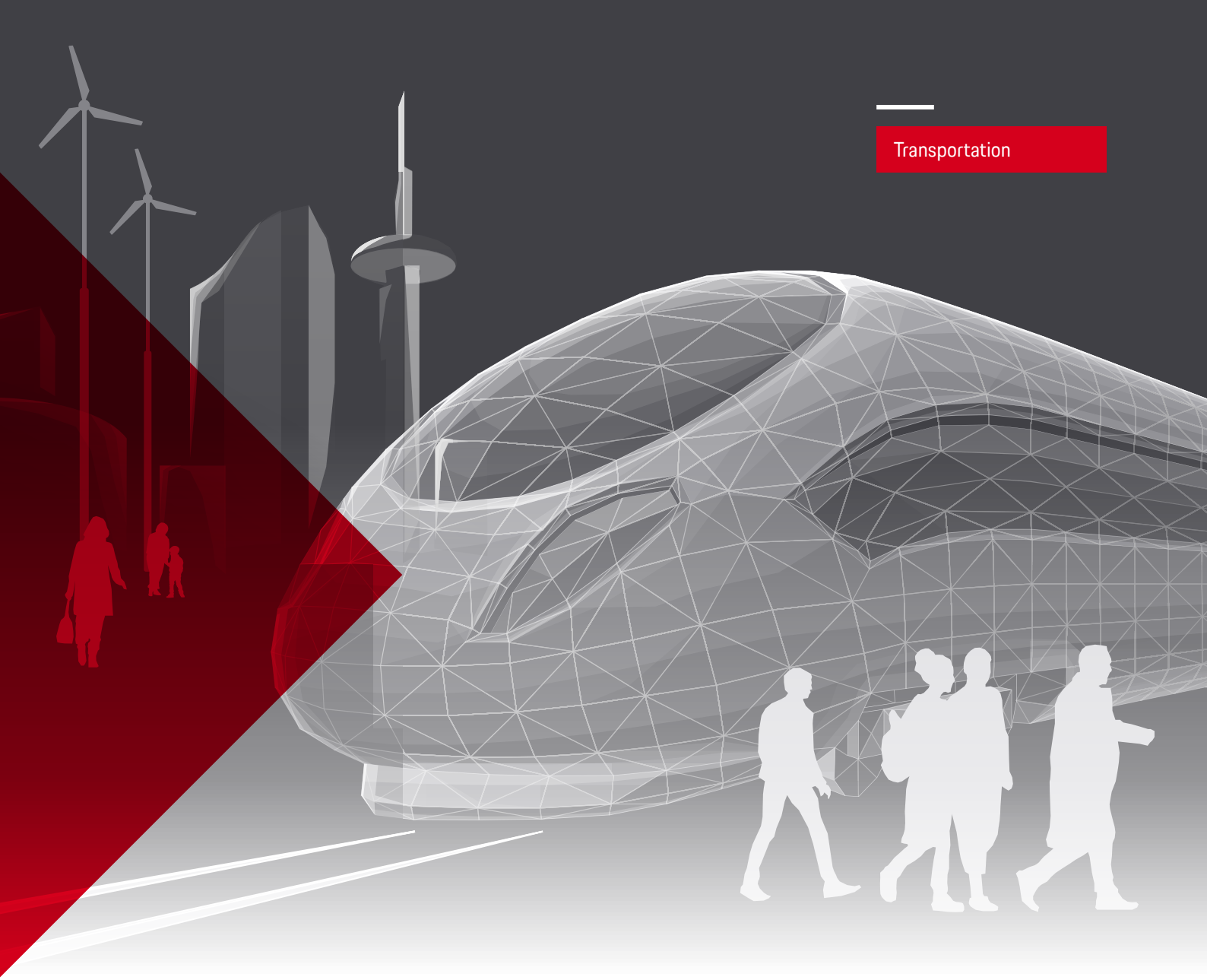


Transportation

# Future of Rail—Seamless, Smart, Enjoyable

A comprehensive analysis of new railway technologies, strategies for train operation, and digital systems to improve travel

**Porsche Consulting**
Strategic Vision. Smart Implementation.

# INSIGHTS

//01

Boosting capacity by more than 20 % without increasing the overall fleet size through strategically scheduling train services and maximizing train utilization during peak times.

//02

Realizing net zero emissions in 2035 through rail network electrification, innovative powertrain alternatives, and sustainable infrastructure.

//03

Improving overall performance by more than 20 % through a full-scale digital transformation—in both operations and infrastructure.

//04

Enhancing passenger engagement by personalized, door-to-door travel solutions that extend across borders and beyond the rail ecosystem.

//05

Improving profitability through proactive demand management based on real-time passenger data and dynamic booking processes.

# INTRODUCTION

Reading the news creates the impression that rail transport seems to be in a constant crisis: delays, outdated infrastructure and rolling stock dominate the discussion. The good old times, when railroads connected people across the continent reliably and inexpensively, seem long ago.

Nevertheless: the future of rail is bright. Public transport is a cornerstone of decarbonization. And trains—especially high-speed ones—are the only sustainable mass-transport system for medium and even longer distance travel.

The European Commission has identified railways as the future solution to providing affordable mobility to the population. The plan is to double high-speed rail traffic by 2030 and triple it by 2050 compared to 2015 levels.

Rail transport has never been more popular with politicians, but also with travelers. They like the experience of high-density connections, which allow you to travel at 300 km/h from city center to city center. They compare the rail services to congested roads and tightly packed passenger planes, which are often delayed as well and on which there is always a chance of losing luggage on the way.

The challenge for operators in particular is to harness this momentum and turn it into opportunities for their businesses. They not only need to invest in concrete, but also in the customer experience. And they must focus on the complete journey taken by their passengers, from the starting point through to the final destination. Traveling by train still has room for improvement.

Rail operators and passengers can profit from a customer-centric infrastructure design. Train stations have the potential to be transformed into dynamic hubs that extend beyond their traditional role in transportation. By offering features such as shopping venues, cultural events, art exhibitions, and dining experiences, train stations can become lifestyle centers inviting a diverse customer base beyond commuters.

As railway stations such as London's St. Pancras have already illustrated, a quarter of its weekly million visitors do not visit the train station for transportation purposes, but instead to enjoy shopping and leisure activities. With an active role played by rail operators in designing these hubs, the new services can be tailored and integrated into the offering and consequently strengthen their position.

Moreover, advancements in powertrain technologies and the development of eco-friendly infrastructure within the green rail industry hold significant potential to further enhance sustainability and achieve the goal of carbon-neutral transportation.

This whitepaper offers a glimpse into the future of rail transportation. It is presenting opportunities to reshape an entire industry. Success will depend on the commitment and ability of rail and public transport operators to create seamless and enjoyable passenger experiences within a smart operational environment.

It outlines six strategic actions for rail operators with a focus on the European passenger rail market. And it provides best-practice examples of customer centricity at work that can make the future of rail even brighter for rail passengers.

