Assessing Multimodal Mobility Systems for Benchmarking Rail-bound Intermodal Pods in ERJU´s FA7-Project Pods4Rail

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Abstract

A "Pod" system, defined as a detachable capsule-chassis vehicle concept operating within a seamless, decentralized and autonomous transport system, presents an innovative solution to transportation challenges. ERJU´s FA7 project Pods4Rail aims to explore an intermodal rail-bound autonomous Pod system and its autonomous transshipment onto road and ropeway modes, serving passenger, freight and combined transport needs, using mainly installed infrastructure. This study evaluates several multimodal Pod systems, analyzing their technical, economic and environmental attributes, along with user needs. The findings reveal a lack of a clear benchmark for Pods4Rail, underscoring the project's significance. Nevertheless, features from various concepts hold potential as benchmarks. Additionally, the safety of handling systems in cargo rail-bound detachable systems requires improvement in order to be applied on passenger Pods. The initial economic evaluation shows that the compatibility with existing infrastructure is a critical criterion, as well as its payload and capacity. Environmental criteria align closely with those of economic efficiency, but special attention should be drawn to noise emissions during transshipment. Moreover, exploratory "Future Thinking" interviews revealed potential users' positive attitudes towards Pods, their assumption that this technology would meet their transport needs and could contribute to mitigate the transport sector's negative impact on the environment.

1. Project Pods4Rail

- ERJU Flagship Area 7 – Pods4Rail
- 14 project partners from 7 European countries
- Duration: Sep23 - Feb25
- Project volume: approx. €3,0 Mio

Timeline for the Pod system development:
- 2025 - 2050 Total development process (simultaneous roll-out)
- 2030 - Demonstration (large scale)
- 2040 - Serial roll-out for ancillary lines
- 2050 - Serial roll-out for entire networks

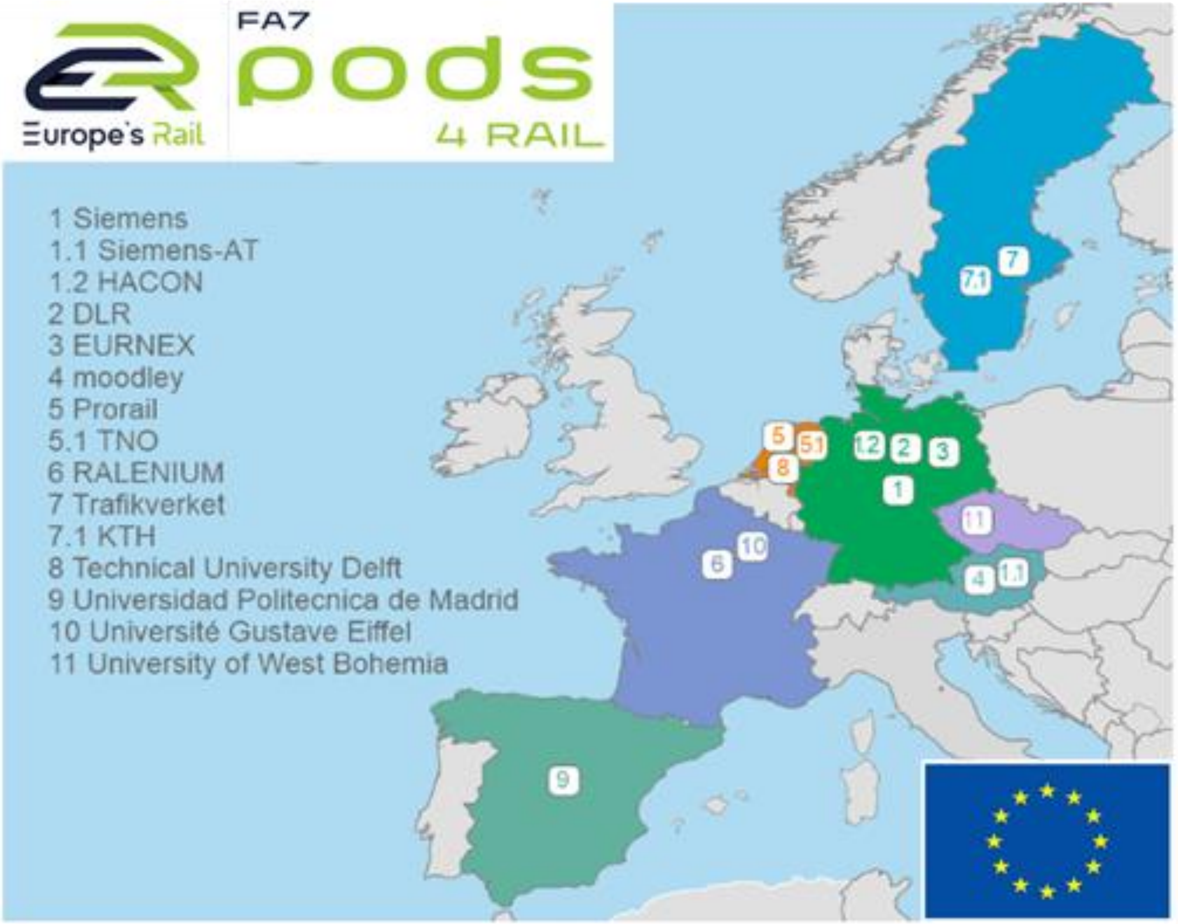


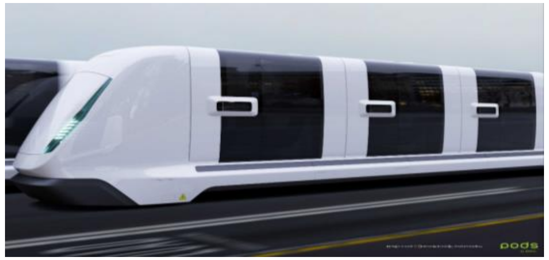
Fig. 1 – Project partners of Pods4Rail. Source: EURNEX, Grant Agreement, 2022

