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Strategieën voor internationale hogesnelheidsspoorvervoerders in de Europese reizigersvervoersmarkt

Proefschrift

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Samenvatting
High-speed rail systemen zijn momenteel een geaccepteerde manier van reizen in verschillende landen in de wereld. In de afgelopen decennia hebben high-speed railsystemen zich gestaag ontwikkeld, voornamelijk in Azië en Europa, maar er zijn ook initiatieven te vinden in de Verenigde Staten, Zuid-Amerika, het Midden-Oosten en Afrika.

Eén van de beleidsdoelstellingen van de Europese Commissie om een duurzame toekomst op te bouwen was om de spoorwegsector te revitaliseren. De liberalisering van de spoorwegsector heeft geleid tot een splitsing tussen nationale infrastructuurbeheerders en spoorwegondernemingen. Een nieuw Europees wettelijk kader is ingevoerd om de nationale netwerken open te stellen voor andere operatoren en om de opbouw van een pan-Europese high-speed railnetwerk op basis van de reeds door de nationale regeringen genomen initiatieven te ondersteunen. Het doel was om de groei van de mobiliteit te vereenvoudigen en vliegreizen met afstanden rond de 500 km te beperken en grensoverschrijdend verkeer te vergemakkelijken. De nieuwe Europese wetgeving heeft geleid tot de opening van de grensoverschrijdende markt voor spoorwegvervoer in 2010. Internationale spoorverkeer bestond al, maar werd geregeld door overeenkomsten tussen nationale spoorwegmaatschappijen. Internationale routes zijn nu open voor competitie en toegankelijk voor alle operatoren.

De hoofdvraag van dit proefschrift is:

> *Welke marktstrategieën zullen treinexploitanten ontwikkelen om internationale hogesnelheidstreindiensten aan te bieden als reactie op de liberalisering van de spoorwegmarkt in Europa?*

Deze vraagstelling is onderverdeeld in zes deelvragen:
1. Wat zijn de doelstellingen op lange termijn voor de Europese reizigersvervoersmarkt?
2. Wat is de noodzaak van hogesnelheidsspoorvervoer en welke vervoersvraag kan het spoorwegnetwerk en rollend materieel accommoderen?
3. Hoe presteren de huidige high-speed rail operators?
4. Wat is de marktstructuur voor hogesnelheidsspoorvervoer voor reizigers?
5. Wat is de invloed van dienstverleningskwaliteit en prijzen op de concurrentie?
6. Welke strategieën zijn te herkennen en welke toegangsdrempels moeten worden overwonnen voor nieuwkomers?

Vervoersbeleid
In de afgelopen decennia heeft de Europese Unie (EU) een eigen vervoersbeleid ontwikkeld op basis van de vier vrijheden van verkeer (goederen, diensten, kapitaal en arbeid) zoals aangegeven in het Verdrag van Rome in 1957. De doelstellingen op lange termijn voor de Europese markt zijn gedefinieerd in de meest recente Witboek "Stappenplan voor een interne Europese vervoersruimte - werken aan een concurrerend en zuinig vervoerssysteem" dat het vervoersbeleid van de Europese Commissie schetst tot 2050. Het beleid is "*op zoek naar een diepe transformatie van het vervoersysteem, het bevorderen van onafhankelijkheid van olie, de creatie van moderne infrastructuur en multimodale mobiliteit bijgestaan door slimme beheer- en informatiesystemen.*" en stelt dat "*de oprichting van een*

gemeenschappelijke Europese spoorwegruimte essentieel is voor dit doel." Tien ambitieuze doelstellingen zijn gedefinieerd voor een concurrerend en zuinig vervoerssysteem. Specifiek voor high-speed railverkeer zijn de doelstellingen om de omvang van het bestaande high-speed spoorwegnet te verdrievoudigen tegen 2030 en dat alle belangrijke luchthavens moeten worden aangesloten op het kernspoorwegnet, bij voorkeur met hoge snelheid, in 2050 (EC 2011). Volgens de geplande projecten is een verdrievoudiging van het netwerk in 2030 realistisch, tenzij projecten worden geannuleerd of uitgesteld.

Vraag en aanbod

De basisvoorwaarden met betrekking tot vraag en aanbod zijn belangrijke input voor de marktstructuur. De vraag is afhankelijk van de mobiliteitsbehoeften van de burgers en het aanbod is nauw gerelateerd aan de beschikbare reismogelijkheden met hun specifieke eigenschappen. Er is een sterke correlatie tussen het inkomen per hoofd van de bevolking en vraag naar hogesnelheidsvervoer in de Europese markt en reizigers schuiven van lagesnelheidsopties naar hogesnelheidsmodi naarmate het inkomen stijgt. Uit historische gegevens blijkt dat in Europa high-speed rail sneller groeit dan het luchtverkeer, wat resulteert in een groter marktaandeel voor high-speed rail operators in vergelijking met de luchtvaartmaatschappijen als deze trend zich doorzet. Passende infrastructuur en rollend materieel zijn nodig voor het leveren van hogesnelheidstreindiensten. Uit de analyse blijkt dat voor Europa het beschikbare spoorwegnet en de omvang van het materieelpark beperkende capaciteitsdrempels vormen voor de vraagscenario's met gemiddelde en hoge groei. De geplande groei van de treinvloot is hierbij meer beperkend dan de groei van het hogesnelheidsnetwerk. Met deze beperkingen in het aanbod, zullen reizigers verschuiven naar luchtvaartmaatschappijen en de high-speed rail marktaandeel zal afnemen.

Prestatie

Om de inzet en het gebruik van high-speed railsystemen te optimaliseren kunnen nationale overheden en spoorwegmaatschappijen profiteren van goede praktijken in de rest van de wereld. Een benchmark van de acht grootste hogesnelheidssystemen in de wereld toonde significante verschillen tussen Europa en Azië in de beschouwde key performance indicators. De treindichtheden in Europa zijn aanzienlijk hoger dan in Azië, omdat hogesnelheidstreinen in Europa niet uitsluitend op hogesnelheidslijnen rijden, maar ook op conventionele lijnen. Uit de vergelijking van de vlootprestaties tussen Europa en Azië, blijkt dat Japan het best presteert en China het slechtst op bezettingsgraad. Voor Europa geeft Frankrijk de beste resultaten. Hogesnelheidslijnen in Azië opereren treinen met meer zitplaatsen en een gelijke of zelfs betere prestatie wordt bereikt met minder treinkilometers. Meer passagiers en kortere reizen zijn ook kenmerkend voor Azië, vooral voor China. Japan realiseert een bezettingsgraad van boven de 70% en is beter dan alle andere netwerken. China is een achterblijver, gezien het feit dat de Chinese netwerk nog volop in ontwikkeling is.

Uit een Data Envelopment Analysis (DEA) is gebleken dat tussen 2007 en 2012, Azië een groei van de productiviteit realiseerde van 26,9%. Europa toonde geen verbetering van de productiviteit in dat tijdsbestek, omdat, ondanks de 16,6% technische verandering, de efficiency met 14,4% daalde. In Azië droegen zowel verbeteringen in technische efficiency (+17,9%) en de technologische veranderingen (+7,6%) bij aan de totale groei van de productiviteit.

