



Deliverable D 13.1

Handling concept for a dedicated use case

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Table of Contents

1	Executive Summary	1
2	Abbreviations and acronyms	3
3	Background	4
4	Objective/Aim	5
5	Pod-carrier interface mechanism – concept proposal for the interface geometry for pairing passenger and cargo pods	6
5.1	Design and implementation of mechanical interface parts	6
6	Pod-handling connection mechanism - concept for standardised interfaces between the vessel and the handling systems	7
6.1	Manipulation procedures	7
6.2	Manipulation of Transport Units	10
6.3	Manipulation of empty Transportation Units	10
6.4	Manipulation of TU occupied by passengers or filled with cargo	12
6.5	Mechanical connection of freight containers – current state of the art	12
6.6	Another types of manipulation	13
7	Stacking – specifics	14
8	Concept for transportation, manipulation and storage of TU	15
8.1	The Logistical concept	15
8.2	Marking system of TUs	17
8.3	Dislocation and service centres	17
9	Conclusions	18
10	List of Figures	19
11	References	20

1 Executive Summary

The Pods4Rail deliverable D13.1 defines a comprehensive handling and logistics concept for modular Transport Units (TUs), also referred to as “Pods,” within a future multimodal mobility and freight ecosystem. The document focuses on the technical and operational framework required to seamlessly integrate passenger and cargo pods across rail, road, and potentially ropeway-based transport systems. Its objective is to establish standardized interfaces, automated handling procedures, and scalable logistics concepts that support efficient, safe, and interoperable multimodal transport operations.

At the core of the concept is the automated connection between the Transport Unit (TU) and the Carrier Unit (CU). The proposed solution uses standardised ISO-based twistlock systems for mechanical coupling, combined with automated electrical and communication interfaces. The system enables fully automated locking, power supply, data communication, and safety verification with minimal human intervention. Wireless communication technologies such as 5G Sidelink and IEEE 802.11p are proposed to support real-time monitoring, authentication, and diagnostics. Safety and interoperability are key design drivers, ensuring compatibility with existing intermodal freight standards and future automated transport systems.

The deliverable further defines standardised handling procedures for three primary operational scenarios:

1. Loading TUs from storage onto carrier vehicles,
2. Transferring TUs between transport modes (e.g., rail-to-road), and
3. Integrating TUs into ropeway transport systems.

These processes are designed as automated workflows supported by cranes, reach stackers, twistlocks, and digital safety protocols. The concept differentiates between handling empty pods, cargo-filled pods, and passenger-occupied pods, recognising that each requires different operational and safety measures. Particular emphasis is placed on minimising transfer times, ensuring safe handling of occupied units, and enabling scalable intermodal operations.

The logistics concept introduces a connected multimodal transport architecture supported by transshipment hubs, storage facilities, digital orchestration systems, and energy infrastructure. The proposed Multimodal Management System coordinates TU movements, charging infrastructure, storage allocation, and operational control across transport modes. Automated terminals equipped with cranes and storage systems are envisioned to reduce dwell times and improve overall system efficiency. The document also highlights the importance of redundancy, interoperability, and RAMS (Reliability, Availability, Maintainability, and Safety) principles for operational robustness.

In addition, the deliverable proposes a standardised TU identification and tracking concept using serial numbering, QR codes, and GPS-based monitoring. Dedicated deployment and service centres are envisioned across participating countries to support TU storage, maintenance, cleaning, monitoring, and operational coordination. These centres would form the operational backbone of the Pods4Rail ecosystem and enable scalable European deployment.

Overall, Deliverable D13.1 establishes a technically feasible and operationally scalable foundation for the Pods4Rail vision of modular, automated, and interconnected transport. By combining proven intermodal handling technologies with advanced automation, digital communication, and multimodal logistics integration, the concept supports a future transport ecosystem that aims to increase flexibility, efficiency, and sustainability for both passenger and freight mobility

2 Abbreviations and acronyms

Abbreviation / Acronym	Description
AC	Air Condition
CAD	Computer Aided Design
CU	Carrier Unit(s)
EN	European (Normalisation) Standard
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Standardisation Organisation
TU	Transport Unit(s)
UC	Use Case(s)
UIC	International Railway Association

3 Background

A summary of connection and interface possibilities based on WP7 ¹ and a summary of requirements, which are defined in WP12 ², are described in this chapter.

The connection between TU and CU is designed as a fully automated, standardised, and safe process enabling reliable multimodal transport. The mechanical coupling is realised mainly through automated twistlock systems that engage with the ISO 1161 ³ corner castings on the pod frame. These twistlocks can be semi-automatic or fully automatic and are integrated with sensors that confirm a secure lock and continuously monitor the connection during transport. Alternative coupling solutions, such as hook locking, hydraulic clamping, or four-point linear actuators, were evaluated, but twistlocks were selected for their proven robustness, ease of automation, and compatibility with existing intermodal transport infrastructure.

