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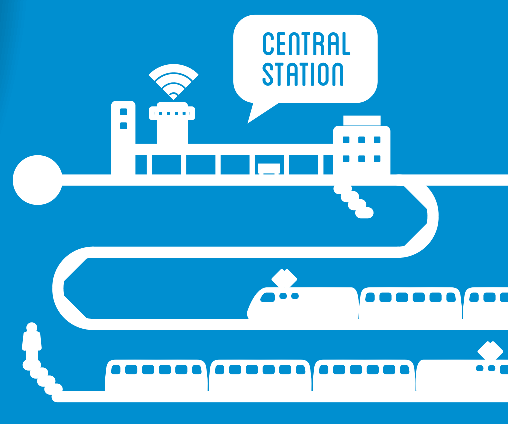
UIC-Study **Night Trains 2.0**

New opportunities by HSR?

Full report



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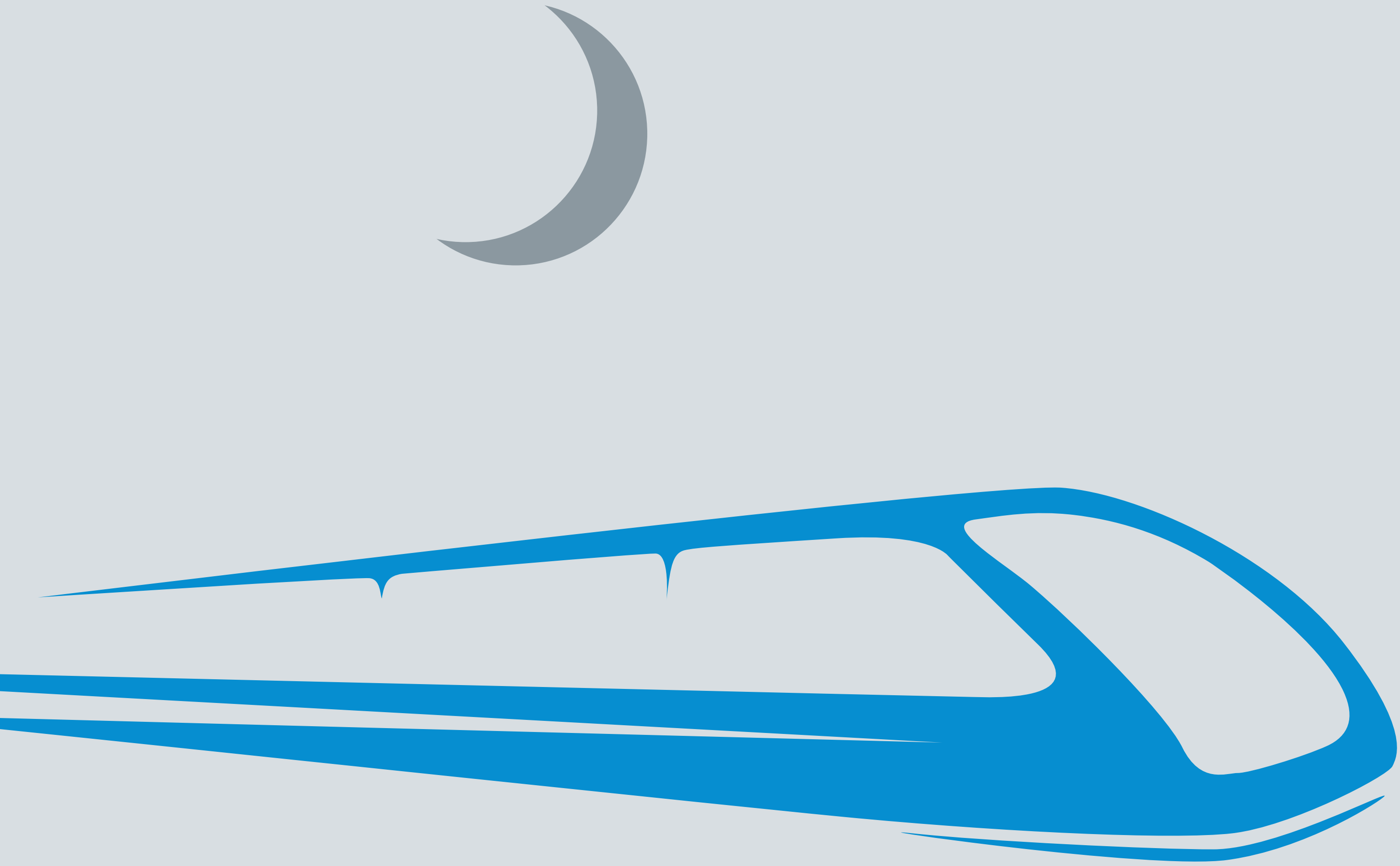

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1 Executive Summary

The market for night train service has declined significantly in recent years due to the introduction of faster day train services and the rapid growth of low-cost airlines. As a result the night train network has shrunk considerably.

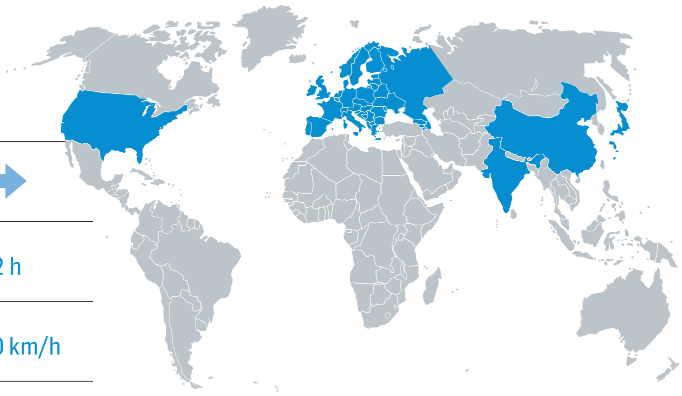
The goal of this study was to identify innovative development paths for night train service. The study focused on investigating the potential for operating night train service on high-speed lines using high-speed rolling stock. This would significantly increase the distance range for night trains and thereby serve a new market segment.

This Very Long Distance Night Train (VLDNT) service could provide comfortable, high quality night train service on corridors over 2,000km long, for example Madrid–London, in 12 hours. Today travel over these distances is dominated by air transport. The study shows that VLDNT service could be feasible if it can attract approximately 10% of the expected 2025 air passenger demand. It should also be noted that market conditions for all types of rail service including VLDNT are expected to improve in coming years due to rising oil prices and stronger climate regulations.

On the other hand, VLDNT service faces several obstacles. First, there are restrictions on the use of high-speed infrastructure due to night time maintenance, freight traffic and capacity bottlenecks in the morning and evening rush hours. However, this study finds that overcoming these obstacles should not be an insurmountable barrier. The major obstacle for VLDNT is track access charges, which are by far the largest cost driver for the proposed service. These infrastructure charges would amount to more than 50% of the total cost on many of the routes studied.

In summary, the study finds that VLDNT is a very environmentally friendly alternative to medium haul flights, but that will only be viable if all stakeholders develop and implement a special pricing model for night trains.

Prioritisation of the competitor – 2,000 km trip



Market share	0 - 5 %	0 - 10 %	0 - 15 %	70 - 90 %	
Price sensitivity	→	↑	↑	↘	→
Travel duration	~ 10 h	~ 30 h	~ 25 h	~ 3 h	~ 12 h
Maximum speed	330 km/h	130 km/h	100km/h	900 km/h	300 km/h

2 Background & Purpose

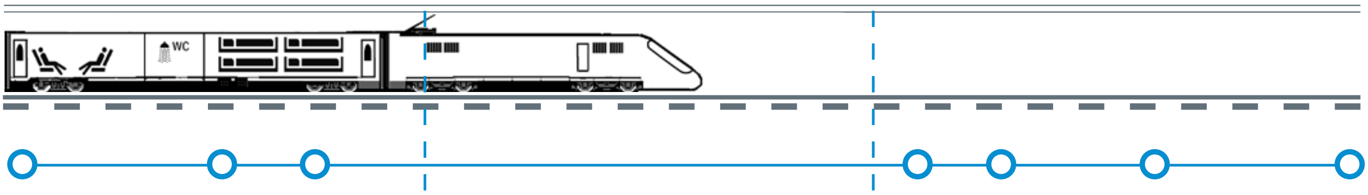
The market for night train service has been declining for many years due to increasing competition from high-speed rail (HSR) service and low cost airlines.[1] This chapter presents an introduction to night train service and summarizes the competitive situation faced by night trains today. This background is used to frame development of a new night train strategy, namely expanding the market range of night trains by operating them on high-speed rail infrastructure. This strategy is then analysed in the following chapters by focussing on travel markets of Europe, India, the United States, China and Japan.