Duitsland, Italië, Korea en Japan laten een bovengemiddelde productiviteitsindex zien tussen 2007 en 2012. De grote verbetering van de productiviteit in Taiwan is opmerkelijk (+157%). Taiwan is het enige land dat een maximale productiviteitsindex in alle achtereenvolgende jaren heeft bereikt. Underperformers zijn de netwerken in Spanje en China, maar om verschillende redenen. De efficiëntie van het Spaanse HSR-netwerk daalde met 34,1% in vijf jaar tijd, maar dit wordt deels gecompenseerd met een technische verbetering van 19,9%. China heeft de efficiëntiescore kunnen houden, maar toont een afnemende technische verandering van 12,2%.

Azië overtreft Europa met betrekking tot de productie-efficiëntie en service-effectiviteit. De Aziatische HSR exploitanten en SNCF zijn de best presterende in de referentiegroep. In alle jaren lijkt Italië de slechtste performer en Duitsland en Spanje zitten in het midden van het spectrum. De resultaten laten een negatieve correlatie zien tussen de productie-efficiëntie en service-effectiviteit. Voor Europa is dit effect veel sterker dan voor Azië, waar een stijging van 10% in de productie-efficiëntie leidt tot een verlies van 7% in service-effectiviteit.

Marktstructuur
Het aantal concurrerende bedrijven in de spoorwegsector is klein. Spoorwegen opereren in monopolistische, duopolistische of oligopolistische markten. Naast intra-modale concurrentie tussen gevestigde spoorwegbedrijven en nieuwkomers en tussen conventionele en high-speed rail operators, ondervindt de spoormarkt ook intermodale concurrentie van luchtvaartmaatschappijen, personenauto's en bussen. De marktstructuur op een specifieke verbinding kan worden gekarakteriseerd als een oligopolie met gedifferentieerde producten omdat diensten van verschillende modi verschillende kwaliteitskenmerken hebben zoals reistijd, frequentie, gemak etc.

De relaties tussen de high-speed marktstructuur voor personenvervoer, het gedrag van luchtvaartmaatschappijen en high-speed rail operators die actief zijn in deze markt en hun prestaties zijn onderzocht met behulp van het Structure-Conduct-Performance paradigma. Het doel was om uit te vinden hoe strategische beslissingen van de exploitanten met betrekking tot de kwaliteit van de dienstverlening en de prijs zijn gerelateerd aan de marktstructuur en prestaties. Het empirische model is toegepast op de verbinding Londen-Parijs voor de periode 2003 tot 2015.

De marktstructuur op de verbinding Londen-Parijs tussen 2003 en 2015 kan worden gekenmerkt als een oligopolie met een neiging tot een monopolie met Eurostar als de dominante speler, leidend tot een minder intense prijsconcurrentie. Uit de analyse bleek dat ticketprijzen van weinig of geen invloed zijn op de marktstructuur- of de prestatievariabelen. De door de exploitanten geboden totale reistijd heeft een sterke correlatie met de prestatievariabele punctualiteit, dat wil zeggen aankomst binnen 15 minuten van de geplande tijd. Voor de overige dienstkenmerken, frequentie van de treindienst en de capaciteit van de vloot, leiden de modellen niet tot uniforme resultaten voor de marktstructuur- of prestatievariabelen.

Concurrentie
Om de kansen voor exploitanten te identificeren om succesvol diensten op internationale routes aan te bieden, is de route Londen-Parijs in detail bestudeerd. Om de concurrentie op

een verbinding tussen steden in een oligopolistische markt te bestuderen zijn met behulp van een gekalibreerd speltheoriemodel simulaties uitgevoerd. Het effect van de hogere infrastructuurheffingen, een hogere kwaliteit van de dienstverlening en de toetreding van een nieuwe high-speed rail operator op de route Londen-Parijs zijn geanalyseerd met feitelijke operationele gegevens en zakelijke prestaties.

De bevindingen tonen aan dat Eurostar een dominant marktaandeel heeft van ongeveer 70% (2012) op de Londen-Parijs markt in verhouding tot de luchtvaartmaatschappijen en de eigen auto. Dit aandeel is gevoelig voor veranderingen in de infrastructuurheffingen. Introductie van nieuwe Velaro-treinstellen met meer zitplaatsen zal de marktpositie van Eurostar nog meer dominant te maken. Een nieuwe high-speed rail toetreder verandert het concurrentiële landschap volledig. Als de nieuwkomer in staat is om de marginale kosten te verminderen, zal het meer dan de helft van het marktaandeel van Eurostar overnemen.

Toegang tot de markt
Hoewel de markt voor internationale grensoverschrijdende spoordiensten open is sinds 2010, zijn er maar weinig spoorwegmaatschappijen die de middelen en de capaciteit hebben om deze diensten aan te bieden. Toetredingsdrempels voor nieuwkomers zijn talrijk zoals potentiële vraag, concurrentie, Europese richtlijnen en verordeningen, gecertificeerd rollend materieel en personeel, toegang tot het netwerk en financiële middelen.

Tot nu toe wordt de Europese high-speed rail markt gedomineerd door de SNCF. Naast het feit dat SNCF de grootste nationale high-speed rail exploitant is, heeft SNCF verschillende belangen in belangrijke grensoverschrijdende joint ventures. De plannen van DB, de op een na grootste high-speed operator in Europa, om diensten aan te bieden tussen Frankfurt en Londen en Amsterdam zijn nog niet gematerialiseerd. De Railteam-samenwerking tussen gevestigde spoorwegen is een extra barrière voor nieuwkomers. Pogingen van toetreding van nieuwe particuliere exploitanten zijn beperkt en mislukt. Het bezitten van adequaat rollend materieel dat de grenzen kan overschrijden is een belangrijk concurrentieel voordeel voor de exploitanten.

Toekomstverwachtingen
Bestaande vervoerders hebben hun marktpositie gevestigd door een vroege betrokkenheid bij de ontwikkeling van het hogesnelheidsspoorwegnetwerk in Europa. Op dit moment is SNCF eigenaar van de meest multisysteem treinstellen met grensoverschrijdende functionaliteit, maar Eurostar, Trenitalia, Renfe en DB hebben grote orders voor interoperabel rollend materieel geplaatst om hun internationale marktpositie te verstevigen. Ondanks de vooruitgang in de liberalisering van de spoorwegen, is er weinig ruimte voor nieuwkomers om zich te positioneren, zolang er geen vervoersdiensten publiek worden aanbesteed voor internationale lijnen. Een complicatie voor nieuwkomers is dat de voorbereidingen voor toetreding tot de markt niet onopgemerkt zullen blijven, wat de gevestigde vervoerders de mogelijkheid geeft om toegang te bemoeilijken. Rechtstreekse concurrentie met productdifferentiatie en lagere prijzen op aantrekkelijke en drukke routes lijkt de enige levensvatbare strategie voor nieuwe spelers. Nieuwkomers kunnen om te beginnen gaan concurreren op winstgevende binnenlandse routes om vervolgens uit te breiden naar naburige landen met grensoverschrijdende diensten als de financiële positie dit toelaat. Gezien de ervaringen tot nu toe, zal dit zal waarschijnlijk minstens vijf jaar duren.

