



Deliverable D 14.4

Proposal for concept of an architecture of a ropeway carrier

Project acronym:	Pods4Rail
Starting date:	2023-09-01
Duration (in months):	34
Call (part) identifier:	HORIZON-ER-JU-2022-01
Grant agreement no:	101121853
Due date of deliverable:	30.02.2026
Actual submission date:	29.06.2026
Code:	Pods4Rail-WP14-SMO-AT-004-02
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Dissemination level:	PU
Status:	I

Reviewed: Yes

Reviewer: UPM, DLR, SMO

Document history		
<i>Revision</i>	<i>Date</i>	<i>Description</i>
0-1	25.04.2026	First issue
1	13.05.2026	Final issue
2	29.06.2026	Revised version

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1 Executive Summary

Deliverable D14.4 describes the first conceptual architecture for a ropeway-based Carrier Unit within the Pods4Rail project. The work provides both (1) a technical overview of current ropeway technologies and (2) a first visualisation and conceptual draft of a ropeway Carrier Unit (CU) capable of transporting Pods4Rail Transport Units (TU).

The ropeway CU is intended as the third supermodal carrier type - next to road and rail - enabling Pods4Rail to operate in terrain where conventional mobility systems become inefficient or impossible. Ropeway systems offer advantages such as low ground impact, high energy efficiency, continuous operation, and suitability for complex topographies, making them relevant for Pods4Rail use cases in urban, interurban, and mountainous environments.

The document outlines ropeway fundamentals and differentiates between funicular systems, pendulum cable cars, and circulating cableways. For D14.4, the technical scope is restricted to 2S pendulum aerial ropeway systems, which consist of fixed track ropes for load bearing and a separate haul rope for cabin propulsion. The Carrier Unit attaches to the haul and track ropes via a hanger system, which forms the essential mechanical interface between TU and ropeway infrastructure.

Based on existing ropeway manufacturers and reference systems, the deliverable derives typical structural dimensions and weight ranges for ropeway carriers. Standard European ropeway cabins with a capacity of around 10 passengers show tare weights between 2.3 and 3 t, with typical component masses estimated for the carriage (400–900 kg), hanger (250–400 kg), and detachable grips (50–120 kg). These benchmarks support the sizing of the Pods4Rail ropeway CU, which is expected to carry a 10-passenger TU with a similar tare mass.

A major finding is the definition of the TU–CU interface: Unlike road or rail CU, the ropeway hanger system cannot transmit power or communication signals. Therefore, the structural interface relies exclusively on mechanical twist-lock connectors, building on standards established in earlier Pods4Rail work packages. The deliverable also identifies required connector platform dimensions and derives preliminary hanger lengths between 1.5 and 3 meters for monocable gondola systems, depending on line geometry and safety clearances.

The outcome of D14.4 is a technical baseline for designing a ropeway CU that integrates into the overall Pods4Rail system while respecting ropeways specific mechanical, operational, and safety constraints. The document provides the conceptual hanger system architecture and a first visualisation of the hanger–TU connection, forming a foundation for the next design stages in WP14 and subsequent detailed engineering work.

Limitations include the early conceptual nature of the work: structural verification, dynamic behaviour studies, safety analyses, and full integration engineering remain tasks for later development phases. Nonetheless, the deliverable achieves its objective of creating a coherent, scalable architectural concept for a Pods4Rail ropeway carrier, enabling its future evolution into a fully functional multimodal mobility component.

2 Abbreviations and acronyms

Abbreviation / Acronym	Description
2S	Bicable ropeway system (two-rope system)
CAD	Computer-Aided Design
CU	Carrier Unit(s)
D	Deliverable
EN	European Standard
ERJU	Europe's Rail Joint Undertaking
EU-Rail JU	Europe's Rail Joint Undertaking
FA	Flagship Area
ISO	International Organization for Standardization
MAWP	Multi-Annual Work Programme
TU	Transport Unit(s)
UC	Use Case(s)
WP	Work Package

3 Background

The present document constitutes the Deliverable D14.4 “Proposal for concept of an architecture of a ropeway carrier” in the framework of the Flagship Area 7, project Pods4Rail as described in the EU-RAIL MAWP.

The Deliverable D14.4 within WP 14 contains the works of two main parts, namely a technical description of current status of ropeway technologies and second one to propose a visualization for the first design of a ropeway carrier unit.

This D14.4 summarises the fundamental work done in Task 14.1 and WP 9 of the Pods4Rail project to provide the technical framework for the design concept of the ropeway carrier unit as well as design draft for the next stages of Pods4Rail.

4 Objective/Aim

This document has been prepared to provide a general description of the architecture of a pod carrier for ropeway which is detailed on a conceptual level here with the requirements of the interface for the TU's and the boundary conditions and requirements in WP 7 and 9.

The main components as well as the interface are conceptual designed. A version is derived from the mechanical design in CAD, which will be figured out in a visualisation / rendering.

5 Introduction to Task 14.4

Ropeway-based transportation systems have gained increasing attention in recent years as an alternative mode of transport for urban, industrial, and geographically constrained environments. Their advantages include low ground footprint, continuous operation, high energy efficiency, and adaptability to complex terrain. Within such systems, the pod carrier plays a central mechanical and functional role, acting as the interface between the ropeway infrastructure and the transport unit. The pod carrier design must simultaneously fulfill structural, kinematic, and operational requirements. It is responsible for transmitting loads from the pod to the suspension system, ensuring positional stability during operation, and enabling safe and efficient integration of the pod within the overall ropeway architecture. Due to these functions, the pod carrier represents a safety-critical subsystem whose conceptual design strongly influences subsequent development stages.

This chapter focuses on the conceptual design of a pod carrier chassis developed within the framework of the present research. The design is informed by requirements and boundary conditions defined in preceding work packages and chapters. The primary goal is not to deliver a finalized structural solution, but rather to establish a technically consistent, scalable, and verifiable architectural concept that serves as a foundation for detailed design and analysis.