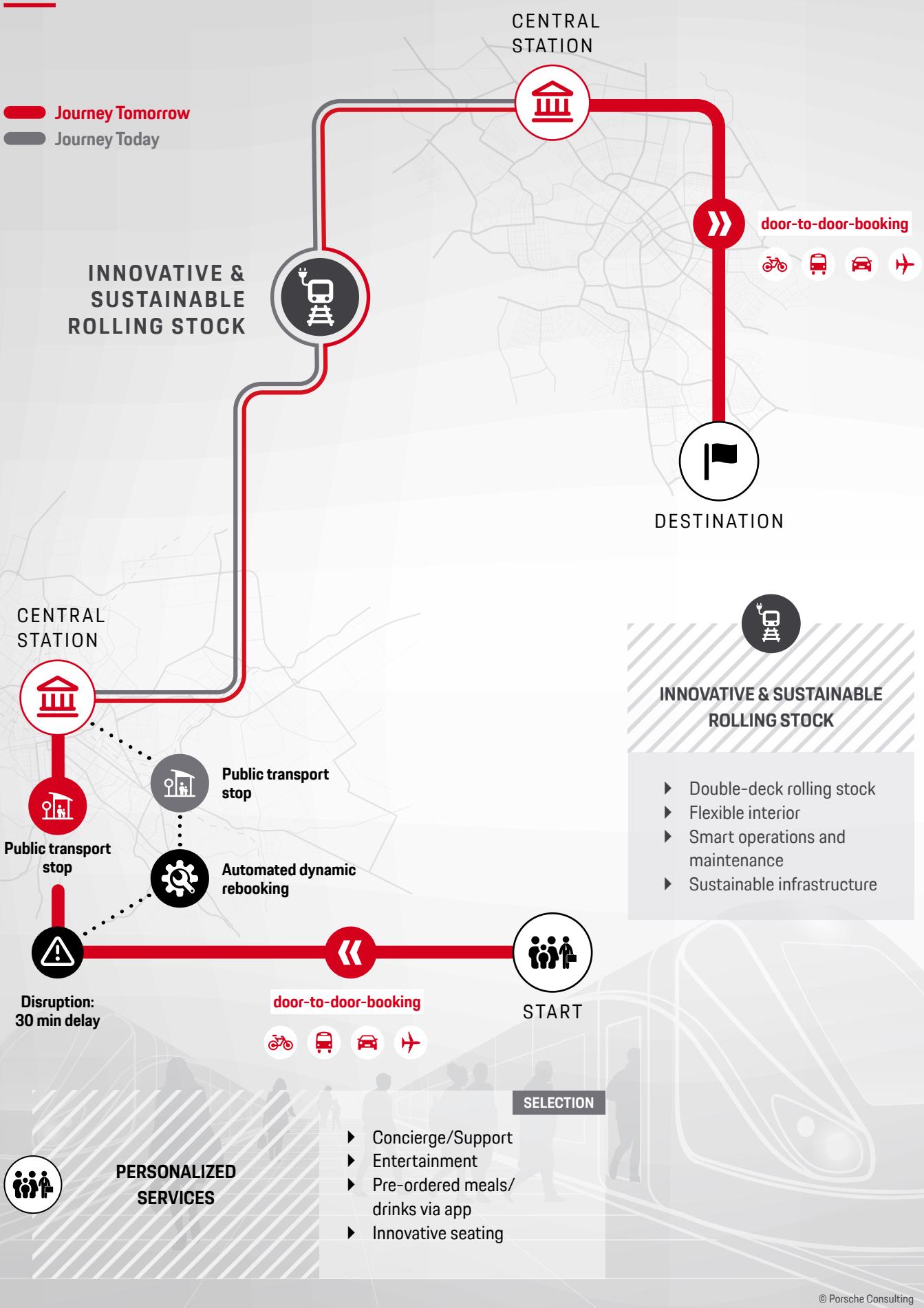





**Fig. 1.** Illustration of a seamless, smart and enjoyable passenger journey and rail operations

01


# Driving demand by implementing inventive capacity levers

To attract more passengers and increase the modal share of rail, operators can leverage capacity and flexibility for higher passenger comfort. There are three ingenious capacity levers that enable operators to independently stimulate demand:

## 1.1 FLEXIBLE TRAIN INTERIORS

Passenger capacity can be significantly increased through a flexible train interior featuring various seating designs and spaces. A design project conducted by the University of Twente analyzed a potential increase of up to 24 % in maximum capacity by means of interior adaptions, whilst maintaining high levels of comfort for different travelers' needs[1].

**24 %**

**increase in maximum train capacity is possible**

Furthermore, converting seats into standing seats in a train can result in a capacity boost of over 50 %. Increasing train capacity involves adopting flexible interior design approaches, e.g. additional standing/leaning areas, optimized seat layouts, and additional storage spaces underneath or in between the seats.

To ensure that passengers arrive on time and enjoy a comfortable journey, it is essential to provide adequate capacity that can be continuously adapted to varying levels of utilization, especially during peak periods. As an example, the Spanish manufacturer Construcciones y Auxiliar de Ferrocarriles (CAF) has developed modular 'Civity trains' that can be customized to meet the demand for regional and commuter transportation, with a particular focus on handling high-capacity passengers loads[2].

### Project 'Proteus': New rail interior system, UK, 2022

The new interior system from the 'Proteus' project transforms pragmatic interior ideas for more flexibility, more comfort, and more functional design into new travel experiences for commuters and leisure travelers. For example, innovative seat layouts and headrests eliminate shoulder clash and improve comfort and privacy; tip-up seat pans on aisle seats allow passengers to keep bulky luggage nearby, or flexible spaces adjacent to all entrance vestibules with longitudinal seating that can be used for multiple purposes, depending on demand.[3]

## 1.2 DOUBLE-DECK ROLLING STOCK FOR THE HIGH-SPEED SEGMENT

The integration of high-speed double-decker trains is gaining traction among European operators due to their potential to significantly boost train capacity. On a double-decker train 40 % more passengers are possible, according to specific design projects.[4]. While regional and commuter rail operators in Europe already use double-decker trains for a significant portion of their fleets, the expansion of double-deckers in high speed rails still needs to overcome several challenges. Nevertheless, the operational, economic, and comfort-related advantages of double-decker trains for long-distance high-speed connections should be considered:

- Reduced investment and operational costs per seat
- Decreased maintenance costs
- More interior space, e.g. for luggage
- More comfort for each passenger
- More possibilities for innovative room concepts, such as 'public viewing' spaces

For example, the French rail company SNCF broadly operates high-speed double-decker trains in Western Europe[5] with its TGV Duplex trains and the upcoming TGV M.

"While regional and commuter rail operators in Europe already use double-decker trains for a significant portion of their fleets, the expansion of double-deckers in high speed rails still needs to overcome several challenges."

### Project 'AeroLiner3000': High speed, high capacity

The German engineering and design project AeroLiner3000 demonstrates a new approach to a high-speed double-decker train for the future of rail. A two-unit trainset of 22 cars in total, and which is virtually coupled, would reach a capacity of 1,400 seated passengers and a max. speed of 400 km/h. The double-decker section is achieved by a lower ceiling height which is counter-acted by a high-quality interior as found in private jets, cars and helicopters. First tests of this concept were made on the high-speed line between Rome and Naples[6].

## 1.3 NETWORK-RELATED CAPACITY IMPROVEMENTS

By shortening the time between train intervals and minimizing station stoppages, operators can increase the number of trains per track and stimulate even greater demand. There are two approaches that can improve network-related capacity:

**a)** Optimizing passenger flows during transfer
**b)** Implementing 'Virtual Train Coupling'

The first approach focuses on smoothing out the way passengers transfer between trains and the passenger flow on station platforms. For example, the implementation of intelligent door systems, platform markings or digital notifications can guide individual passengers to exactly where to enter or exit during transfers. This not only improves customer comfort, but also reduces waiting times at stations.

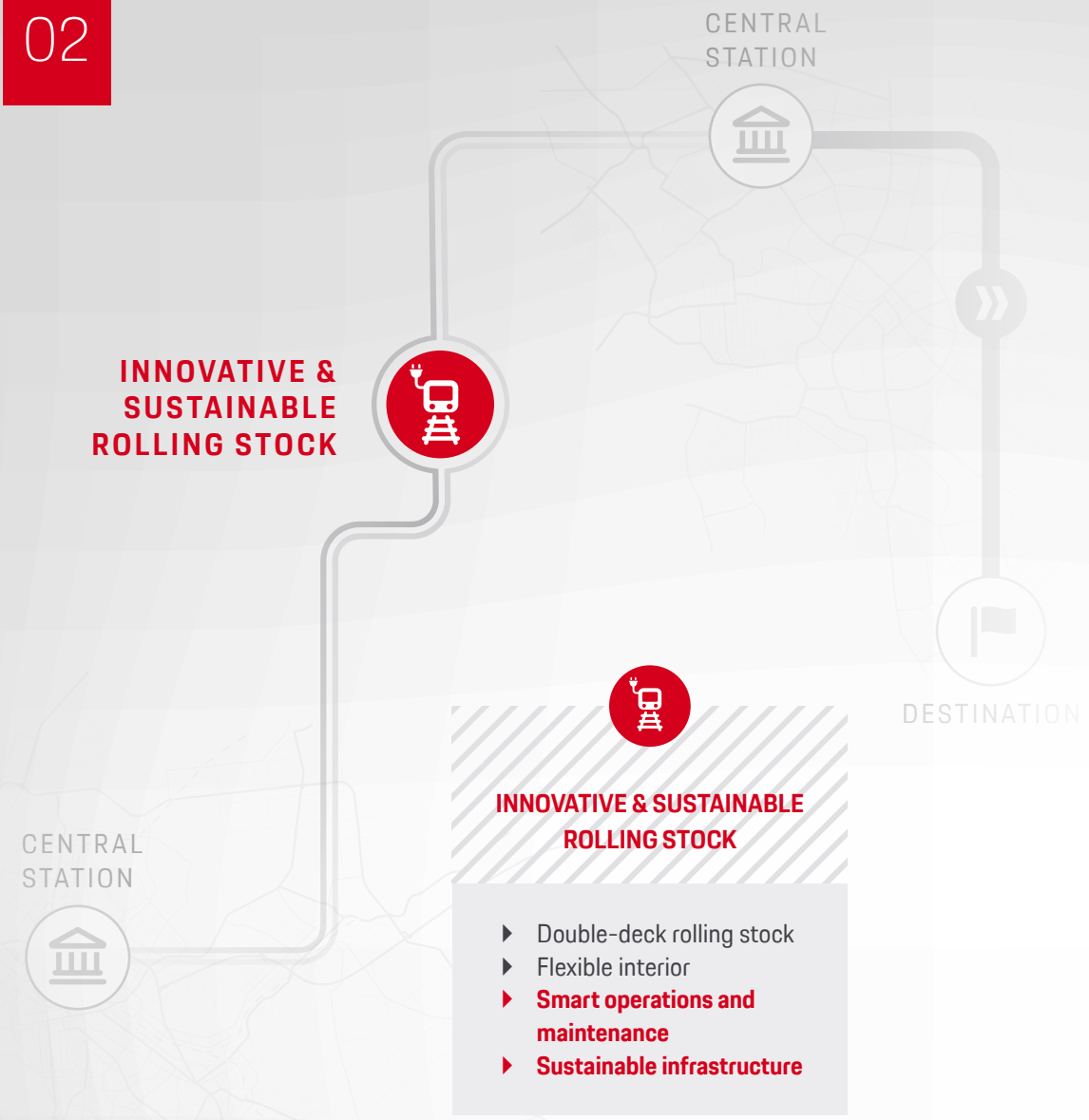
Boosting rail line capacity significantly can be achieved through an innovative approach known as 'Virtual Coupling'. This concept involves 'virtually' linking trains operating on the same route, forming a connected platoon, which can be managed as a single train unit. Much like the way cars maintain relative braking distances on the road, Virtual Coupling (VC) allows multiple trains to run in close proximity, dynamically adjusting their speed based on the preceding train, resulting in the optimization of space and time usage on the existing rail infrastructure. The study 'Impact Assessment of Train-Centric Rail Signaling Technologies' by TU Delft has revealed that VC can reduce both the minimum space and time intervals between trains by 66 % and 16 % respectively when compared to the European Train Control System (ETCS) Level 3. Since the railway industry in Europe is clearly targeting the implementation and evolvement of ETCS Level 3 to enhance capacity on existing lines, Virtual Coupling is emerging as a viable bridging technology for applicable rail sections[7].