Conclusies en aanbevelingen
In de eerste plaats is het raadzaam om de uitvoering van de overeengekomen vier spoorwegpakketten te voltooien en het liberaliseringsproces te versnellen in landen die achterlopen. In de tweede plaats kan de invoering van een vijfde spoorwegpakket worden overwogen om op basis van de ervaring uit het liberaliseren van het binnenlandse spoorvervoer de resterende belemmeringen voor vrije toegang tot de markt weg te nemen. Een gemeenschappelijke Europese spoorwegruimte zou baat zou hebben bij een onafhankelijke pan-Europese spoorweginfrastructuurmanager voor internationale routes. Aanbesteding van vervoersdiensten op internationale routes, naar analogie van de aanpak in het binnenlandse spoorwegvervoer, zorgt voor een gelijk speelveld voor alle betrokken partijen.

De vele verschillen in de structuur en prijsstelling van tariefsystemen beïnvloeden de concurrentiepositie van high-speed rail operators. Harmonisatie van de nationale tariefsystemen op internationale routes zou grensoverschrijdend verkeer vereenvoudigen. Om een gelijk speelveld voor alle modaliteiten te creëren zouden de werkelijke gebruikskosten en externe kosten in een internationaal tariefsysteem moet worden opgenomen.

Bij een vrij toegankelijke internationale spoorwegmarkt, biedt rechtstreekse concurrentie met productdifferentiatie op drukke verbindingen de beste kansen voor nieuwkomers om een deel van de markt te veroveren. Het marktaandeel op een bepaalde route hangt in de eerste plaats af van de geboden frequentie en capaciteit ten opzichte van de concurrenten en in de tweede plaats van de prijs en kwaliteit van de dienstverlening. Kopen van tweedehands treinen of leasen van bestaand rollend materieel om de operatie te starten, zal het risicoprofiel voor een nieuwe vervoerder aanzienlijk verlagen. Overname van treinstellen die al op de beoogde netwerken zijn goedgekeurd zal een concurrentievoordeel te geven omdat hiermee de time-to-market wordt verkort.

Summary

High-speed rail systems are currently an accepted mode of travel in various countries in the world. Over the last decades, high-speed rail systems have developed steadily, mainly in Asia and Europe, but also initiatives are found in the US, South America, the Middle East and Africa.

One of the policies from the European Commission to build a sustainable future was to revitalise the railway sector. A liberalisation process for the railway sector resulted in a split between national infrastructure managers and railway operators. A new European legal railway framework is put in place to open the national networks for other operators and to promote the building of a pan-European high-speed rail network based on the initiatives already taken by national governments. The goal was to facilitate growth in mobility, to limit air travel on distances less than 500 km and to ease borderless traffic. The new European legislation led to the opening of the cross-border rail market in 2010. International railway traffic already existed, but is arranged by agreements between national railway companies. International routes are now open an accessible for all operators and competition.

The main question for this thesis is:

> *What market strategies will train operators develop to run international high-speed rail services in response to the railway market liberalisation in Europe?*

This research question is broken down into six sub-questions:

1. What are the long-term objectives for the European passenger transport market?
2. What is the need for high-speed rail transport and what can be accommodated?
3. How do current high-speed rail operators perform?
4. What is the market structure for high-speed rail operations?
5. What is the influence of service quality and pricing in competition?
6. What market entry strategies can be recognized and which access barriers need to be overcome?

Transport policy

Over the last decades, the expanding European Union (EU) has developed its own transport policy based on the four freedoms of movement (goods, services, capital and labour) as declared in the Treaty of Rome in 1957. The long-term objectives for the European market are defined in the latest White paper "Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system" that outlines the transport policy of the European Commission until 2050. It aims at "*seeking a deep transformation of the transport system, promoting independence from oil, the creation of modern infrastructure and multimodal mobility assisted by smart management and information systems.*" and states that "*The creation of a single European Railway Area is essential to this purpose.*" Ten ambitious goals are defined for a competitive and resource-efficient transport system. Specifically for high-speed rail traffic, the objectives are to triple the length of the existing high-speed rail network by 2030 and that all important airports should to be connected to the core rail network, preferably high-speed, by 2050 (EC 2011). According to the projects planned, a tripling of the network size in 2030 is realistic, unless projects are cancelled or postponed.

Demand and supply
The basic conditions regarding demand and supply are important inputs that structure the market. Demand depends on the mobility needs of citizens and supply closely relates to the available travel options with their specific characteristics. There is a strong correlation between income per head of the population and the high-speed travel demand per capita in the European travel market and travellers shift from low-speed to high-speed travel modes as income rises. Historic data shows that in Europe high-speed rail grows faster than air traffic, resulting in a larger market share for high-speed rail operators compared to airlines when this trend continues. Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. For Europe, evidence is found that the available rail network and rolling stock are capacity thresholds for the medium and high growth demand scenarios, where the planned growth of the train fleet is more stringent than the growth of the high-speed rail network. With these supply limits, travellers will shift to airlines and the high-speed rail market share will decrease.

Performance
To optimise the deployment and utilisation of high-speed rail systems, governments and railway companies may benefit from good practices in the rest of the world. A benchmark of the eight largest high-speed railway systems in the world revealed significant differences between Europe and Asia in the key performance indicators considered. The train densities for Europe are considerably higher than for Asia as high-speed trains in Europe not exclusively run on high-speed track, but on conventional lines as well. By comparing the fleet performance between Europe and Asia, it is found that Japan is performing best and China worst on seat occupancy. For Europe, France is giving the best results. High-speed railways in Asia operate trains with larger seat capacity and equal or even better performance is achieved with less train kilometers. More passengers and shorter trips are also characteristic for Asia, especially for China. Japan realises seat occupancies above 70% and is outperforming all the other networks, with China being an underperformer, bearing in mind that China's network is still under development.

A Data Envelopment Analysis (DEA) revealed that between 2007 and 2012, Asia achieved a productivity growth of 26.9%. Europe didn´t show any productivity improvement in that timeframe because, despite the 16.6% technical change, efficiency dropped by 14.4%. In Asia, both technical efficiency improvements (+17.9%) and technology change (+7.6%) contributed to the overall productivity growth.

Germany, Italy, Korea and Japan show an above-average productivity index between 2007 and 2012. The high productivity improvement in Taiwan is remarkable (+157%). Taiwan is the only railway that has achieved a productivity index above unity in every successive year. Underperformers are the networks in Spain and China, but for different reasons. Efficiency of the Spanish HSR-network dropped with 34.1% in five years' time, but this is partly compensated for by a technical improvement of 19.9%. China has achieved to keep up efficiency, but shows a decreasing technical change of 12.2%.

Asia outperforms Europe regarding production efficiency and marketing and sales efficiency. The Asian HSR operators and SNCF are the best performers in the peer group. In all years, Italy appears to be the worst performer and Germany and Spain are in the middle of the spectrum. The results show a negative correlation between production efficiency and marketing and sales efficiency. For Europe, this effect is much stronger than for Asia, where a 10% increase in production efficiency comes with a 7% loss in marketing and sales efficiency.

Market structure
In the railway industry, the number of competing firms is small. Railways operate in monopolistic, duopolistic or oligopolistic markets. Besides intra-modal competition between incumbent railways and new entrants and conventional and high-speed rail, the rail market faces inter-modal competition from airlines, private cars and busses. The market structure on a specific origin-destination pair can be characterized as an oligopoly with differentiated products, as services of different modes have different quality characteristics like travel time, frequency, convenience etc.

