléphérique de Brest reversible aerial ropeway in Brest, France

*Table 1: Project example: Téléphérique de Brest*

| | |
|---|---|
| **Cable car system** | Special reversible aerial ropeway construction (cabins travel above and below one another) |
| **Manufacturer** | Bartholet Maschinenbau AG |
| **Number of cabins** | 2 cabins |
| **Cabin size** | 60 persons |
| **Cabin equipment** | Video and intercom<br>Panoramic windows and lighting system<br>Privacy glass (windows tint for certain sections of the route) |
| **Number of lines** | 1 line |
| **Number of stations** | 2 stations |
| **System length** | 420 m |
| **Maximum distance between pylons** | 231 m |
| **Operator** | Bibus (subsidiary of RATP Dev) |
| **Began operation** | 2016 |
| **Daily operating hours** | 7:30 am to 0:30 am (17 hours) |
| **Speeds** | Normal speed: 4.5 m/s (16.2 kph)<br>Top speed (during periods of high demand): 7.5 m/s (27 kph) |
| **Frequency** | 5 min. in rush hour, 10 min. all other times |
| **Maximum transport capacity** | 1,220 pphpd |
| **Number of passengers** | 850,000 (2019) |
| **Staffing requirements** | Operation (regulation): 18 persons<br>On call: 4 persons<br>Servicing: 14.5 persons |
| **Station ground staff** | No |
| **Number of service disruptions** | 2 weeks per year for servicing and annual inspection<br>0.25 days per week for weekly servicing<br>-> 26.5 days per year in total for service and inspection work<br>Around 5 times a year for 1 to 5 hours due to heavy winds and storms |
| **Cost per trip** | Single trip: € 1.60<br>Day ticket: € 2.00 |
| **Fare integration** | Yes |




Transport network plan for Ritten, South Tyrol, including the Rittner Seilbahn line

*Rittner Seilbahn in Bolzano, Italy*

Background: Bolzano is the capital city of the Italian province of South Tyrol and sits in a valley surrounded by high mountains in the heart of the Alps.

The Rittner Seilbahn connects Bolzano with Oberbozen, climbing a total height of around 950 metres. The old reversible aerial ropeway from 1966 was closed in 2007 and replaced with a modern circulating tricable ropeway (3S). Although used mainly by holidaymakers and day trippers, the cable car system also serves the residents of the community of Ritten.

*Table 2: Project example: Rittner Seilbahn, Bolzano*

| | |
|---|---|
| **Cable car system** | Circulating tricable ropeway |
| **Manufacturer** | LEITNER AG |
| **Number of cabins** | 10 cabins |
| **Cabin size** | 30 persons |
| **Cabin equipment** | Standing room available,<br>bicycle and pushchair transport possible |
| **Number of lines** | 1 line |
| **Number of stations** | 2 stations |
| **System length** | Around 4.56 km |
| **Maximum distance between pylons** | Around 960 m |
| **Operator** | SAD Nahverkehr AG |
| **Began operation** | 2009 |
| **Daily operating hours** | 15 h/d to 15.75 h/d |
| **Speeds** | 7.0 m/s<br>25.2 kph |
| **Frequency** | 4 min. (varies throughout the day) |
| **Maximum transport capacity** | 720 pphpd |
| **Number of passengers** | About 1.04 million per year |
| **Cost per trip** | € 6.00 |
| **Fare integration** | Yes |

*Téléphérique Urbain Sud in Toulouse, France*

Background: The city of Toulouse is situated in the south of France on the banks of the Garonne. Although there are several city-centre bridges spanning the river, south of the city there are few opportunities to cross despite the area being home to a large number of important institutions. To establish better transit links between the south-eastern and south-western parts of the city, Toulouse opted to build a cable car to provide an attractive and direct link flying high over obstacles on that ground which would otherwise prove difficult to traverse.

The new cable car opened in May 2022. It takes 10 minutes to travel the around 3-kilometre-long route. The same journey in a car would take some 30 minutes.

Téléphérique Urbain Sud 3S system in Toulouse, France

*Table 3: Project example: Téléphérique Urbain Sud, Toulouse*

| | |
|---|---|
| **Cable car system** | Circulating tricable ropeway |
| **Manufacturer** | Pomagalski S.A.S. (POMA) |
| **Number of cabins** | 15 cabins |
| **Cabin size** | 34 persons, including seating capacity for 20 |
| **Cabin equipment** | Digital screens, emergency call points, CCTV<br>Standing room available, bicycle and pushchair transport possible |
| **Number of lines** | 1 line |
| **Number of stations** | 3 stations |
| **System length** | Around 3 km |
| **Maximum distance between pylons** | Around 1,010 m |
| **Operator** | Tisséo |
| **Began operation** | 2022 |
| **Daily operating hours** | 19.25 h/d |
| **Speeds** | 7.5 m/s<br>27 kph |
| **Frequency** | 1.5 min. |
| **Maximum transport capacity** | 1,360 pphpd |
| **Cost per trip** | € 1.70 |
| **Fare integration** | Yes |

*Mi Teleférico in La Paz, Bolivia*

Background: The neighbouring cities of La Paz and El Alto together form the most populous metropolitan area in Bolivia. Both cities are located in the Andes, and La Paz is the highest capital city in the world.

The local topography poses several challenges when travelling between the two cities. There are only a handful of well-developed roads, all of which lead through the city centre and are often heavily congested due to the high volume of traffic. La Paz has no rail-bound transport links. Local public transport is made up of a dense network of taxis and pick-up buses with no permanent stopping points. Not only are these taxis and buses themselves affected by the traffic congestion, but they also contribute to and further exacerbate the problem.

La Paz decided to combat congestion by creating an entire network of cable car lines with the goal of establishing the cable car as the backbone of the city's transit system. The first three lines began operation in 2014. The network has been expanded continually ever since, and at present comprises ten lines including links to neighbouring El Alto.

While neither the political and social circumstances nor the existing public transport services prior to the construction of the cable car in La Paz are comparable to the situation in Germany, from a technical perspective the cable cars in La Paz and other South American cities still serve as a relevant example, especially with regard to potential capacities. The safety standards applied in South America also conform to EN standards.

Mi Teleférico circulating monocable aerial ropeway in La Paz, Bolivia

*Table 4: Project example: Mi Teleférico, La Paz*

| | |
|---|---|
| **Cable car system** | Circulating monocable aerial ropeway |
| **Manufacturer** | Doppelmayr Seilbahnen GmbH |
| **Number of cabins** | 1,364 cabins |
| **Cabin size** | 10 persons |
| **Cabin equipment** | Video, two-way intercom, Wi-Fi, lighting |
| **Number of lines** | 10 lines |
| **Number of stations** | 44 stations (multiple stations in one building possible) |
| **System length** | Around 31 km |
| **Maximum distance between pylons** | Around 300 m |
| **Operator** | Empresa Estatal de Transporte por Cable "Mi Teleférico" (EETCMT) |
| **Began operation** | 2014 (with further lines added continually since then) |
| **Daily operating hours** | 17 h/d |
| **Speeds** | 5.0 m/s – 6 m/s<br>18 kph – 21.6 kph |
| **Frequency** | 9 s – 12 s |
| **Maximum transport capacity** | 4,000 pphpd |
| **Number of passengers** | Around 100 million |
| **System availability/number of service disruptions** | One interruption per line per year for servicing, average duration 5 to 6 days, up to a maximum of 1 week;<br>short-term disruptions also possible due to inclement weather;<br>availability: over 99.7 % |
| **Cost per trip** | 3.00 Bolivianos<br>(€ 0.42, exchange rate as of 15 August 2022) |
| **Fare integration** | No |

### *6.1.4 Accessibility*

Article 8 of the Act on Equal Opportunities for Disabled Persons (BGG) requires publicly accessible transport facilities and public modes of transport to be designed in compliance with the relevant statutory provisions on accessibility in Germany. Further-reaching provisions under federal state law remain unaffected. Accordingly, accessibility – i.e. usability for people with physical disabilities – in urban spaces must be realised to the maximum extent possible. Passengers must face no barriers to using a mode of transport or to moving between other transport systems.