However, it is essential to recognize that the concept of Virtual Coupling faces technical and ethical barriers such as 'Vehicle-to-vehicle communication' and concerns regarding safety risks. Nonetheless, the ever-growing need for capacity in a fast-evolving world of mobility provides a compelling rationale to further explore this concept in the future.

## 'MOVINGRAIL'—increased capacity and reduced infrastructure costs through Virtual Coupling

Results of the EU-financed research project MOVINGRAIL illustrate that Virtual Coupling can be attractive to customers of high-speed, main line, regional routes and, in particular, freight segments. Major strengths are the substantial increase in capacity and reduction potentials in operational costs comparing to the 'Moving Block' concept. Weaknesses are limited capacity gains at diverging junctions (since trains still need to be separated by a full braking distance) and the large investments required to upgrade the overhead line system, platform lengths, and technology switches. However, overall Virtual Coupling has potential to completely revolutionize and improve current train operations to induce a sustainable shift to railways[8].

02




# Providing emission-free rail through more sustainable operations

Rail is the most sustainable means of transport. While the network carries 8 % of the world's passenger transport and 7 % of freight transport, only 2 % of energy consumption attributable to the transport sector is used for rail[9]. Nevertheless, due to the climate crisis and ever-increasing sustainability demands, the status quo must be challenged, and further opportunities developed to reduce the ecological footprint. The French operator SNCF and German operator Deutsche Bahn, for example, have set targets to be carbon neutral by 2035 and 2040 respectively[10]. Three action fields can help to achieve these ambitious goals.

## 2.1 ELECTRIFICATION OF THE RAILWAY NETWORK

To further reduce the carbon footprint and push rail emissions to zero by 2050, there is still a way to go toward a broad railway electrification in Europe. Today, 57 % of the European rail network is electrified, the rest mainly frequented by diesel powered locomotives[11]. In Austria, Italy and the Netherlands, the degree of electrification is high, at 70 to 76 %, while the pioneer in electromobility in rail is Switzerland at almost 100 %. The German rail network is electrified by 61 % which results in about 25.000 km. The goal is to achieve 70 % electrification by 2030. Therefore, further investments in electrification of the railway network need to be made where there is high demand for rail service and high levels of utilization[12]. However, a high degree of electrification only improves the $CO_2$ balance if the electricity used is generated sustainably. SBB therefore uses hydropower to cover 90 % of the train's electricity consumption[13].

Still, there will be regions in Europe where the rail network will not be reached by electrified lines due to high cost of investment. In these cases, rail operators can increasingly profit from technical developments in alternative powertrains and boost their 'green credentials' comprehensively—especially in local passenger rail transport. Apart from electrifying rail passages in entirety, operators can also electrify sections of railways to allow trains to charge their integrated batteries along their route at terminal stops. This is a feasible method to allow more emission-efficient trains to operate before having to electrify rail routes entirely. Deutsche Bahn is currently implementing a system of charging infrastructure in the northern part of Germany[14].

"The German rail network is electrified by 61 % which results in about 25.000 km. The goal is to achieve 70 % electrification by 2030."

## 2.2 APPLICATION OF NEW POWERTRAIN TECHNOLOGIES

### Porsche Consulting Future Powertrain Model (2023)

To meet customer demands for emission-free travel and stricter regulations, rail operators should promote three powertrain technologies for non-electrified rail connections:

- Battery-electric powertrains
- Fuel-cell powertrains
- E-fuels or HVO (Hydrotreated Vegetable Oil) for existing engines

Batteries chemically store electrical energy after being charged using the electricity grid. Fuel cells produce electrical energy by the conversion of hydrogen and oxygen into water. E-fuels are synthetic fuels that are produced from carbon dioxide and hydrogen, and can be burned in conventional combustion engines. Deciding which powertrain is most suitable depends on the train's requirements, such as power needed, weight, fuel consumption, investments, and usage time between refueling. According to the Porsche Consulting study, total cost of ownership (TCO) is a key purchase criterion in the railway industry, these factors must be considered in determining the right powertrain. An analysis of the TCO of a typical regional train is shown in figure 2.