6 Scope definition

Following chapter will define the technical boundary of the carrier system for a ropeway system. The ropeway system will use conventional technology as used for modern transportation in urban areas.

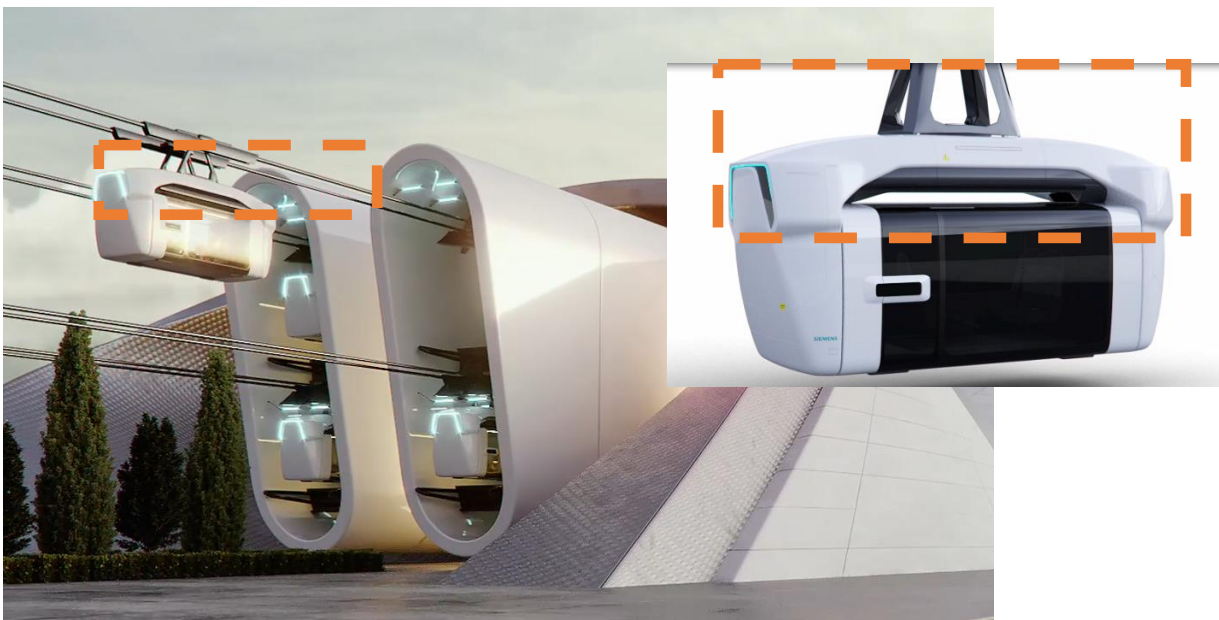


Figure 1: Ropeway System for One4All: A TU is carried by a ropeway carrier system into a connection hub. (Siemens/moodley, 2019)

The pod carrier can be seen as a surrogate for the Transport Unit (TU) for Road and Rail in WP 14.1 and 14.2. and 14.3. Herewith we define the technical scope to a 2S – pendulum arial ropeway system.

7 Introduction to the ropeway technologies

7.1 General Overview

In general, there are three major groups of ropeways:

- A: Funicular railway
- B: Pendulum cable car
- C: Circulating cable car

A funicular railway and an aerial tramway (pendulum cable car) differ mainly in their mechanical design, guidance system, and load transfer.

Ad A)

A funicular railway operates on a track-based system. Two rail vehicles run on fixed rails along a steep incline and are connected by a haulage cable that passes over a drive pulley at the upper station. The system works on a counterbalance principle: as one car ascends, the other descends, which significantly reduces the required drive power. Guidance, braking, and safety systems are like those of rail vehicles, and traction forces are transmitted through the cable while vertical and lateral loads are carried by the rails.

Ad B)

An pendulum cable car or aerial tramway is a ropeway system in which cabins are suspended from one or more stationary track cables and moved by a separate haul rope. The cabins travel freely through the air without ground contact, oscillating back and forth between stations. Structural loads are transferred to towers and anchor stations via the cables, allowing the system to span long distances and large height differences. This design is particularly suitable for rugged terrain, deep valleys, and high-alpine environments.

In summary, a funicular is a rail-guided, cable-hauled inclined railway, whereas a “Pendelbahn” is a cable-suspended, aerial transport system designed for long spans and extreme topography. (Nejez, 2021)

Ad C)

In a circulating cable car, the vehicles travel in a constant direction. The vehicles can be permanently attached to the cable or detachable during operation.

Examples for such systems are: (BMIMI, 2026)

- Gondola lift: A circulating cable car with enclosed vehicles (cabins).
- Chairlift: A circulating cable car with open vehicles (chairs) whose attachment to the cable is detached at the stations.
- Chairlifts: A circulating cable car with open vehicles (chairs) where the attachment to the cable is not detached at the stations.
- Combined cable car: A circulating cable car with cabins and chairs.

7.2 Overview of existing ropeway technologies

Figure 2 shows the technical layout of an aerial tramway (Pendelbahn) and its main mechanical components.