An urban cable car must be usable for all potential passengers without the need for instructions on its use. All relevant passenger information both in regular operation and in the event of disruptions must be provided in at least one additional accessible format.

The system design and in particular the stations should be oriented to the standard of other transport systems in application of DIN 18040 'Construction of accessible buildings – Design principles'. Furthermore, the mechanical system must comply with Commission Regulation (EU) No 1300/2014 on the technical specifications for interoperability relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility.

**Cable car station:** Access to stations must be provided via a staircase in addition to a ramp, escalator or lift system element.

**Cable car cabins:** Since the individual cabins move very slowly (< 1.8 kph) once inside the station, boarding and deboarding is generally possible for people of all physical abilities. If required, the cabins can be brought to a complete stop to enable boarding and deboarding. The ground staff can help with this. The cabin floor must be level with the platform and the distance between the cabin and the platform kept to an absolute minimum; in order to meet accessibility requirements, horizontal and vertical gaps must not exceed 5 centimetres.

Passengers must be able to travel in the cabins with all items and mobility aids permitted under public transport regulations. Seating and standing areas must be designed to take this into account. The minimum door width is ≥ 0.90 metres. Emergency call facilities and intercoms must be fully accessible. A visual and an acoustic signal must be emitted when the doors open and close.

**Info box 13: Passenger transfer**

Experience has shown that boarding and deboarding in particular can be problematic for people with physical disabilities. The cabin speed of most circulating ropeways is reduced dramatically for passenger transfer.
The cabins are detached from the rope inside the station and slowed almost – but not quite – to a halt. The very low speeds generally do not prove an obstacle for passengers boarding and deboarding. In order to test out the usability of the system, it is possible to make on-site visits to comparable installations (such as the tourist cable car in Koblenz) with corresponding interest groups. However, especially in urban areas it is possible that, in the interests of full accessibility, a complete standstill of the cabins is desired in order to enable a comfortable passenger transfer.

While it is technically possible to halt the cabins entirely, this has a knock-on effect on journey time and above all the capacity of the cable car system. When the cabins are moving, there is no fixed point for boarding and deboarding, and the cabins can pass through the station in quick succession. Since it is a possibility that multiple cabins are waiting in the station ready to depart, the interval between departures can also be chosen freely. The only constraint is the requirement to maintain the minimum safe distance between cabins on the rope. However, if the cabins are brought to a complete standstill, this must take place at predefined points. A cabin behind can only approach this point for passenger transfer when the cabin in front has moved away. The interval between cabins is thus automatically longer than the downtime scheduled for passenger transfer. The reduced departure frequency resulting from the longer intervals between cabins also reduces capacity.

However, it is worth pointing out that configuring the densest possible and technically feasible cabin frequency generates capacities that exceed those generally required in Germany. In most cases, if demand for a connection is so high, it will already be served by local public transport. It is therefore likely that the system will still offer sufficient capacity even where cabins are brought to a standstill. This must be clarified case by case on the basis of projected demand.

### 6.1.5 Safety

#### General

All new installations, major restructuring work or updates, and modifications to the technical cable car parameters require a detailed risk and safety assessment in accordance with European cable car standards. These include, for example, EN 17064 'Safety requirements for cableway installations designed to carry persons – Prevention and fight against fire'. The safety analysis must be carried out by a body appointed by the responsible supervisory authority in the respective federal state, and must identify all scenarios that could potentially pose a risk to passengers.

The technical inspection of cable cars is uniform across Germany. Cable cars are subject to annual inspections by the supervisory authority or a certified body. During the inspection, all parts and components, as well as the entire cable car installation and its surroundings, are checked for safety and proper functioning (ropes, brakes, entryway, coupling and detachment, all electronic monitoring equipment, etc.). These inspections can normally be carried out during scheduled downtimes. If a cable car installation is designed or operated on the basis of a special license or deviates from standard technical regulations, or experiences or expects to experience particular challenges in relation to individual components, the type and scope of inspection is determined according to the specifics of the case.

Additionally, the operator is required to carry out an interim inspection every six months and report the outcome to the appointed body/supervisory authority.

A key element of the overall safety concept is acceptance testing before the installation begins operation. In order to assess operating safety, a detailed inspection is carried out of the cable car technology, the steelwork and structural engineering, the risk analysis and the fire prevention concept. Acceptance testing includes testing all safety equipment to ensure it is working correctly. Trial runs and brake tests are also carried out under maximum load. Further information is provided below on safety-related influences and aspects connected to the operation of cable cars.

#### Fire prevention

Fire prevention measures are unique to each project and must comply with the safety and fire-prevention requirements for stations, cabins and the track, as well as technical regulations and applicable laws and guidelines (see 'Sources: Laws and ordinances' and 'List of EN standards on safety requirements for cable cars used for passenger transport').

The fire load along ropeway routes in urban areas is not to be underestimated. The central question is always 'What is beneath and in close proximity to the cable car?' In accordance with fire protection standard EN 17064, the assessment must cover a radius of 12 metres from the cable car axis. An on-site track assessment must always be carried out beforehand to determine the location of critical structures and assess their level of risk. To ensure appropriate consideration is given to cable car-specific issues, it is advisable to have this assessment carried out by interdisciplinary experts with expertise in cable cars.

It is advisable to keep fire loads in cabins to an absolute minimum. Where cable cars offer mixed passenger and goods (freight) transport, the fire load in goods cabins must be assessed critically. An approved fire extinguishing device must be provided in all cabins. Due to extensive misuse, it is preferable in some cable cars to provide fire blankets instead of hand-held fire extinguishers.

Fire can potentially break out in several locations (surrounding area, station, cabin). In all cases, the absolute first priority is to empty the cable car (i.e. continue operation to bring passengers to the nearest station for evacuation). At all times it must be ensured that there is no risk to the operational safety of the rope. The requirements for 2S and 3S systems are stricter than for circulating monocable aerial ropeways, since the carrying rope does not move position. This results in higher spot heat build-up and potentially reduces its mechanical resilience. In the case of a cabin fire, the cabin will be brought back to the station where necessary action can be taken.

The following four points are decisive in the event of fire:

- Detection of the fire

- Rapid implementation of organisational measures (e.g. quick emptying of the cable car, prevention of further boarding)

- Effective measures to reduce the fire load (cabin equipment, restrictions on carrying flammable goods, similar to in the aviation industry)

- Adequate dimensioning of ground clearances in the planning stage (third-party fire)

**Info box 14: Safety analysis**

A safety analysis is an essential step in the construction of any urban cable car. Risks that are not covered in cable car Regulation (EU) 2016/424 or in the harmonised European (EN) standards must be taken into account accordingly.
This relates primarily to external influences from the urban environment. The risks must be categorised and significant factors in the probability of occurrence, as well as the scope of the incident, assigned to the risk category. The analysis should also include a description of the risk situations identified and the resultant measures.