The relations between the high-speed passenger transport market structure, the conduct of airlines and high-speed rail operators that operate in this market and their performance is investigated using the structure-conduct-performance paradigm. Our specific interest was to find how the operators' behaviour in terms of strategic decisions concerning service characteristics and pricing is related to market structure and performance. The empirical model is applied to the London-Paris link for the time period 2003 till 2015.

The London-Paris passenger market structure between 2003 and 2015 can be characterized as an oligopoly with a tendency to a monopoly with Eurostar being the dominant player, indicating a less intense price competition. The analysis revealed that ticket prices are of little of no influence on any of market structure or performance variables. The offered total travel time by the operators has a strong correlation with performance variable punctuality i.e. arrival within 15 minutes of the scheduled time table. For the other service characteristics, service frequency and fleet capacity, the models did not produce uniform results for any of the market structure or performance variables.

Competition
To identify the chances for operators to successfully run high-speed services on international routes, the case for the London-Paris route is studied in detail. For this purpose, simulations are carried out using a calibrated game theory model for competition on city-to-city routes in an oligopolistic market. The effect of higher infrastructure charges, higher service quality and the entrance of a new high-speed rail operator on the London-Paris route is analyzed with data from the actual operational and business performance.

The findings show that Eurostar has a dominant market share of about 70% (2012) on the London-Paris market compared to airlines and private car. This share is sensitive to changes in infrastructure charges. Introduction of new Velaro trainsets with more seat capacity will make Eurostar's market position even more dominant. A new high-speed rail entrant would completely change the competitive landscape. If the new entrant is capable of reducing its marginal costs, it will capture more than half of Eurostar's market share.
Market entry

Although the market for international cross-border rail services is open since 2010, there are only few railway operators that have the resources and capabilities to provide these services. Entry barriers for new entrants are numerous like market demand, competition, European rail directives and regulations, certified rolling stock and staff, network access and financial resources.

Up till now, the European high-speed rail market is dominated by SNCF. Besides being the biggest national high-speed operator, SNCF has several stakes in key cross-border joint ventures. The plans from DB, being the second largest high-speed operator in Europe, to run services between Frankfurt and London and Amsterdam have not materialized yet. The Railteam cooperation between incumbent railways is an extra barrier for new entrants. Attempts of entrance by new private operators are limited and failed. Owning adequate rolling stock that can cross borders is an important competitive advantage for operators.

Future expectations

Existing operators have established their market position by an early involvement in the development of high-speed rail network in Europe. At present, SNCF owns the most multi-system trains with cross-border functionality, but Eurostar, Trenitalia, Renfe and DB have placed large orders for interoperable rolling stock to strengthen their international market position. Despite progress in the liberalisation of the railways, there is little room for new entrants to position themselves as long as no public transport services are out to tender for international lines. A complication for newcomers is that their preparations for market entry will not go unnoticed, which gives the incumbent carriers the possibility to hamper access. Head-on competition with product differentiation and lower prices on attractive and busy routes seems to be the only viable strategy for new players. Newcomers can start to compete on profitable domestic routes and then expand to neighbouring countries with cross-border services as soon as the financial condition permits. Given the experiences so far, this will likely take at least five years.

Conclusions and recommendations

In the first place, it is recommended to complete the implementation of the agreed four railway packages and to speed up the liberalisation process in countries that are lagging behind. In the second place, introduction of a Fifth Railway Package may be considered to remove the remaining barriers for open access, based on the lessons learned from opening the domestic markets. A single European railway area would benefit from an independent pan-European rail infrastructure manager for international routes. Tendering of Public Service Contracts for international routes, in analogy to the approach in domestic railway markets, creates a level playing field for all interested parties.

The many differences in structure and pricing of tariff systems affect the competitiveness of high-speed rail operators. Harmonization of national tariff systems on international routes would facilitate cross-border traffic. For a level playing field for all modes it would be beneficial to create an international tariff system on a fair basis with other modalities that includes the actual running costs and all externalities.

As there exist many differences in the structure, pricing principles and levels of tariff systems that impact the fares and market competitiveness of high-speed rail operators, harmonisation of the national tariff systems across international routes would be beneficial to ease cross-border traffic. To create a level playing field across modalities the actual infrastructure costs and external costs should be incorporated in the tariff system and balanced with other modalities.

In the open access model, head-on competition with product differentiation on high-demand connections gives the best opportunities for new entrants to capture a fair share of the market. The market share on a specific route depends in the first place on the capacity and service frequency that can be offered relative to the competitors and in the second place on the price and service quality. Buying second-hand trains or leasing existing rolling stock to start the operation, will lower the risk profile for the operator considerably. Acquisition of trainsets that are already approved on the targeted networks will give a competitive advantage as it reduces the time-to-market.

Acknowledgements

After 25 years of working in the railway business, I decided to investigate the market strategies of high-speed rail operators in the European market. This thesis is the tangible result of my PhD study. An early involvement in tackling the issue of the running quality of pantographs on high-speed trains running cross-border services as part of a UIC commission has triggered my interest in high-speed rail developments. The incompatibility of various power supply systems and train designs was investigated by using simulation models, lab measurements and full-scale test runs in an international context. Besides the technical issues that need to be overcome to run cross-border services, many more issues need to be tackled to build a successful commercial operation. During my marketing studies at Tias Business School, I discovered that proper market research and careful business planning were important ingredients as well. It surprised me that, although a big effort was made by the European Commission to restructure and liberalise the European railway market, little effect could be observed in daily practice.

The idea for this PhD project was born during the preparations and execution of the first version of the Antwerp Rail School, a joint initiative of Antwerp University and Lloyd's Register Rail Europe. During a full week, we tried to bring together the latest scientific insights and practical rail business issues in front of an audience of PhD students, academics and business people. The biggest challenge for me as a technical engineer was to translate the business issues into a proper economic and scientific context and to build and validate the models that could produce results for the analysis.

Discussions with my supervisors Thierry Vanelslander and Eddy Van de Voorde and conversations with colleagues within Lloyd's Register, have greatly contributed to guiding the research in the right direction. In addition, the contributions of colleague students of the Antwerp University have been of great help for providing me with feedback during the doctoral days and seminars. The presentations and discussions during the Antwerp Rail School and conferences gave me new ideas and the spirit to continue. The mental support and ideas from my PhD-colleague Daniel Behr have been of great value to me. I would like to thank Tom Duffhues from the Technical University Twente in the Netherlands and Els Struyf from Antwerp University in Belgium for identifying the proper DEA software tools, Geraint Roberts for being so kind to share his results from his Master Thesis at the Strathclyde University in the UK, Adrian Ng from Lloyd's Register Rail in Hong Kong, Mr. Wu from Beijing University, Liehui Wang from East China Normal University and Rang Zong from Shanghai University for helping to find the right data on the CRH operation in China.

Although it started as an open-end project, the time and support offered by Avans University of Applied Sciences has accelerated the project considerably. A successful conclusion of this report would have been impossible without the understanding and support from the home front. I would like thank Roos for her love and patience to finish the job. My children Simon, Myrthe, Maxim and Diederick have always been a source of inspiration. The hours spent on the thesis and not with them will be compensated for. Special thanks to my father and mother who have always stimulated and supported me to achieve my goals. I am proud to dedicate this thesis to them.