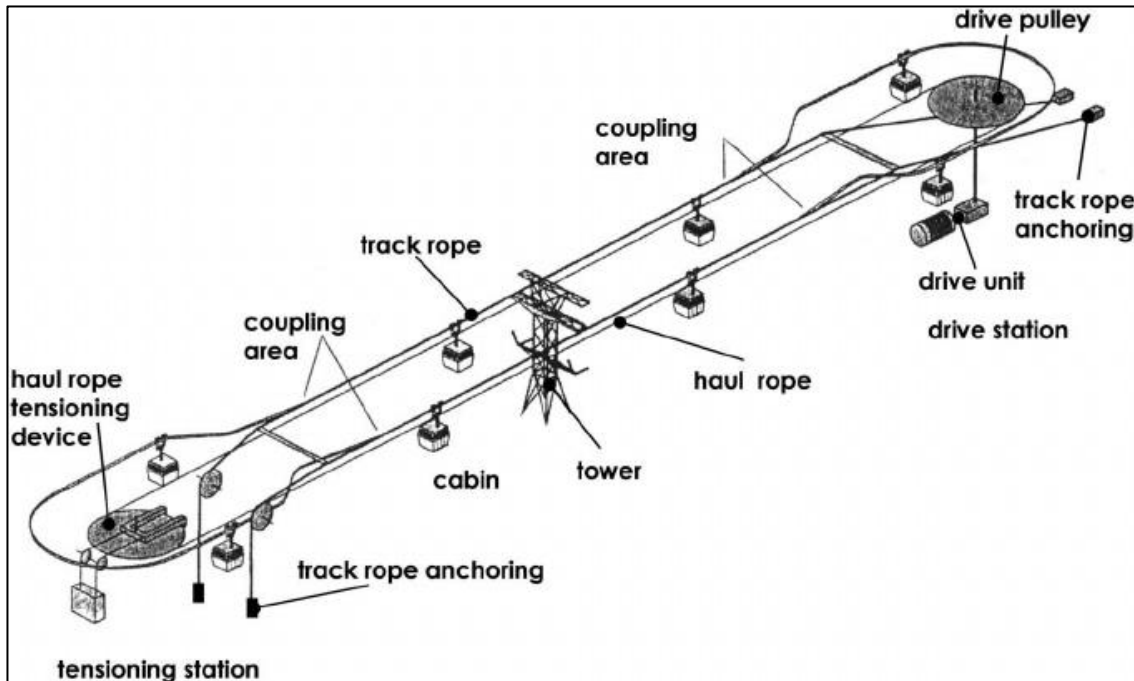


Figure 2: Schematic figure of a pendulum aerial rope way (Petrova, 2007)

The system consists of two fixed track ropes that are stretched between the lower and upper stations. These track ropes are anchored at both ends and carry the entire weight of the cabins. In the middle of the line, the track ropes are supported by a tower, which transfers loads to the ground and controls rope geometry.

The cabins are suspended from the track ropes and are mechanically connected to the haul rope in the coupling areas. The haul rope is responsible only for the horizontal movement of the cabins, not for load bearing.

At the drive station, an electric drive unit rotates the drive pulley, which moves the haul rope back and forth. As the haul rope circulates, one cabin is pulled uphill while the other moves downhill, operating in a pendulum motion.

At the opposite end, the tensioning station contains a haul rope tensioning device. This system maintains constant rope tension despite temperature changes, rope elongation, or varying loads, ensuring safe and smooth operation. This separation of load bearing and traction functions is a key engineering principle of aerial tramway systems

The hanging system of a ropeway - comprising the carriage, the grip, and the hanger - is responsible for attaching the cabin or chair to the rope and guiding it safely along the line.

In the drive station, the tractive cable is guided from the drive pulley via deflection pulleys onto the track. There, it runs, if necessary, over the tractive cable support rollers on the pylons to the

vehicles, where it is attached to the suspension axles (connection between the suspension and the running gear of the aerial tramway cars), usually by means of cast ends. Another tractive cable runs from the suspension axles of the vehicles, if necessary, over the support rollers to the deflection and redirection pulleys in the opposite station. The tractive cable above the vehicles is called the upper tractive cable, and the lower one, usually with a smaller diameter, is called the lower tractive cable. Figure 3 shows the running gear of an aerial tramway car with the designations of the afore mentioned structural elements. The upper and lower tow ropes can also be designed as a closed, spliced loop. In this case, the vehicles are attached to the tow rope with clamps (Nejez, 2021).