*Passenger recovery and 'integrated rescue'*

The aim of the 'integrated rescue' approach is to define technical, organisational and operational measures to ensure the safe return of passengers to the stations for evacuation. The following precautions must be taken to ensure 'integrated rescue' is at least equally as safe as conventional recovery methods (abseiling from carriers, recovery along the line to the next pylon, separate rescue ropeways, helicopter rescue, etc.):

- Installation of a redundant emergency drive (including proof of propulsion capability)

- Safeguarding of sufficient battery capacities in the event of an emergency or availability of a separate emergency power generator for the emergency drive

- Emergency operating mechanisms on all bull wheels
- Availability of mechanisms to remove a carrier blocking passage through the station (circulating monocable aerial ropeways)
- Installation of rope monitoring systems on all pylons (circulating monocable aerial ropeways)
- Tools to hoist a partially slipped carrying/haul rope on the pylons, dimensioned to cope with a fully loaded rope (circulating monocable aerial ropeways)
- Safeguards to ensure staff access to pylons (from the ground or along the ropeway)
- Operational measures (e.g. barriers, checks for obstructions)
- Spare parts inventory for selected components

The 'integrated rescue' concept for urban cable car installations is complementary to the conventional recovery methods. The associated additional safety mechanisms help to minimise the likelihood of the need to evacuate passengers through abseiling (difficult in bad weather and for passengers with reduced mobility). It is important to involve an intervention team comprising representatives of various safety-mandated organisations (e.g. fire brigade) in the 'integrated rescue' concept.

In principle, 'integrated rescue' can be applied for cable cars with carrying ropes (2S, 3S). There are many examples of 3S projects in which this has been accepted by the authorities, but there are no cases of 2S projects to date. For circulating monocable aerial ropeways, the EN cable car standards stipulate that the concept of 'integrated rescue' cannot be used on its own to replace conventional recovery. Circulating monocable aerial ropeways thus require an additional back-up concept (e.g. recovery along the ropeway carried out by local rescue teams, annual recovery drills).

*Wind*

In accordance with EN 12930:2015 'Safety requirements for cableway installations designed to carry persons – Calculations', an external pressure of 250 N/m² during operation is acceptable for all ropeways. This corresponds to a wind speed of up to 72 kph.

The maximum operating wind speed is determined on the basis of the rope safety case. Depending on the design (free rope spans, swing clearance, etc.) and the type of cable car system, operation is possible at lower or higher wind speeds. The lateral wind load on the ropeway is the decisive factor here. The topographical conditions and surrounding buildings also have a major impact on the wind speed.
From a purely technical perspective, operation is possible at significantly higher wind speeds.

Wind sensors must be positioned on exposed pylons and stations and should preferably also provide data on the wind direction. The wind speed data is read by the control centre. Normally, the monitoring system activates a warning signal when the wind speed hits around 80 % of the technically permissible maximum threshold. The signal informs the operating crew that they need to pay close attention to the wind. The control centre must emit a visible and acoustic alarm signal as soon as the wind speed reaches or exceeds the maximum permitted for operation. The cable car automatically slows as a result. As with other local public transport services, overall responsibility lies with the operations manager.

### *Ice and snow*

Under certain climate conditions, the accumulation of ice on ropes can be a decisive factor in the dimensioning of the cable car. Localised freezing can occur over rivers, lakes and other areas. It is advisable to determine the potential ice and snow loads during the planning phase by obtaining an expert meteorological opinion.

Generally speaking, ice and snow pose no safety hazard during operation, since the constant movement of the rope prevents accumulation. In many cases, the rope is run empty prior to commencing morning operation to free the installation from ice and snow.

### *Lightning*

The haul rope or carrying rope are always exposed to potential lightning strikes. For this reason, the cable car installation is emptied during thunderstorms and lightning and switched off to protect the electrical installations in the stations and prevent any technical outages.

Due to the Faraday cage effect of the cabins, there is no danger to passengers travelling in the cabins should lightning strike during running.

Construction measures can be taken to reduce the risk of lightning striking the haul or carrying ropes; many systems use a rope tensioned centrally or directly above the haul and carrying ropes to take the hit of a potential lightning strike and protect the system ropes.

If lightning does strike a haul or carrying rope, individual rope wires may catch fire. Depending on its type and purpose, the rope can have a diameter of between 30 and 60 millimetres; lightning is not capable of penetrating through the rope and can merely alter or destroy the structure of the wires, thus reducing their tensile strength. This can lead to long-term degradation of the rope strength, but this takes place over an extended period of time and is apparent during visual inspections of the rope. A visual inspection of the haul and carrying rope must therefore be carried out immediately if there is a suspicion that one or both have been struck by lightning.

Because lightning strikes cannot be grounded through pylons (grounding resistance too high), with the power instead travelling along the haul rope into the stations where the resultant surge can damage electrical installations, at the end of every working day technicians manually earth the haul rope via earthing rods in the stations.

### 6.1.6 Extension options

As a rule, the line of a detachable cable car system can be extended without the need for passenger transfer by inserting a new section (additional rope loop with a drive and return unit). The current terminal station is re-purposed as or converted into an intermediate station.

Any extension options should be considered from the start of planning and dimensioning in order to minimise service disruptions during the work. In this case, it is advisable to incorporate sufficient space for storing the cabins during extension measures (ideally in one location). It is also essential to incorporate any plans to expand passenger capacity (by adding cabins or increasing speeds) in the static rope line calculation and station dimensioning from the outset.

## 6.2 Operation

With so many cable car technologies to choose from, it is possible to meet even ambitious demands in any surroundings and under challenging conditions.

Their simple technological design and high level of automation make it easy to reach the operating phase and implement long-term operating and servicing concepts. As with all local public transport systems, and urban cable cars are no exception, it is vitally important to provide comprehensive and regular training for the operating staff and to ensure the reliable assessment of safety cut-off mechanisms.

### 6.2.1 Operating concept

While the full integration of the cable car with conventional transport systems begins during the planning phase, it is the operating concept that guarantees reliable coordination throughout the installation's entire life cycle.

In this context, the future operator is advised – in addition to compliance with the applicable standards and regulations – to draw up an operating concept integrating the cable car into the existing transport network. The operating concept should cover the following points:

- Precautions and processes (standard operating procedure) to guarantee maximum availability
- Robust service plans to safeguard the reliability of the technical components and ensure the necessary tools are on hand
- Regular training and testing to maintain a high level of staff expertise
- Adequate precautions to ensure the safe conveyance of passengers and a safe working environment for staff
- A financially transparent organisational model

### 6.2.2 Organisation and management system

Although cable cars are a time-tested means of transport, in the urban environment they are a new solution to mobility challenges. Given this, the operator models must also be adapted to incorporate this innovation and ensure that cable cars are comprehensively considered and accepted by the transport sector and by local authorities. In principle, both the public authorities (in the form of a municipal transport operator) and a private cable car operator can take on the operation of an urban cable car. For further information on potential cable car operators, please see Section 4.4.

The aim of the operating model is to demonstrate that operational safety is maintained on a systematic basis and that all availability criteria are met (as is required of other public transport services). The cable car technology itself has undergone continuous improvement and has since reached technical maturity. In terms of the characteristics of cable cars, operating models have been developed for the most common applications.

Applicable guidelines stipulate the minimum requirements for the operating model and the operating organisation (see 'List of EN standards on safety requirements for cable cars used for passenger transport').

However, in order to become the operator of a cable car in an urban context, where the system is regarded and accepted as public transport, expectations and demands must be fulfilled which go above and beyond the requirements mentioned above. The operating model must be continually further developed and take inspiration from simplified models used in existing standard local transport systems.

Simplified, modern operating models that reflect the specific environment and the technological approach of cable cars help to achieve this and keep outgoings down over the life cycle.

The acceptance of an urban cable car depends on the ability to reduce overall costs over the installation's life cycle. From planning to operation to retirement, a cable car must be able to compete with alternative solutions offering similar capacities and operating conditions.

*Management systems and tools*

The organisational framework should support daily operating and servicing activities and take account of tools needed to administer and monitor organisational performance.
Well-defined framework conditions, as they are implemented in local transport systems, should be in place in urban operation.
Their scale and complexity should be adapted to the requirements of the cable car.

To further develop the management systems, the operators of cable cars can employ asset management systems or building information modelling and integrate these into long-term quality control planning. All of these tools support the requisite level of organisational robustness, risk management processes and system reliability that is expected of conventional transport systems.