2.1. Night Train Service

Night trains have long provided a good way to travel long distances in reasonable amounts of time. The number of night trains has fallen since the advent of affordable air travel but there are still several viable market niches for night train service. There are two main types of night train service:

- **Classic Night Trains** leave the origin station in the evening and reach their destination station on the morning of the following day. These trains can be subdivided into three categories (simple, traditional or hotel) depending on the quality of service they provide. Service quality is generally defined by the type of passenger cars used: standard seating cars, couchette coaches and/or sleeping cars.
- **Multiday Night Trains** are trains that operate in one direction for several days. They can be subdivided into simple multiday night trains and luxury night trains. Simple multiday night trains are generally offered in regions where flying is not affordable to residents. They are often also used by tourists seeking a unique travel experience (e.g., Siberian Express). Luxury night trains are designed to provide very high quality service where the train ride itself is an important and memorable part of the whole experience.

1 Cf. Sauter-Servaes 2007



Boarding area	Night time	De-boarding area
Night Train stops several origins ▮ Boarding time of high quality Night Trains usually ends at midnight ▮ Boarding after midnight is not attractive ▮ Travel time 0 – 3 hours ▮ Travel distance 0 – 400 km	Nonstop run to cover distance ▮ Defined boarding and de-boarding areas lead to a quiet night time for the passengers ▮ Travel time 6 – 12 hours ▮ Travel distance 1,100 – 2,200 km	Train stops at several destinations ▮ De-boarding starts not before 6 a.m. due to attractive time level ▮ Travel time 0 – 3 hours ▮ Travel distance 0 – 400 km
Expample: ▮ London ▮ Lille ▮ Paris	Night time between Paris and Barcelona	▮ Barcelona ▮ Zaragoza ▮ Madrid

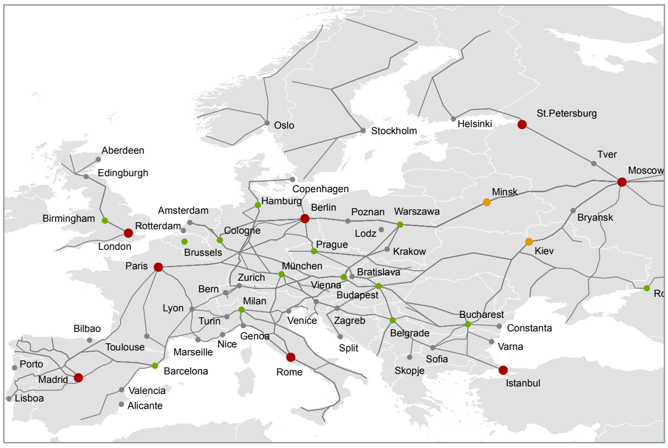
Classic night train services follow a three phase operational scheme. During the first phase the train stops in several cities to pick up travellers (this is called the ***boarding area***). The boarding process usually ends around midnight. The second phase consists of non-stop travel through the night (about midnight to 6 a.m.). This nonstop service provides a quiet night for passengers and does not impact demand because few people want to board or alight a train during this period. During the third phase the train stops in several cities to drop off passengers (this is called the ***de-boarding area***). The third phase begins about three hours before reaching the terminal station (generally about 6 a.m.).

Night trains are currently operated in almost all parts of the world, although the type of night train service and particular market niche differs significantly.

In **Europe** the night train network is considered a supplement to the long-distance network. They are generally classic night trains. The night train network is largely concentrated in the centre of the continent and the German railway operates the most extensive network. Given Europe's geography many night trains operate across political borders. Many night trains have recently been eliminated as Europe's high-speed rail network and low cost air services have expanded.

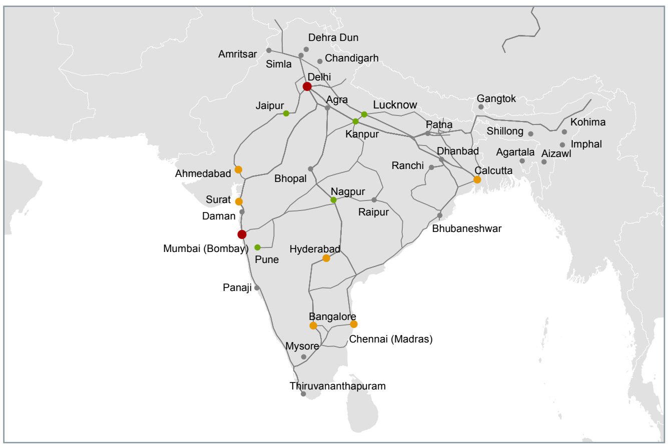
In **India** night trains operate on almost all main railway routes (electrified and non-electrified). Night trains are very popular as a result of the considerable distances between major agglomerations, the country's socio-economic structure and noticeable price advantages compared to other transport modes (e.g. private car or plane). The market for night train service in India is increasing as new rail lines are built.

Europe Main Night Train Network 2012



Population ● > 3 million; ● 2 – 3 million; ● 1 – 2 million; ● < 1 million
Night train network — Night lines

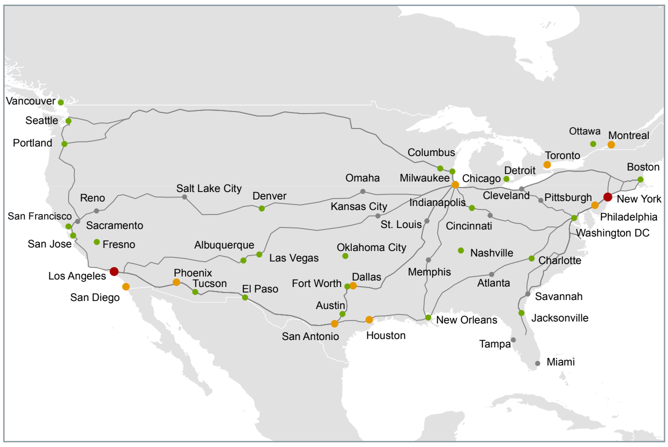
India Main Night Train Network 2012



Population ● > 9 million; ● 4 – 9 million; ● 2 – 4 million; ● < 2 million
Night train network — Night lines