1. Project Pods4Rail

– ERJU **vision: Intermodal transport for ancillary lines**
  - *Pod-based systems should primarily strengthen the role of rail in the European transport, particularly through **seamless integration** of lines with **low and very low demand** for **passenger and freight**.*

– **Specific goals** of the Pods4Rail project:
  - **Assessment of the utility and economic viability** of a (rail) Pod system
  - Development of a **technical concept for pod capsules,** and for the operational and logistics network system
  - Development of a **technical concept for the rail-bound vehicle carrier**, the coupling system, handling, loading/unloading, and storage technologies.

- Other vehicle concepts predecessors to the rail-pod:



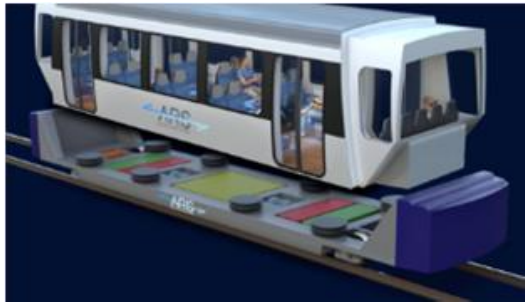



Fig. 2 (upper left) **–** Siemens-moodley „one-for-all", 2022
Fig. 3 (upper right) – CargoMover, RWTH Aachen, 2003
Fig. 4 (lower left) – UpBus, RWTH Aachen, 2021
Fig. 5 (lower right) – ARS, RWTH Aachen, 2022

2. Terms and definitions

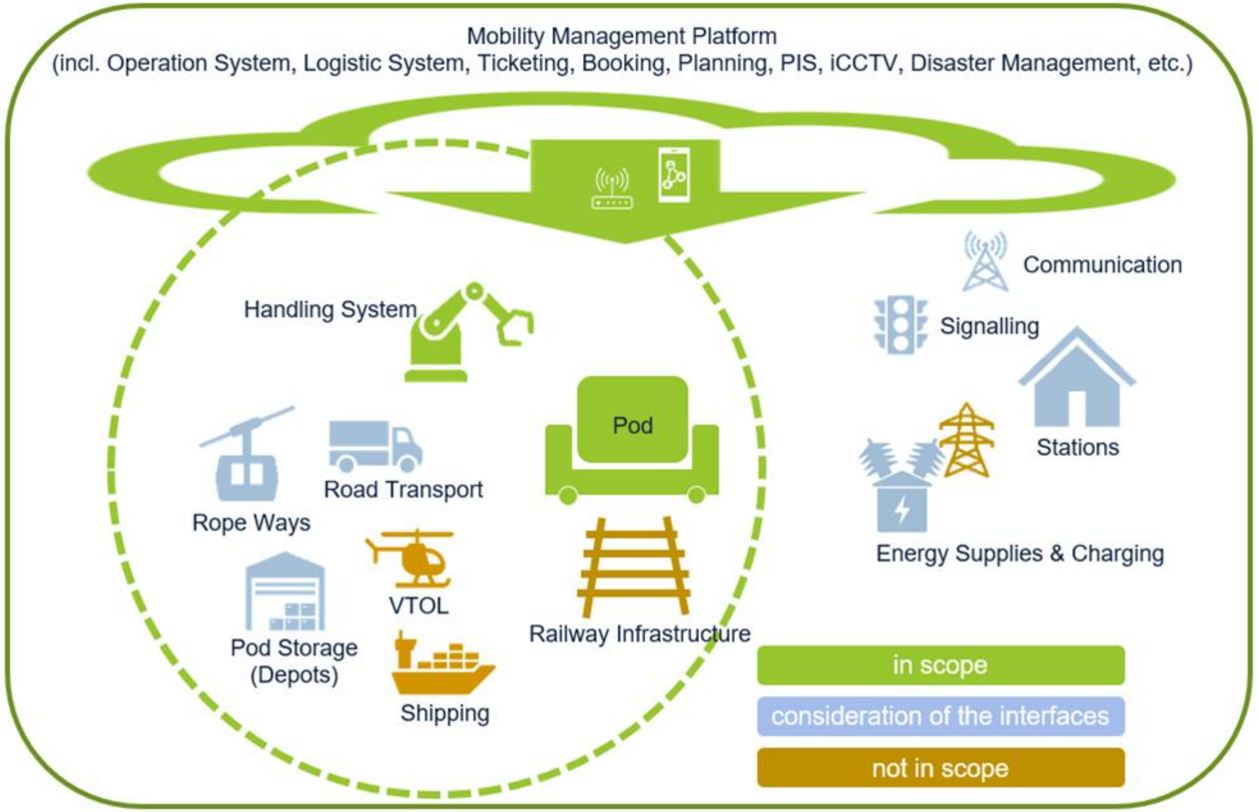


Fig. 6 – Scope of a Pod system and its main subsystems. Source: Pods4Rail D2.1 (Siemens)