An asset management system supports technology planning and availability. It enables data analysis to maintain safe, reliable and cost-effective operation and servicing of the cable car.

The data and information available should cover operation, servicing, training and safety so as to identify areas for improvement and support reporting.

Building information modelling (BIM) systems can play a key role in this context, since the interfaces between the cable car-specific areas and the attached rooms/buildings must be determined during conceptual planning and later operated and maintained. A BIM system helps to safeguard the transfer of information between the relevant organisations (e.g. building operator/cable car operator).

A quality control plan covers the processes for scheduling verified activities and audit programmes to support ongoing improvements. The plan helps with the goal of monitoring essential requirements as defined by the authorised representative, who is supervised by the operator.

### 6.2.3 Organisational structure and operating plan

*Organisational structure*

The following aspects influence the structure of the organisation and thus the necessary resources/staffing requirements:

- Technical configuration and location of the cable car
- Operating plan
- Operating environment
- Reachability of the stations for staff

In the planning/design phase, cities and local authorities should require design concepts to be accompanied by operating concepts, and vice versa. These can be provided either internally or with external help from operational experts. This approach enables decision-makers to review whether cable cars can be integrated into existing transport organisations or if the future operator has the option to develop and propose an organisation that is optimised for a long-term time horizon.

Of all of the factors mentioned above, the configuration of the cable car (number of stations) and the operating plan (operating and servicing times) have the biggest impact on the size and structure of the organisation. The following sub-sections provide further information on the specific roles, which correspond to the organisation and shift composition.

*Operating plan*
Typically, a cable car organisation will consist of management (operations management), technicians, operators and station staff.

Management leads and oversees the various tasks required to deliver reliable and safe service and operation. Like in other service organisations, the main activities comprise operation, servicing, training, safety and financial transparency.

The division of responsibility across management is different from project to project and is based on factors such as the size of the team as a whole, the operating environment, or the complexity of the new cable car installation.

*Staffing requirements and positions*
The operator is solely responsible for operation and maintenance, and thus also for the safety of the cable car. It thus falls to the operator to decide which positions and how many employees are required in order to render the necessary operating services and servicing tasks. Generally speaking, the following positions are found in every organisation:

- The **operations manager** is responsible for the entire organisation and thus for compliance with relevant provisions and standards.

- The **deputy operations managers** assume the duties of the operations manager in their absence.

- The **maintenance crew** carries out servicing on the system components and perform troubleshooting measures in the event of an unplanned outage.

- The **operating staff** visually monitor the cable car operation and periodically review relevant parameters via the human-machine interface (HMI). The HMI helps the maintenance crew to locate defects and the station staff to monitor the platform during peak times.

- The **station staff** watch the platform and ensure safe cabin boarding and deboarding.

- Consideration must also be given to the staff required for services beyond technical operation, such as access control, security, cleaning, etc.

*Shift planning*
The minimum number of staff required during the hours in which the cable car publicly transports passengers is regulated in the respective federal state laws on cable cars. If a shift is scheduled with the sole task of performing servicing activities, the operator decides how many staff are needed to fulfil the requirements stipulated in the maintenance schedule.

The respective federal state law on cable cars requires a shift to comprise at least one operations manager or deputy, one technician and one operator per control room.

Additionally, the safety analysis (see info box ‘Safety analysis’, Section 6.1.5) may give rise to the requirement for personnel to oversee and monitor the boarding and deboarding side of the station platform. Although the standard does not specify which role is responsible for station platform staffing, it is standard practice in the industry to assign station attendants.

*Processes and guidelines*

As it currently stands, the law on cable cars guarantees the effective and safe operation of cable car installations. Regularly reviewed processes and guidelines allow the organisation to safely and effectively handle any events, operational circumstances or incidents as and when they occur.

Similar to the time-tested procedures used elsewhere in the transport sector for other modes of transport, the procedures cover the following scenarios and circumstances:

- **Normal operation**, where the cable car moves in automatic mode without an active alarm. The operating staff's main tasks are to monitor passenger activity and maintain communication with passengers and other employees.

- **Limited operation**, where the cable car is in operation, but due to an error, system outage or other external factors, restrictions are in place that indicate reduced safety or operating capacity (e.g. due to inclement weather such as wind).

- **Emergency operation**, where passengers require evacuation in order to prevent a catastrophe that jeopardises the safety of passengers or staff following an error, system outage, or due to other external factors (e.g. fire). In this case, the rescue services such as the police, fire brigade and ambulances require effective coordination (further information on drills is provided in the following sub-sections).

The staff member in charge of operation is responsible for managing and implementing the necessary procedures and coordinating the rescue services.

The operator is required to keep records of the cable car's operating performance. An operating log must contain at the very least information on factors relevant for daily operations; the minimum contents are defined in EN 12397 'Safety requirements for cableway installations designed to carry persons – Operation'.

Many years of practice have shown it is advisable to maintain a log of all disruptions (whether or not they relate to availability). The reports include information on the cause, the procedure followed by staff to restore the system, and information on the evacuation of passengers or the deactivation of safety mechanisms.

*System performance*

With an organisation in place as described in the sub-sections above, alongside appropriately developed and implemented procedures, a cable car can operate up to 17 or 18 hours a day. This is comparable to conventional modes of transport.

Provided the requisite staffing and material resources are available, the cable car can be opened for extra hours on certain days to fulfil the servicing requirements set by the manufacturer. It is thus not the technology that limits decisions on the operating plan, but rather the interplay of demand and available resources (staff and material).

### 6.2.4 Servicing and maintenance

#### Maintenance schedule

Servicing and maintenance are regulated in EN 1709 'Safety requirements for cableway installations designed to transport persons – Precommissioning inspection and instructions for maintenance and operational inspection and checks'.

The maintenance schedule contains plans and instructions on system overhauls, regular inspections and testing. The maintenance schedule includes a preventive maintenance programme with extensive forward planning with the goal of minimising downtime and maximising system availability, while also ensuring that there is always an adequate inventory of spare parts and consumable items available.

Components with a limited operating life are scheduled for replacement as part of the preventive maintenance programme. The goal of the preventive maintenance programme is to schedule maintenance activities during off-peak operating hours and thus avoid causing disruptions during peak times.

#### Purpose and content

The maintenance schedule spreads servicing tasks over the calendar year. The primary factors for operators to consider are the operating plan, i.e. the hours during which the system is available for servicing, and the rota for the employees trained to carry out these safety-critical tasks.

It is standard practice to schedule the tasks during periods of reduced demand, but this is only possible if demand fluctuates seasonally or annually. The practice of defining a certain number of days on which more major, safety-critical servicing can be carried out has proved to work well for other local transport systems.

The maintenance schedule includes inspections of the condition, function testing, cleaning and any scheduled replacement of parts prior to their expected failure (especially due to wear and tear). The servicing tasks that together make up the maintenance schedule can be triggered on the basis of time intervals (e.g. daily, monthly, etc.) or specific metrics (e.g. grip cycles or operating hours). The frequency of certain servicing tasks will therefore vary according to operating plan and operating hours for a certain cable car, while the frequency of other tasks will vary depending on the cable car's configuration.

A very limited number of tasks must be outsourced to third parties, the most relevant of which is the non-destructive testing of components. Individual checks, such as non-destructive testing of the grip, may be performed by operating staff without support from authorised third parties. However, it must be ensured that the employee performing the check has received corresponding training and certification from an authorised representative. Non-destructive testing of the rope must be performed by an authorised third party who will measure the number of broken wires per metre and submit the necessary documentation. At present, the standard requires the inspector to carry out the inspection on site. It is not possible to inspect the rope remotely, even using pre-installed equipment, since the standard requires a visual inspection of the splice.