© ivanikova

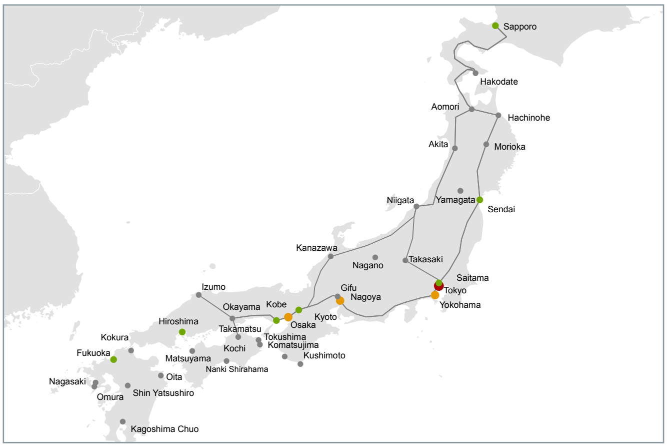
USA Main Night Train Network 2012



Population ● > 3 million; ● 1 - 3 million; ● 0,5 - 1 million; ● < 0,5 million

Night train network —Night lines

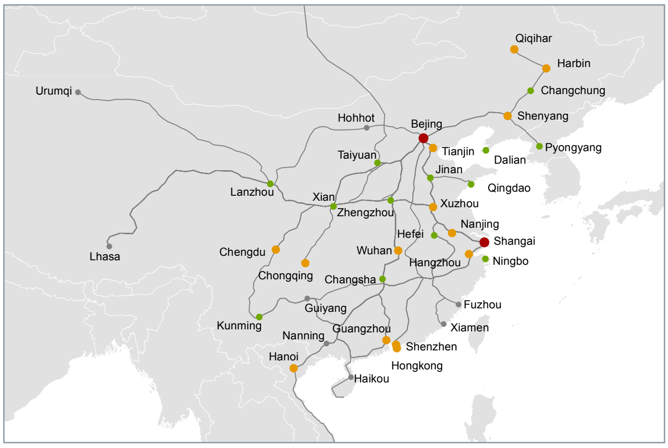
Japan Main Night Train Network 2012



Population ● > 4 million; ● 2 - 4 million; ● 1 - 2 million; ● < 1 million

Night train network —Night lines

China Main Night Train Network 2012



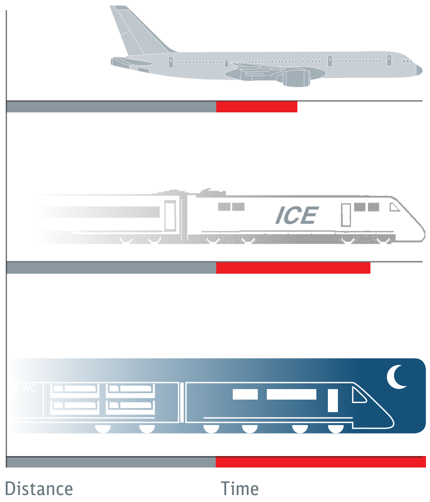
Population ● > 15 million; ● 5 - 15 million; ● 3 - 5 million; ● < 3 million

Night train network —Night lines

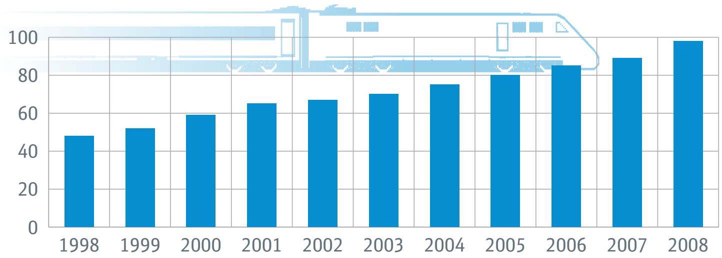
In the **United States** the night train network focuses on connecting the major cities in the Eastern and Western parts of the country. Most of the long distance services are multi-day night trains. In the USA Amtrak, the passenger rail operator, has dispatching priority over freight trains. The market for night train services in North America is essentially stable at a very low level. In the USA most multiday night trains are used by travellers seeking a special travel experience and sleeping accommodations are relatively expensive.

China's night train network is concentrated in the eastern portion of the country, but, as in India, night trains are operated on almost every major train route. The market for night trains continues to increase in China as new rail lines are built.

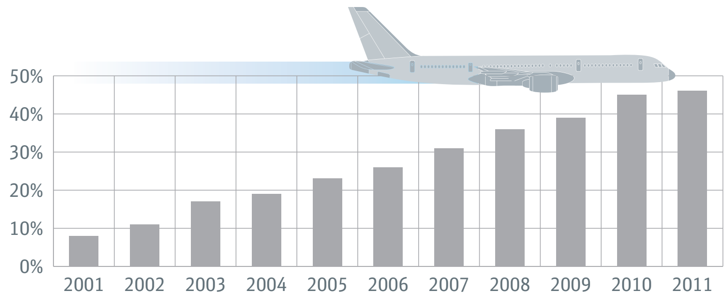
In **Japan** night train service is limited due to the country's geography. The number of night trains is decreasing as more high-speed rail lines are built and low cost airlines enter the market.



Increase in number of HS pkm in Europe, in billion pkm per year



European Market share of Low Budget Airlines



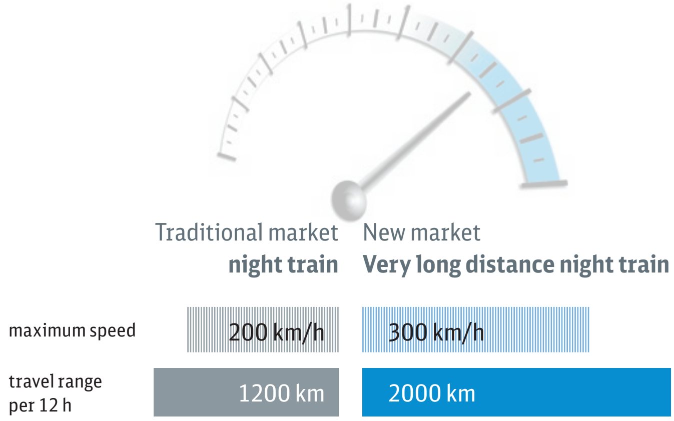
2.2. Competitive Pressure on Night Train Service

Night train services increasingly find themselves in an uncomfortable position sandwiched between high-speed rail services, which are increasing the distance passengers can travel within a reasonable time during the day, and low cost airlines, which offer passengers very low ticket prices for medium distance travel.

The European high-speed rail network has grown rapidly and today links almost all major cities. New multi-country HSR services are providing fast and convenient service on many routes formerly served by night trains. The HSR network will continue to grow as new lines built and new operators enter the market.

At the same time liberalization of the air transport market has led to the creation of many new low cost airlines. These airlines have aggressively expanded their route networks and increased service in short and medium haul markets.[2] The low ticket prices offered by these airlines on many traditional night train markets has significantly reduced night train ridership and impacts the price night train operators can charge for tickets.

Railway companies have responded to growing competition by reducing the number of night trains and improving the efficiency of their networks. The goal of this research was to investigate new business strategies that could lead to a strategic transformation of the night train business model.



The research considered a wide range of measures designed to transform night train service. These measures included developing more efficient operating schemes such as combined daytime/night-time use of fast convertible vehicles and introducing innovative ideas for night-time rail travel.[3] Another measure considered how traditional night train services could use the HSR network to achieve much higher average speeds with existing conventional rolling stock. This would allow later departure times, earlier arrivals and/or a more robust schedule.

However a more interesting idea is to develop new high-speed rolling stock for night trains and to use this rolling stock on the HSR network. This new service could cover much longer distances within the traditional night train time window. Train service featuring these characteristics has been defined as Very Long Distance Night Train (VLDNT).

2 Case study Europe c.f. Berster/Kuhne 2009; Berster 2012

3 Cf. Troche (1999), Actima (2004), Sauter-Servaes 2012

High Speed ZEFIRO CRH1 – Sleeper, Seat arrangement 2+3 (2nd class)

© Bombardier

2.3. Very Long Distance Night Train (VLDNT)

The Very Long Distance Night Train (VLDNT) is a new category of night train. While traditional night trains generally cover approximately 1,000 km in a 12-hour time window, the VLDNT, operating with a top speed of 300 km/h, could cover over 2,000 km in the same time window. (Even longer distance ranges would be possible using multiday operations, e.g., in India.)

VLDNT would operate on high-speed infrastructure wherever possible to achieve a high average speed. This requires the use of new HSR rolling stock similar to the modern Electric Multiple Units (EMU) operated on many HSR networks today.

VLDNT would offer comfort levels consistent with today's classic night trains, allowing the passengers to choose between seats, couchettes and luxury beds. In this study the passenger capacity of a VLDNT operating in Europe and United States was assumed to be 500 passengers, while 620 passengers per train are assumed in India, China and Japan due to tighter seating used in these countries to archive higher passenger capacity.

The increased range provided by VLDNT means the network can be expanded significantly and new high-demand destinations can be served. This would allow night trains to enter a market segment that is currently dominated by air transport. Today it is simply not convenient for most people to travel by car, coach or daytime train over distances of 2,000 km.

An important benefit of VLDNT service is that rail transport has a lower environmental impact than air travel due to its electrical propulsion. This means that rail transport will be less impacted by stronger climate regulations (e.g. EU Emissions Trading Scheme) than the aviation sector. Rail travel will also benefit as more companies adopt sustainable transport goals and programs. Finally, rail transport will be less impacted from projected increases in the cost of oil. Together these factors are expected to increase the appeal of VLDNT for users (price), companies (CSR[4] goals, image) and politicians (climate protection goals) in the coming years.