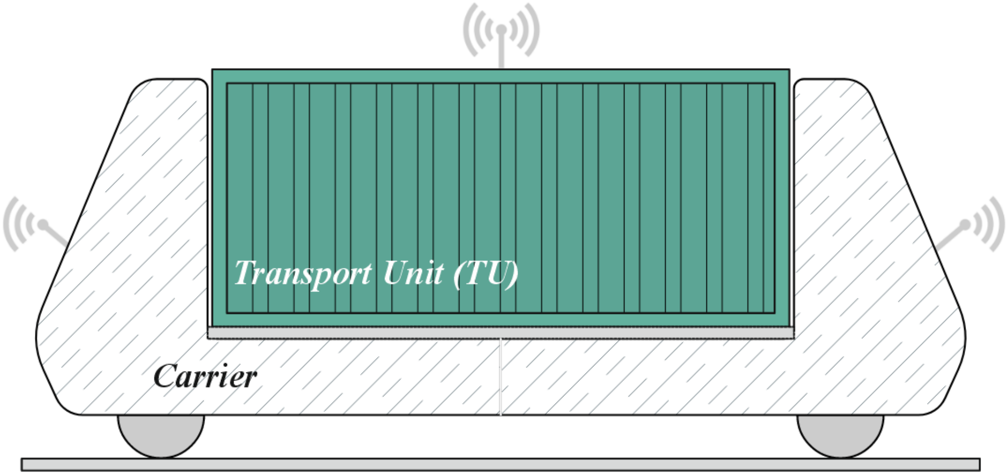


Fig. 7 – Terms for the components of a Pod in Pods4Rail. Source: DLR, 2024

- Carrier and passenger capsule or container (Transport Unit – TU) are separable.
- Flexibility in design -> Variety of use cases.
- Autonomous handling system as crucial subsystem
- Autonomous driving and autonomous loading are the basis for seamless mobility -> Intermodal transport

3. Methods: Technical evaluation

1. Identification of pod-like concepts
2. Data gathering and characterization of pod-like concepts according to parameters
3. Clustering of the vehicle concepts: rail-bound, road-bound, ropeway, other related concepts
4. Formulation of evaluation criteria oriented by VDI 3780 and its categories and priorities:

	Categories	Derived evaluation criteria
1	Functionality	Rail-bound, autonomous, intermodal and modular
2	Safety	Safety of swap handling, of coupling of additional modules (VC) and of the battery charge
3	Operational efficiency *	Suitability for existing infrastructure, payload efficiency, max. capacity
4	Environmental quality *	Suitability for existing infrastructure, payload efficiency, max. capacity, noise emissions
5	Health, personal development and societal quality*	Accessibility, comfort

** Data on economic, environmental and societal aspects of the researched concepts was scarce, therefore, its characterization only allowed for an initial qualitative estimation of these parameters*

5. Scoring from project expert group
6. Multicriteria analysis

Pods4Rail Evaluation - Railways 2024 - Emerging Technologies_wtb_2.pdf

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3. Methods: Future Thinking (User research)

- **Exploratory qualitative user research with Future Thinking (FT) Method**[1]
- FT interviews construct future scenarios while simultaneously measuring them
- Materials:
  - Short, written future scenario
  - Interview guide
  - Images of the DLR U-Shift prototype, and a 3D-render of the upBUS concept
  - Explanation of the concept of intermodal transport