The time taken for servicing can be optimised by ensuring additional components are available and that both preventive and corrective maintenance work carried out during operating hours takes place in the service workshop. Examples of this are the cabins and the associated grip checks.

The following comparison shows the effects that operating hours have on the various components and their service intervals, and contrasts a conventional alpine cable car with an urban cable car with opening hours comparable to those of local public transport.

*Table 5: Comparison of operational parameters in an alpine and urban setting*

| Example parameters/systems | Alpine system | Urban system I | Urban system II |
|---|---|---|---|
| System length [m] | 1,000.00 | 1,000.00 | 1,000.00 |
| Number of stations | 2.00 | 2.00 | 2.00 |
| Capacity [pphpd] | 2,500.00 | 2,500.00 | 1,250.00 |
| Average speed [m/s] | 6.00 | 6.00 | 3.00 |
| Operating hours per day [h] | 10.00 | 18.00 | 18.00 |
| Operating days per year [d] | 150.00 | 360.00 | 360.00 |
| Operating hours per year [h] | 1,500.00 | 6,480.00 | 6,480.00 |
| Operating hours over 10 years [h] | 15,000.00 | 64,800.00 | 64,800.00 |
| Rope kilometres per year [km] | 32,400.00 | 139,968.00 | 69,984.00 |
| Grip cycles per year [cycles] | 60,000.00 | 259,200.00 | 129,600.00 |

### *Processes and guidelines*

It falls to the operator to ensure compliance with and to monitor the guidelines on the proper and safe performance of servicing tasks.
The published EN standards are a set of safety requirements for passenger cable car installations based on technical standards, which define, inter alia, basic principles for the performance of checks and inspections (see 'List of EN standards on safety requirements for cable cars used for passenger transport'). Likewise, these basic principles also relate to operation.

### *6.2.5 Training and reviews*

Most of the individuals who work in operating and maintenance roles possess multi-disciplinary expertise. On the technical side, this is a result of the cable car system's individual configuration consisting of mechanical, hydraulic, electronic and automated sub-systems. The operator's management team steers the entire business organisation, coordinates the necessary activities and guarantees compliance with laws and guidelines.

#### *Training requirements and additional expectations*

The guidelines require the operator to provide adequate training to ensure that cable car staff can perform their assigned duties and possess the requisite expertise. The operator must also check that the training is adequate in terms of its content and structure.

The requirements which the operations manager and their deputy must fulfil are defined in the respective federal state laws on cable cars and in some cases are regulated in more detail in implementing regulations. Federal state-specific standards and provisions may require certain certified training, certain documented know-how in a technical field and a certain degree of experience in operating or servicing cable car systems in order to be considered for the position of operations manager and/or deputy operations manager.

The integration of the cable car into the local public transport network places additional demands on the cable car operator. In line with the regulations governing existing local public transport systems, it may be necessary for cable car operators to define, implement and monitor training plans. These may cover, e.g. provisions for new hires, and regular, documented training throughout the entire duration of the employment relationship. It is also standard practice to carry out practical and theoretical evaluations on a regular basis and not only during the induction period. The goal is to prevent a loss of knowledge that could endanger the safety of passengers and staff or the reliability of the cable car.

#### *Training and training plan*

At present, for most positions and in most federal states there are no statutory requirements regarding prior experience or training (see Section 6.2.3). In this context, and in order to be considered for employment, it is sufficient that the individual meets the criteria defined in the operator's job description for a certain position.

The deployment of operations managers and their deputies requires a legally admissible order on their appointment from the federal state's technical supervisory authority. The basic principles and requirements for appointment by the respective technical supervisory authority are:

- The necessary reliability and expertise

- Minimum of 21 years old, and physically and mentally able to carry out the work involved

- Competency must be evidenced by way of satisfactory conclusion of the operations manager examination

- Knowledge of the essential operational and technical skills required for the specific installation

- Meets the minimum standard of vocational training (vocational or academic qualification)

The technical supervisory authority may authorise exceptions where evidence is provided of certain abilities and expertise.

The training plan should be structured logically and include an adequate number of training staff in order to meet the goals set in respect of knowledge and skills.

A training plan ensures that new employees are taught the necessary processes, guidelines and technical know-how. Throughout the employment relationship, a training plan serves to keep skills up to date and guarantees not only that tested processes and guidelines are communicated immediately to the employee, but also that this is documented in line with requirements.

In addition to the training plan, the operator should implement processes for holding training meetings whenever there is a need to implement new guidelines or instructions.

The most common approach to training plans is to identify the training requirements for each individual role in the organisation and assign these requirements to each role. In order to receive a training certificate, the trainer and trainee must confirm that the training has taken place and that both sides are satisfied with the type and way in which the topic was presented.

The training plan should also include theoretical or practical evaluations.

*Training content*

The core purpose of training is to communicate content on the safe conveyance of passengers, safe working practices for employees, and the reliable rendering of services. Training can also be used to train local staff without a background in cable car installations and deploy them in cable car operations.

The training plan should contain descriptions of the cable car sub-systems to enable new employees to familiarise themselves with the specifics of this technology.

Safety procedures, risk assessments and hazard controls (see Section 6.2.6) should form an integral part of this training programme. However, it is urgently advised to communicate safety-critical information in dedicated training sessions.

Training must be provided on operational measures including operating procedures in all phases of operations.

Technical training covers the information required for system servicing, including cable car-specific tools and processes. In this context, the operator is responsible for closing any gaps in technical knowledge of cable car systems.

*Processes and documentation*

The operator should introduce processes for monitoring the training methods, including materials for training and evaluating staff, as well as for staff to use. It is ultimately the operations manager who is responsible for ensuring that all staff maintain the requisite skill level, and a documented process must be in place to safeguard the performance and success of training.

In accordance with the applicable guidelines, the documents evidencing completion of the training plan can be kept in hard copy or in digital format.

### *6.2.6 Safety and documentation*

All systems must be constructed, operated and maintained so as to ensure operational safety at all times. This includes aspects of pre-commissioning and of regular inspection in accordance with the provisions in the respective federal state.

The appointed operations manager is responsible for the performance of all checks and inspections required by EN 1709 'Safety requirements for cableway installations designed to transport persons – Precommissioning inspection and instructions for maintenance and operational inspection and checks'. The operations manager can engage employees and deputies, as well as external specialist companies, to assist with fulfilling this obligation.

Where employees or specialist companies are deployed, responsibility for both the substantive element and for the assigned scope of the inspection lies with the operations manager.

Periodic regulatory auditing is a minimum requirement. This audit determines the operational safety/existence of defects at the date of audit and in respect of further inspection periods. Furthermore, the audit must take account of further developments in established engineering practice and the experience gained from operation thus far.

EN 12397 'Safety requirements for cableway installations designed to carry persons – Operation' focusses mainly on preventing and mitigating risks. It describes a large collection of situations for illustrative purposes. Nowadays, most of the requirements applicable to safety plans and precautionary measures are defined predominantly in the relevant guidelines, as amended. Added to this are local requirements, such as those stipulated by the public utility companies or transport operators.

### *Purpose and scope*

The overriding goal of a safety plan is to ensure the safe performance of operating and servicing activities. These safety precautions apply to:

- passengers,
- employees operating and servicing the cable car, and
- all staff providing services on site.

### *Risk assessment*

The risk assessment is the process for identifying hazards and determining mitigation measures. The process covers control mechanisms that aim firstly to eliminate the threat. If the threat cannot be clearly eliminated, the operator should attempt to implement, isolate or apply technical controls.

The following elements form part of an end-to-end plan:

- Hazard identification
- Hazard mitigation
- Hazard monitoring
- Hazard control

As a rule, the manufacturer performs a hazard assessment to reduce or preclude these factors by taking constructive action. Any residual risks then transfer to the cable car operator who incorporates the potential risks into the safety plan and mitigates them further by implementing staff-related and organisational measures. The 'as low as reasonably practicable' principle is applied.