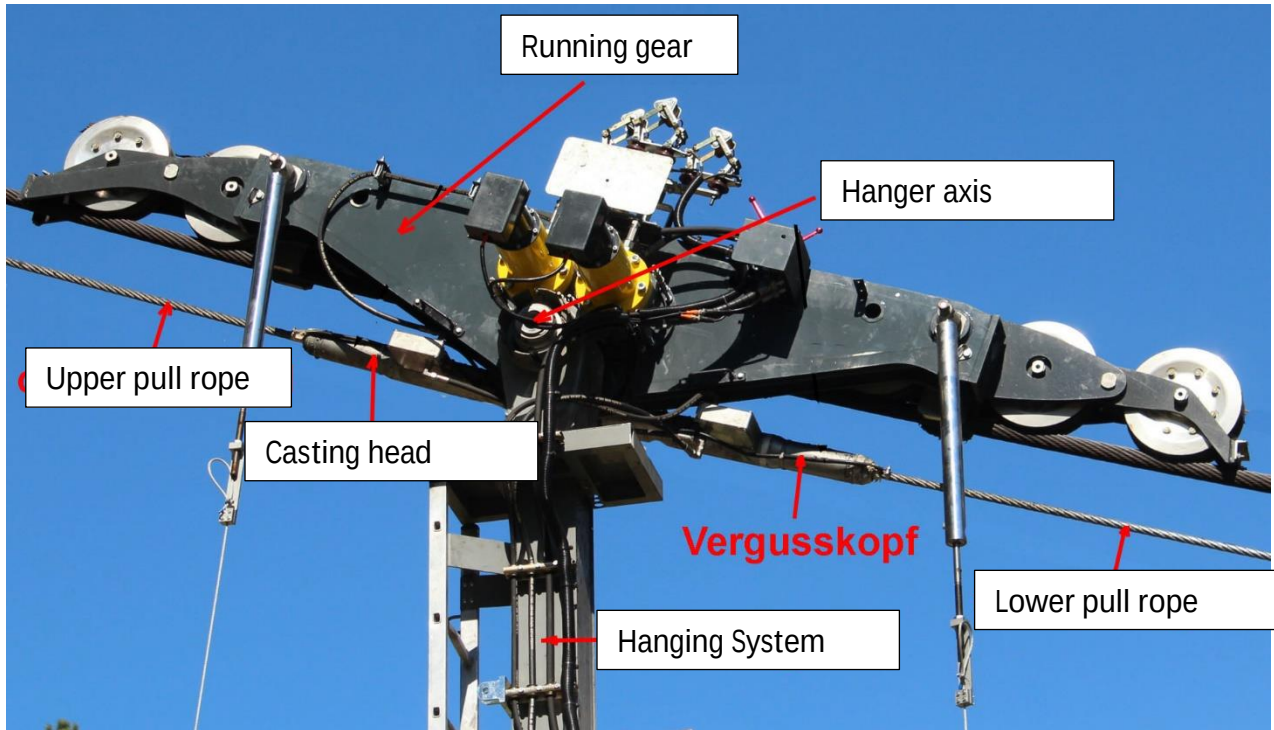


Figure 3: Traction Cable Guidance (so called running gear) of a ropeway carrier with the designations of the construction elements (Nejez, 2021)

The hanger is the vertical steel structure between the cabin and the carriage. It is often asymmetrical, a geometry that helps ensure that the hanger does not strike towers and maintains safe clearance even during lateral sway or oscillation. The hanger transfers cabin loads to the carriage and can include additional components such as ladders for maintenance personnel, depending on the ropeway type (Leitner, 2026).

7.3 Technical data of existing pendulum car systems

Following chapter will figure out engineering estimations on typical technical data of exiting pendulum car systems considering the carriage, hanger system and running gear.

In modern ropeway systems - including monocable gondola lifts, detachable chairlifts, and reversible aerial tramways - the hanger system constitutes a critical structural component facilitating safe load transfer, dynamic stability, and operational reliability. Although visually simple, the hanger is integral to ensure the correct mechanical interface between the rope grip, the vehicle, and the station infrastructure. Standards such as EN 12929-1 (ISO-12929-1, 2023) define fundamental safety and design principles for ropeway components, including those related to load transfer and structural requirements.

Table 1: Data of existing supplies (CWA,2026)

Manufacturer	Cabin model	Passenger capacity	Payload	Source
CWA	OMEGA V	8–10 passengers	800 kg	CWA, 2026
CWA	STELLA	Up to 20 passengers	1,500 kg	CWA, 2026
CWA	ATRIA	Up to 34 passengers	2,560 kg	CWA, 2026

The evaluation of the available technical data from various revealed that a typical standard system in Europe weighs (excluding tare weight) between 0.8 and 2.5 tons (depending on maximal capacity and system design).

Table 2: Typical component weights in kg for ropeway systems

Component	Weight	Source
Typical hanger	250–500 kg	CWA, 2026
Typical carriage	400– 1000 kg	CWA, 2026
Detachable grip	50–120 kg	CWA, 2026

Herewith the total Pods system (TC and TU) should not exceed for UC 1 a typical capacity of 10 passengers (for 10 ft TU) and 2 t total weight (pay load plus tare weight).

8 Necessary derivation for Pods4Rail

8.1 Interface position between TU and CU

The hanger system will be the main interface between TU and CU. In contrast to the road or rail carrier the hanger system cannot transmit energy nor communication. The hanger system consists of the hanger beam and the connector platform. The connection technology for TU will be the “Twist Lock” system as described in WP 7 (Pods4Rail, 2025).

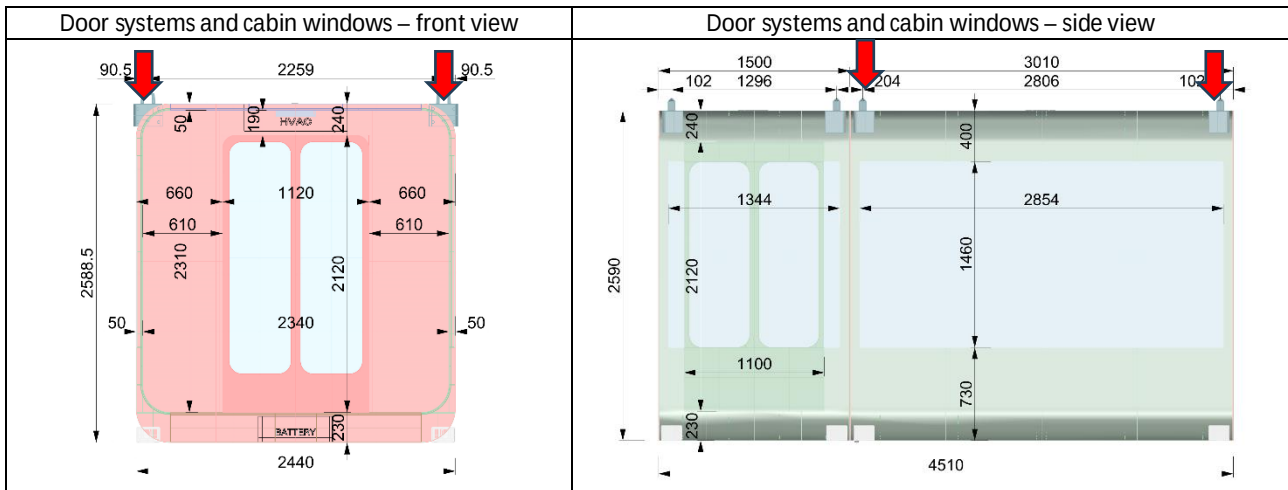


Figure 4: Dimensions of 5ft and 10ft TU (Pods4Rail, 2025) positions of twistlocks are marked with red arrows.

Based on figure following dimensions of the connector position (position of twistlocks) can be anticipated.