In summary, VLDNT is a strategic idea with the potential to create an attractive new business. However, the idea must be investigated from the perspective of economic potential, railway operations and policy environment to determine its feasibility. This research investigated all three of these issues. The results are presented in the following sections.

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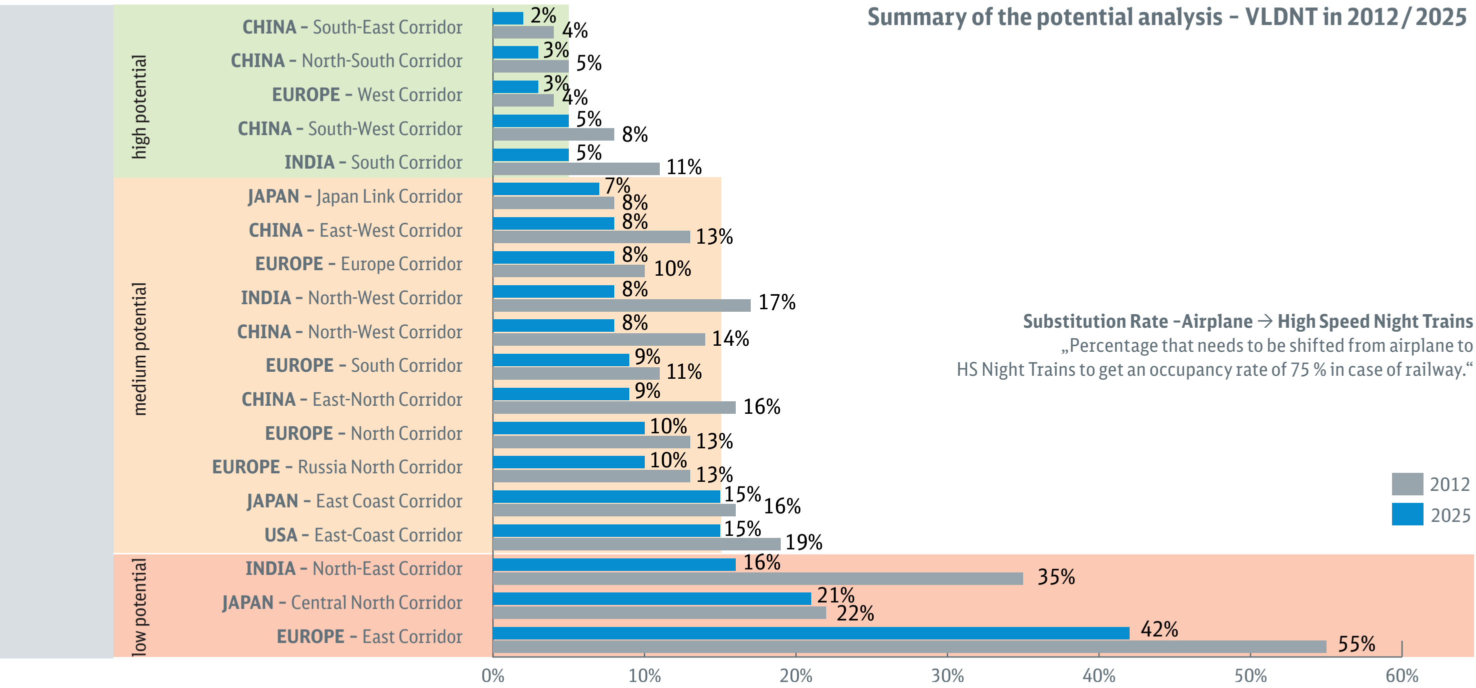
4 CSR – Corporate Social Responsibility



3 Potential for VLDNT

This section summarizes the potential of VLDNT service. The process for analysing potential consisted of three steps. First, population figures were used to identify potential VLDNT markets in the five study regions: Europe, India, United States, China and Japan. Next, VLDNT operating characteristics were used to define potential VLDNT corridors in the study regions. Finally, air passenger demand was calculated for these corridors (since VLDNT would compete mainly with air transport) and the air traffic substitution rate (defined as the percentage of corridor airline passengers who would need to take the VLDNT to ensure a 75% train utilisation) was calculated. The air travel substitution rate gave a first indication of whether the VLDNT service was reasonable.

3.1. VLDNT market identification

The first step in the potential analysis used a gravity model to identify markets where there is sufficient traffic demand for successful VLDNT service. This consisted of identifying which cities will be part of the corridor. The gravity model assumes that traffic demand between two cities increases with population and decreases with distance. In this study the most important cities in the five regions (Europe, India, United Stated, China and Japan) were ranked as a function of the region's average city size. This insures that all five market areas were fully considered in the analysis.

3.2. VLDNT corridor identification

The second step consisted of identifying suitable corridors that could serve the cities. The suitability of a corridor depends on geography (e.g. the proximity of cities), available rail infrastructure and VLDNT operating characteristics.

The VLDNT were assumed to operate following the same general pattern as traditional night trains, in other words by dividing the total journey into a boarding phase, a non-stop phase and an arrival phase. This pattern works well because it provides passengers with a pleasant night by eliminating stops between midnight and 6 a.m., and also offers multiple stops in the boarding and the arrival areas. Having multiple stops in the boarding and arrival areas enlarges the zone of attraction and is a fundamental competitive advantage for VLDNT compared to airlines.

The corridors were also chosen so that the VLDNT service uses the HSR infrastructure as much as possible. Most European railways do not currently allow night trains to use their HSR infrastructure for technical and regulatory reasons. However, as outlined in Section 5 below, these obstacles should not be insurmountable.

3.3. Substitution rate analysis

After the corridors were identified the potential demand was estimated. This study estimated the demand for each VLDNT route based on the number of airline passengers using substitutable non-stop flights since air transport is expected to be the main competition for VLDNT. Good quality air travel data is also quite accessible. The estimate is conservative since it did not consider possible modal shifts from day trains, coach or car to VLDNT.

The demand estimation process consisted of counting the number of daily flights between each city pair in the corridor, then estimating the number of passengers flying between the cities. The number of passengers for all the city pairs in the corridor was then summed to obtain the total corridor demand.

Estimating the number of passengers flying between the corridor cities required creation of a database on average seat capacity, emissions and model codes for approximately 40 commonly used medium range aircraft. Next, load factor estimates were made for each city pair (load factor is the number of passengers carried divided by the number of seats). Finally, it was necessary to estimate how many passengers were connecting to/from other flights on the route. Estimating the number of connecting passengers was particularly important for major airline hub cities.

The number of daily air passengers in the corridor was calculated by multiplying the number of daily flights by the appropriate values from the aircraft database, city pair load factors and connecting passenger factors. To be conservative, the number of daily flights was based on the maximum number of flights operated on any weekday (often fewer flights are operated on low demand days).

This process was used to determine the average daily number of flight passengers between each city in the boarding and the arrival areas of all corridors for the year 2012. These data were then used as input for the 2025 forecast, which was estimated using the commonly accepted annual traffic growth rate published by Airbus.[5]

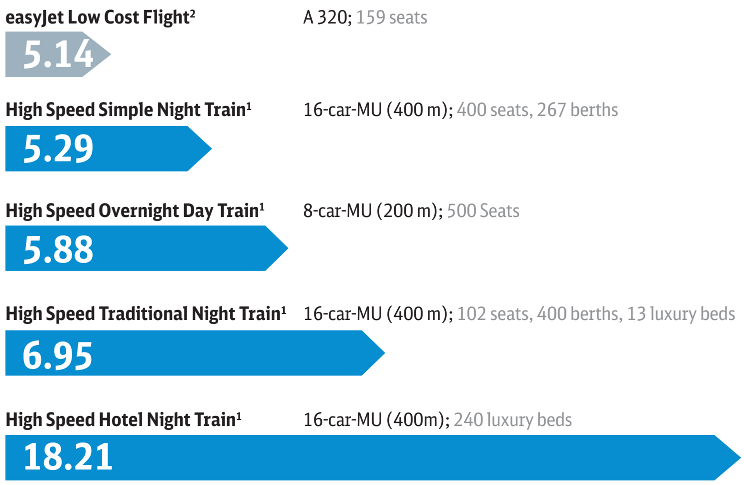
A risk analysis was performed on the estimation of daily corridor passengers. The analysis was designed to identify the robustness of the assumptions and therefore the final results. The analysis includes a variation of the variables e.g. number of flights per week, connection rate as well as the growth rate for the projection of the rate to 2025. The results of the applied Monte Carlo Simulation show all in all robust results.