### *Contingency planning*

A further aspect highlighted in EN 1909 'Safety requirements for cableway installations designed to carry persons – Recovery and evacuation' is the preparation and use of protocols to be executed in emergencies. The operator is required to develop a set of procedures and protocols which then become part of the evacuation plan. This plan, together with the risk assessment, is a cornerstone of the cable car's safety plan. Modern cable cars are configured with redundant recovery systems to ensure the smooth and safe transport of passengers back to the stations, even in the event of disruptions where normal operation cannot be guaranteed. The evacuation plan should take account of the existing methods of evacuating passengers and coordination with the rescue services on site.

The evacuation plan can also include contingency plans in the event of a loss of sub-systems or catastrophic events. The aim here is to safeguard the necessary levels of safety at all times, even under extraordinary circumstances.

EN 1909 'Safety requirements for cableway installations designed to carry persons – Recovery and evacuation' requires the operator to provide regular training for and to monitor staff responsible for leading and coordinating the evacuation. A drill, including coordination with the emergency services (police, fire brigade and rescue services), should be carried out annually, even where this is not required by the guidelines. However, some local regulations may specify an annual drill as a requirement. The drill should demonstrate to a sufficient degree the processes that are activated in an emergency.

### *Safety management system*

A general safety management system defines a framework that provides processes for the entire operating organisation and maintains safe working practices.

Generally speaking, all safety management systems specify overarching strategies which are fulfilled through application-specific procedures. The safety management system must contain and apply plans in order to monitor compliance with the pre-defined processes and ensure continual improvements through regular audits and control verifications.

At present, the standards on cable cars do not require the implementation of a safety management system. However, the integration of the cable car system into existing systems or networks can require compliance with existing safety strategies (safety management plan). The most common standard is ISO 45001, which although not transport-specific, is widely used in the industry. The application of this standard offers an expedient enhancement to the laws on cable cars as they stand at present.

The safety management system should be structured in a way that strengthens the understanding of safety and the safety culture within the organisation and minimises the occurrence of incidents and/or injuries. The safety culture is normally subsumed in the operating organisation's safety guideline.

### *Documentation*

As is the case for all of the organisational activities described in this sub-section, the operator must maintain transparent records on compliance with relevant processes and regulations.

Operations managers are required to keep suitable documentation on the operating organisation, daily operations and servicing, and on all events occurring before, during or after public operation. The operator is required to disclose the following incidents (non-exhaustive list) to the supervisory authority:

- Accidents and damage of significance to the system's operating safety
- Passenger recovery and evacuation operations
- Service disruptions of a longer duration

### *6.2.7 Total cost of ownership*

There are many factors that affect the overall costs involved in operating a cable car system. While some of these factors are out of the operator's control, many can be influenced and should therefore be monitored continually.

An effective way of achieving an end-to-end approach to total cost of ownership is to be involved in designing the system and the building in the initial phases. In many cases, an initial capital expenditure or a decision on the installation design can help to minimise long term the resources required for operation (such as staff, tools, materials). These decisions can have far-reaching implications for the total cost of ownership.

The main parameters influencing the total costs of a cable car are:

- the location of the system and its surroundings,

- the configuration of the technical components,

- the number of stations,

- the number of operating hours,

- the operating speed, and

- the energy costs.

3S system in Koblenz, Germany,
not yet integrated into local public transport

# 7 Evaluation, investments and funding

The new version of the procedural guide to evaluating projects entitled 'Standard evaluation of investments in transport routes in local public transport' ('standard evaluation') from July 2022 can now, for the first time, be applied to cable car projects in order to prepare an adequate evaluation. The standard evaluation can be used to determine the eligibility of an urban cable car for funding in the same way as for other local public transport projects.

As with other local public transport systems, there will be urban cable car projects that offer economic benefits and those that do not. This is not a failing of the standard evaluation, but is rather its fundamental purpose.

## 7.1 Procedures in the standard evaluation

Where infrastructure is publicly financed, the amount of funding available is determined as a result of political will. This decision is driven by a multitude of factors (such as the general budgetary situation, relevance in the context of achieving climate goals, contention between different areas of responsibility).

Generally speaking, it is to be assumed that there is never enough funding available to finance all desired projects, since no polity is furnished with unlimited (financial) resources. Thus all planned transport projects must undergo economic evaluation to determine the best-possible use of resources.

Of all of the potential courses of action and alternatives, those that make the biggest contribution to public welfare using the limited resources available are to be selected. **Economic feasibility studies** that contrast costs and benefits to identify the preferred measures are carried out to ensure funds are directed wherever possible in line with objective considerations. This is also a requirement of the Law on Budgetary Principles (HGrG) and the Federal Budget Code (BHO).

Economic feasibility studies for transport projects eligible for public financing are carried out in the form of a **benefit-cost analysis**. This looks at technical and commercial criteria, as well as the effects on the general public, the users and the environment. A benefit-cost analysis to determine the funding eligibility of local transport projects which qualify for partial funding under the Local Authority Transport Infrastructure Financing Act (GVFG) must be carried out in accordance with the procedure in the standard evaluation.

The standard evaluation allows differing local, technical and transport-related projects to be evaluated according to the same standards. The standard evaluation has been the established nationwide procedure for evidencing funding eligibility under GVFG for 40 years. It has been extended and updated several times throughout this period, most recently in 2022. One addition to the standard evaluation has been the incorporation of urban cable cars into the procedure. It is now possible to evaluate cable car projects under the same procedure that is applied for rapid transit railways, trams and similar projects.

A measure is considered economically expedient when the total benefits are higher than the costs. The costs are used in the procedure as the basis for calculating the depreciation and interest (debt service) on the infrastructure investment. All further costs (for staff, energy, etc.) are interpreted as 'negative benefits' and included on the benefit side. A cable car project is eligible for funding in accordance with GVFG where the economic benefits outweigh the costs. In the standard evaluation, this corresponds to a benefit-cost index of over 1.0.

## *7.2 Contents of a cable car evaluation*

The evaluation of an urban cable car using the procedure defined in the standard evaluation is essentially the same as the procedure for the transport systems that were already included. The procedure identifies and contrasts the commercial and economic benefits and costs of a project. These are grouped as follows:

- **Passenger benefits** (e.g. reduced journey times, better connections, more services)

- **Financial impact on the partner** (infrastructure costs, operating costs, fare proceeds)

- **Benefits for the general public** (e.g. reduction in accidents and emissions, limited use of ground space, reduction in primary energy consumption)

In this context, urban cable cars achieve the same positive effects as other local public transport projects (e.g. shifting private motorised transport journeys to public transport and reducing pollution). These effects can be predicted using traffic models (see Section 5.1.1). Alongside the benefits for passengers and the general public, costs are generated for the infrastructure and for running. As continuous conveyors with driverless carriers, there are several special aspects of cable cars that play into the evaluation. These are described in the sub-sections below.

### 7.2.1 Calculating the investments

All investments required to build the cable car are included in the evaluation. They must be sufficient to achieve the planned capacity and maintain safe operation in accordance with current laws and regulations. This includes, for example, the acquisition of land, investments in accessibility or in noise and fire prevention.

In addition, the investments required for third-party installations must also be considered where there is a causal relationship to the construction of the cable car. This includes, for example, re-routing cables or adapting roads, squares and green spaces. In addition, the standard evaluation applies a standard rate for the expenses required to plan and approve the cable car of 10 % of the total investments.

As is the case for other local public transport systems, infrastructure investments are spread across plant components. These comprise general plant (e.g. land or transport buildings), as well as plant specific to cable cars: the drive system, pylons, carrying ropes, carrying/haul ropes. Both the service life and the maintenance cost rate for every plant component are specified in the standard evaluation's costing and valuation. These are used to calculate the debt service and the maintenance costs to be used in the evaluation.