TOTAL COST OF OWNERSHIP

**Typical Regional Train without powerline 2030 (€/km)**

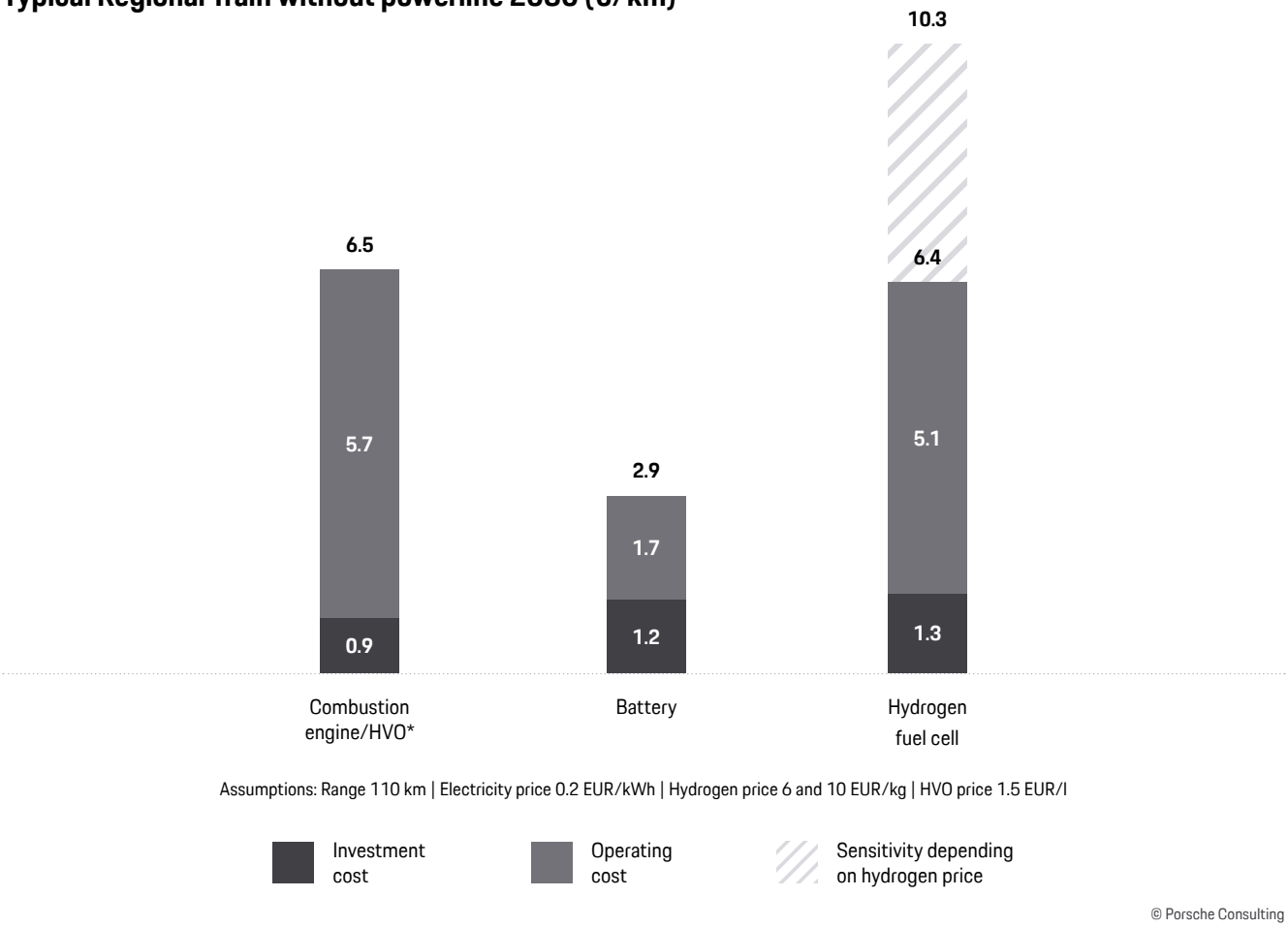




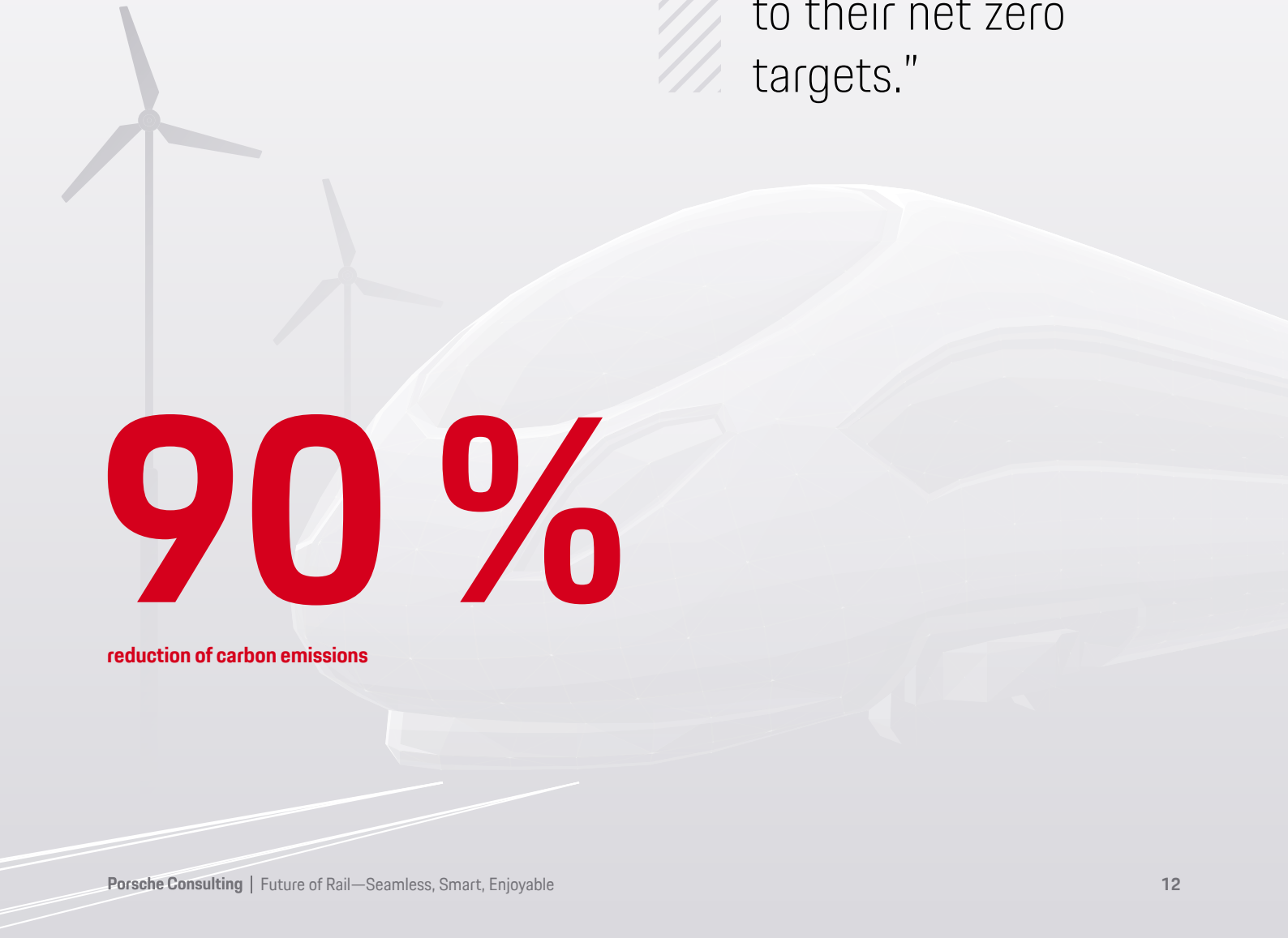

**Fig. 2.** Comparison of total cost of ownership 2030 of a typical regional train 2030 in EUR/km

* Hydrotreated Vegetable Oil

Under the current assumptions for electricity prices, battery powertrains have lowest cost per kilometer (2.9 EUR/km) and are therefore most competitive option for regional trains with a range of 110 km where no overhead lines exist. Potential advantages of hydrogen powered trains are reduced refueling times compared to battery charging, and a lower initial investment cost for the operator.

European rail operators already use multiple powertrains to bring the railway industry closer to their net zero targets. DB Regio and Alstom have successfully tested battery-electric regional trains in passenger service. France's SNCF has ordered multiple hydrogen fuel cell trainsets from Alstom for their intercity passenger line Régiolis[15]. Regarding alternative fuels, DB Regio is already using HVO (Hydrotreated Vegetable Oil) as a drop-in fuel in a fleet of 90 regional trains, allowing for a reduction of carbon emissions of about 90 %.

"European rail operators already use multiple powertrains to bring the railway industry closer to their net zero targets."



**90 %**

**reduction of carbon emissions**

## 2.3 SUSTAINABLE SUPPORT BY INFRASTRUCTURE

Achieving sustainability goals needs a comprehensive rail system approach that not only focuses on more sustainable operations, but also considers ecological contributions by the infrastructure segment. Both train stations and railway construction are relevant areas that require closer study. Stations face particular challenges in achieving energy efficiency, primarily because they must contend with frequent interruptions in heat insulation caused by people entering and exiting, as well as the constant need for lighting. They can contribute to more sustainability by deploying three measures:

- By converging the circular economy, great potential can be harnessed in the construction of tracks and station buildings, as they require large quantities of steel and concrete, whose production releases huge amounts of $CO_2$. A positive example is the new maintenance facility in Cottbus, which proved that up to 30 % less $CO_2$ emissions are possible in the construction by integrating sustainable cement. The circular economy also includes efforts to further increase the longevity of rail infrastructure, e.g. through consistent maintenance[16].

- By enhancing smart energy systems such as solar panels and heat recovery systems, ventilation and air conditioning (HVAC) systems, and using intelligent lighting systems, the energy consumption by train station buildings can be significantly reduced without diminishing user comfort[17].

- By providing extensive greening and dedicated areas for insects a positive impact on biodiversity and the microclimate around stations can be achieved. In addition to the stations, measures along the tracks can also lead to a better compatibility of rail traffic and biodiversity. In areas in particular need of protection, consistent noise barriers and safe wildlife crossings at regular intervals can significantly reduce the impact of rail traffic on ecosystems[18].

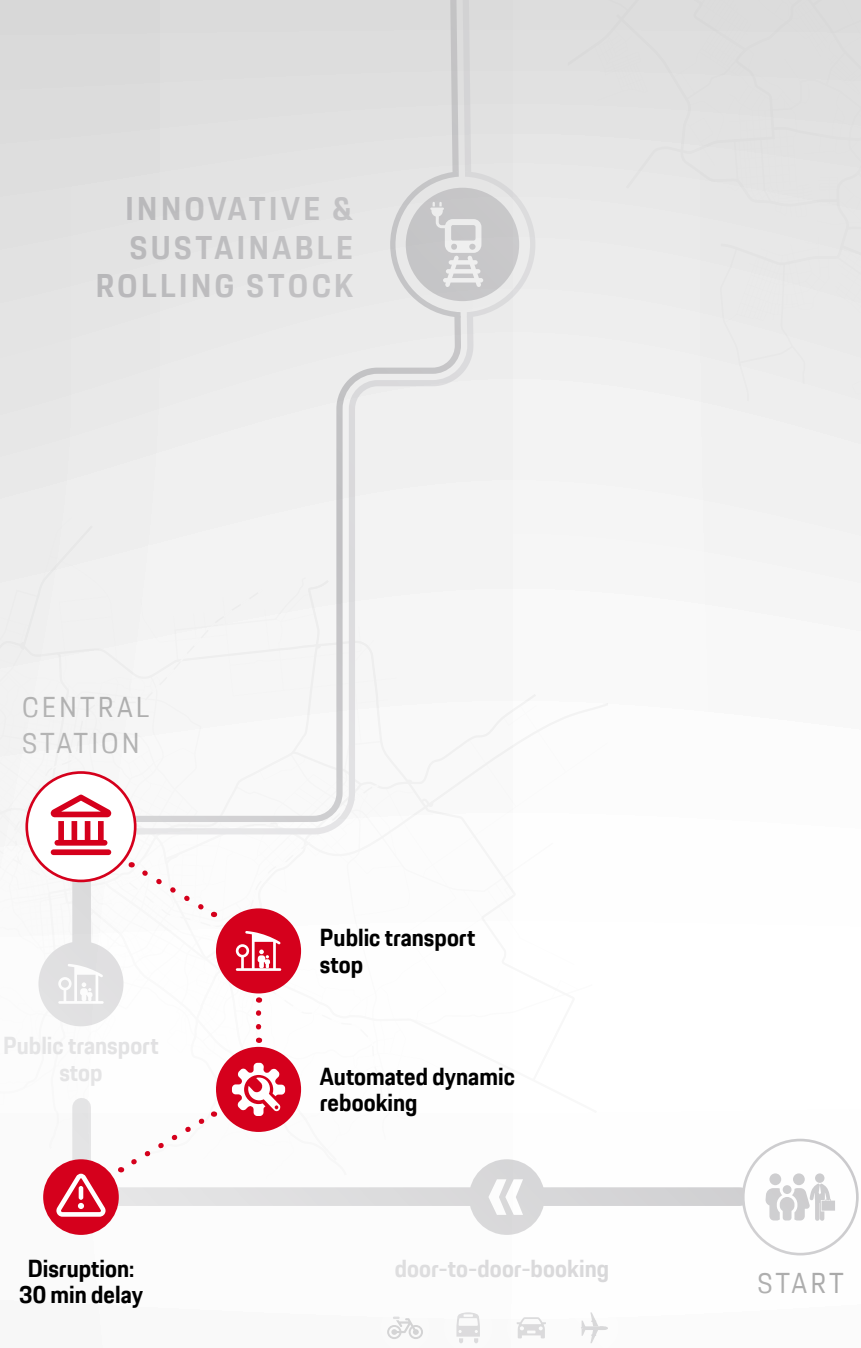
### 'H2goesRail': Innovative overall hydrogen system for rail—DB and Siemens Mobility

The new Mireo Plus H train will save up to 45,000 tons of $CO_2$ emissions over its service life of 30 years compared to corresponding travel with cars. It currently runs in Baden-Württemberg and will be operating between Tübingen, Horb and Pforzheim as of 2024. Furthermore, to make hydrogen technology competitive, DB has developed a new method for fast fueling with green electricity taken directly from overhead power lines. For the first time, a hydrogen train can be refueled as fast as a diesel-powered train[19].