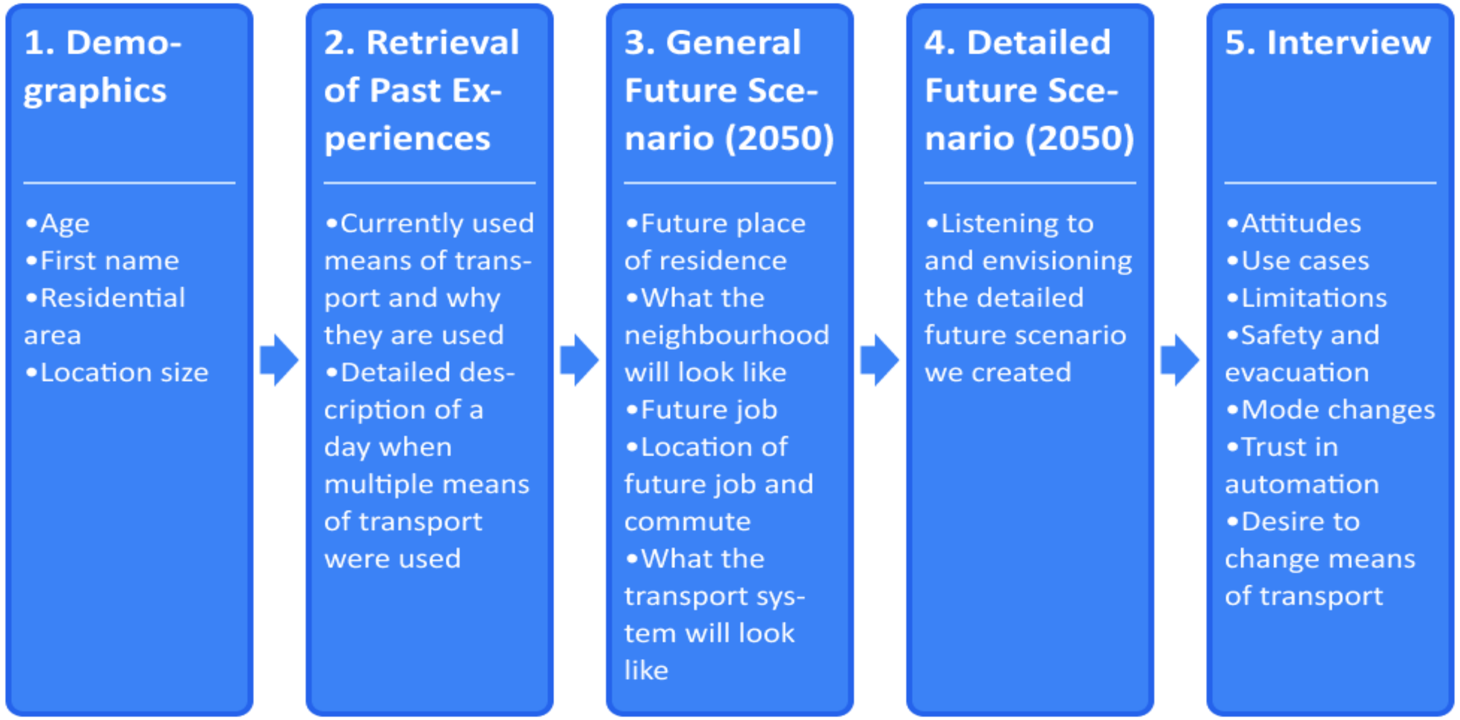


Fig. 8 – Overview of the study design. Source: DLR-VF & Pods4Rail, 2023

[1] C. Colin, A. Martin, F. Bonneviot, E. Brangier, "Unravelling Future Thinking: A Valuable Concept for Prospective Ergonomics", 2022.

4. Characterization of pod-like concepts

Characterization according to parameters such as: TRL (Technology Readiness Level), modes, application, architecture, configuration, mass, coupling, propulsion system, range, charging technology, GoA (Grade of Automation), noise emissions, …
- Very wide range of vehicle concepts to be parametrized
- Literature bias to round-bound concepts

Clustering in rail-bound pod systems and pod systems of other modes of transport:

Pod-related rail-bound vehicle concepts:

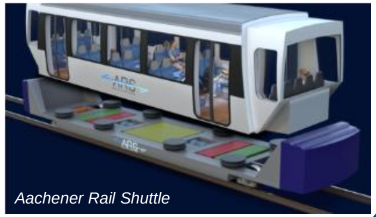

Siemens-moodley One-for-all


Parallel Systems

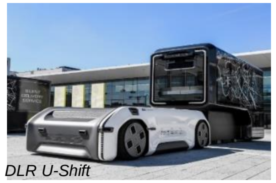

CargoMover


Minimodal


Nevomo Cargo MagRail


Aachener Rail Shuttle

Pod concepts of other transport modes:


DLR U-Shift


LEITNER ConnX


Toyota ePalette


Rinspeed Metrosnap


UpBus


Citroen Autonomous Mobility Vision


Fabio Martin's Tesla Pod System

Fig. 9 (upper left) **–** Siemens-moodley „one-for-all“, 2022
Fig. 10 (upper mid) – Parallel Systems, 2022
Fig. 11 (upper right) – CargoMover, Anselm, F., 2003
Fig. 12 (lower left) – Minimodal, Rail Freight Limited, 2022
Fig. 13 (lower mid) – Nevomo Cargo MagRail, 2023
Fig. 14 (lower right) – ARS, RWTH Aachen, 2022

Fig. 15 (upper left) **–** DLR U-Shift, 2019
Fig. 16 (upper mid) – LEITNER ConnX®, 2021
Fig. 17 (upper mid) – Toyota e-Palette, 2018
Fig. 18 (upper right) – Rinspeed Metrosnap, 2020
Fig. 19 (lower left) – upBUS, RWTH Aachen, 2019
Fig. 20 (lower mid) – Citroen Autonomous Mobility Vision, 2021
Fig. 21 (lower right) – Fábio Martins Tesla Pod System, 2019