### 7.2.2 Calculating operating costs

In the interests of establishing comparability between transport projects in different regions, the operating costs are calculated using largely standardised methods as well as fixed costing and valuation to ensure a uniform price level.

Cable car cabins are interpreted in the standard evaluation as vehicles and not as part of the infrastructure. The debt service and maintenance costs for the cabins are thus assigned to operating costs. The debt service is calculated as the depreciation and interest on the cable car cabins assuming a service life of 25 years. Cabin maintenance costs are bundled under a time-dependent cost rate.

For staff costs, a staffing requirement of one person per station is assumed. As with other local public transport systems, the fixed rate for staff costs also covers staffing for operations (e.g. in the control centre). In the case of unattended automated systems, other rates must be agreed.

To determine the energy requirements, the instructions to the standard evaluation contain a simplified calculation method which is based on physical principles and adjusted according to real/planning data. In addition to the metrics on operational planning (e.g. line length, departure intervals, cabin mass, etc.), only two further data points are required for the calculation (rope speed and mass per metre of moving rope).

The calculation differentiates between circulating monocable, 2S and 3S ropeways, as well as reversible ropeways. The energy costs and the emissions are derived from the energy consumption calculated. It is possible to account for the use of electricity from renewable sources.

## *7.3 Infrastructure financing/ funding under GVFG*

Infrastructure investments for local public transport projects (such as new light rail services or rapid transit routes) are principally financed through the Local Authority Transport Infrastructure Financing Act (GVFG). Following the amendment to GVFG in spring 2020, the construction and expansion of cable car systems is now explicitly listed in Article 2 (1) para 1 c), meaning that urban cable cars have been included in the spectrum of projects eligible for funding. Funding is conditional upon the submission of a final business case in accordance with the procedure defined in the standard evaluation (see Section 7.1) as well as fulfilment of the essential pre-conditions required by the EU laws on state aid.

Cable car projects with a minimum project volume of 30 million euros qualify for funding of up to 75 % of eligible costs under the GVFG's federal programme. Project funding must align with EU laws on state aid. This will need to be discussed on a case-by-case basis. Depending on the local rules, cable car projects that fall below the threshold of 30 million euros may qualify for funding from the respective federal state.
The federal states may also take on co-financing for projects supported under the GVFG's federal programme. Total funding can thus reach over 90 %. It is important to note here that the funding relates to the funding-eligible infrastructure investments and not to the subsequent operating costs. The operating costs comprise the cabin costs (investments and maintenance), staff costs and energy costs. As is the case with buses or trams, etc., the respective partner must make up any gap in the operating costs not covered by fare proceeds.

For many years and up until 2019, the funding volume of the GVFG federal funding programme was capped at 333 million euros per year.
This is being raised significantly as part of efforts to meet climate goals. Funding of 1 billion euros per year is available from 2021 to 2024, rising to 2 billion euros per year from 2025 and to be adjusted dynamically from 2026 onwards.

# 8 Outlook and innovations

The majority of experts in the cable car industry see the implementation of a first real-world project in Germany using 'conventional' cable car technology (see Section 6.1.2) as both prudent and likely. Nevertheless, in the context of future national and international projects it is important that cable car technology continues to advance and for niche products to emerge which address transport needs optimally and offer an expedient and targeted way of expanding local public transport services.

Cable car manufacturers and start-ups are continually working on innovations in rope-propelled mobility with the goal of making these a reality in the future. New approaches are being developed in parallel to the refinement of existing systems and components. Some of these developments may be particularly advantageous in urban settings. More compact 3S systems are just one area. These allow better integration into the urban landscape. Additionally, smaller cabins are being used which are often more in line with expected demand.

Other innovations focus on systems that equip the cabins with a small electric motor. The motor enables the cabins to be driven autonomously and operated inside the station, eliminating the need for tyre conveyors in the turnaround and boarding/deboarding areas. The cabin's destination can be selected upon boarding and the additional switching mechanisms in the stations are set according to the station chosen. If no passenger transfer is desired, the cabins can enter a station at low speed and also overtake waiting cabins. It is even possible to travel along multiple lines in the stations without changing cabins.

Given the corresponding demand structure, these developments can reduce journey times and improve the cable car's catchment effect.

Another important topic is autonomous operation. The first unattended installations are already up and running (see info box 'Autonomous operation', Section 4.4). Intelligently connected technology monitors the installation and works to keep it running safely. The system recognises situations that deviate from normal operation and automatically switches off when such an event occurs (e.g. the cabin door is unable to close due to a blockage). Operating staff monitor the system from the control centre and switch it back on as required. Since there is no need for attendants, this can reduce operating costs and improve the economic efficiency of the cable car. It is therefore expected that the trend will increasingly move in this direction going forward. It is nonetheless advisable to deploy ground staff on site during the introductory phase of a new installation to help users gain familiarity with the system.

Hybrid solutions constitute a further field of development. These combine the pros of a rope-propelled system with autonomous operation on a separate at-grade track. The systems are based on a cable car, but upon arrival in the station the cabins are transferred to autonomous vehicles which either operate on a dedicated track or use existing road infrastructure.
The combined system comprising cable car and autonomous vehicle offers potential for needs-based integration in the urban environment.
As a 'dual solution', it allows the obstacles posed by structures and terrain to be overcome using cable car technology. At the same time, the system can reach into regions not suited to the construction of a ropeway route. This eliminates the need for passenger transfers and can improve the catchment effect and in turn enhance the attractiveness of the transport system. Hybrid concepts are currently in the development phase and have not been put to the test in pilots. It is therefore uncertain whether these will ever reach market maturity.

The innovations described here are up to date as of 2022. They show that the cable car market is set to unlock an even broader spectrum of potential solutions to urban transport problems. Whether a cable car can help solve these problems and which cable car system is the optimal solution must always be evaluated for the individual project, based on the specific requirements.

## *Abbreviations*

| | |
|---|---|
| **ALARP** | 'As low as reasonably practicable' principle |
| **BCA** | Benefit-cost analysis |
| **BGB** | German Civil Code |
| **BGG** | Act on Equal Opportunities for Disabled Persons |
| **BHO** | Federal Budget Code |
| **BIM** | Building information modelling |
| **BMDV** | Federal Ministry for Digital and Transport |
| **CENELEC** | European Committee for Electrotechnical Standardization |
| **CEP** | Courier, express and parcel services |
| **CMAR** | Circulating monocable aerial ropeway |
| **$CO_2$** | Carbon dioxide |
| **DIN** | German Institute for Standardization |
| **EN** | European standard |
| **ESG** | Environmental, social and governance |
| **EU** | European Union |
| **GVFG** | Local Authority Transport Infrastructure Financing Act |
| **HGrG** | Law on Budgetary Principles |
| **HMI** | Human-machine interface |
| **HWB** | Health and well-being |
| **LCA** | Life cycle assessment |
| **LCC** | Life cycle costing |
| **LPT** | Local public transport |
| **LRPS** | Local passenger rail services |
| **NDT** | Non-destructive testing |
| **NIMBY** | 'Not in my backyard' effect |
| **NMPT** | Non-motorised private transport |
| **PMT** | Private motorised transport |
| **pphpd** | Passengers per hour per direction |
| **SDG** | Sustainable Development Goal |
| **SOP** | Standard operating procedure |
| **UN** | United Nations |
| **UVPG** | Environmental Impact Assessment Act |
| **VWI** | Institute of Transportation Research Stuttgart |
| **2S** | Circulating bicable ropeway |
| **3S** | Circulating tricable ropeway |

## *Sources: Laws and ordinances*

All laws mentioned in this guideline are referred to in the version, as amended, as of October 2022. Future amendments and updates must be complied with throughout the implementation process. The following list of legal texts is in no way intended to be complete or accurate and any applicable laws beyond this must be complied with.