Rosmalen, June 2017.

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List of Abbreviations

AC	Access Capacity
AF	Air France
AMS	Amsterdam airport
ASK	Available Seat Kilometers
ATC	Air Traffic Control
BA	British Airways
CAA	Civil Aviation Authority
CAPEX	Capital Expenditures
CDG	Charles De Gaulle airport
CEF	Connecting Europe Facility
CNR	China North Locomotive and Rolling Stock Industry Corporation
CPA	Country Portfolio Analysis
CRH	China High-speed Rail
CRRC	China Railway Rolling Stock Corporation
CSR	China South Locomotive & Rolling Stock Corporation
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DV	Dependent Variable
EC	European Commission, Efficiency Change
EU	European Union
EUKL	Eurostar UK Limited
FP	Fleet Performance
FRA	Frankfurt Airport
FRP	First Railway Package
FS	Fleet Size
FSC	Full Service Carrier
GDP	Gross Domestic Product
HHI	Herfindahl Hirschman Index
HSA	High Speed Alliance
HSR	High Speed Rail
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICE	Intercity Express
IPS	International Passenger Survey
IV	Independent Variable
KTX	Korea Train Express
LCC	Low Cost Carrier
LDN	London
LF	Load Factor
LHR	London Heathrow airport
LTMC	Long Term Marginal Cost
LSR	Least Square Regression
LTN	Luton airport
MATOF	Market Administrative Technological Operational Financial
MIMO	Multiple Input Multiple Output

MKS	Market share
MPI	Malmquist Productivity Index
MTR	Mass Transit Railway (Hong Kong)
NDEA	Network Data Envelopment Analysis
NL	Network Length
NTV	Nuovo Trasporti Viaggiatori
ONS	Office for National Statistics
OPEX	Operational Expenditures
ORY	Orly airport
PAR	Paris
PPM	Partial Productivity Measure
PRIME	Platform of Rail Infrastructure Managers (in Europe)
PSC	Public Service Contract
QQS	St. Pancras Railway station (IATA code)
RA	Ratio Analysis
RS	Ridership
SCP	Structure Conduct Performance
SE	Scale Efficiency
SERA	Single European Railway Area
SFA	Stochastic Frontier Analysis
SRMC	Short Run Marginal Cost
SNCF	Societé Nationale des Chemins de Fer
SO	Seat Occupancy
ST	Station Throughput
TC	Train Capacity, Technical Change
TD	Train Density
TE	Technical Efficiency
TEN-T	Trans European Network for Transport
TFP	Total Factor Productivity
TGV	Train a Grand Vitesse
TOC	Train Operating Company
TOTEX	Total Expenditures
TP	Train Performance
TSI	Technical Specification for Interoperability
TV	Travel Volume
TTT	Total Travel Time
U2	EasyJet (IATA code)
UIC	Union Internationale des Chemins de fer
VIF	Variance Inflation Factor
VRS	Variable Returns to Scale
VoIVT	Value of In-Vehicle Time
VOT	Value Of Time
WX	CityJet (IATA code)
XPG	Gare du Nord Railway station (IATA code)

1 Research context

High-speed rail systems are currently an accepted mode of travel in various countries in the world. The first introduction of “bullet trains” on the Tokyo-Osaka connection in Japan goes back to 1964, more than 50 years ago. In Europe, high-speed rail was introduced by opening the TGV Paris-Lyon connection in 1981. The French TGV initiative was followed by projects mainly in Germany, Italy and Spain in the nineties. In the meantime, in Asia, the expansion of the Japanese high-speed rail network continued and new initiatives were taken in Korea, Taiwan and China, with China being a special case. China succeeded to build up a high-speed rail network in less than ten years and CRH, the Chinese high-speed rail operator, is currently the largest operator in the world. Over the last decades, high-speed rail systems have developed steadily, mainly in Asia and Europe, but also initiatives can be found in the US, South America, the Middle East and Africa.

Over the last decades, the expanding European Union (EU) has developed its own transport policy based on the four freedoms of movement (goods, services, capital, and labor) as declared in the Treaty of Rome in 1957. A drastic change in the railway sector in Europe is apparent. Market liberalisation has led to the introduction of new regulation for rail freight and passenger transport. The European transport policy is aimed at revitalizing railway traffic in order to increase the competitive strength of the region and to bridge social and cultural differences. Its focus is on the development of a new trans-European high-speed network in order to facilitate growth in mobility, and to limit air travel for distances less than 500 km. The legislative framework for liberalising the railway sector is almost ready and is currently being implemented in the European Member States. Train operations were split off from the infrastructure management activities and independent rail regulators took up their role. In 2007, the European freight market is fully opened as stipulated in the First Railway Package (FRP). New entrants have shown up and incumbent freight operators reacted, leading to shifts in their strategy, positioning and organization. This is a dynamic process that has not been finalized yet. It also appeared that the approach, the extent and the pace of liberalisation in the EU Member States is rather diverse, so the picture varies by country. Not only market opening plays a role, but also the positioning of rail transport in different countries, the financing arrangements and level of charges for rail use and the positioning and strategies of infrastructure managers and rail regulators. Freight operators have followed more and less successful strategies. New start-ups have entered the market and incumbent operators have repositioned themselves. On January 1, 2010, the European market for international passenger traffic has opened. A logical next step that has not been fully effectuated yet, is the opening of the domestic passenger market on the national core networks being part of the fourth EU railway package. There are only some examples where national governments have liberalised regional rail traffic. The success of this market liberalisation is still under debate.

1.1 Aim of the study

This research aims at a better understanding of the market developments and competition mechanism for high-speed rail operators in the European passenger transport market and for an empirical contribution, applying existing theoretical models to the research area. In this thesis, it is analysed how high-speed rail operators respond to the liberalisation of the European cross-border rail market.

After an overview of high-speed rail operations in the world, the study focuses on strategies of passenger train operating companies (TOC's) in the European market (EU 28) that will run cross-border train services. First investigations are carried out at regional and country level followed by more detailed analysis at meso level, i.e. the TOC as unit of analysis in interaction with its environment (clients, infrastructure managers, authorities, competitors) within the context of the EU transport policy.

1.2 Problem statement and objective

The European transport policy aims at revitalising railway traffic in order to increase the competitive strength of the region and to bridge social and cultural differences. Its focus is on the development of a new trans-European high-speed network in order to facilitate growth in mobility, and to limit air travel for distances less than 500 km. The legislative framework for liberalising the railway sector is ready and is currently being implemented in the European Member States. With the foregoing in mind, the following problem statement is formulated:

> *If the European transport policy on railway market liberalisation doesn't give way to train operating companies to develop their business in a competitive and sustainable way, train services cannot be improved and the railway's market share will not grow.*

Considering the European ambition to make railway transport grow and to open the railway market to stimulate train operating companies to develop their business in competition, the following objective arises:

> *To identify and analyse market strategies for train operating companies to obtain a sustainable competitive advantage triggered by the opening of the international passenger train services market.*

In order to be able to meet this objective, the conceptual model has been further elaborated into the following main research question:

> *What market strategies will train operators develop to run international high-speed rail services in response to the railway market liberalisation in Europe?*

This research question is broken down into six sub-questions:

1. What are the long-term objectives for the European passenger transport market?
2. What is the need for high-speed rail transport and what can be accommodated?
3. How do current high-speed rail operators perform?
4. What is the market structure for high-speed rail operations?
5. What is the influence of service quality and pricing in competition?
6. What market entry strategies can be recognized and which access barriers need to be overcome?