5. Scorings (rail-bound)

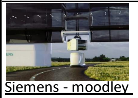
System	Evaluation. TRL (estimation)	Functionality (I): Rail-bound concept	Functionality (II): Full autonomous drive concept	Functionality (III): Intermodality concept to rail mode, from road or ropeway mode	Functionality (IV): Modularity (rapid scalability to train formations - virtual/automatic coupling)	Functionality (V): Range without charging	Safety (I): Swap Handling
 Siemens - moodley "one for all"	1 - TRL 1	5 - Yes	5 - Yes. GoA4/SAE5	5 - Yes, rail-road-ropeway	5 - Yes, virtual coupling	3 - Estimated 50 - 150 km	2 - Aerial (non-crane)
 Parallel Systems	3 - TRL 5	5 - Yes	5 - Yes. GoA4/SAE5	4 - Yes, rail-road	5 - Yes, virtual coupling	3 - Estimated 50 - 150 km	1 - Crane or non-detachable "on the road"
 Aachen Rail Shuttle ARS	2 - TRL 2 - 4	5 - Yes	4 - Driverless, with attendant. GoA3-SAE4	1 - No	1 - No	3 - Estimated 50 - 150 km	1 - Crane or non-detachable "on the road"
 CargoMover	5 - TRL 7	5 - Yes	5 - Yes. GoA4/SAE5	4 - Yes, rail-road	2 - Conventional railway coupling	1 - Self-propelled by combustion engine	1 - Crane or non-detachable "on the road"
 Minimodal Boxes	4 - TRL 8 - 9	5 - Yes	1 - No	4 - Yes, rail-road	2 - Conventional railway coupling	1 - (only container waggion)	3 - Ground handling, three dimensional with external infrastructure
 Nevomo | (Cargo) MagRail	1 - TRL 2	5 - Yes	5 - Yes. GoA4/SAE5	4 - Yes, rail-road	1 - No	1 - Not self-propelled or combustion engine	1 - Crane or non-detachable "on the road"

Fig. 22 – Overview of scoring of pod-like rail bound concepts. Source: DLR & Pods4Rail, 2023

TRL estimation
5 - TRL 9
4 - TRL 8 - 9
3 - TRL 5 - 7
2 - TRL 2 - 4
1 - TRL 1

Rail-bound concept
5 - Yes
4 - Currently under development with TRL 7 - 9
3 - Currently under development with TRL 4 - 6
2 - Currently under development with TRL 1 - 3
1 – No

Grade of Automation
5 - Yes. GoA/4-SAE/5
4 - Driverless, with attendant: GoA3/SAE4
3 - Concept prepared for autonomous driving.
1 – No

Intermodal incl. rail mode
5 - Yes, rail-road-ropeway
4 - Yes, rail-road
3 - No, but road-ropeway and planned for rail
2 - No, but road-ropeway
1 – No

Modularity (scalability to vehicle formations)
5 - Yes, virtual coupling
4 - Yes, automatic coupling
2 - Conventional railway coupling
1 – No

Range without charging
5 - Estimated greater than 150 km
3 - Estimated 50 to 150 km
2 - Estimated lower than 50 km on road or rail
1 - Not self-propelled

Safety of swap handling
5 - Ground handling, horizontal
4 - Ground handling, three dimensional without external infrastructure
3 - Ground handling, three dimensional with external infrastructure
2 - Aerial (non-crane)
1 - Crane or non-detachable "on the road"

5. Scorings (other modes)

System	Evaluation. TRL (estimation)	Functionality (I): Rail-bound concept	Functionality (II): Full autonomous drive concept	Functionality (III): Intermodality concept to rail mode, from road or ropeway mode	Functionality (IV): Modularity (rapid scalability to train formations - virtual/automatic coupling)	Functionality (V): Range without charging	Safety (I): Swap Handling
 U-Shift - DLR	3 - TRL 5 - 7	1 - No	4 - Driverless, with attendant. GoA3-SAE4	1 - No	1 - No	3 - Estimated 50 - 150 km	5 - Ground handling, horizontal
 ConnX® - LEITNER	3 - TRL 5 - 6	1 - No	3 - Concept estimated to be prepared for automated guided driving.	2 - No, but road-ropeway	1 - No	2 - Estimated < 50 km on road or rail	2 - Aerial (non-crane)
 upBUS - RWTH Aachen	3 - TRL 5 - 6	2 - Currently under development with TRL 1 - 3	3 - Concept estimated to be prepared for autonomous driving.	3 - No, but road-ropeway and planned for rail	1 - No	2 - Estimated < 50 km on road or rail	2 - Aerial (non-crane)
 Rinspeed - Metrosnap	3 - TRL 5 - 7	1 - No	5 - Yes. GoA4/SAE5	1 - No	1 - No	3 - Estimated 50 - 150 km	5 - Ground handling, horizontal
 Rinspeed - Snap	3 - TRL 5 - 7	1 - No	5 - Yes. GoA4/SAE5	1 - No	1 - No	3 - Estimated 50 - 150 km	4 - Ground handling, three dimensional without external infrastructure

System	Evaluation. TRL (estimation)	Functionality (I): Rail-bound concept	Functionality (II): Full autonomous drive concept	Functionality (III): Intermodality concept to rail mode, from road or ropeway mode	Functionality (IV): Modularity (rapid scalability to train formations - virtual/automatic coupling)	Functionality (V): Range without charging	Safety (I): Swap Handling
 Rinspeed - Microsnap	3 - TRL 5 - 7	1 - No	5 - Yes. GoA4/SAE5	1 - No	1 - No	3 - Estimated 50 - 150 km	3 - Ground handling, three dimensional with external infrastructure
 Citroën Autonomous Mobility Vision	2 - TRL 2 - 4	1 - No	5 - Yes. GoA4/SAE5	1 - No	1 - No	3 - Estimated 50 - 150 km	5 - Ground handling, horizontal
 e-Palette | Toyota	3 - TRL 5 - 7	1 - No	4 - Driverless, with attendant. GoA3-SAE4	1 - No	1 - No	5 - Estimated > 150 km	1 - Crane or non-detachable "on the road".
 Schaeffler Mover 1.0 - Poschwatta	3 - TRL 5 - 7	1 - No	3 - Concept estimated to be prepared for autonomous driving.	1 - No	1 - No	3 - (Estimated) 50 - 150 km	5 - Ground handling, horizontal
 Tesla's pod - Fábio Martins	1 - TRL 1	1 - No	5 - Yes. GoA4-SAE5	1 - No	1 - No	3 - (Estimated) 50 - 150 km	5 - Ground handling, horizontal