### Victoria Station, UK—Recycling scheme

At Victoria Station in London, UK, Network Rail has partnered with an innovative waste management company called Green Block to improve waste collection processes. A system that uses a dashboard to record real-time inbound and outbound waste has been implemented. Recycling rates were at 12 and 15 % before implementation and have risen to around 90 % since[20].

03




# Enhancing performance in operations through improved collaboration and digital evolution

Digitalization offers a promising opportunity to provide rail customers with available, reliable, and efficient transportation. To enhance performance across these key dimensions, the following three critical key developments should be considered:

## 3.1 INCREASED EFFICIENCY AND AVAILABILITY THROUGH AI-DRIVEN OPERATIONS

Full-scale digitalization of rail operations and infrastructure offers customers improved reliability, and increased availability, through personalized schedules and faster service frequencies. This transformation is possible by digitalizing the physical infrastructure, incorporating digital signal systems and control centers, as well as digitalizing the rolling stock.

The data generated from digitalized infrastructure opens valuable potential through consolidation, standardization, and intelligent analysis:

**01** Real-time monitoring and control
**02** Autonomous driving

The real-time digital monitoring and control does not only enhance operational efficiency but also robust planning of regular operations. This is achieved through improved and prompt responses addressing both internal factors (e.g. staff shortages) and external disruptions (e.g. track closures). Additionally, enhancing the data with information such as bookings, compensations, personnel planning etc., and integrating AI, enables optimization of decisions related to customer satisfaction, schedule stability, costs, and personnel allocation.

Another noteworthy application involves the utilization of autonomous trains, as are already being used in subway systems today. To facilitate their widespread adoption in public transportation and long-distance travel, expediting their introduction on test routes is recommended. This approach allows valuable operational experiences to be gathered, and early identification of necessary adaptations in the digitalization of infrastructure and rolling stock.

A major role for autonomous train operation is played by the implementation of the European Train Control System (ETCS). ETCS vehicles do not require multiple types of equipment with different train control systems. Today, various train control systems are installed on vehicles, resulting in high costs for purchase, installation, and maintenance. Standardization and the simultaneous expansion of ETCS infrastructure is the basis for automated driving and should continue to be a high priority for the EU and rail operators.

"The real-time digital monitoring and control does not only enhance operational efficiency but also robust planning of regular operations."

## 3.2 ESTABLISHING RAIL AS THE MOST RELIABLE WAY OF TRANSPORT THROUGH PREDICTIVE MAINTENANCE

Intelligent maintenance is crucial for increasing rolling stock availability, minimizing failures, and enhancing reliability and punctuality to benefit customers.

To achieve this, a close collaboration between operators and manufacturers (OEMs) is essential for the development of two key elements:

**01** Predictive Maintenance—forecast of maintenance needs
**02** 'Digital Twin'—digital image of rail and train

Leveraging sensor data and its intelligent interpretation is necessary for mitigating costly and time-consuming unscheduled maintenance for both infrastructure and rolling stock. Experience from other industries proves there is potential to reduce repair times and associated costs by at least 15 %. The primary focus of predictive maintenance should center on the maintenance of critical systems (e.g. doors, air conditioning, toilets or wheel sets), all of which feature sensor availability and well-established fault patterns. Due to the long-term use of rail assets, it is essential to work in collaboration with OEMs to anticipate rolling stock operations and potential critical failures, and to proactively integrate relevant sensor technology into new assets.

### Lufthansa Group & Google 'Operations Decision Support Suite'

Lufthansa Group established a modular system that optimizes operational decisions, e.g. flight plan changes due to irregularities based on real-time data. The system takes into account all relevant framework conditions (e.g. airport, ATC, weather) and resources (e.g. aircraft, crew)[21].

### Fully autonomous rail— 'Project Automated Train'

In Stuttgart, Deutsche Bahn is testing the autonomous operation of regional trains together with Siemens Mobility, Bosch and other partners. Equipped with intelligent sensor technology, the train can travel from the stabling facility to the first station without any human control. In the event of obstacles, the train brakes automatically. The project is collecting data to allow autonomous trains to also be used in regular operations in the future[22].

### Comprehensive digital twin of the German rail network— 'Project Sensors4Rail'

Deutsche Bahn has been working on creating a digital twin of the entire German rail network since 2019. With the help of NVIDIA, a digital photorealistic copy of the tracks can be used to simulate various special situations during train operations. The data obtained from this can be used, among other things, for training AI and autonomously running trains[23].

The concept of the digital twin represents a progression through three distinct tiers.

- **Level 1: a single system's digital twin**
- **Level 2: groups of systems to an entire train**
- **Level 3: an ecosystem that integrates data from rail infrastructure, rolling stock, and other components, can simulate its state and behavior virtually utilizing artificial intelligence integration without the requirement for additional physical sensors**

thereby providing a holistic view of the entire system to continuously enhance its reliability.

"Quick response teams, a dynamic schedule, and fallback solutions for high-risk routes minimize the impact and improve operational performance."

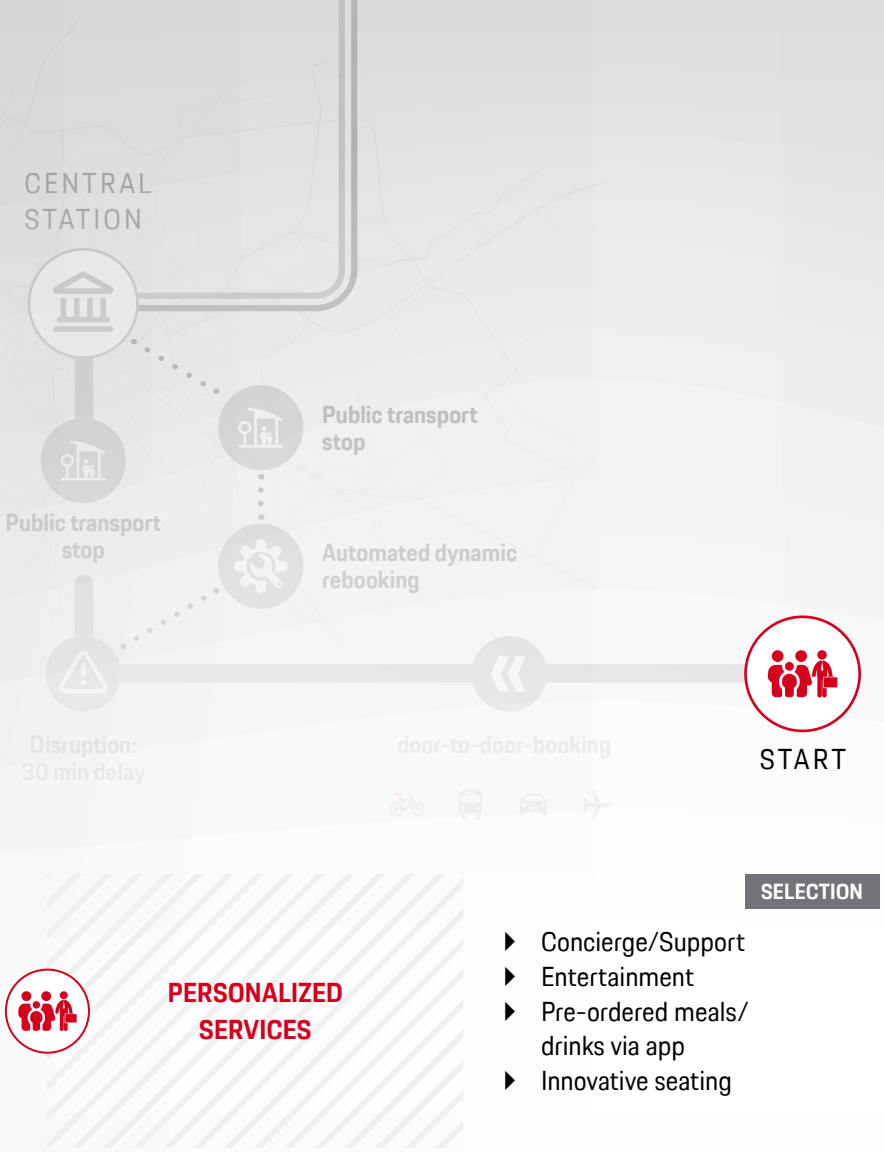
## 3.3 BETTER COORDINATION OF SCHEDULES AND NETWORK MODERNIZATION

A stronger focus on anticipating the impact of planned track modernization and unplanned maintenance works has significant positive effects on the robustness of scheduled train operations. Two measures help to achieve the desired results:

**01** Better coordination of network modernization and operator schedules
**02** Risk-based anticipation of unplanned track maintenance and provision of redundancies

Despite powerful interfaces between rail infrastructure and operating companies, both parties have not yet utilized the full potential to contribute to robust rail operations. Proactively coordinated planning of modernization or maintenance works with the network services and products of rail operators can help avoid sudden divergencies in schedules, and improve customer satisfaction. Therefore, construction planning must be aligned in terms of location and time with the routes offered and travel times needed by the operator, as well as the impact on other routes affected by potential detours. Furthermore, the risks due to sudden maintenance requirements for detour and crowded routes must be assessed and considered in the overall construction planning. Quick response teams, a dynamic schedule, and fallback solutions for high-risk routes minimize the impact and improve operational performance.