The high-speed rail operators are the central focal point in this thesis. The research consists of five main building blocks that were found to be important to understand the behaviour of high-speed rail operators: governmental policy, transport demand and supply, market structure, performance of high speed rail operators and inter- and intra-modal competition. Various analysis techniques are selected and applied to the main research areas. Performance is investigated by applying ratio analysis and Data Envelopment Analysis (DEA) to eight high-speed rail operators in the world between 2007 and 2012. A quantitative approach of the structure-conduct-performance paradigm is applied to study the performance and behaviour of transport providers in the London-Paris market between 2003 and 2015. To study inter- and intra-modal competition, a game theory approach is developed and applied on the London-Paris link in 2012. In order to maintain sufficient focus and depth, the research is limited to the market development of international train services that will take place during the next 10 years in Western Europe.

1.3 Methodology

The conceptual research model is organised according to the Structure-Conduct-Performance (SCP) paradigm (Lipczynski et al. 2013, Hazersloot 2013, Panagiotou 2005). This model interrelates the key elements that are fundamental to understand industrial organisations. In this thesis, we follow the approach of the New Industrial Organisation to explain the strategy, behaviour and performance of firms in the context of the market and industry they belong to by using empirical data (Lipczynski et al. 2013). In our approach, high-speed rail operators are seen as active decision-makers, capable of implementing diverse strategies. To refute the criticism that SCP is a static model that can only provide a snapshot of the situation at one point in time, we use in addition game theory as one of the tools to model the interaction.

The SCP model relates the market structure, the conduct of firms that operate in this market and their performance in the context of supply and demand conditions and government policy (figure 1.1). The SCP elements are closely related and have forward and backward links. All elements of the SCP framework are interrelated and all influence and impact on each other (Panagiotou 2005). On the one hand, the market structure defines the environment in which companies plan and execute their strategies; while on the other hand, the way these companies operate in this market will affect the market structure. The same principles apply to the interaction of the firms' behaviour and their technical and economic performance. This theory was first developed by Mason in 1939 and refined by Bain in 1951. In the first instance, the SCP framework has been applied to the manufacturing industry, but more recently also to service industries like search and selection, banks, telecommunications and accountancy (Lee 2012). The conceptual model is based on the assumption that demographic, economic, social, technological, environmental and political megatrends are a fact and can be identified. Megatrends like globalization, urbanisation, ageing, growing prosperity, individualization, environmental and technological development will have their effect on the mobility of citizens. These trends will both affect government and companies in the market. The public sector will take these trends as a starting point in policymaking and the drafting of regulations and legislation. This will be input for the market, together with the future scenarios derived from the megatrends. They will develop market strategies that meet their mission and vision. The dynamic process with the public sector and various train operating companies will result in market developments like growth or decline or a shift between transport modes. In which direction and to which extent these developments will take place is a result from the strategies and behaviour and interactions of the various actors. Of course, there will be some feedback effects. Trends like climate change for example can be influenced by policy makers taking measures to reduce CO_2 production.

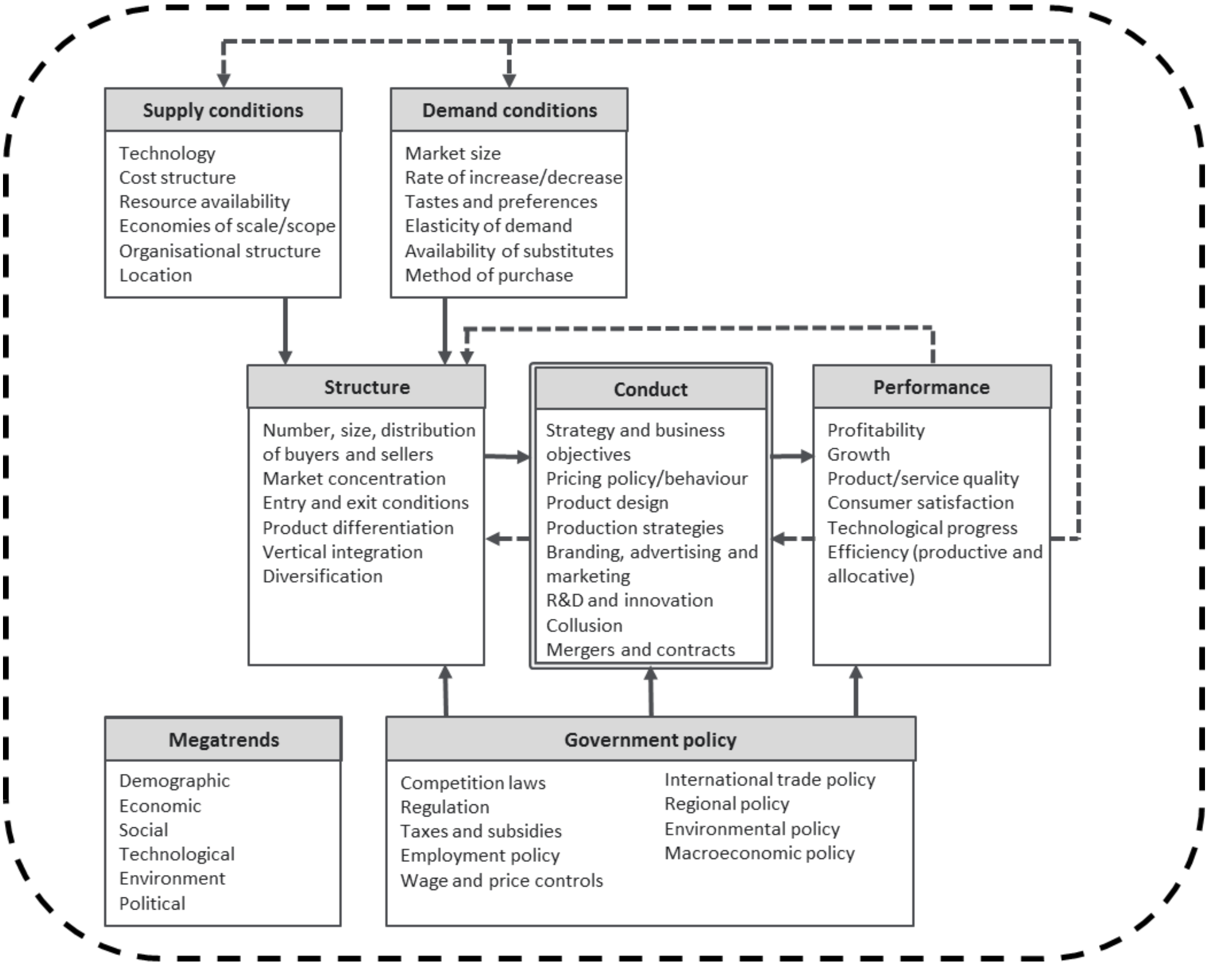

Figure 1.1 - The conceptual research model

Source: Own composition based on Lipczynski et al. 2013; Hazersloot 2013; Panagiotou 2005
Note: The Conduct element that covers the behaviour of companies is the focal point in this thesis

In this thesis, we focus on the strategy and behaviour of high-speed rail operators represented by the conduct element in the SCP-model. It is impossible to understand the operators' conduct without taking the market structure, the operators' performance, the basic demand and supply conditions and government policy into account. On the demand side, a growing need for mobility in general and for high-speed modes specifically can be recognised. More airline connections, highways and high-speed rail links can accommodate this increasing demand. The development and availability of high-speed rail connections is key on the supply side. The development towards a sustainable pan-European transport system is supported by the EU transport policy. White papers, railway packages and railway directives are directing and supporting this development. The market structure for high-speed rail operators is strongly related to the development of the railway network. On the one hand, new and existing links give opportunities to operating companies to enter the market or grow their services; on the other hand, capacity is always limited and a restriction for growth when insufficient infrastructure is available to deliver the requested train paths.