Fig. 23 – Overview of scoring of pod-like road-bound and cable car concepts. Source: DLR & Pods4Rail, 2023

6. Results: Evaluation of pod-like rail-bound concepts

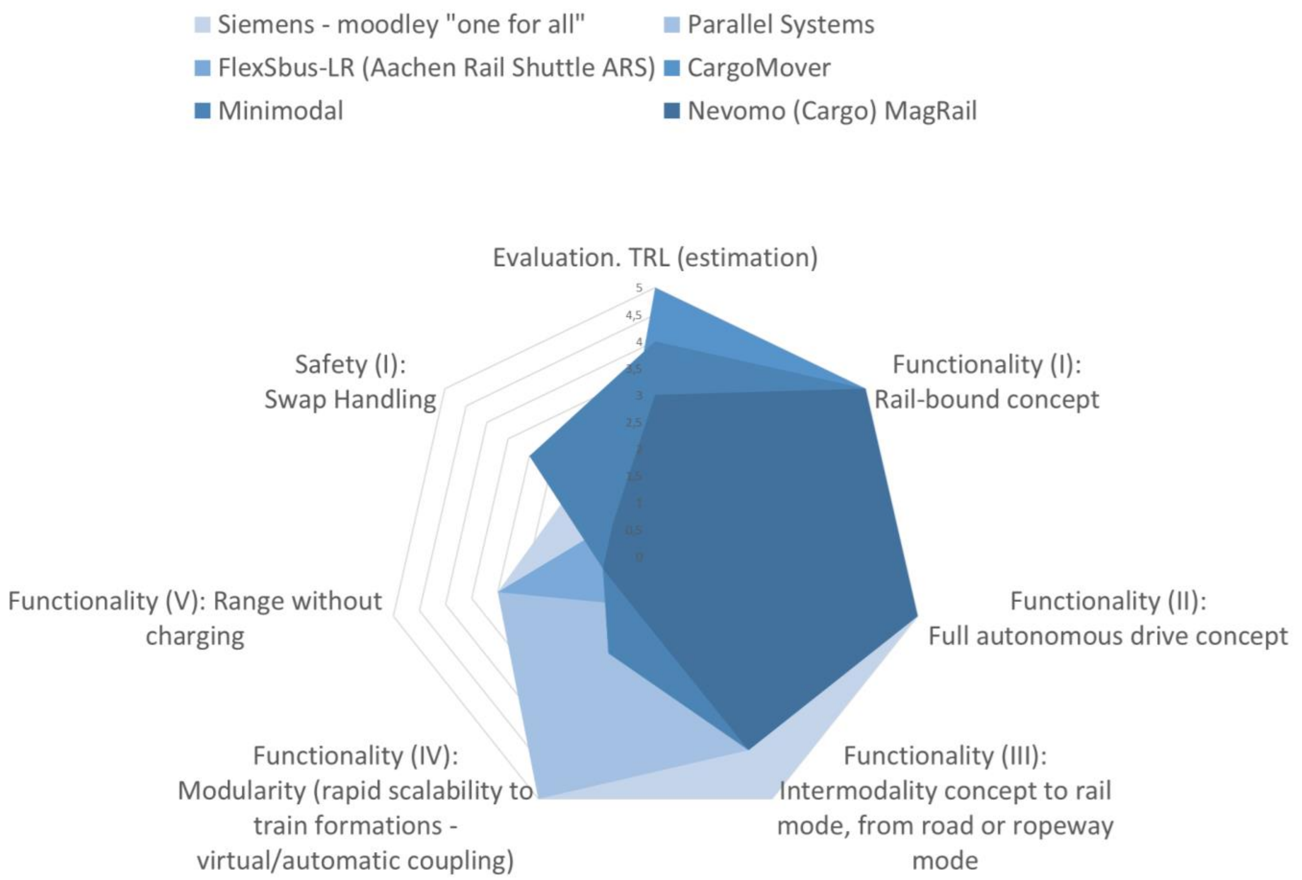


Fig. 24 – Illustration of the technological assessment of rail-bound pod systems. Source: DLR & Pods4Rail, 2023.

- Multicriteria analysis after expert group scoring.
- Most of the technological criteria are fully met by at least one of the analyzed concepts.
- Two parameters lag behind:
  - Range without charging: Energy storage technologies for rail pods need further development.
  - Safety of intermodal handling: Low scores -> it must be addressed in the development of rail-bound pod systems.