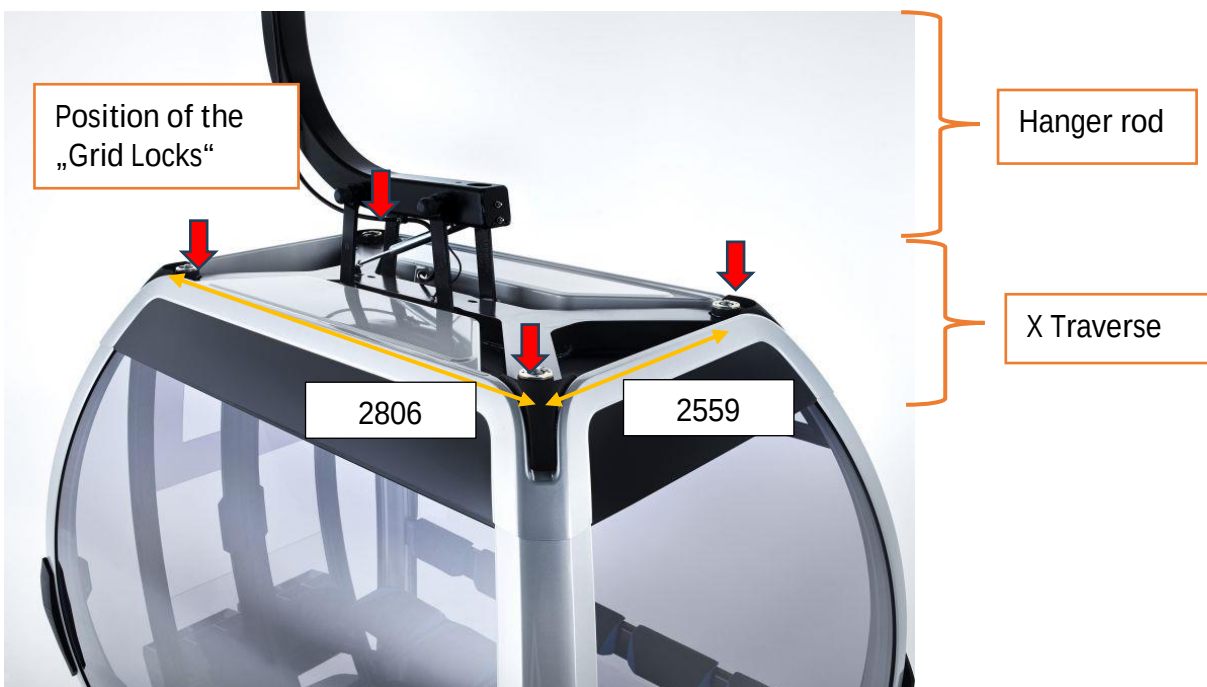


Figure 5: Interface dimension in mm for the connection traverse (based on WP 7). Original picture was taken from CWA (Doppelmayer, 2026)

8.2 Derived technical parameters for the hanger design

Typical hanger dimensions vary depending on the operating environment. In the following section, the length of the suspension system represents a critical dimensioning parameter for the gondola system. The other parameters described below also influence the single-cable gondola lift (gondola/chairlift). The hanger connects the grip on the rope with the cabin or chair. It must be long enough to ensure that:

- Towers can be safely passed
- Cabins/chairs are correctly aligned in the station areas
- Oscillations remain controllable

Typical hanger lengths for gondola lifts (8–10 passenger cabins):

- approx. 1.5 m – 2.5 m (hanger rod between grip and cabin roof)
- For larger cabins (15+ passengers), more likely 2.5 m – 3 m