Providers, having their own strategy and business objectives, will structure the market depending on the type of service and the associated pricing they offer, where the outcome can range from monopoly to perfect competition. Transport operators will adjust their behaviour to the market conditions and the realised performance. Governmental policies regarding transport, competition, taxation, trade etc. will affect companies operating in the market and provide important boundary conditions for shaping the market structure.

1.4 Thesis outline

The structure of this doctoral thesis is given in figure 1.2. It follows the elements of the SCP model (figure 1.1), where chapter 6 on "Competition" and chapter 7 on "Market entry", which are closely related to the behaviour of HSR operators, cover the "Conduct" element. Although specifically designed to study the high-speed rail market in Western Europe, the structure is generic and can be applied for the assessment of other transport markets as well.

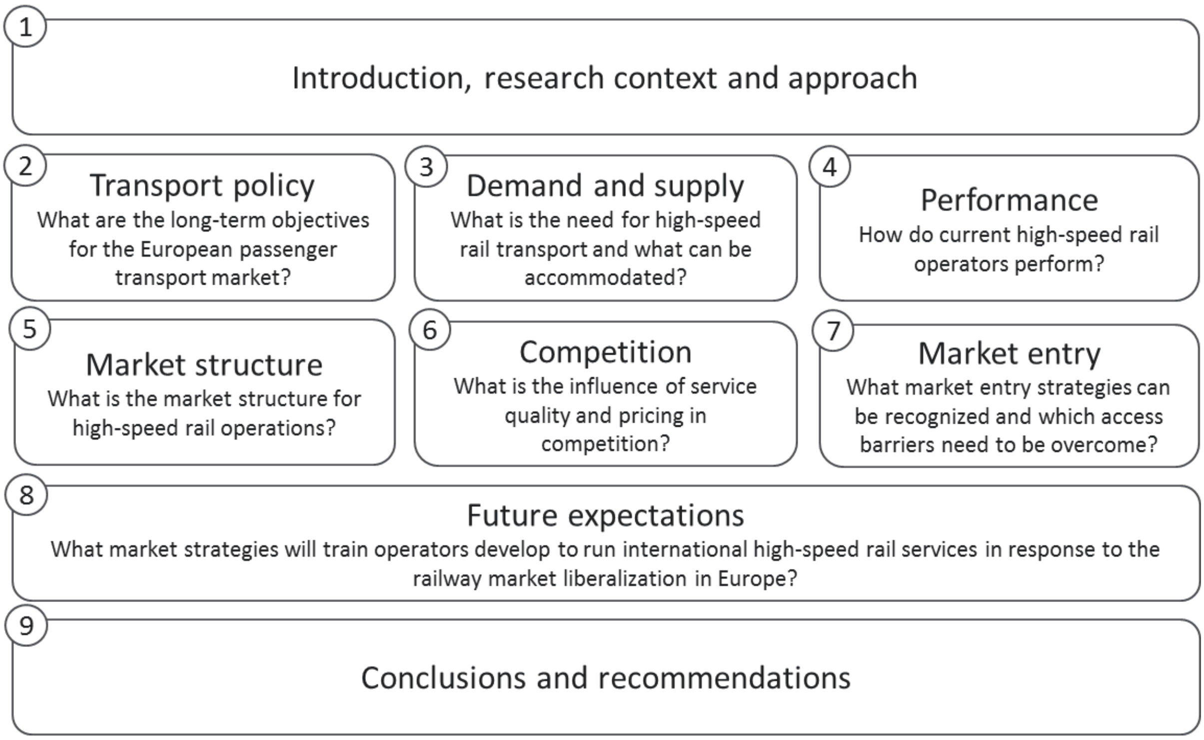

Figure 1.2 - Structure of the thesis and research questions

Chapter 2 gives an outline of the European transport policy and the implications for international cross-border traffic. Attention is paid to the market structure and a comparison is made with international rail freight transport and the airline industry.

Chapter 3 describes the market for international high-speed train services, starting with the need and demand for high-speed passenger transport and the evolution of high-speed rail traffic in the world[1]. The relation between income and the high-speed travel demand is investigated. On the supply-side, the evolution of the available rail network and rolling stock fleet is analysed in relation to high-speed rail growth. The market size and market share is

[1] This chapter is based on the presentation at the 8th UIC Congress on High-Speed Rail in Philadelphia in July 2012 and the paper presented at the 13th World Conference on Transport Research in Rio de Janeiro in July 2013.

explained based on the current market situation, the growth perspectives and the attractiveness of routes.

In chapter 4, an international performance comparison is made between eight high-speed rail operations, four in Europe (France, Germany, Spain, Italy) and four in Asia (Japan, Korea, Taiwan, China) to identify the best HSR practices in the world and to clarify operational performance and efficiency[2]. For this purpose, the HSR system is represented as a Multiple Input Multiple Output (MIMO) system. In the first part, a multiple dimension ratio analysis with selected key performance indicators is used to compare performance. In the second part, a Network DEA model was applied to compare the overall efficiency and the efficiency of the production and marketing process of the eight selected HSR systems.

Chapter 5 presents an analysis of the six-forces model for the high-speed passenger transport industry to identify the market structure and players. The Structure-Conduct-Performance model is used to structure relevant variables to investigate the behaviour and performance of air and rail transport providers. A multi-linear regression analysis is used to identify the importance of the conduct variables of all market players involved. This model is applied to the London-Paris market which is also described in detail in this chapter. In the first place the analysis was done for all market players (Eurostar and airlines) and in the second place with Eurostar only.

A game theory model is presented in chapter 6 for price competition with differentiated products in an oligopolistic market and applied to the London-Paris-Brussels passenger transport market[3]. The goal of this chapter is to clarify the inter- and intra-modal competition in the Western European cross-border high-speed railway market and to analyse the market effect of rail policies and strategic behaviour of high-speed rail operators. Cost structures of air, rail and road transport are analysed to make an accurate estimation of marginal costs. Simulation results for three different scenarios are presented i.e. the increase of infrastructure charges, the introduction of new trains with higher seating capacity and the entry of a new rail competitor.

Before discussing strategies for high-speed rail operators, the current behaviour of international high-speed rail operators and inter-modal competition on five important cross-border links in Western Europe are reviewed in Chapter 7. Market entry is clarified from the viewpoint of the European Commission and from the operators' perspective. It gives an overview of possible market strategies operators may adopt and access barriers for new entrants in high-speed rail transport are discussed using the MATOF framework to give insight into the market, administrative, technological, operational and financial hurdles that can hinder market entrance for operators. In the same chapter, we analyse the progress of the rail liberalisation process in Europe and the way rail infrastructure is managed and charged in the EU Member States.