- Regulation (EU) 2016/424 of the European Parliament and of the Council of 9 March 2016 on cableway installations and repealing Directive 2000/9/EG
- Act on Equal Opportunities for Disabled Persons (BGG)
- Local Authority Transport Infrastructure Financing Act (GVFG)
- Environmental Impact Assessment Act (UVPG)
- Passenger Transportation Act (PBefG)
- Act on cableway installations (SeilbDG)

Specific provisions relating to the approval, operation, monitoring and supervision of cable cars can be found in the individual federal state laws on cable cars. Brandenburg is the only federal state not to have adopted a separate cable car act. The regulations are laid down in the Brandenburg Building Ordinance (BbgBO).

- Baden-Württemberg state act on cableway installations (LSeilbG BW)
- Bavarian Railway and Cableway Act (BayESG)
- Berlin state act on cableway installations (LSeilbG)
- Bremen Cableway Installations Act (BremSeilbG)
- Hamburg cableway installations act (SeilBG HA)
- Hessen cableway installations act (HSeilbG)
- Lower Saxony railway and cableway act (NESG)
- Mecklenburg-Western Pomerania state act on cableway installations (LSeilbG M-V)
- North Rhine-Westphalia cableway installations act (SeilbG NRW)
- Rhineland-Palatinate state act on cableway installations (LSeilbG)
- Saarland railways act (EisenbG SL)
- Saxony-Anhalt state act on cableway installations (SeilbG LSA)
- Saxony state act on cableway installations (LSeilbG)
- Schleswig-Holstein state act on cableway installations (LSeilbG)
- Thuringia mountain railway and miniature railway act (ThürBPBahnG)

## *List of EN standards on safety requirements for cable cars used for passenger transport*

The standards mentioned in this guideline, which require consideration throughout planning, execution and operation, are referred to in the version, as amended, as of October 2022. Future amendments and updates must be complied with throughout the realisation process. The following list of standards is in no way intended to be complete or accurate and, if applicable, any further standards, technical documents and requirements must be complied with.

EN 1709 Safety requirements for cableway installations designed to transport persons – Precommissioning inspection and instructions for maintenance and operational inspection and checks

EN 1907 Safety requirements for cableway installations designed to carry persons – Terminology

EN 1908 Safety requirements for cableway installations designed to carry persons – Tensioning devices

EN 1909 Safety requirements for cableway installations designed to carry persons – Recovery and evacuation

EN 12397 Safety requirements for cableway installations designed to carry persons – Operation

EN 12408 Safety requirements for cableway installations designed to carry persons – Quality control

EN 12927 Safety requirements for cableway installations designed to carry persons – Ropes

EN 12929-1 Safety requirements for cableway installations designed to carry persons – General requirements – Part 1: Requirements for all installations

EN 12929-2 Safety requirements for cableway installations designed to carry persons – General requirements – Part 2: Additional requirements for reversible bicable aerial ropeways without carrier truck brakes

EN 12930 Safety requirements for cableway installations designed to carry persons – Calculations

EN 13107 Safety requirements for cableway installations designed to carry persons – Civil engineering works

EN 13223 Safety requirements for cableway installations designed to carry persons – Drive systems and other mechanical equipment

EN 13243 Safety requirements for cableway installations designed to carry persons – Electrical equipment other than for drive systems

EN 13796-1 Safety requirements for cableway installations designed to carry persons – Carriers – Part 1: Grips, carrier trucks, on-board brakes, cabins, chairs, carriages, maintenance carriers, tow-hangers

EN 13796-2 Safety requirements for cableway installations designed to transport persons – Carriers – Part 2: Slipping resistance tests for grips

EN 13796-3 Safety requirements for cableway installations designed to carry persons – Carriers – Part 3: Fatigue testing

EN 17064 Safety requirements for cableway installations designed to carry persons – Prevention and fight against fire

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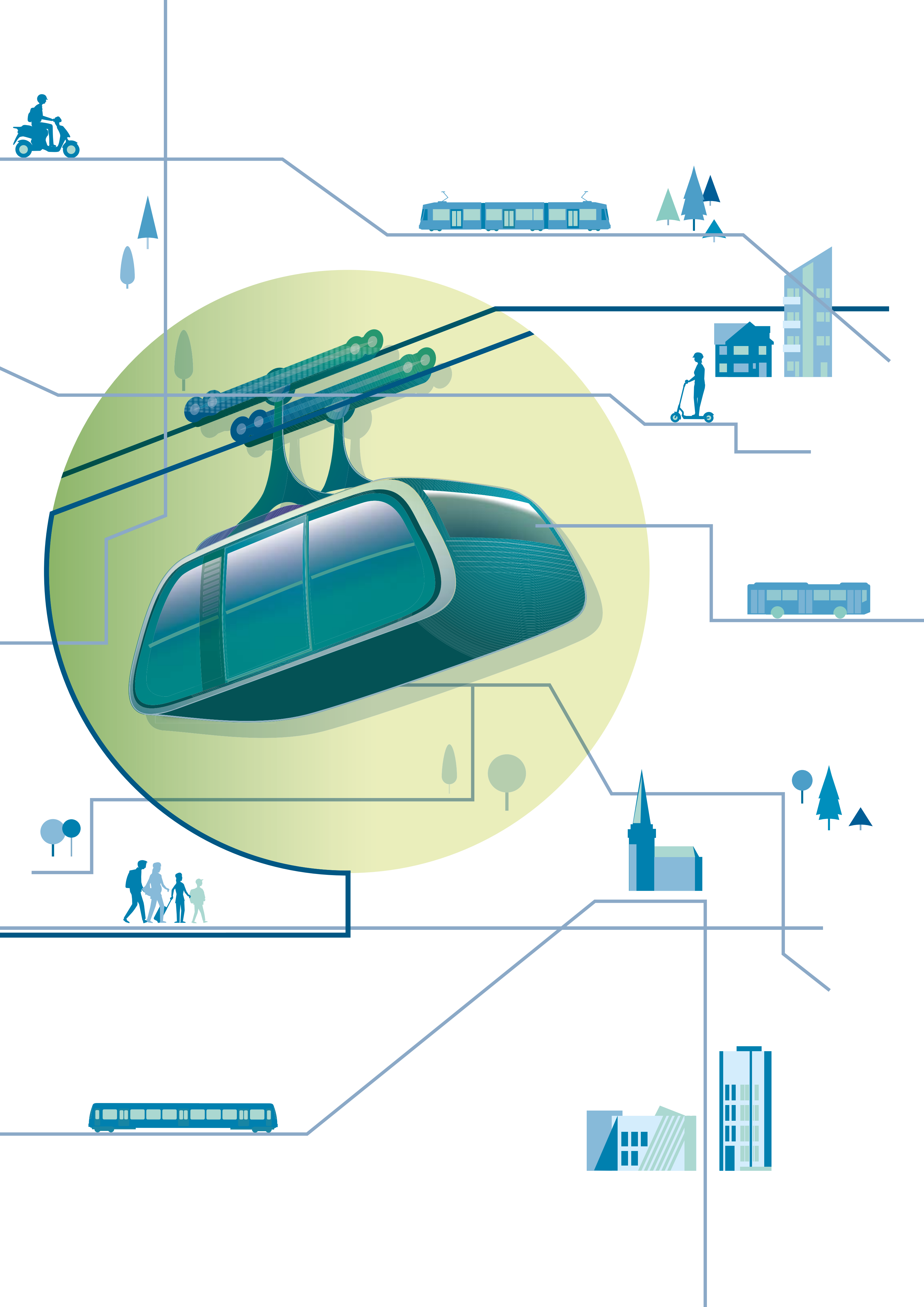

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