04




# Fulfilling customer wishes by using product and service innovations as a foundation

Enhancing the passenger experience not only boosts demand, but has also the potential to increase profits with well-designed product and service innovations. Both are essential to help realize what is an expensive shift to reliable and sustainable rail transport. There are three key approaches to improving the passenger experience and demand within the rail sector:

- Creating engaging and inspiring train interiors
- Generating innovative on-board services
- Engaging customers in the co-creation of innovations

### 4.1 CREATING ENGAGING AND INSPIRING TRAIN INTERIORS

The key to a better passenger experience and attracting a broader customer base to rail services lies in offering captivating rail products and experiences, and this in two dimensions: the diverse customer needs, and the travel situations. A closer look at innovative offerings from leading rail operators reveals inspiring passenger approaches such as:

- Exclusive passenger classes
- Overnight journeys with the ambience of a 'hotel on wheels'
- Family-friendly facilities

Introducing product differentiation within trains that emphasizes exclusivity, unique comfort, spacious interiors, and top-tier services, all of which not only meets but actually exceeds expectations of rail travel. For example, Trenitalia introduced the Frecciarossa Executive Class, a prime example of a customer-focused approach[24]. Beyond providing ten spacious seats and first-class amenities, the exclusive class even includes a dedicated meeting room, catering specifically to business requirements.

Furthermore, innovative night train solutions are opening up new possibilities for (business) travelers across Europe, who often face overnight stays before important meetings at home or at the hotel. There is a chance for rail operators to entice business travelers away from short-haul flights or long car journeys to the train, especially by targeting the '500 km gap'[25]. These journeys fall into the category of being too far to drive and too close to justify a flight. And this is precisely where the concept of a 'rolling hotel' comes into play.

To encourage this transition, a high level of comfort in terms of direct connections, modern rolling stock, and comfortable interiors is required, as well as effective marketing strategies such as vouchers, direct destinations with a high appeal, or the introduction of price campaigns are key elements in driving this change[26].

Given the rising trend for family trips, there are many appealing ideas to encourage families to switch from using cars or planes to a much more relaxed and convenient mode of train travel. For instance, German Intercity Express trains operated by Deutsche Bahn or Swiss Intercity double-decker trains operated by SBB have introduced dedicated family zone carriages designed to cater to children's needs. These carriages offer adventure areas, onboard entertainment programs, and private compartments for toddlers, making family travel by train an appealing option[27].

## Dreamstar Lines

The US-based startup is developing a luxurious night train hotel as an alternative to flying. Its launch is slated for summer 2025 with an initial focus on the L.A. to San Francisco corridor[28]. The company is considering running two trains every night on this route. One heading north, the other one heading south, departing respectively at 10:00 p.m. and arriving the next day at 8:30 a.m.

## 4.2 GENERATING INNOVATIVE ON-BOARD SERVICES

In the future, train journeys will evolve into being a passenger-centric experience that extends beyond the underlying transportation service. This transformation can be achieved not only by introducing diverse interior facilities, but also by providing innovative services for different train-based experiences:

- Immersive virtual reality experiences
- Downloadable content such as e-books, movies, music, and games
- Pre-ordered food and beverages using a dedicated app, or walk-in cafés
- In-train cinema
- Dedicated shopping areas
- Wellness facilities
- Workout area

## 4.3 ENGAGING CUSTOMERS IN THE CO-CREATION OF INNOVATIONS

Beside recognizing the existence of innovations and their potential applications, it is also vital for operators to understand how to design new products and services that meet passengers' expectations. The process of identifying and developing new ideas and design concepts are more likely to succeed in the market when customer needs are consciously integrated into the creative process. The concept of 'Co-creation approaches' is already a common practice in various industries.

Example: Lufthansa Group has set up a 'Co-Creation Hub' to establish a customer-focused community that gather insights about what customers truly want. (Potential) customers can take part in different ongoing projects and share experiences, preferences, ideas, and suggestions, all of which are carefully considered in the product development process[29].

## 'Ideenzug' by Deutsche Bahn

The 'Ideenzug' by DB illustrates a wide range of innovative services, including:

- Work-out areas
- Social areas such as public viewing areas
- Augmented-reality windows facing the outside of the train[30]

Modeling and experiencing the future of rail travel not only increases customer enthusiasm for rail, but also uncovers which innovations inspire the highest interest and demand. The focus of the 'Ideenzug' was on rest and relaxation as well as socializing and communication.

05

# Attracting new customers by extending services and integrated mobility

Seamless integration of mobility services enables customers to travel swiftly and conveniently from door to door. Through strategic partnerships, train operators can provide passengers with services and products along the entire journey, consequently attracting new customers to rail travel. To create a seamless and fully integrated mode of transportation, three key domains must be coordinated:

## 5.1 FACILITATING CROSS-CONTINENTAL TRAVEL IN COLLABORATION WITH EUROPEAN RAIL PARTNERS

Cross-border train connections in Europe not only offer travelers enhanced connectivity along with convenient alternatives to individual mobility and air travel, but also have the potential to further position themselves as an attractive and sustainable means of mobility in Europe. The potential of international rail travel has been confirmed by e.g. the latest developments in long-distance traffic departing from Germany. The European Commission aims to double high-speed rail traffic by 2023 and triple it by 2050, considering better cross-border connections and the sustainability goals[31].

"The European Commission aims to double high-speed rail traffic by 2023 and triple it by 2050, considering better cross-border connections and the sustainability goals."

To create competitive advantages on transnational long-distance routes, collaborative partnerships across different operators are essential and should focus on:

**a)** Expanding European high-speed rail networks
**b)** Establishing a standardized ticketing system

One major step for more international rail travel is to expand the high-speed network with the goal of connecting the nearest metropolitan areas within a maximum travel time of three hours. There is already an initiative to develop a Europe-wide high-speed network that will connect 60 % of the European population in 230 major cities by 2050, involving a doubling of high-speed rail by 2030 and a tripling by 2050, as outlined in the 'Metropolitan Network' study[32]. In addition, the 'New Action Plan' issued by the European Commission could prove to be an effective initiative for advancing rapid European train travel in the future[33].

Beside the expansion of the cross-continental rail network, enhanced digital platforms for convenient booking and payment of international tickets must be developed. Legal matters, including cross-border travel agreements, must also be addressed, guaranteeing that both the train journey and the connection of urban or suburban services abroad are covered within a unified ticketing system. For example, the train journey and local urban or suburban connecting services abroad should be included in the ticket.

## 5.2 EXTENDING NETWORK COVERAGE AND END-TO-END SERVICES THROUGH MOBILITY PARTNERSHIPS

Partnering with regional mobility operators to cover the first and last mile is essential for a seamless and comfortable rail travel experience, as well as for gaining new customers. By integrating various transportation options into rail services, such as public bus routes, car-sharing, e-bikes, and e-scooters, passengers can easily travel from door to door, even if they live far from central train stations. For urban areas, micro-mobility providers such as e-scooters, bike-sharing services, and autonomous shuttles offer attractive connectivity solutions. In contrast, rural regions, where rail often face infrastructural limits (as an example, only 60 % of residents in rural areas in England, Wales, and Scotland have a bus stop nearby[34]) are actively working toward the development of extensive mobility networks. Combining transport options such as shared cab services, on-demand shuttles, car sharing, or public transport is of significant relevance in such areas.