After a secure mechanical connection is established, the system proceeds with the electrical coupling. This is based on high-voltage connectors comparable to those used in Scharfenberg couplers and designed to withstand vibrations, shocks, and environmental influences. These connectors transfer power for HVAC systems, lighting, onboard electronics, and monitoring equipment. Each TU is equipped with a battery buffer that allows limited operation while uncoupled and acts as a redundant power source in case of CU power failure. Electrical connectors are protected by automated covers and are engaged only after mechanical locking is confirmed by the control system.

Communication and data exchange between TU and CU are handled primarily via wireless technologies, with 5G Sidelink and IEEE 802.11p being identified as the most promising solutions for signalling and wireless communication due to their low latency and high reliability in dynamic environments. These enable real-time TU identification, authentication, and monitoring of mechanical and electrical states, battery levels, and fault diagnostics. For critical safety functions, a wired or redundant backup communication channel can be provided to guarantee fail-safe operation even in the case of wireless link disruption.

The entire connection process follows a structured and automated workflow: the pod is positioned above the carrier by a handling device, lowered until mechanical coupling can take place, twistlocks engage automatically and are verified by sensors, protective covers over electrical connectors open, and finally, power and data connections are made. Once all systems confirm a successful connection, the handling device detaches, and the pod is ready for operation.

Safety and interoperability are key design drivers of this connection concept. The system integrates automatic status verification, emergency release mechanisms for manual decoupling in case of failure, anti-lift protection for lightweight passenger pods, and compliance with relevant ISO, UIC, and EN standards. This should ensure structural integrity under dynamic loads, crashworthiness in impact scenarios, and seamless interoperability between different TU sizes (5, 10, and 20 ft) and transport modes, including rail, road, and potentially cableway systems.

Overall, the connection methods between pods and carriers combine proven mechanical solutions, standardised electrical interfaces, and advanced digital communication to create a safe, efficient, and highly automated coupling system. This approach reduces manual intervention,

minimises operational risks, and supports the Pods4Rail vision of modular, intelligent, and supermodal transport.

4 Objective/Aim

The objective of Work Package 13 (WP13) is to describe the following two sections:

First, a concept for the interfaces between the transport unit (TU) and the freight unit (CU) will be developed, specifically a conceptual proposal for the interface geometry for coupling passenger and freight transport units on a single CU.

Second, a logistics concept will be presented that describes the fundamental principles of practical, non-theoretical processes. The elements of the logistics system encompass areas such as transport, storage, handling, order picking, and (informational) order processing. The logistics concept aims for greater efficiency while simultaneously reducing costs. Key system parameters include availability, storage locations, hubs and terminals, deployment location, delivery location, vessel type, delivery time, and service and maintenance requirements.

5 Pod-carrier interface mechanism – concept proposal for the interface geometry for pairing passenger and cargo pods

5.1 Design and implementation of mechanical interface parts

The definition of all mechanical parts in CAD has to be done and describe in D7.1, chapter 5. ⁴ The initial design is shown in the following picture.

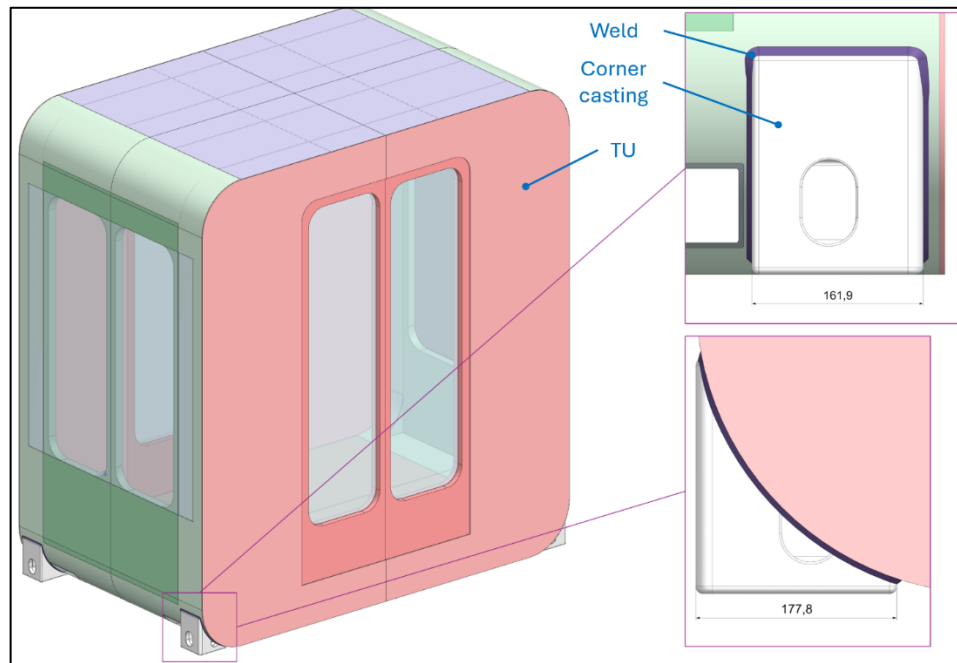


Figure 1: Initial CAD concept of the mechanical interface between Transport Unit (TU) and Carrier Unit (CU) (Source: ⁵)