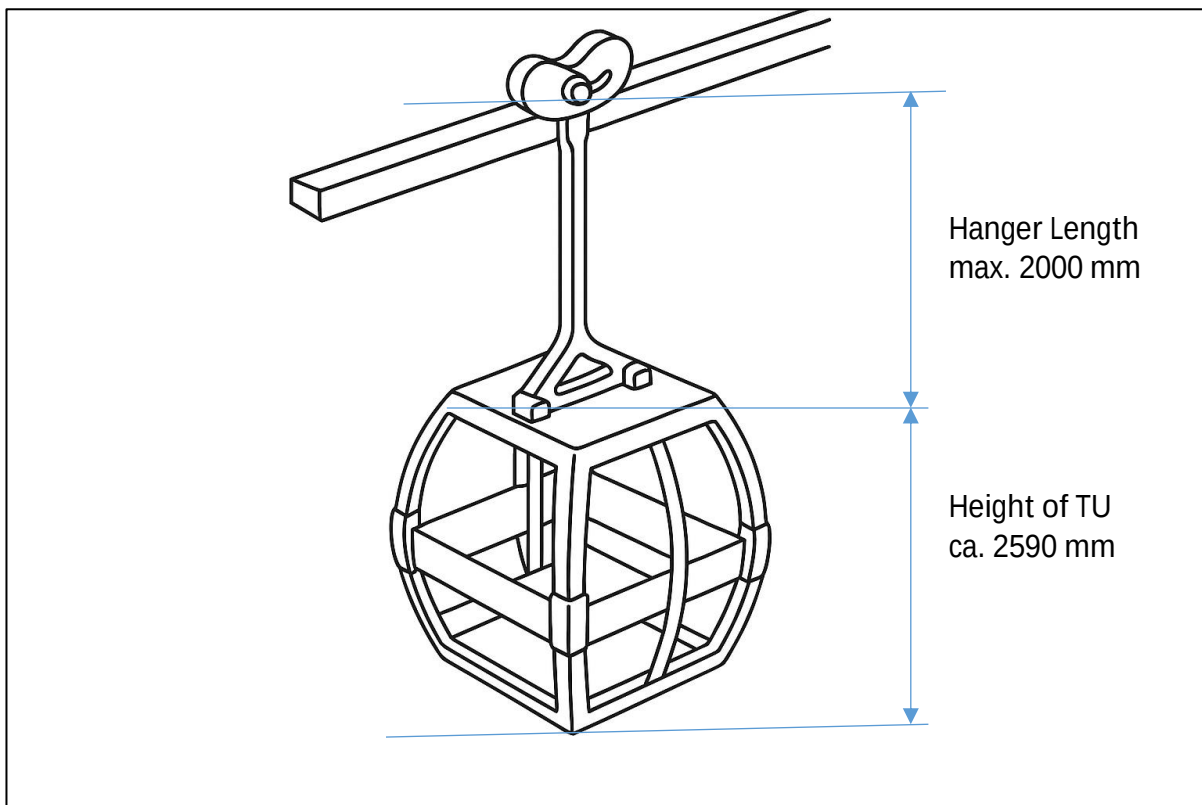


Figure 6: Symbolic figure of an aerial rope gondola incl. hanger rod and rope clamp (AI generated drawing)

The hanger length is determined by different parameters, and it is calculated individually for each installation:

- Line geometry
- Tower spacing

- Oscillation behaviour
- Vehicle size
- Station layout
- Safety clearances

Standard European ropeway cabins with a capacity of around 10 passengers show tare weights between 2.3 and 3 tons, with typical component masses estimated for the carriage (400–900 kg), hanger (250–400 kg), and detachable grips (50–120 kg). These benchmarks support the sizing of the Pods4Rail ropeway CU, which is expected to carry a 10-passenger TU with a similar tare mass. Therefore, the use of a 2000 mm long suspension pole with a movable X-traverse system is recommended. The X-traverse system features an adjustment mechanism for flexible use with 5-ft and 10-ft TU systems.

The X-traverse system must be connected to the hanger rod to be fully compatible with the ropeway carrier unit.

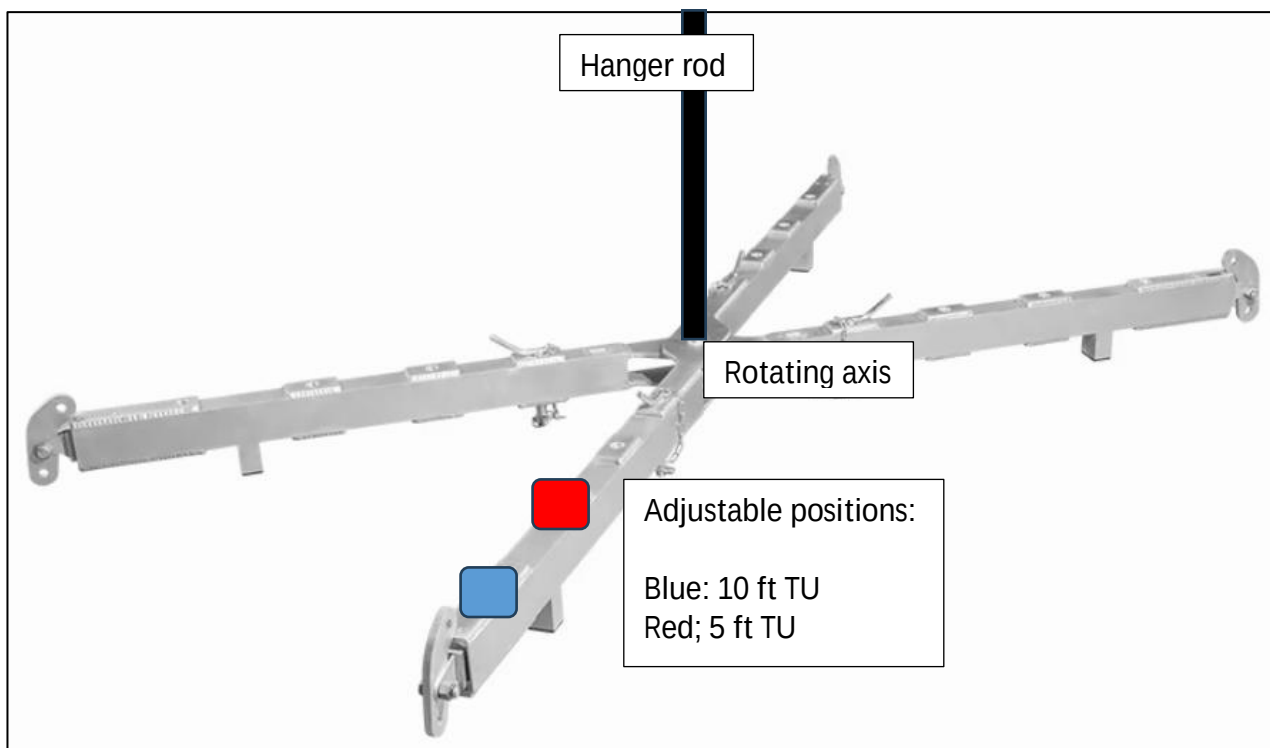


Figure 7: Flexible X-Traversal for different TU sizes (10 ft and 5 ft). The adjustment must be done mechanically. The maximum payload is 10 tons with a variable length of 2.5 to 5.4 meters. (Wacker, 2026)

9 Visualisation of the hanger system for gondola system

The hanger system represents a critical structural and functional component within gondola transport systems, directly influencing load distribution, stability, and operational safety. A clear and precise visualization of this system is therefore essential for both engineering analysis and communication of design concepts.

This chapter focuses on the graphical and conceptual representation of the hanger system, highlighting its geometric configuration for the 5ft and 10ft TU, key components of the infrastructure, and interaction with the gondola and supporting CU. By translating complex mechanical relationships into structured visual formats, the chapter aims to enhance understanding of system behaviour under operational conditions.

Furthermore, the visualisation serves as a foundation for subsequent analysis in phase 2 of the upcoming Pods4Rail project, including stress evaluation, dynamic response, and design optimization. Emphasis is placed on clarity, accuracy, and the ability to convey both functional dependencies and structural constraints within the system.