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6. Results: Evaluation of pod-like road and cable car concepts

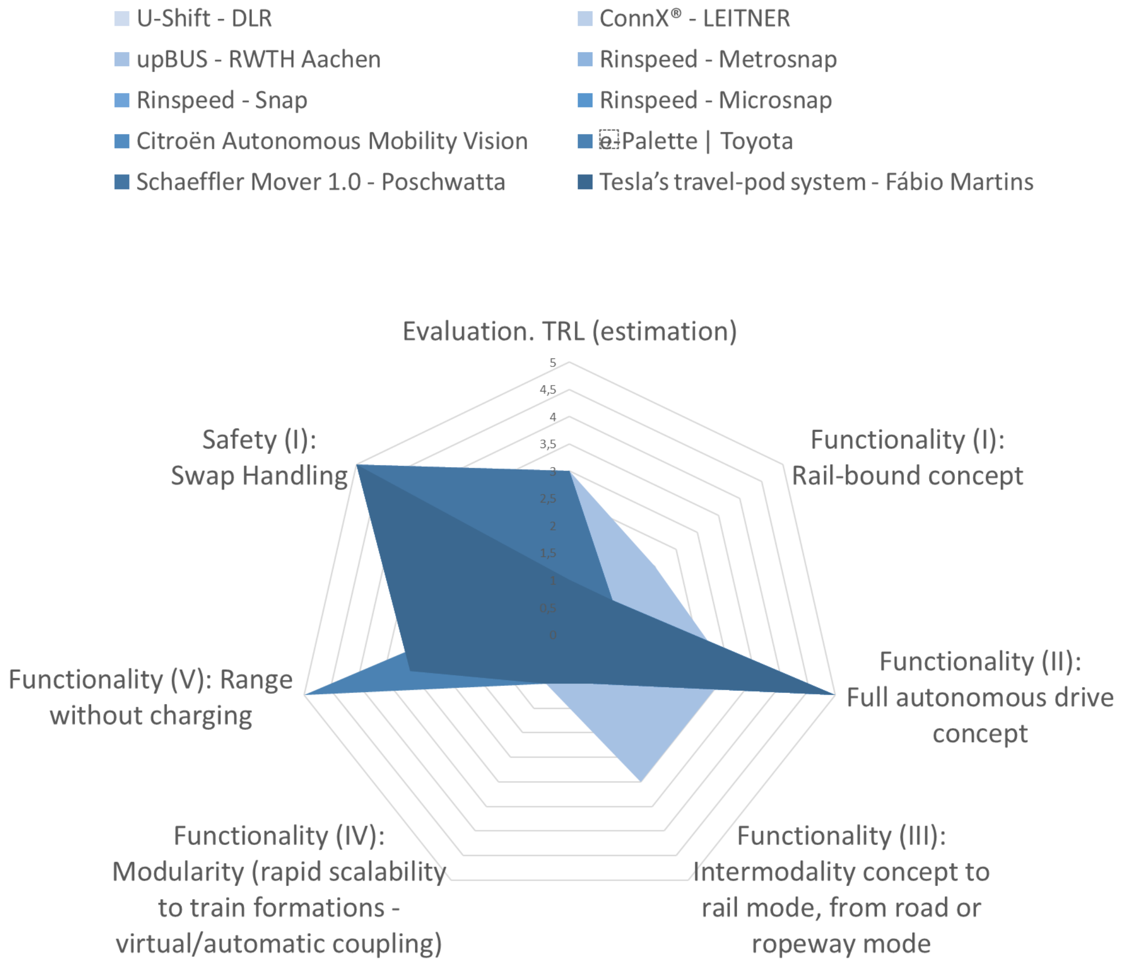

Fig. 25 – Illustration of the technological assessment of pod systems in other modes of transport. Source: DLR & Pods4Rail, 2023

- Road-bound pods seem to be relatively advanced in the development of autonomous driving and battery propulsion technologies

- Road-bound and cable car pod systems show little development towards intermodality with rail vehicles -> confirmation of need for research on rail-pods

- Road-bound pods lack the scalability to couple multiple wagons/vehicles, as is common in rail concepts

- The safety of the handling process reaches high levels in road-bound concepts, indicating robust designs that could serve as a benchmark for the rail-pod development