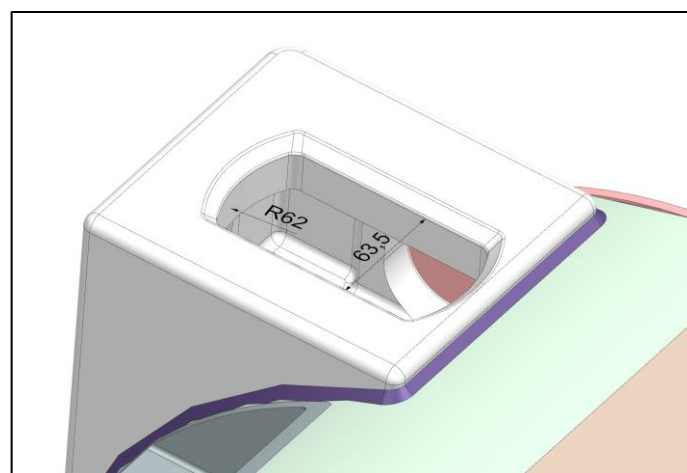


Figure 2: Detailed view of corner locking mechanism with automated twistlock interface for TU coupling (Source: ⁶)

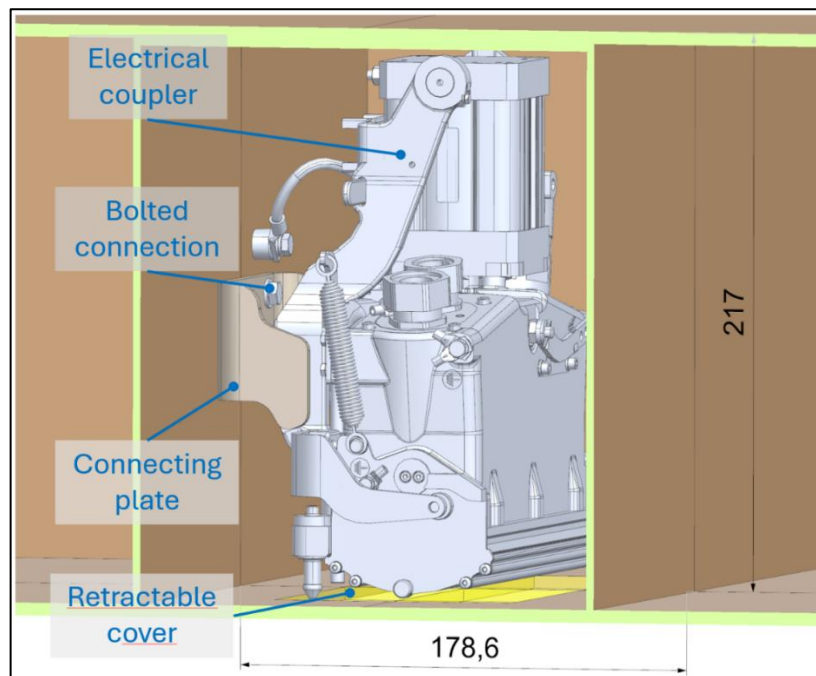


Figure 3: CAD assembly of pod-carrier connection components (Source: ⁷⁾)

6 Pod-handling connection mechanism - concept for standardised interfaces between the vessel and the handling systems

6.1 Manipulation procedures

The manipulation procedure can be summarised in three “Situations:

Situation I: Transferring the TU from the warehouse and loading it onto the carrier unit (CU)

1. Selection of the TU based on the customer's demands (input: transport order specification, output: order confirmation, if no TU available: cancel order)
2. Locating the TU in the warehouse, adding the transfer request to the queue (output: estimated time)
3. Transferring the TU via forklift (or other means) to the loading area
4. Loading the TU onto the carrier via a crane (or other means)
5. Establishing a connection between the TU and the crane hook
6. Safety assessment, i.e., ensuring the loading area is unoccupied, and the carrier is braked to prevent accidents
7. Lifting the TU up
8. Manipulating the TU above the CU
9. Putting the TU down
10. Establishing a connection between the TU and the CU
11. Guiding the vessel via twistlocks (first contact point)
12. Further lowering to allow for mechanical coupling

13. Automatic interlocking of twist locks
14. Signalling for further connection
15. Electrical coupling
16. Media coupling
17. Confirming the connection
18. Disconnecting the crane hook
19. Moving the Pod out of the loading area to allow for the loading of another TU
20. The Pod is on its way to the customer (output: estimated time of arrival)

Situation II: Transferring the TU between CU, i.e., switching between rail and road