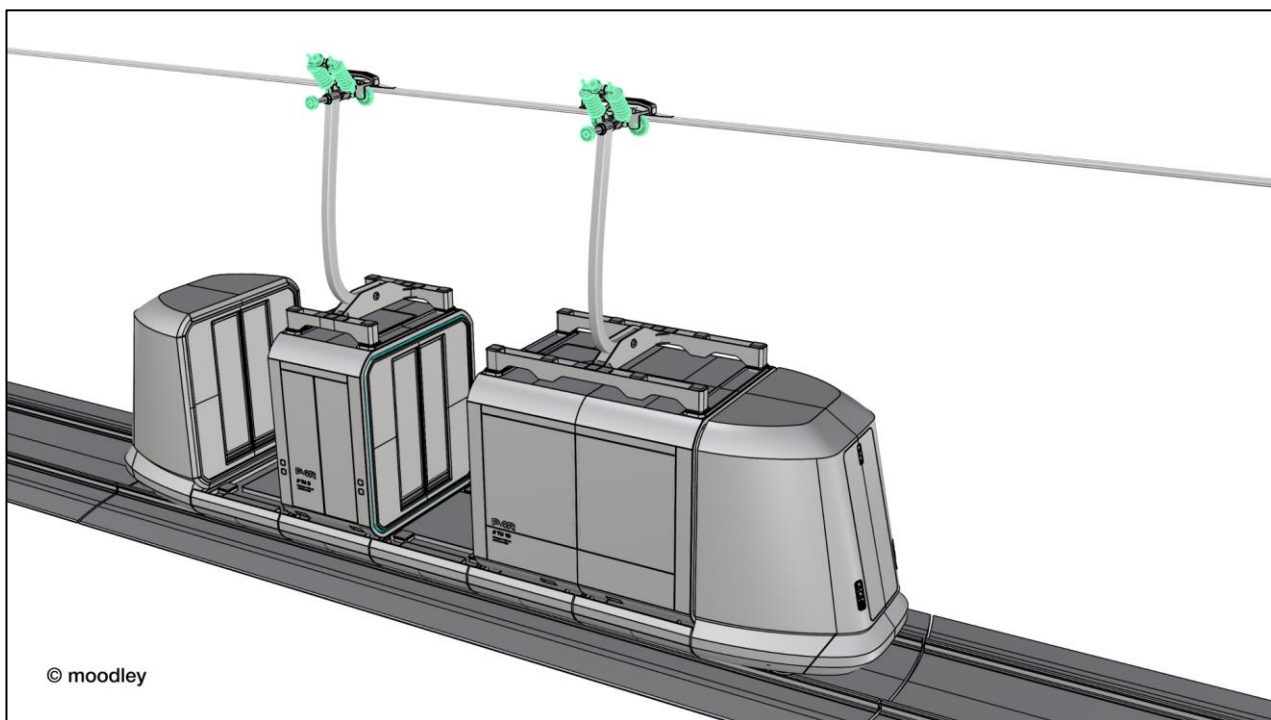


Figure 8: Simplified perspective illustration of the ropeway suspension system for 5 ft and 10 ft TUs, showing the cable, clamp/grip, hanger rod and TU support frame (Source: moodley).

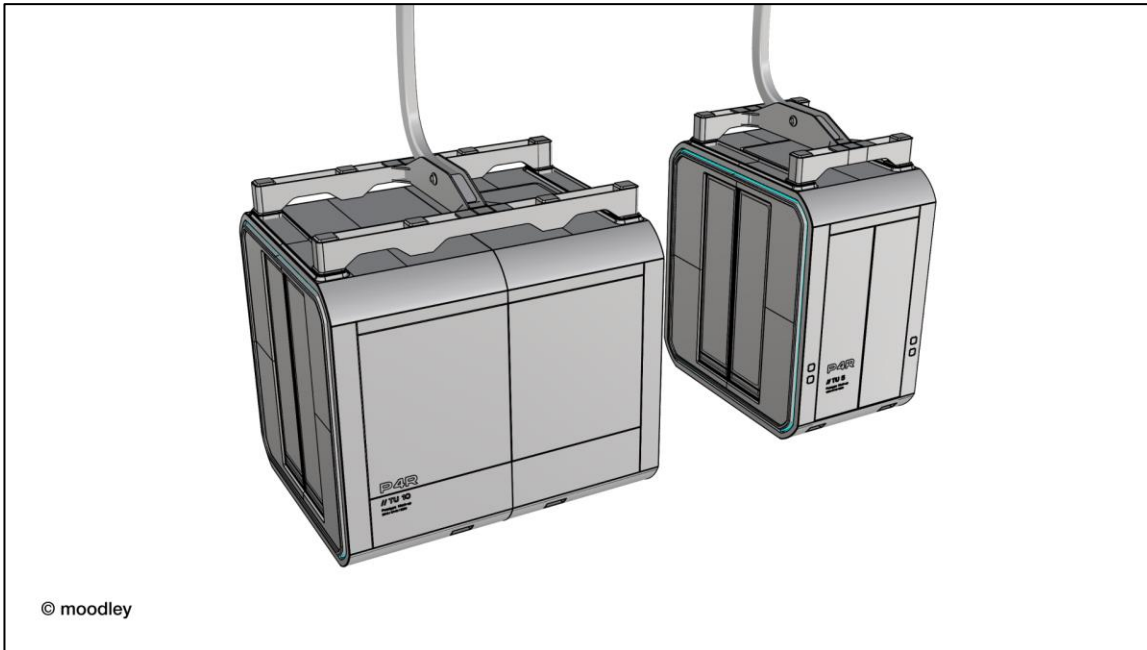


Figure 9: Simplified perspective illustration showing the TU support frame including integrated twist locks at the corners for the mechanical coupling of 5 ft and 10 ft Transport Units (TUs) to the ropeway structure (Source: moodley).