Finally, the number of daily air passengers was used to calculate the air passenger substitution rate. This rate is defined as the percentage of corridor air travellers that need to shift to night train service to achieve a pre-defined utilization rate of train capacity (75% in this case).

The air passenger substitution rate provides a good estimation of corridor reasonableness, but since no cost aspects are captured by this approach, an additional economic feasibility analysis was done to calculate the minimum load factor needed for economic operation. The next chapter presents results of this economic feasibility analysis.

5 Airbus (2012): Navigating the future. Global market forecast 2012-2031. Blagnac.

Costs per available seat-kilometre, Case EUROPE: Madrid–London
[EUR-Cent per seat-kilometre, 2012]



1 Route- specific calculation on the adapted basis „Relationship between rail service operating direct costs and speed" (UIC 2010)
2 Network average based on financial reports 2011, without Marketing & Selling

4 Economic feasibility analysis

This section summarizes results of the economic feasibility analysis and presents a case study describing how the potential analysis was completed for the Madrid-London Corridor. The economic feasibility analysis consists of two parts: an analysis of costs and an assessment of the business case for VLDNT based on comparing rail to air costs.

4.1. Cost analysis

The cost analysis consisted of four steps. First, the 2012 unit costs were determined. Next, the costs for operating each of the corridors were estimated. Third, the 2012 costs were projected to 2025. Finally, a risk analysis was completed to help verify the assumptions and results.
The cost analysis was only completed for the European corridors. This was due to the greater availability of data on European costs and especially on the availability of infrastructure charge data. Estimating the costs for other regions would have required making many assumptions and would have led to cost estimates with a relatively low level of accuracy. Once the costs of VLDNT had been estimated for 2012 and 2025, these costs were compared to airline costs to assess the business case (presented in Section "Business Case").

Unit cost estimation

The unit costs for rail were generally based on previous UIC studies[6] complemented by consultant assumptions. The calculation of unit costs used the categories train ownership, maintenance and cleaning, energy, operating personnel and the infrastructure.

6 UIC Study „Relationship between rail service operating direct costs and speed" (12/2010) http://www.uic.org/IMG/pdf/report_costshs.pdf | Costs for workshops are not applied due to the small amount as illustrated in the study. 2 UIC study on railway infrastructure charges in Europe (11/2012)

Table 1: **Share of Track Access Charges on Total costs on European corridors**

Corridor	Route	Travel Distance [km]	Total costs [EUR-Cent/ seat-km]	Track Access Charges (TAC) [EUR-Cent/ seat-km]	Share of TAC on total costs	Average Track Access Charges (TAC) [EUR / train-km]
North Corridor 1:	London - Hamburg	1.500	7,74	4,27	55%	22
North Corridor 2:	London - Berlin	1.500	7,75	4,07	54%	21
West Corridor 1:	Madrid - London	2.200	6,95	4,07	59%	21
West Corridor 2:	Madrid - Amsterdam	2.200	5,59	2,72	49%	14
Europe Corridor 1:	Amsterdam - Rome	1.800	5,49	2,33	42%	12
Europe Corridor 2:	London - Rome	1.800	7,43	4,27	57%	22
South Corridor:	Madrid - Rome *most economic route of the considered corridors*	2.200	4,62	1,75	38%	9

The cost analysis used an HSR day train (200m train length and 500 seats) as a basis since, although a comparable night train is already being used in China (Bombardier ZEFIRO 250 Sleeper), no cost data for this HSR night train were available and no other HSR night trains exist. The HSR day train costs were adjusted to estimate the costs for night trains in simple or traditional versions. The night trains were assumed to be similar to existing night trains: 400m train length with 102 seats, 400 couchette berths and 13 luxury beds. A key cost difference between light and traditional night trains is in maintenance and cleaning costs.

Several assumptions were needed to estimate infrastructure costs due to the wide ranges of costs within and between countries. Here, track access charges per section were defined and then summed to calculate a weighted average value (distance) for each corridor analysed.

The study used easyJet as a comparable means of transport. EasyJet's exclusive operation of medium-haul flights as well as its practice of operating to/from airports close to the city centres makes it a good choice for the comparison. The cost per available seat-kilometre for easyJet is 5.14 EUR–cent[7] not including marketing and sales costs (which were also not included in the rail costs).

2012 Corridor costs
The total costs for operating VLDNT service in a corridor were estimated for the year 2012 by applying the unit costs to the appropriate corridor data. These costs were then divided by distance and seats to calculate a cost per available seat-kilometre. This was done for seven corridors in Europe.

7 Source: Business report easyJet 2011

Track access charges are by far the biggest cost driver and prohibit competitive VLDNT offers

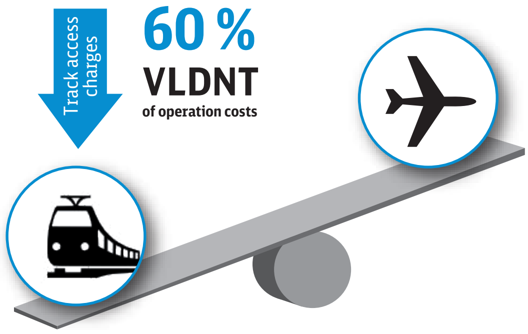


Table 1 summarizes the costs for track access charges for several key European corridors. As shown the costs of operating VLDNT on some corridors are relatively high. The high track access charges range between 40% and 60% of total costs.

For example, the share of track access charges for the Madrid-London corridor is 60%, based on an average track access charge of 21 EUR per train-kilometre and a line distance of 2,200 kilometres. The long distances travelled by VLDNT are especially responsible for the high charges.

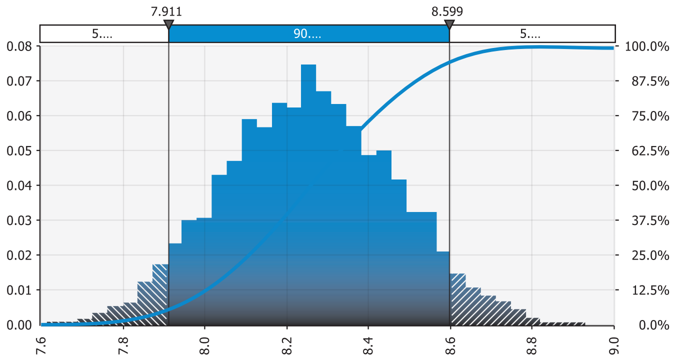
2025 Corridor costs
The next step in the analysis consisted of projecting the 2012 costs to 2025. The projection was done considering four cost categories: energy, vehicle, staff and infrastructure. The projection was done for both night trains and airlines. The projections were made using assumptions developed by the Consultant based on published values in international sources. The same projection factors were used for rail and air in the vehicle and infrastructure categories, different projection factors were used in the case of energy and operating staff.

Cost development until 2025, Madrid - London, easyJet vs. HS Traditional NT

	Rail			Air			Assumptions[1]
	2012	Trend[3]	2025	2012	Trend[3]	2025	
Energy/Fuel	10 %	110	11 %	30 %	200	60 %	Crude oil price, increase in electric energy, reduction of consumption: rail traffic as well as air traffic, introduction of kerosene tax and VAT
Vehicle	26 %	120	31 %	13 %	120	16 %	More complex technology, optimizations close to physical limits lead to intensive maintenance
Operating staff	4 %	100	4 %	13 %	110	14 %	Reduction of allowed working time for pilots from 2015
Infrastructure[2]	60 %	120	72 %	44 %	120	53 %	More extensive user financing due to limited state finances and reduction of subsidies, Increase in cost for flight control
Madrid - London Total Cost EUR-Cent / seat-km	7.0	120	8.2 (118 %)	5.1	140	7.3 (143 %)	**Cost disadvantage for railway**

[1]Based on international sources and Consultant assumptions (see Backup); [2]easyjet: includes 6 % „Other Costs"; [3]Assumptions by the Consultant using available information

HS Traditional Night Train / EUR-Cent per seat-kilometer



Using the assumed projection factors on the Madrid-London corridor, the cost per seat-kilometres increases from 6.95 to 8.21 EUR-cent for rail and from 5.14 to 7.35 EUR-cent for air travel. While this analysis indicates that flying will remain less expensive than rail on this corridor, on other corridors, e.g., Madrid – Rome and Madrid – Amsterdam, rail becomes less expensive than flying in 2025.