1. Verification of arrival: The rail pod arrives at the intermodal transfer station (output: arrival confirmation)
2. Situation readiness assessment: Checking that the transfer area is prepared, including proper positioning of the road CU and the availability of cranes
3. Safety protocol initiation: Ensuring all personnel are clear of the work zone, both CU are properly braked and secured, and the area is marked as an active transfer zone
4. Pre-disconnection communication: Signalling the start of the disconnection sequence to all systems, establishing that the CU will remain stationary during the operation
5. Electrical disconnection: Disconnecting the power lines between the TU and the rail carrier, establishing that the TU switches to battery power for onboard systems
6. Media disconnection: Closing and securing all media connections, confirming no fluid leakage occurs
7. Mechanical decoupling initiation: Preparing the automated decoupling system, confirming that all twistlocks can be released
8. Twistlock release: Automatically unlocking all twistlocks, verifying complete disengagement via sensor confirmation
9. Crane positioning: Positioning the crane above the TU and establishing the connection to the lifting mechanism
10. Safety inspection: Verifying that the TU is securely gripped by the crane before lifting
11. Lifting operation: Lifting the TU vertically away from the rail CU, while continuously monitoring the lifting height and stability
12. Lateral manipulation: Moving the TU horizontally above the transfer zone and positioning it directly above the road CU positioned in the adjacent loading area
13. Lowering operation: Lowering the TU toward the road CU
14. Guiding the TU via twistlocks (first contact point)
15. Automatic interlocking of twist locks
16. Signalling for further connection
17. Electrical coupling
18. Media coupling
19. Confirming the connection
20. Disconnecting the crane hook

21. Departure of the Pod for road transport

Situation III: Connecting the TU for use in ropeway transport

1. Operational preparation: The TU, equipped for ropeway transport (with specialised overhead connection hardware), arrives at the ropeway station, confirming the ropeway system is ready to receive the TU (output: station status confirmation)
2. Station positioning: Positioning the TU in the loading zone of the ropeway station, either via forklift, reach stacker, or platform lift, depending on available equipment
3. Safety protocol initiation: Announcing the start of the ropeway connection procedure, ensuring all personnel are clear of the loading zone and overhead cable areas, confirming the ropeway cable is stationary, and no other TU are moving on the line
4. Pre-connection inspection: Visually inspecting the TU overhead connection points and gripper hardware to ensure they are clean, undamaged, and correctly aligned for cable engagement
5. Ropeway cable positioning: Positioning the moving ropeway cable so that the cable gripper is directly above the TU connection points
6. Gripper lowering: Carefully lowering the overhead cable gripper toward the TU, using precision controls to guide the gripper to the correct height and alignment
7. Gripper engagement: Confirming mechanical engagement of the gripper jaws around the TU overhead connection hardware
8. Locking confirmation: Automatically engaging the locking mechanism of the cable gripper; receiving sensor confirmation that all gripping jaws are fully secured and locked
9. Load security check: Performing a pull-test by applying slight tension to the cable to verify that the TU is securely held by the gripper without any movement or slipping
10. Electrical connection to cable system: Establishing an electrical connection between the TU and the ropeway power/communication system, confirming data transfer and power supply to onboard systems
11. Safety interlock verification: Confirming that the ropeway control system recognises the TU as properly connected and ready for transport, verifying that the ropeway safety systems are actively monitoring the connection
12. Weight distribution assessment: Confirming that the TU weight is evenly supported by the cable gripper, checking that no tilting or asymmetric loading is occurring
13. Station departure procedure: Signalling the ropeway operator that the TU is ready to depart, confirming that the path ahead is clear of obstacles and other TU

Transport units are small containers for transporting people and cargo. Their dimensions correspond to freight containers – 5 ft, 10 ft and 20 ft. Normally, 5 ft and 10 ft containers are not used in freight transport. The concept of TU corresponds to their purpose for transporting people, so it is significantly different from freight containers.

The dimensions are as follows:

- 5 ft container: length 1514 mm, width 2438 mm, height 2590 mm;

- 10 ft container: length 3029 mm, width 2438 mm, height 2590 mm;
- 20 ft container: length 6058 mm, width 2438 mm, height 2590 mm.

6.2 Manipulation of Transport Units

It is necessary to distinguish between the types of manipulation:

- manipulation of an empty TU.
- manipulation of a TU occupied by passengers.
- manipulation of a TU filled with cargo.

Additionally, depending on the situation, further specification is possible:

- transferring the TU from a warehouse and loading it onto the carrier.
- transferring the TU from one carrier to another.

The manipulation also depends on the type of carrier:

- carrier for rail transport.
- carrier for road transport.
- carrier for cable car transport.

6.3 Manipulation of empty Transportation Units

This manipulation is less demanding on the handling of the TU. It can be considered for storage (stacking), where up to five empty cargo containers are stacked on top of each other. This is made possible by their robust construction. For the Pod system, the stacking of two empty TU on top of each other is considered. This is because their construction is significantly different from that of cargo containers. It is less robust and has windows, doors, AC unit and other equipment. It would be possible to manipulate an empty TU with a forklift; this is considered for a 5ft TU, but it would have to be modified at the bottom for "forks", which is very challenging due to the need for structural integrity.

As pictured below, a special container handling device called a Reach stacker is usually used for standard gripping from above. This device has a long arm, at the end of which there is a gripping mechanism equipped with hydraulically operated twistlocks. At first, the machine grips the TU from above. Then, the twistlocks fit into the upper corner castings of the TU. Finally, twistlocks are locked via hydraulics, and the TU can be manipulated. The Reach stacker moves on tires and can lift and handle empty TUs, manipulating them into any position.