6. Results: Combined evaluation

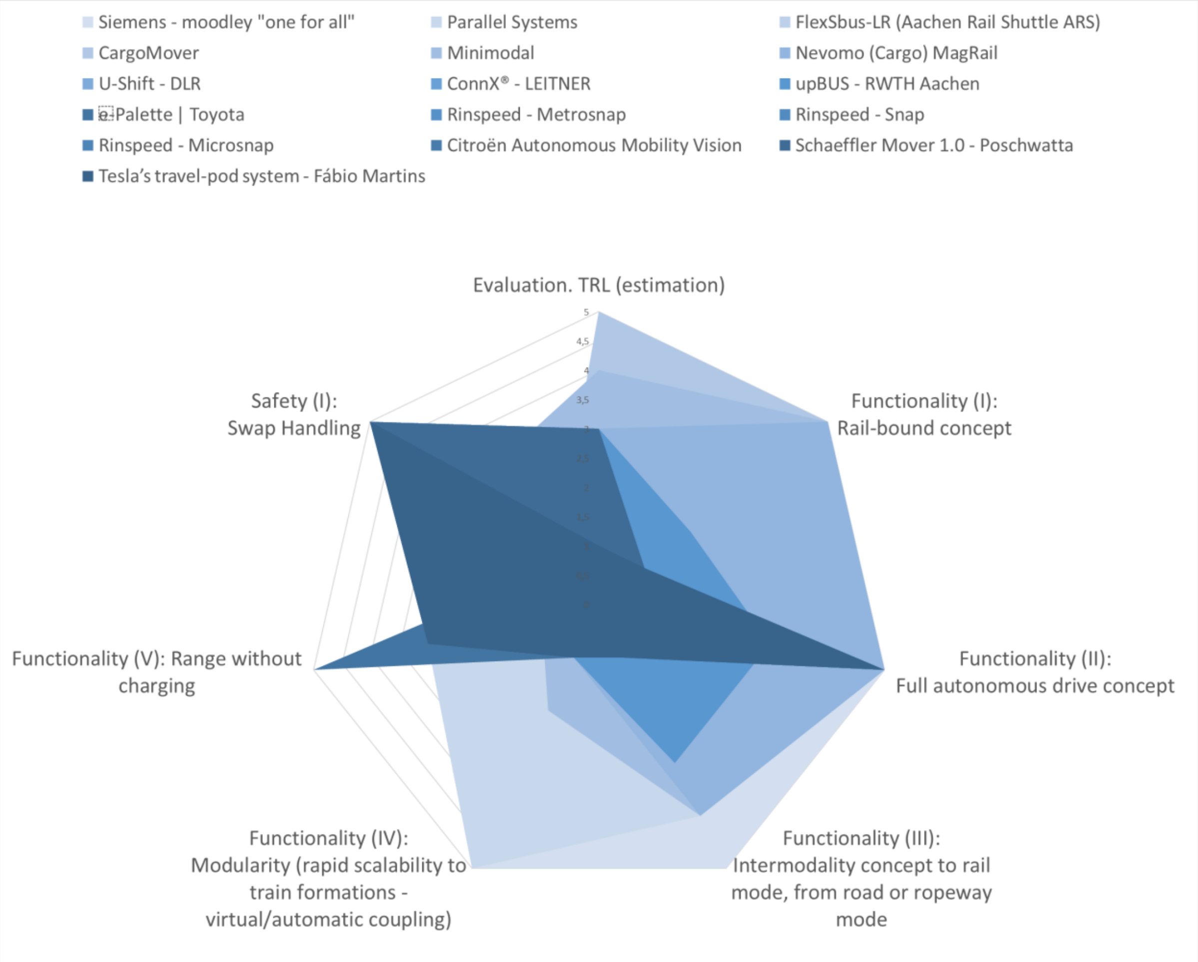

Fig. 26 – Combination of Fig.24 und Fig.25 to illustrate the technological assessment of pod systems in rail transport and other modes of transport. Source: DLR & Pods4Rail, 2023.

- Complementary relationship of the technological capabilities of rail-bound pod-like systems and pod systems of other transport modes.
- This synergy between both polygons suggests that these system components should be closely monitored as benchmarks in the development of a rail-bound pod.
- Advantage of intermodal transport: each transport mode is optimally utilized.

6. Results: Initial user research

Exploratory qualitative user research with Future Thinking (FT) Method (Institute of Transport Research)

- Sample size of 8 (3m, 5f). All participants were recruited in Germany. Each process took 45 to 60 minutes.

Participants‘ professions	
Health care	2
Software engineering	1
Designers	2
Government clerk	1
User research	2

Participants‘ geographical area	
> 100.000 inhabitants	6
20.000 .. 100.000	1
5.000 .. 20.000	0
< 5.000	1

Participants‘ age	
> 59	0
50 .. 59	1
40 .. 49	0
30 .. 39	5
18 .. 29	2

- -> Broader survey in following project phases with more consolidated basic principles of the Pod system

- Key Insights:

- Positive Attitudes: Generally favourable views on Pod systems
- Combined Transport: Valued for multifunctionality and environmental benefits
- Seamless Travel: Seen as comfortable and desirable
- Preference for Pods over car ownership
- Handling System: Sliding mechanism preferred over crane; concern over crane-induced anxiety
- Cargo Storage: Preferred below passenger capsule
- Sharing: High willingness to share Pods
- Security Concerns: Need for security measures like video surveillance, particularly for women
- Crowding: Pods should be less crowded than current public transport
- Privacy: Desire for quiet, private spaces in premium Pods

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7. Conclusions

No clear benchmark: No single existing pod-like vehicle concept offers a comprehensive benchmark for the rail-pod development -> this highlights the need for research on a rail-pod concept

Target icon by Icons8

Partial features of analyzed systems identified as benchmarks:

Puzzle icon by Icons8

Rail-bound passenger pod-like systems scored lower in **handling system** compared to other transport modes -> these could serve as benchmark for the rail-pod development

crane icon by Icons8

User research findings: Users openness to future pod systems; perceived benefits in environmental efficiency

Thumbs Up icon by Icons8

User research findings: Pods **could influence residence choices**, increasing the appeal of suburban areas

House With a Garden icon by Icons8

Challenges: Limited data availability, literature bias towards road-bound pods, need for a bottom-up analysis to better understand user needs -> in upcoming Work Packages

Obstacle icon by Icons8

Seamless mobility concept of Siemens-moodley „one-for-all“

Lightweight detachable Aachen Rail Shuttle

Carrier concept (without powertrain) of Nevomo Cargo MagRail

Minimodal **freight bundling** of up to six small containers

DLR U-Shift‘s **modular multipurpose carrier** and its docking system

Gondola designs and transshipment of upBUS and ConneX®

Rinspeed‘**s transshipment concepts** by either lifting or sliding the capsule

References in slide 8

FA7 pods 4 RAIL

Thank you for your attention!

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