Risk analysis

A risk analysis was done to better understand the robustness of the results. In this analysis, ranges were identified for the main cost influences such as energy and infrastructure. Separate risk analyses were done for the 2012 and 2025 data. A Monte Carlo Simulation was run and shows mean value, standard variation as well as the 90% confidence interval for the calculated costs 2012 and 2025. Overall, the analysis shows a robust simulation and supports the analysis results.

4.2. Business case

The business case for VLDNT depends on the night train operator being able to cover the costs of train operation and to make a profit. This depends on how much the train operator can charge for tickets.

Unfortunately no data is available for VLDNT ticket prices since the service does not exist. Ticket prices for day high-speed trains are not directly comparable since there are no transfer-free connections on the selected VLDNT-corridors. Moreover, it is difficult to obtain ticket prices for HSR journeys involving transfers given the lack of cooperation between rail operators in ticketing information. And, even where data is available it is often meaningless since prices are extremely market dependent. Thus, very low prices may appear due to a special offers (e.g., when an operator plans to enter the market), while very high prices appear when there is a high demand (e.g., holiday periods, or shortly before the departure dates).

Since it is not possible to accurately estimate the price of VLDNT tickets today, the study compared the cost of airline travel in the corridor to the cost of operating the rail service. The analysis focused on calculating the occupancy rate needed in order for the VLDNT to fully recover its operating costs and then assessing the possibility of operating the train at that level of occupancy.

The first step was to estimate the cost of airline and railway service in the corridors. The cost per trip was calculated by multiplying the cost per seat-kilometre (from Section 4.1) by the distance travelled. Next these costs per trip were divided by occupancy rate to obtain the costs per passenger trip.

Table 2: **Intermodal cost comparison Europe 2025**

HS Traditional Night Train (conservative view)		**Seat Cost** per Travel EUR	**Load Factor** %	**Total Cost** per PAX EUR	**Load factor to match** TC easyJet %
North Corridor	London – Hamburg	137	50	274	**203**
	London – Berlin	134	50	267	**158**
	easyJet London – Hamburg +	59	87	68	
	London – Berlin	73	87	84	
West Corridor	**Madrid – London**	181	50	361	**153**
	Madrid – Amsterdam	145	50	289	**107**
	easyJet Madrid – London +	103	87	118	
	Madrid – Amsterdam	118	87	135	
Europe Corridor	Amsterdam – Rome	116	50	232	**98**
	London – Rome	158	50	316	**107**
	easyJet Amsterdam – Rome	103	87	118	
	easyJet London – Rome	110	87	127	
South Corridor	Madrid – Rome	119	50	238	**94**
	easyJet Madrid – Rome	96	87	110	

Finally the cost per trip by rail was divided by the cost per passenger trip for air to calculate the percentage occupancy needed for rail to have the same cost per passenger trip as air. These calculations were made for all corridors examined in the analysis.

Table 2 summarizes the analysis results for the European corridors in the Year 2025. In the case of the Madrid–London corridor (described in a case study below), Table 2 shows that the cost per seat-kilometre is 8.21 EUR-cent. Multiplying this value by the travel distance gives a cost of EUR 181 per seat for the trip. Dividing by the normal occupancy rate for night trains (50%) means that the cost per passenger would be EUR 361 per trip. This is compared to a cost of EUR 118 for an easyJet trip.

Table 2 also shows the necessary rail occupancy rate for the corridors evaluated in this research. In this London–Madrid corridor for example, the necessary occupancy rate was calculated by dividing the EUR 181 rail trip cost per seat by the EUR 118 air cost per passenger trip. As shown, the occupancy rate needed for the Madrid-London corridor (2025) was a load factor of 153% to match the airline costs. In other words matching the airline costs is infeasible and VLDNT in this corridor cannot compete successfully with air travel.

The most attractive corridor identified in this analysis was Madrid–Rome corridor with a necessary load factor of 94%. However, this is a quite high occupancy rate and it is questionable whether it is sufficient for a successful market entrance.

These results show that VLDNT service is nearly non competitive with airline service operated by low cost airlines similar to easyJet. The main reason is due to the very high track access charges. VLDNT service would only be competitive if network operators were to reduce track access charges. Otherwise the ticket prices would be too high or the occupancy rates would need to be much higher than the feasible maximum capacity of a night train.

4.3. Case Study Analysis: Madrid – London Corridor

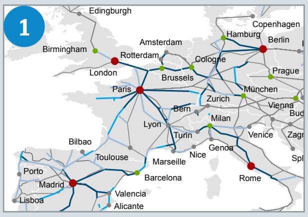
This section presents a short description of the analysis completed on the European West Corridor between Madrid and London.

Step 1: Identify suitable markets
The first step consisted of preparing a map of the largest cities in Europe. The map shows cities in three categories: red dots are cities with populations over 3 million, yellow dots represent cities with populations between 2 – 3 million, and green dots represent cities with populations between 1 – 2 million.

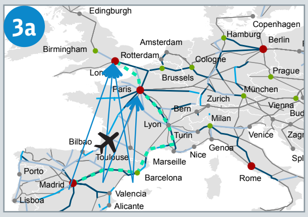
Step 2: Identify corridors
Figure 1 presents a map of Europe with all the high-speed lines and the major cities are shown with the appropriate coloured dot.
Corridors were identified with the following steps:

- Step 1 identified the cities that should possibly be linked by VLDNT. In conformity with the VLDNT definition travel time should be less than 12 hours and therefore distances of up to 2,200km are possible.
- The main question is how to connect the biggest cities using a maximum of HSR infrastructure. The map presented in Figure 1 shows a strong concentration of high-speed infrastructure in Spain and France.
- As shown in Figure 1, HSR infrastructure connects three of Western Europe's biggest cities: Madrid, Paris and London. Therefore, it seems reasonable to link Madrid with Paris and London.
- Barcelona and Zaragoza, both relatively large cities, are located in the boarding area of the potential VLDNT corridor and are part of Spain's high-speed railway network. Thus, the proposed line could also easily serve them.

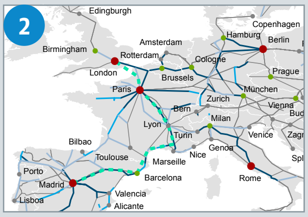
Three step potential analysis for London – Madrid



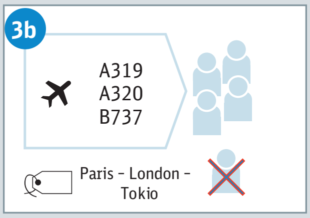
- Identification of the of the European **cities with the highest population density**
- Four-colour system for **city categorization** according to size



- Identification of all **nonstop air connections covered by "West axis"**: flights starting in London or Paris and landing in Madrid, Barcelona or Zaragoza



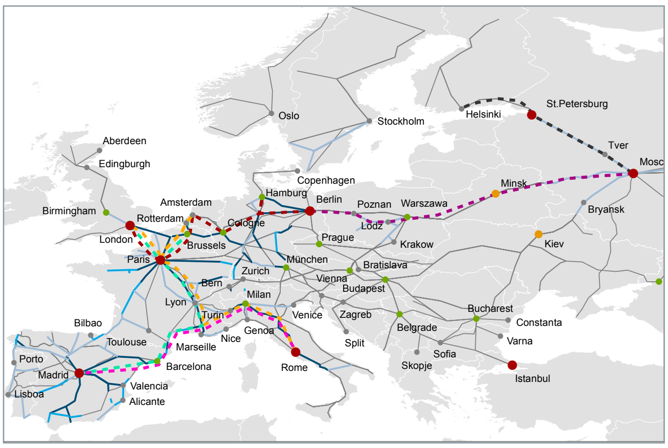
- Sketch of **corridors connecting a maximum of big cities** within range of max. 2,200 km
- In fact, **12 h travelling time** and an **average speed of 180 km/h** is assumed
- **One option:** London – Paris – Barcelona – Zaragoza – Madrid ("West Axis")



- **Calculation of flight PAX** per day based on number of flights, seat capacities of used aircraft types and average load factors
- **Correction of shifting potential** by discounting PAX with connecting flights at start or destination airport
- **Risk analysis** for testing the **robustness** of the results

- The train would travel nonstop during the night through France since the country's HSR network provides fast connections between provinces and the capital.
- Paris would be the first stop in the arrival area. The VLDNT could also be split here allowing one part to serve London and the other to serve Brussels, Antwerp, Rotterdam and Amsterdam. All of these cities are part of Europe's "Blue Banana".
- Travel times on the proposed corridor were calculated based on existing timetables and planned infrastructure improvement projects.
- The resulting corridor is called West Corridor. Its boarding area is Spain (Madrid, Zaragoza, Barcelona) while the arrival area is Central Europe (London, Amsterdam, Antwerp, Rotterdam, Brussels, Paris). The corridor would serve almost all the large cities in the general area (except Marseille and Lyon) and is served by a very good high-speed infrastructure.