Figure 4: Reach stacker usable for lifting and transporting empty Transport Unit (Source: UWB)



Figure 5: Empty TU manipulation using top-lift spreader equipment (Source: UWB)



Figure 6: Cargo container handling via Reach stacker (Source: UWB)

6.4 Manipulation of TU occupied by passengers or filled with cargo

During the research and analysis of existing devices for transferring standardised transport containers, one system was selected as a potentially preferred option. The advantage of this system lies in its small footprint and the procedure for transferring the containers from one vehicle to another. The device has previously been introduced under the term Telescopic rotary forks and is used for transferring small containers.

An example of a systems developed by AFB GmbH ⁸ can serve as an illustration. This equipment allows the TU to be lifted, rotated, and precisely positioned in limited spaces. It is suitable for automated terminals, storage areas, and transshipment hubs where fast and flexible handling is required. For the Pods4Rail concept, this solution could be used mainly for empty or cargo-loaded TU.



Figure 7: Rotary telescopic forks ⁹

6.5 Mechanical connection of freight containers – current state of the art

Freight containers do not need to be mechanically coupled to railway freight wagons. They are simply placed on the guides as shown in the picture. They do not need to be secured on the wagon using twist locks, as they are sufficiently heavy. On trucks, a more complex fastening using twist locks is required as pictured. The loading the container onto a truck bed, the twistlock also serves as a guiding pin. This should be preserved for the Pod system, but the twistlock should be automatic, i.e., electrically operated. Details could be found in D12.1 “Definition and concept of the coupling system”. ¹⁰

6.6 Another types of manipulation

Telescopic rotary forks

An additional TU handling concept for Pods4Rail can be based on autonomous mobile robots (AMRs), such as the systems developed by Seegrid¹¹. These vehicles are able to automatically pick up, transport, and precisely position loads using onboard sensors, computer vision, and fleet management software. For the Pods4Rail project, such robots could be used in terminals, storage centres, and transshipment hubs for efficient movement of empty or cargo-loaded Transport Units (TUs). This solution can reduce handling time, improve safety, and support continuous automated operation of the multimodal logistics system.



Figure 8: Antonomous Lift EL1 AMR¹²

Cranes

Cranes are another option for transshipment, but they require a lot of space and investment. Ideally, an occupied TU should be handled with a crane, suspended from above. For example, the handling of a cargo container can be considered as pictured below. The picture shows a crane cat (a spreader pictured on the right) with a mechanism for hanging cargo containers from above. It consists of two bridges, between which the cat moves. This solution enables the rotation of large cargo containers, including those up to 40' in size. All containers are secured from above with a hydraulically operated twist lock.

A similar device can be utilised for the Pod system, as it accommodates varying TU sizes in empty and loaded states. This equipment should be installed at all stations where passenger-occupied TUs are anticipated to be transferred from one means of transport to another.

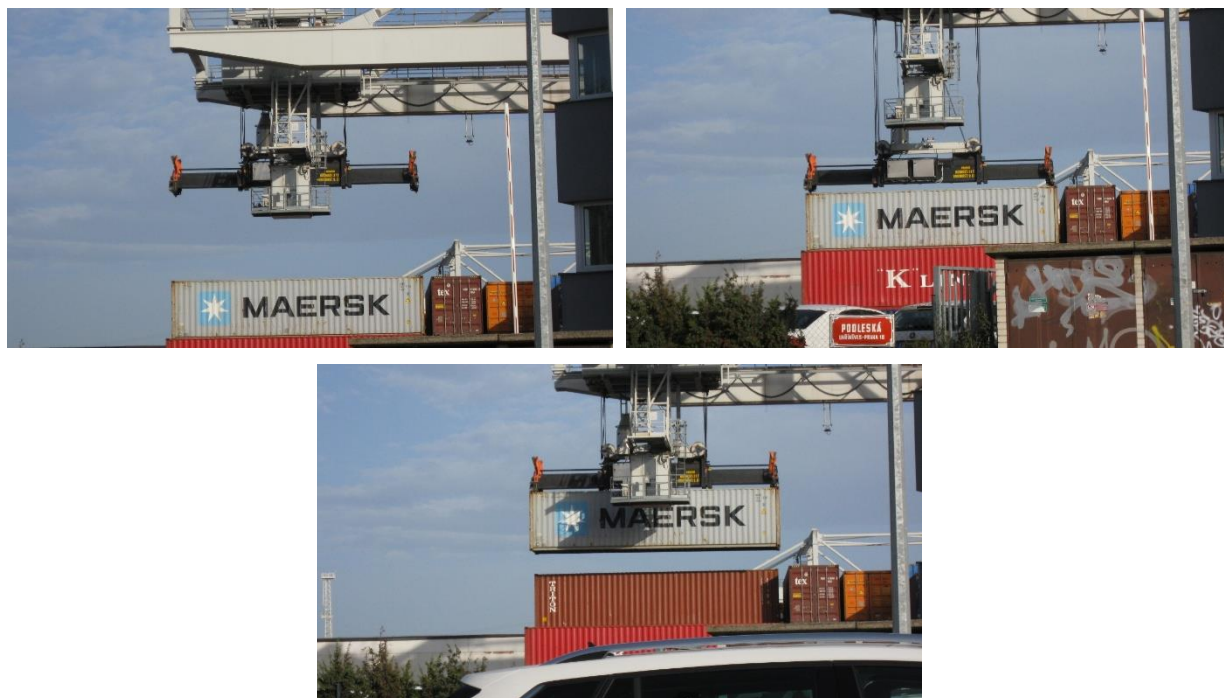


Figure 9: Handling of cargo containers via crane (Source: UWB)