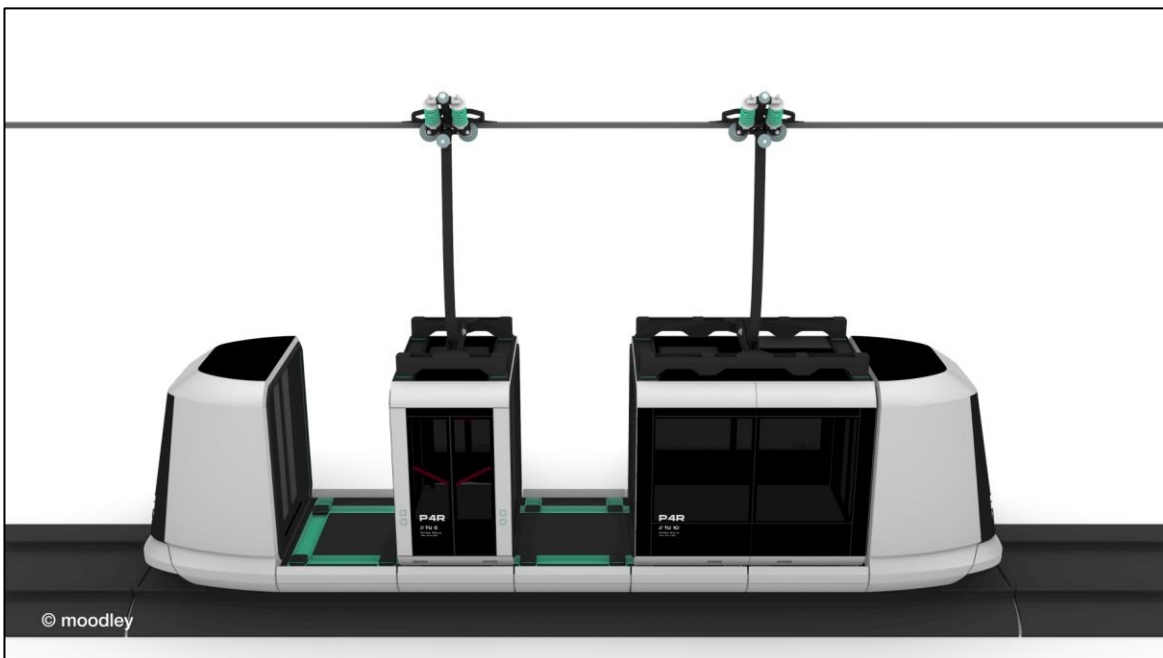


Figure 10: Example positioning of 5 ft and 10 ft TU on the rail Carrier Unit within the defined grid (twistlock positions) (Source: moodley).

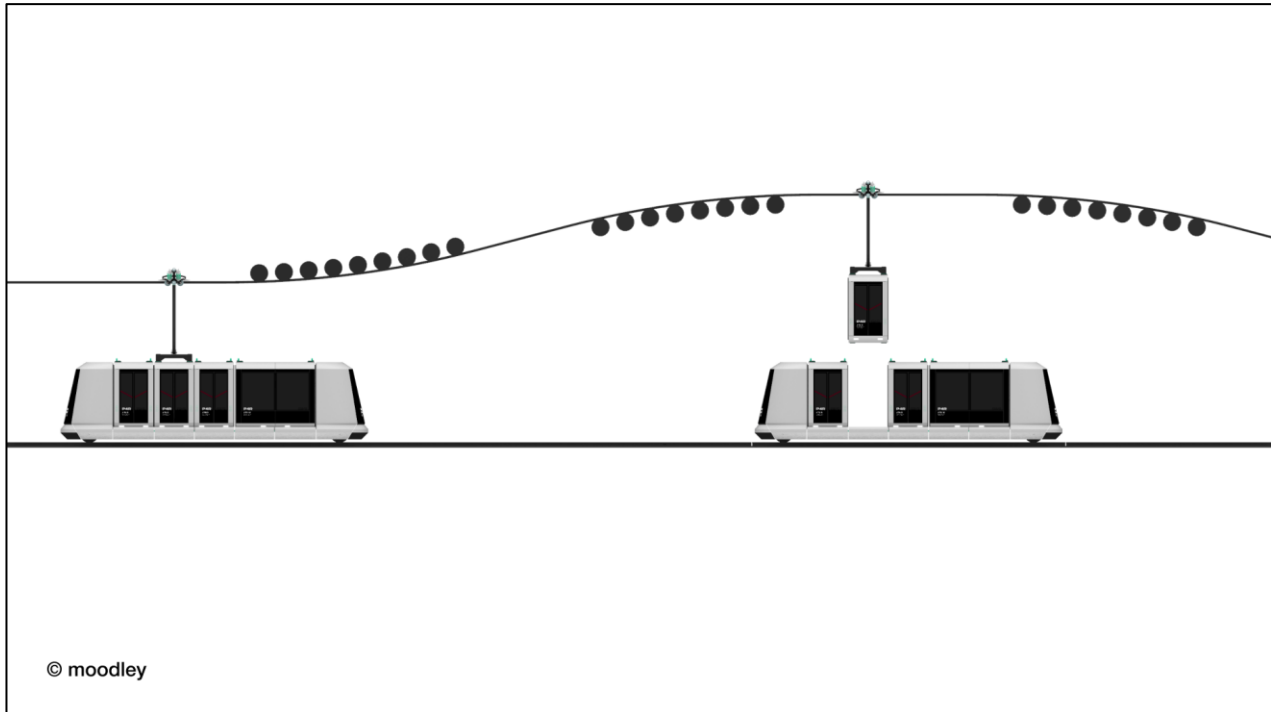


Figure 11: Simplified schematic illustration of the removal of a 5 ft TU from the rail carrier unit (CU) (Source: moodley).

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