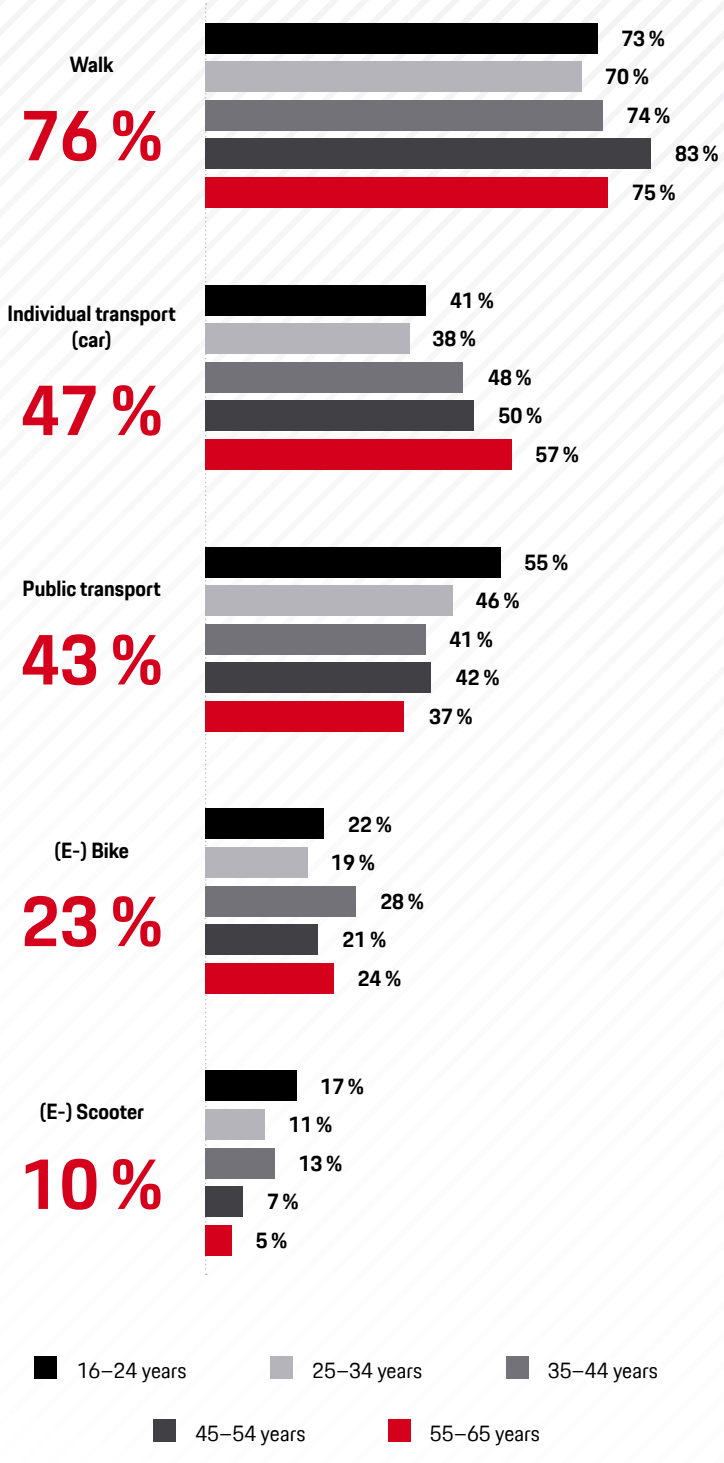





**Fig. 3.** Frequency of use of means of transportation in German cities.
Source: Appinio (2023)[35]

## 5.3 PLACING RAIL AT THE HEART OF INTEGRATED MOBILITY WITH TECHNOLOGY PARTNERS

Customers can fully benefit from the advantages of integrated mobility when various mobility services are digitally integrated into what is often referred to as 'Seamless Integrated Mobility Systems' (SIMSystem). This integration offers customers a one-stop solution for their mobility needs, and to organize and book train journeys conveniently from door to door. Even international travelers can benefit from it with the integration of Europe-wide timetables. Partnerships with technology companies enable railway companies to develop, scale, and continuously refine an integrated mobility platform. State-owned operators, due to their size and financial stability, can assume leadership in this initiative.

"Partnerships with technology companies enable railway companies to develop, scale, and continuously refine an integrated mobility platform."

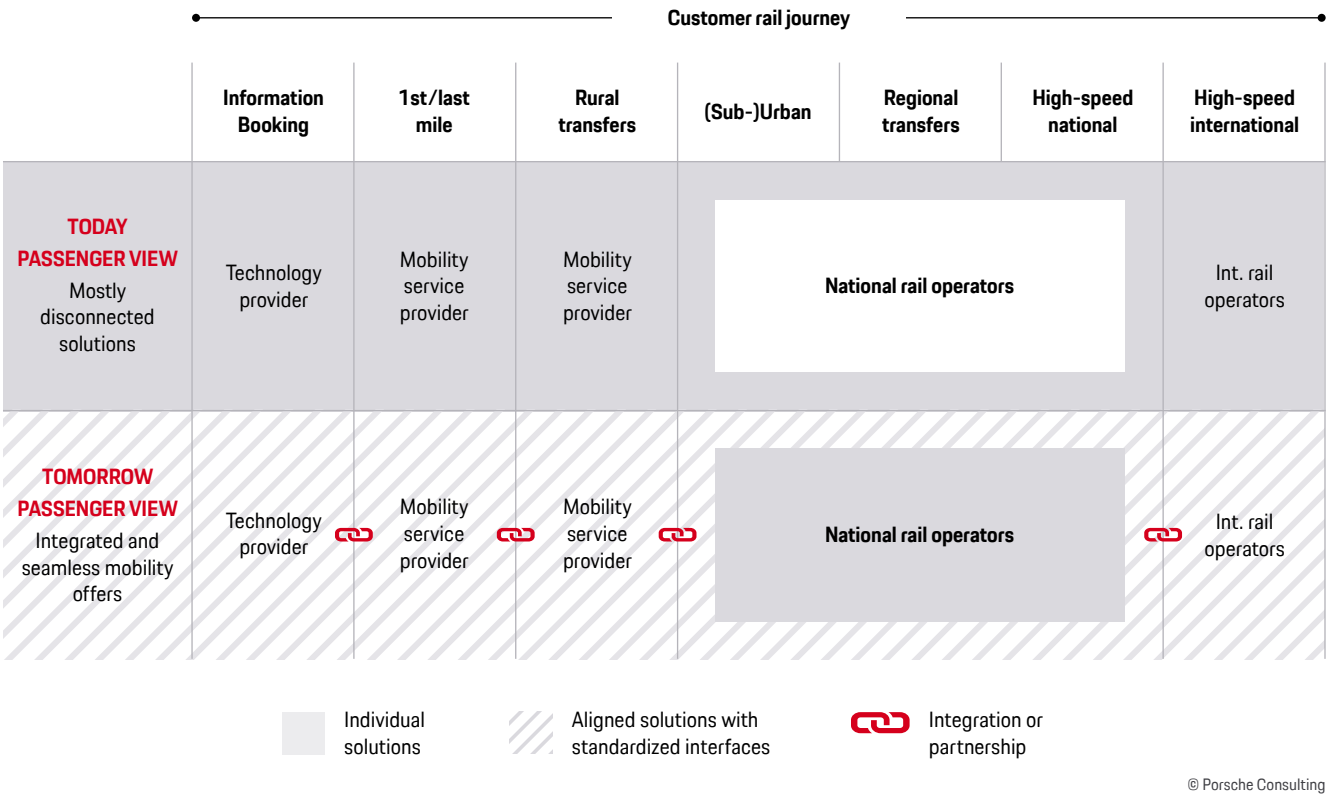





**Fig. 4.** Focus of rail operators today and tomorrow

06


# Boosting passenger satisfaction by designing a seamless and personalized door-to-door journey

Rail customers today demand seamless and comfortable door-to-door journeys with tailored travel experiences satisfying individual needs. Rail operators can ultimately boost customer satisfaction and foster long-term transition to rail-based mobility by means of:

## 6.1 PERSONALIZED SERVICES THROUGH LEVERAGED TRAVEL INFORMATION

Rail passengers enjoy traveling with personalized services throughout the entire journey. Emphasizing comfort and services is a powerful strategy to make rail more attractive, considering that passengers can efficiently use up to 96 % of their actual travel time[36]. From travel planning to reaching destination and post-travel services, personalization plays a decisive role in addressing individual passenger requirements. By using travel information shared by the passenger, operators can gain insights into individual preferences and needs, enabling them to offer tailored services that can significantly improve the overall experience. Service offers vary along the journey, depending on criteria such as travel purpose (e.g. business, leisure), number of travel companions (e.g. solo traveler, family), or specific service needs for elderly (e.g. heavy luggage) or passengers with impairments.

Some ideas for personalizing services may include:

**Prior to travel:** Passengers receive essential travel information such as pre-travel notifications, specific travel coaches, and personalized travel recommendations and options.

**At the station:** Passengers use one single app to get to the train station and navigate their way to the right platform and wagon. Special assistance services are available, such as escorting passengers from the pick-up or taxi area directly to the designated departure area, ensuring a smooth and convenient transfer.

**During travel:** The passenger has access to designated seating areas that are flexible in size, e.g. for families, allowing them to stay together and to share space with passengers with similar preferences. Additionally, an app can allow them to pre-order and pay for their favorite foods and beverages, including the beloved Monday morning hot drink for business travelers.

A special luggage service for families traveling together to their vacation destination.

Seating options closer to the entrance to facilitate overall comfort (e.g., for senior citizens or travelers with bikes).

## 6.2 SEAMLESS DOOR-TO-DOOR JOURNEYS WITH INTEGRATED DYNAMIC BOOKING PROCESSES

Passengers appreciate ease of effort when planning and booking a trip. Customer satisfaction can be positively influenced by two characteristics when booking journeys:

- Convenient door-to-door-booking
- Dynamic rebooking in case of travel disruptions

The 'door-to-door' booking is tailored to the passenger's preferences, such as number of transfers, level of comfort on board, or overall travel time. This approach creates more eco-friendly modes of transport, with a streamlined planning and ticketing process from start to the destination, eliminating all fractional and time-consuming approaches for each transportation mode.

Secondly, the implementation of dynamic rebooking of individual journeys in the event of delays or cancelations will give priority to helping passengers to reach their destination as smoothly and comfortably as possible. Systemic adjustments of existing bookings automatically provide passengers with alternative routes and travel options as soon as planned connections are disrupted, or will be affected. Passengers are easily informed about these changes proactively (e.g. push notifications) and—if necessary—are rerouted according to individual preferences such as overall travel time, seat availability, or frequency of transfers. These strategies ensure that passengers feel looked after in unforeseen situations, and show a clear recognition of their needs.