7 Stacking – specifics

To maximise storage space, empty TU can be stacked on top of one another, much like freight containers. As a result, it's necessary to modify the roof structure to include corner castings as pictured below. While this solution may not be visually appealing, as it disrupts the external appearance of the TU, it is essential due to the expected weight of the TU. Additionally, a flat, preferably concrete surface must be available for storing the TUs. The number of rows of stacked Transport Units will depend on the available handling equipment.

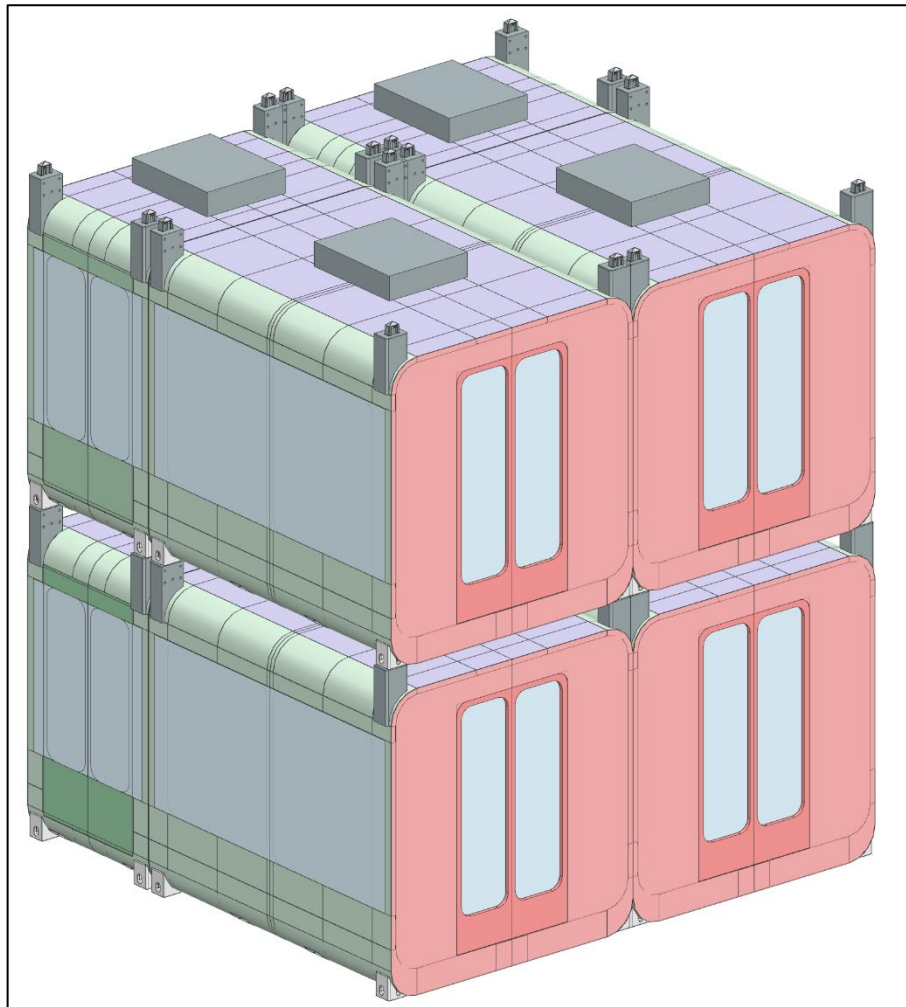


Figure 10: Visualisation of stacking of empty TUs (Source: UWB)

8 Concept for transportation, manipulation and storage of TU

8.1 The Logistical concept

A connected inter-modal logistics system is an integrated transport and handling framework that enables the seamless movement of goods and passengers across multiple transport modes - typically for rail, road, and, in specific cases, cable-based or automated pod systems - through coordinated infrastructure, standardised interfaces, and digital control mechanisms.

At its core, such a system consists of physical transport networks, transshipment facilities, and a digital orchestration layer integrated in the Multimodal Management System. The physical layer includes linear infrastructures (e.g., railway tracks, roadways, cable lines) and nodes such as terminals, stations, and depots. These nodes function as intermodal interfaces (transshipment areas), where the TU are transferred between transport modes. Transshipment operations for TU (goods and passengers) are enabled through standardised loading units (e.g., containers, swap bodies, or modular pods), allowing efficient and rapid transfer.