Figure 1



Population ● > 9 million; ● 4 – 9 million; ● 2 – 4 million; ● < 2 million
Night train network — Night lines
HSR network — Operation — Planned — Under construction
Corridors – – Central Europe Eastern Europe – – Northern Europe-Russia
– – Northern Europe – – Southern Europe – – Western Europe

- If a conventional (and thus slower) night train was used instead of a high-speed night train, travel time would increase. In this case the stops in Madrid and Zaragoza would need to be eliminated with a strong effect on the percentage of substitution described below.

Step 3: Potential analysis

Once the corridor is defined the analysis of potential can be completed. This analysis consists of the following steps:

- First, all air connections starting from Madrid, Zaragoza, Barcelona (boarding area) to Paris, London, Brussels, Antwerp, Rotterdam, Amsterdam (arrival area) are listed to ensure that all airline passengers are considered. At the end of October 2012, approximately 150 daily flights with a total capacity of more than 23,000 seats were operated between these city pairs.
- The load factor for these flights was assumed to be 79% (European average) and the transfer rate (share of connecting passengers) ranges between 15% and 35%, depending on the combination of hub- and non-hub airports. The given seat capacity of each aircraft is multiplied with these factors in order to obtain a realistic number of passengers travelling in the corridor.
- The analysis showed that approximately 9,500 people travel daily between the corridor's boarding and arrival cities. Almost 2,000 passengers travel from Madrid to Paris, followed by around 1,800 passengers between Madrid and London. 1,200 passengers fly from Barcelona to London and around 550 from Amsterdam to Barcelona.
- The forecast data presented above was used to calculate the potential of the corridor. This figure, the so called substitution rate shows what percentage of flight passengers would need to switch to rail to ensure a 75% utilization of the VLDNT. In the case of Europe's West Corridor, the substitution rate is about 3% by 2025.

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5 Infrastructure and Operations Considerations

A fundamental part of the study was analysing the infrastructural and operational limitations that might be influence the operations of the VLDNT in the selected regions. The analysis shows that while there are currently several infrastructure and operational limitations that prevent night trains from using high-speed infrastructure, these limitations are not insuperable obstacles. The main obstacles are: limited capacity at major nodes (stations), rolling stock requirements and interoperability, HSR line maintenance, freight train conflicts, and security measures.

One of the major obstacles to VLDNT in all regions is limited capacity at major nodes on the potential corridors. In these areas slower passenger and freight trains might conflict with the VLDNT on shared infrastructure. Additional challenges are rising traffic density and capacity deficits (especially during morning and evening peak periods) in metropolitan areas. Many of these track networks are already operating at maximum capacity and additional train paths are unavailable. A good example is in Japan where unpunctual trains are not allowed to enter train stations since they would disrupt the entire timetable.

A second obstacle is rolling stock requirements such as maximum incline parameters on Passenger Dedicated Line maximum gradients and speed limits. Train length and noise emission standards play a relatively minor role. In any case, it should be possible to address all these requirements in the design and procurement of new VLDNT rolling stock and it is also likely that existing night trains could be adjusted to meet the HSR line requirements.

Technical incompatibilities might occur due to different gauge widths, power supply systems or signalling systems. This is mainly a problem in Europe, where different power supply systems and different signalling systems exist in the different countries and are partly incompatible (on the other hand, new HSR rolling stock is often compatible with several different systems). Similarly Japan has two different power supply systems but it should be possible to solve this incompatibility with technology.

Technical incompatibility is less of a problem in the other regions considered in this research. No serious incompatibilities were found for the USA or India.

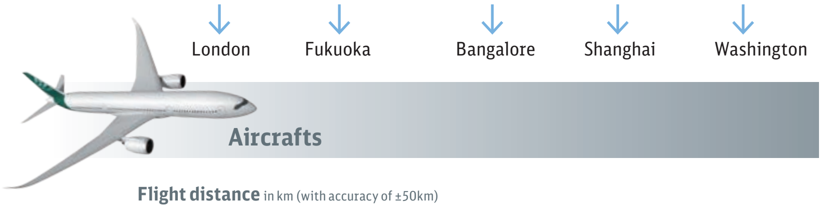
Another potential obstacle is the limitation on using HSR tracks at night due to freight train operations and track maintenance. However, on most railways passenger trains have priority over freight trains, and freight trains mostly operate on conventional networks. With respect to track maintenance, these projects are limited in duration and, since the lines lightly used during the night, trains can often operate despite maintenance. An exception is India where permanent construction activities, the high number of single track lines, and low capacity infrastructure currently causes interruptions to night train operations.

A final obstacle could be security measures and cross border controls. Security measures are becoming more frequent in rail transport, but in almost all cases the security screening is done at check-in or before boarding the train. Some controls are made on board trains, but generally the train can be moving while these are completed.

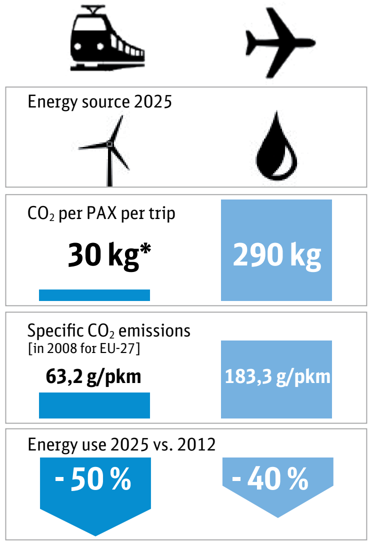
Similarly, most cross border controls take place on the trains themselves. More specifically, in Europe, U.S and China border controls take place mostly inside the train

Current CO_2 emissions for airplanes and trains

Region: Corridor:	Europe West Madrid → London	Japan Central North Sapporo → Fukuoka	India West-South Mumbai → Bangalore	China South-East Hong Kong → Shanghai	USA East Coast Ottawa → Washington
Flight distance in km (with accuracy of ±50km)	~1,350	~1,650	~900	~1,300	~800
CO_2 emission kg per trip per person***	245 - 280	290 - 345	180 - 205	230 - 290	135 - 185
g per pkm	185 - 215	175 - 210	200 - 225	175 - 220	170 - 230
kg per trip per person	24 - 29	42 - 95	n/a	26 - 68	120 - 135
g per pkm	11 - 13	20 - 45	n/a	15 - 40	101 - 115
Rail distance in km (with accuracy of ±50km)	~2,200	~2,100	~1,400	~1,700	~1,200



Comparison of environmental characteristics



* Average CO_2 emission in kilogram per trip per person with current rolling stock, sample of European city connections of around 2,000 km

by customs and immigration officials. Since there are no border crossings of HSL corridors in India and Japan, no controls are required.

As this discussion indicates, it is very important to carefully coordinate the schedules of VLDNT with other trains and infrastructure requirements (e.g. maintenance needs) to realize a trouble-free operation of VLDNT. Wherever possible the time intervals of passing trains as well as the time in the stations should be reduced. It will also be necessary to extend the HSR network further and especially into major nodes and stations. Furthermore, future rolling stock for VLDNT will need to be equipped with the required equipment to run on different systems and not to be limited due to technical incompatibility.