### 'Zipabout' is a UK platform that guides passengers from door to door, providing the following services[37]:

**1. Live updates** on passenger journeys, including alternative options, via push notification

**2. Journey watch** for regular travelers with updates on specific journeys, prices, route changes etc.

**3. Realtime door-to-door** updates on everything leading to and from the journey, such as construction updates, weather conditions, traffic etc.

**4. First and last mile support** by working with partners to develop intelligent last mile assistant that proactively offers real-time assistance with reaching the final destination via different modes of transport

**5. Rewards** for choosing sustainable transport options by working with partners to provide special treats

### 6.3 SHIFTING TOWARDS PROACTIVE DEMAND MANAGEMENT FOR INCREASED PASSENGER COMFORT

Passenger satisfaction and higher comfort levels can be achieved through proactive demand management, with two recommendations:

- Leveraging attractive off-peak travel options through actively managed demand
- Ensuring sufficient capacity during high-demand periods

Systems can provide passengers with personalized and efficient travel options, eliminating the need to endure crowded trains. By incorporating passenger preferences and real-time data, the proposed solution offers various route options that prioritize either the fastest, most comfortable (e.g. with available seat reservations), or most affordable connections. Through proactive demand management, peaks can be managed and passenger experiences improved.

Another key aspect in balancing demand and capacity is increasing flexibility in the size and allocation of rolling stock. Intelligent steering systems will optimize the allocation of trains based on passenger flow data. Through the continuous monitoring of both current and future passenger demand, and the adjustment of the rolling stock size and composition, rail operators can efficiently respond to the shifting demand patterns. These systems can utilize predictive analytics and optimization algorithms to dynamically allocate trains to routes with higher demand, reducing overcrowding and enhancing passenger comfort.

"Systems can provide passengers with personalized and efficient travel options, eliminating the need to endure crowded trains."

## Movement map—'Project Darwin' (Trenord in Milan)

In the Milan area (IT) Trenord has partnered with telephone companies to receive data about people's movements recorded by telephone cells. This data is used to identify new potential passengers and focus on improving the most-used routes. In addition, the data provides a reliable basis for future funding and investments in rail infrastructure.

**Forecast example:**
On the twelve Regio Express lines, which today carry around 160,000 passengers a day (Domodossola-Milan, Verona-Milan, Como-Milan, and so on), a 15 % increase in speed would increase passenger numbers by 38 % to 230,000 a day[38].

## Porsche Consulting mobility study—
## Customer decision criteria in relation to railways

Porsche Consulting has conducted a study asking 138 local railway users via online and in-person surveys which criteria they value most when deciding for a mode of transport. The results show that reliability is considered the most important decision factor, followed by frequency and speed.

Addressing these pain points with new technologies, innovations, and a customer-centric approach is the key to providing an improved customer experience and increasing the rail usage. The respondents were clustered into six persona archetypes.

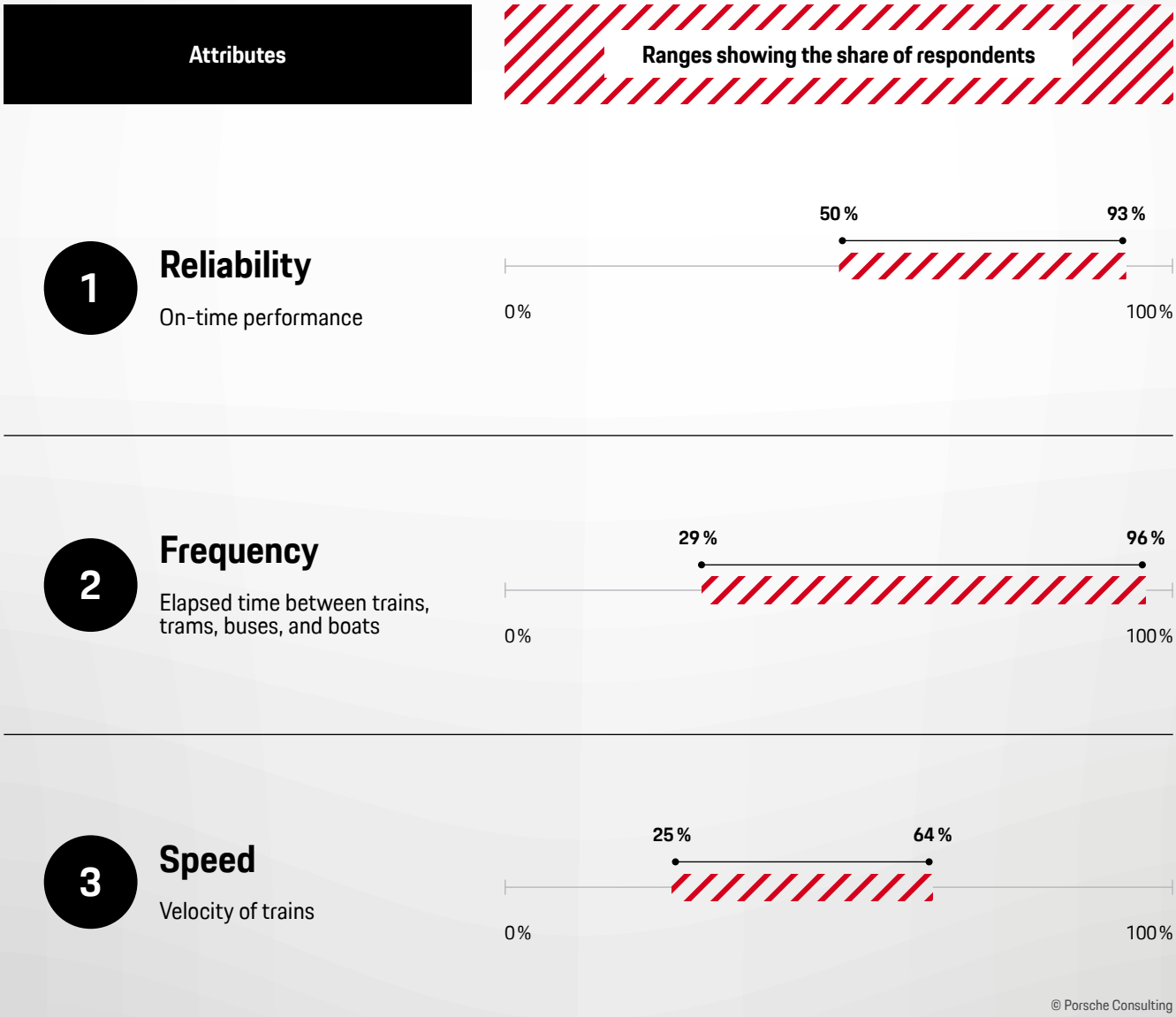





**Fig. 5.** Decision criteria for choice of transportation and ranges showing the share of respondents (selection of up to 3 criteria possible)

# CONCLUSION

This paper provides valuable insights into the future of rail transport and the opportunities to reshape the industry. Achieving the EU Commission's goal of doubling rail passenger numbers within 15 years requires a holistic approach that considers six key perspectives:

**01** Meeting growing demand by increasing capacity with adaptable train interiors, double-deck high-speed trains, and network improvements to support future growth.

**02** Rail operators can further enhance sustainability by electrifying rail networks and adopting advanced powertrain technologies to reduce emissions. Investing in eco-friendly infrastructure is essential to promote an environmentally conscious future for rail transportation.

**03** Rail operators are advised to concentrate their efforts on three elements: increasing efficiency and availability (e.g. through AI-driven solutions) as well as improved coordination of construction and schedules between network and operating companies to increase stability and support growth without the need for significant expansion.

**04** Involving customers in the co-design of innovative solutions will not only meet passengers' expectations, but also ensure that their preferences are satisfied at the same time.

**05** Expanding the core business vertically and horizontally with selected services and business partners to increase competitiveness compared to other modes of transport.

**06** Improving passenger convenience by proactively managing demand and introducing an integrated dynamic booking process that supports core operations and improves customer satisfaction.

Incorporating these perspectives is crucial for the future of rail transport. Successfully managing these aspects will lead to a new era in which rail travel becomes seamless, intelligent, and enjoyable.

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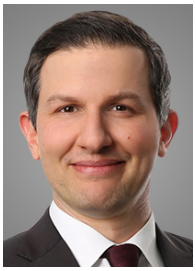

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Porsche Consulting GmbH is a leading German management consultancy and employs 950 people worldwide. The company is a subsidiary of the sports car manufacturer Dr. Ing. h.c. F. Porsche AG, Stuttgart. Porsche Consulting has offices in Stuttgart, Hamburg, Munich, Berlin, Frankfurt am Main, Milan, Paris, São Paulo, Shanghai, Beijing, Atlanta, and Palo Alto. Following the principle of "Strategic vision. Smart implementation," the consultants advise industry leaders on strategy, organization, brand, sales, development, technology, and operations. Porsche Consulting's worldwide network serves clients in the aerospace, automotive, construction, consumer goods, energy, financial services, industrial goods, life sciences, and transportation sector.

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As a leading consultancy for putting strategies into practice, we have a clear mission: we generate competitive advantage on the basis of measurable results. We think strategically and act pragmatically. We always focus on people—out of principle. This is because success comes from working together with our clients and their employees. We can only reach our aim if we trigger enthusiasm for necessary changes in everyone involved.

# Appendix

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