Transshipment areas are engineered for high efficiency and minimal dwell time. They incorporate

automated handling technologies such as robotic cranes, conveyor systems, or guided vehicles. These facilities often include buffer storage (e.g., pod storage or warehouses) to decouple transport processes and absorb variability in arrival and departure times.

Energy supply is another critical aspect, particularly in electrified and automated systems. Charging stations, grid connections, and possibly local energy storage systems are integrated into the infrastructure to support electric vehicles and handling equipment. Energy management systems optimise consumption and ensure system reliability.

From a control perspective, the system adheres to safety, reliability, availability, and maintainability (RAMS) principles. Redundant communication paths, fail-safe mechanisms, and continuous monitoring ensure robust operation. Interfaces between subsystems are standardised to maintain interoperability and scalability.

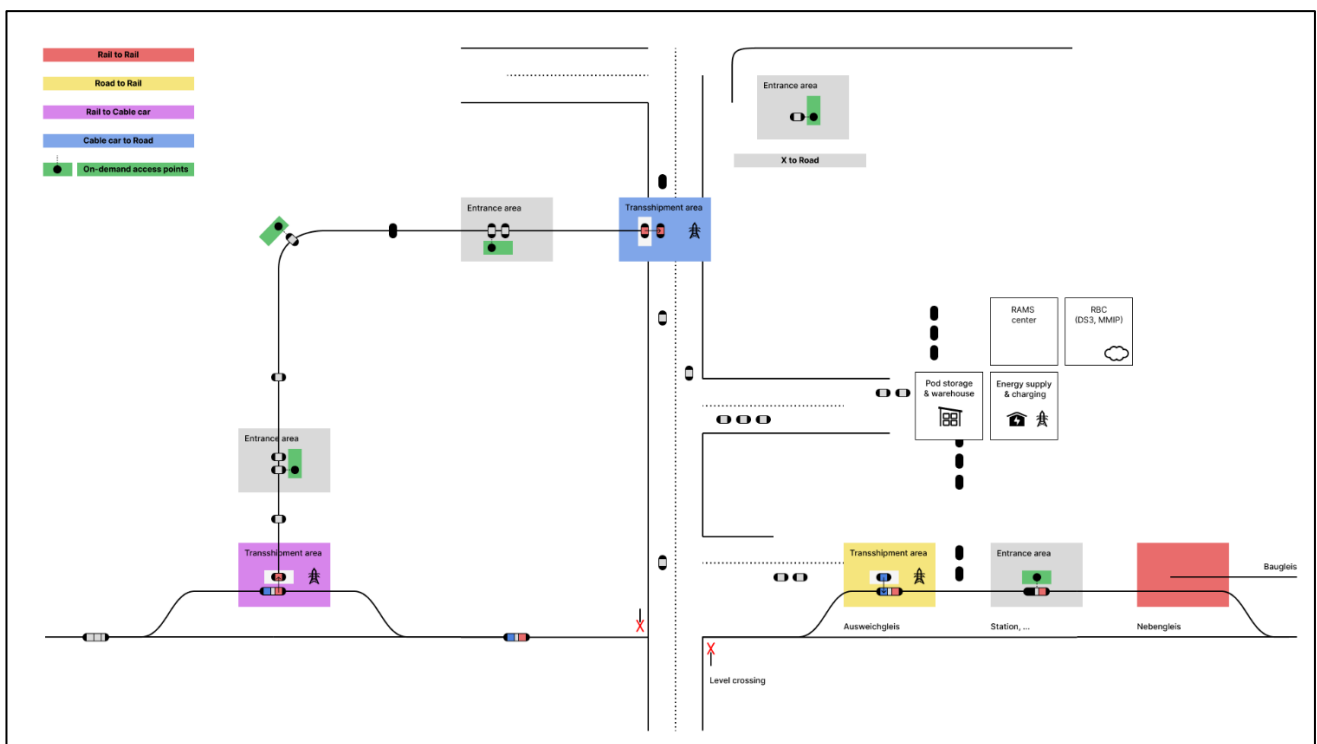


Figure 11: Overview of connected multimodal logistic system (Source: MID)

Figure 11 schematically depicts a multimodal transportation and logistics concept that integrates different modes of transport and their interconnections via transshipment points. The focus lies on illustrating the flow of goods and/or passengers between rail transport, road transport, and cable car systems, considering access points and infrastructural facilities.

Color-coded legends indicate the different modal transitions: red represents “rail to rail,” yellow “road to rail,” violet “rail to cable car,” and blue “cable car to road.” In addition, green symbols denote on-demand access points. This coding enables a clear differentiation of the respective transshipment processes.

The left-hand side of the figure 11 shows a closed network structure featuring several entrance

areas and a central transshipment zone between rail and cable car systems. The representation suggests a continuous flow of traffic with defined stopping points and transfer interfaces. Vehicles or TU are illustrated schematically along the route.

The right-hand side of the figure extends this concept by incorporating a more complex infrastructure. Additional functional units are included, such as a pod storage and warehouse facility, energy supply and charging infrastructure, as well as digital control centres (e.g., RAMS Center, RBC). These elements indicate an automated or digitally controlled logistics system. Furthermore, typical railway infrastructure components, such as passing loops, sidings, stations, and level crossings, are depicted, reflecting relevant operational constraints.