6 Policy Considerations: Environment

The transport sector is one of the largest sources of man-made Carbon Dioxide (CO_2) and other Greenhouse Gases (GHG) emissions and its contribution continues to rise[8]. Therefore an important question for this study was to compare the environmental impacts of VLDNT versus its main competitor: air transport.

A key European Union goal is shifting transport demand from air to rail because this shift will reduce GHG-emissions and environmental impacts. It's also worth noting that medium distance flights also generate additional climate damage by impacting the Radiative Forcing Index (RFI).

As part of this study the GHG-emissions per person per trip as well as for a passenger-kilometre (pkm) for flying and VLDNT train service were evaluated. Since no reference values for night trains exist, the study compared standard trains with airplanes on the most efficient corridors identified in Europe, India, U.S., China and Japan (based on the market analysis substitution rate).

Data on GHG emissions for flights can be found on several online platforms including Atmosfair. Data on GHG emissions from rail service was more difficult to obtain. In Europe data was available from numerous emission comparison calculators (e.g. Ecopassenger, Ecocomparateur or DB Umwelt-MobilCheck), these websites help consumers choose the most environmental friendly way of transport. In the other regions there were either no data easily available or it was only available for freight transport.

The research shows that the average emission ranges between 190 and 215 g CO_2 per pkm for airplanes, but is only 15 to 45 g CO_2 per pkm on rail. The comparison points out a clear environmental advantage of railway passenger transport. One study comparing the carbon footprint of transport modes on the route Valence – Marseille in France showed that high-speed trains generate up to 15 times less emissions than airplanes even when emissions generated during the infrastructure construction and rolling stock production are included.[9]

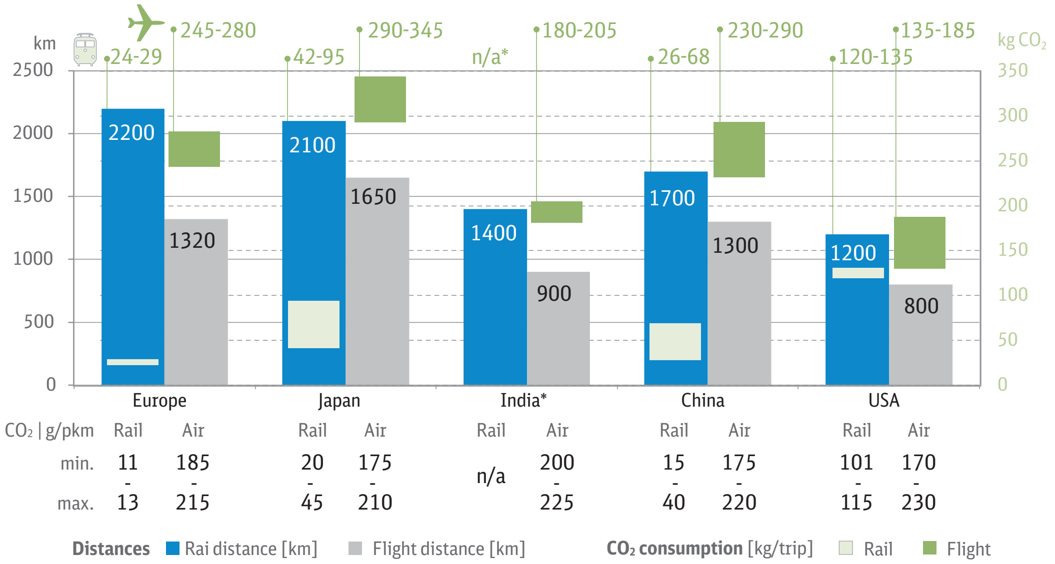
A second study compared the environmental impact of day trains versus night trains on two corridors Berlin – Munich (Germany) and Paris – Toulouse (France). The study found that the environmental advantage of night trains is slightly less than day trains, however it is still significantly better

8 UIC High Speed Rail and Sustainability; EEA TERM Report 2009; Allianz pro Schiene

9 UIC Carbon Footprint of High Speed Rail from 2011, Chapter 2)

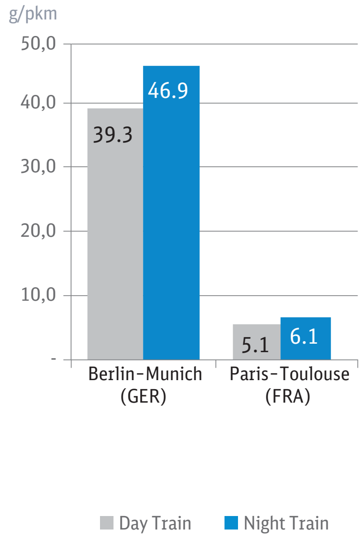
CO_2 emissions – comparison of air and rail traffic

Average CO_2 emission in kilogram per trip per person with current rolling stock



* India cannot be confirmed since the basis for the emissions per trip with only 5,5g CO_2 per pkm is inconceivable

CO_2 emissions of day and night trains



Source: DB UmweltMobilCheck

than air transport. The emissions per passenger per trip during daytime were found to be approximately 20% less than emissions of the night train. This difference might be the result of lower numbers of passengers per meter of wagon, significantly reduced passenger capacity in sleepers and more dead load due to additional fixtures and equipment provided in night trains.

In summary, night trains are an efficient and effective solution to mitigate the impact of transport on the environment and climate change and therefore are an essential part of sustainable mobility systems. Night trains running on HSR lines are 100% powered by electricity thereby reducing environmental impacts compared to air travel.

Future technological changes and regulations are important factors to consider when evaluating environmental impacts. It is likely that the environmental advantages of rail over air transport will increase in the coming years as more renewable energy sources are substituted for oil and gas used to generate electricity. It will be more difficult for air transport to develop and change to renewable energy sources.

It is also true that both air and rail transport will become more energy efficient in the coming years. For air transport the introduction of new information and communications technologies for more efficient routing, as well as optimized aircraft ground handling by new types of tugs and alternative drive concepts are expected to reduce emissions by 40% in 2025. On the rail side, next generation trains have already been developed that can reduce energy consumption by up to 50% compared with today's ICE3 trains.[10] Many railway companies have already started extensive programs to be able to fully operate CO_2-neutral in the near future.

Finally, environmental regulations will play a key role in future transport decisions and market strategies. Many of the regulations being considered by political bodies to reduce environmental impacts would likely increase the market advantage of rail transport. A good example is the introduction of carbon taxes or carbon trading schemes. These would impact air travel much more than rail. However its worth noting that these are extremely political decisions and very difficult to implement (as shown by the EC's backing down in requiring airlines to participate in its emissions trading scheme in early 2013).

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10 Bombardier

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7 Conclusion

This research demonstrates that there is some potential for operating very long distance night train (VLDNT) service on high-speed networks. Being able to cover distances of 2,000 km while allowing passengers to sleep undisturbed through the night but still providing several possibilities for boarding and alighting at either end of the trip make the VLDNT service potentially quite attractive.

Furthermore, high-speed rail networks exist today in many regions of the world and in China high-speed rail night train rolling stock is already operating. The key question is the economic viability of high-speed night train service.

To answer this question the research first considered the percentage of air passengers in a corridor who would need to switch to VLDNT service in order to fill night trains operating in the corridor to 75% capacity. The research showed that this substitution rate is relatively low, indicating that the corridor has sufficient travelers to be viable for VLDNT service.

In addition to substitution rate the research considered the economic feasibility of VLDNT service. It found that VLDNT service would accrue very high track access charges due to the extremely long distances covered. In some cases these access charges would amount to 60% of costs. These high costs make the business model unattractive since passengers would not be willing to pay more to travel by rail than air. Therefore, in order for VLDNT service to be marketable, track access charges must be reduced.

It might be attractive for infrastructure owners to reduce track access charges for VLDNT service since this would provide a new source of income and the service would use the infrastructure at a time when the tracks are currently not very heavily used.

The research found that there are no unsolvable infrastructure or operational problems caused by operating night trains on high-speed rail infrastructure, but that service must be very carefully planned and managed to eliminate any impacts on track maintenance and operations.

Finally the research found that VLDNT is greatly superior to air travel from the environmental perspective. Even today, rail transport can be operated with 100% renewable energy. Increasing the share of rail transport can help countries reach their climate targets and meet the expected tougher environmental regulations in the transport sector.

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