The vertical dashed line can be interpreted as a system boundary or interface between two operational domains. Multiple transshipment areas along the route highlight the modular structure of the system, in which transport units can flexibly switch between different modes of transport.

Overall, the figure illustrates an integrated, inter-modal transportation network with a focus on efficient transshipment processes, automation, and energy supply. The schematic representation serves as a conceptual basis for analysing traffic flows and infrastructure requirements in a future interconnected mobility and logistics system.

8.2 Marking system of TUs

To make the organisation seamless, a marking system should be developed to easily identify different TUs. A numerical marking based on the size, serial number and owner of the TU is offered as follows:

XX – YYYY – ZZZZ,

where X is the TU size in ft, e.g., 5 or 10; Y is the serial number, e.g., 0001, 0025, etc.; and Z is the marking of the owner, which can be characterised according to the country code, e.g., DE, FR, CZ, etc. In addition, each POD can be marked with its own QR code and tracked using a GPS locator.

8.3 Dislocation and service centres

Dislocation and service points will be part of the POD system infrastructure. Dislocation and service centres should be created in individual countries. Their number should be proportional to the size of the country. For example, there will be 16 of these points in Germany and France, 12 in Spain, 4 in the Czech Republic, etc..

Each country should have at least one control dislocation centre; the other dislocation centres are auxiliary. Larger countries, for example, Germany or France, should have more control dislocation centres. Each dislocation centre should have a storage area for the stacking of TUs and other equipment.

The movement of Pods in a given area should be controlled from the main dislocation and service centre. It should be equipped with the relevant computing equipment and equipment for monitoring the movement of Pods. It should also be equipped with equipment for the stacking of

empty TU. It should also have cranes for loading occupied TU. There should also be a fully equipped workplace for major Pod repairs, including service facilities for cleaning.

The auxiliary deployment and service centre should be equipped with computer technology to monitor the movement of Pods and with equipment for service and minor repairs. Service includes cleaning, water supply to the Pod with a toilet, and equipment for minor repairs, e.g. door defects. It should have equipment for stacking empty Pods and a crane for handling occupied Pods.

The circulation of Pods should be controlled from the main deployment and control centre using special software. The software for POD circulation should be connected to the software for ticket reservation.

9 Conclusions

This deliverable presented a handling and logistics concept for the Pods4Rail system, focused on the operation of modular Transport Units for passenger and freight transport.

The interface between the TU and the carrier unit was based on the concept developed in D12.1, which relies on proven container technologies, particularly automated twistlock systems. This solution enables the secure and efficient connection of pods of different sizes and supports future automation processes.

The deliverable also described possible key handling scenarios, including loading TU from storage, transferring TU between rail and road carriers, and integration with ropeway systems. Existing handling equipment such as cranes and reach stackers can be adapted for these operations.

Storage and stacking of empty TU were also considered. Due to their specific design, adapted structural solutions and dedicated handling procedures are required.

Finally, a connected inter-modal logistics concept was proposed, including terminals, storage areas, charging infrastructure, and digital control systems.

Overall, the studies show that the Pods4Rail concept would be technically feasible and could build on existing logistics principles, while simultaneously offering the highest levels of automation and flexibility for highly inter-modal networking.

Despite all this, the concept needs to be further developed to offer a simple and cost-effective solution, in order to ultimately offer all the usage possibilities described in the use cases.

10 List of Figures

Figure 1: Initial CAD concept of the mechanical interface between Transport Unit (TU) and Carrier Unit (CU) (Source:	6
Figure 2: Detailed view of corner locking mechanism with automated twistlock interface for TU coupling (Source:	6
Figure 3: CAD assembly of pod-carrier connection components (Source:	7
Figure 4: Reach stacker usable for lifting and transporting empty Transport Unit (Source: UWB)	11
Figure 5: Empty TU manipulation using top-lift spreader equipment (Source: UWB)	11
Figure 6: Cargo container handling via Reach stacker (Source: UWB).....	11
Figure 7: Rotary telescopic forks	12
Figure 8: Autonomous Lift EL1 AMR	13
Figure 9: Handling of cargo containers via crane (Source: UWB)	14
Figure 10: Visualisation of stacking of empty TUs (Source: UWB).....	15
Figure 11: Overview of connected multimodal logistic system (Source: MID).....	16

11 References

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- ³ International Organization for Standardization, 2016. *Series 1 freight containers – Corner and intermediate fittings – Specifications*. ISO Standard No. 1161:2016.
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- ⁶ Pods4Rail Deliverable D12.1 “Definition and concept of the coupling system”, available on <https://pods4rail.eu/>
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- ¹¹ Seegrid, 2026. *Autonomous mobile robots (AMRs)*, available on <https://seegrid.com/autonomous-mobile-robots/>, last visit 09.02.2026.
- ¹² Seegrid, 2026. *Autonomous mobile robots (AMRs)*, available on <https://seegrid.com/autonomous-mobile-robots/>, last visit 09.02.2026.