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[2] The material of this chapter has been presented at the 13th World Conference on Transport Research in Rio de Janeiro in July 2013 and at the European Transport Conference in Frankfurt in September 2014.

[3] The material of this chapter has been presented at the 14th World Congress on Transport Research, 10-15 July 2016, Shanghai, China.

In Chapter 8, we pull the information together structured according to the SCP elements to outline future expectations for high-speed rail in Europe in the short, medium and long term. It discusses the expectations for the future based on potential market strategies high-speed rail operators may adopt. Lessons are taken from experiences with open access competition in the domestic market in various European Member States.

The answers to the research questions, the research conclusions and the recommendations for the European Commission and high-speed rail operators are presented in Chapter 9, together with some indications for further research. The conclusions are organised in line with the research questions as listed and the associated chapters in this thesis (see figure 1.2), before answering the main research question "*What market strategies will train operators develop to run international high-speed rail services in response to the railway market liberalisation in Europe?*"

The appendices contain background information on performance of high-speed rail between 1964 and 2015, the development of the high-speed rail network and rolling stock fleet in the world, the results from the NDEA performance benchmark for six Asian high-speed rail operators, an outline of the simulation process and associated calibration and validation results and specific information and preprocessing results regarding the input data on market shares, fares and operating costs needed to run the economic models as presented for the London-Paris market. A separate model is presented, specifically for the calculation of the rail operating costs.

2 Transport policy

2.1 Introduction

Over the last decades, the expanding European Union (EU) has developed its own transport policy based on the four freedoms of movement (goods, services, capital and labour) as declared in the Treaty of Rome in 1957. Traditionally, the railway sector in Europe was characterised by monopolistic structures and a strong presence of public ownership (Valri 2013). Referring to the SCP-model in chapter 1, the European transport market is governed by a number of policies regarding competition, free movement, trade, environment and regional development. The European transport policy as described in White Papers, Railway Directives and Railway Packages have set the direction and framework for the introduction of competition and liberalisation of the railway market.

2.2 European railway policy

A first White Paper from the European Commission named “A Strategy on Revitalising the Community’s Railways” was published in December 1996. This was followed in 2001 by the White Paper “European transport policy for 2010: time to decide” (EC 2001). It recognises that a common transport policy and the development of Trans-European Networks (TEN) are of vital importance for improving the competitive strength of the region and for bridging social and cultural differences. That this is necessary is apparent from the following passage; *“The road transport currently accounts for 44% of the total goods transport, against 41% by short distance shipping, 8% by rail and 4% by inland shipping. Concerning passenger transport, the road has an even more dominant position with a market share of 79 %, while air travel with a market share of 5 % has almost caught up with the railway’ 6%.”* (EC 2001, p. 11). Mainly the development of freight transport and the integration of modes of transport in the transport chain are of strategic importance to Europe: *“the international goods transport achieves an average speed of just 18 km/hour: which is slower than an icebreaker keeping a shipping lane free in the Baltic Sea!”* (EC 2001, p. 29 and p. 31). The high speed trains that have been operational in Europe since 1981 are a good alternative, on many routes, to air travel qua travel time, comfort and price: *“The market share of the airways between Madrid and Sevilla has fallen from 40 to 13% since the arrival of the high speed line”* (EC 2001, p. 58).

The 2001 White Paper has an accompanying action programme in which revitalising the railway plays an important part. Four actions are mentioned in this respect: i) Opening up the European railway market, ii) Improving safety on the rails, iii) Building new infrastructure and iv) Decreasing environmental hindrance.

The mid-term review of the White Paper entitled “Keep Europe moving - Sustainable mobility for our continent" (EC 2005) commissioned by the European Commission forecasts an increase in transport by rail of 13% for goods and 19% for people between 2000 and 2020. As all other forms of transport (road, inland shipping, pipelines, and shipping) will grow faster in the same period, the share in the modal split for rail transport will decrease: from 11 to 8% for freight – and from 6 to 5% for passenger transport.

The latest White Paper “Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system” is taking on the challenge of *“seeking a deep transformation of the transport system, promoting independence from oil, the creation of modern infrastructure and multimodal mobility assisted by smart management and information systems.”* (EC 2011, p. 8). An efficient and low carbon transport system is needed to guarantee the “*well-being of people and the competiveness of businesses in Europe.*” (EC 2011, p. 32). “*The creation of a single European Railway Area is essential to this purpose.*” (EC 2011, p. 31)

The EC has defined ten goals for a competitive and resource-efficient transport system. Specifically for high-speed rail traffic, the goals 4 and 6 are of paramount importance (EC 2011, p. 34):

> *“(4) By 2050, complete a European high-speed rail network. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050, the majority of medium-distance passenger transport should go by rail.*
>
> *(6) By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system.”*

The EU set itself the goal of creating new dynamics in railway transport in order to be able to compete better with other modes of transport. Since 1991, significant legislation efforts have been made concerning public service obligations (Regulation 1893/91/EEC amended 1191/69/EEC), the development of the Community’s railways (Directive 91/440/EEC), the licensing of railway undertakings (Directive 95/18/EC) and the allocation of railway infrastructure capacity and charging of infrastructure fees (Directive 95/19/EC) (Valeri 2013). In order to achieve an integrated rail space in the entire Union, the European Commission adopted a number of guidelines and directives that were contained in three Railway Packages. The First Railway Package that was proposed by the EC in 1998 consisted of three directives (2001/12/EC, 2001/13/EC and 2001/14/EC) that enabled operators to offer international train services on trans-European freight corridors under the same conditions. In April 2004, the Second Railway Package was adopted with three guidelines (2004/49/EC, 2004/50/EC and 2004/51/EC) in order to secure railway safety and to accelerate achieving interoperability between national networks, and a directive (881/2004) to establish an European Railway Agency (ERA). The focus of the Third Package was mainly on the certification of the train drivers and the opening up the market for cross-border passenger services by 1 January 2010 laid down in two directives (2007/58/EC and 2007/59/EC) and a regulation ensuring basic rights for passengers and quality standards (EC 1371/2007). As a result of the three Railway Packages, the legislative framework for rail transport in Europe was more or less ready[4]. Implementation however, is the challenge that will require a lot of attention during the next decade. We should not look primarily at the “law in books” but at the “law in action”, that means at the markets themselves and the entry options and

[4] The technical pillar of a fourth railway package regarding the opening of domestic markets has been approved in April 2016, but the political pillar is still under debate.

obstacles that exist in reality. (Eisenkopf 2006). The Rail Liberalization Index gives an overview per Member State regarding the implementation status of the Railway Packages. Following earlier reports from 2002, 2004 and 2007, this study was carried out in 2010 for the fourth time in succession (Kirchner 2011). An interesting finding in the latest report is that the number of external operators and their market share within a country shows & positive correlation with independence and competences of the rail regulator (figure 2.1). *"In countries that have a special regulatory body with greater powers and more independence, there is more competition than in those countries where the regulatory body is incorporated in a Ministry or railway authority."* (Kirchner 2011)

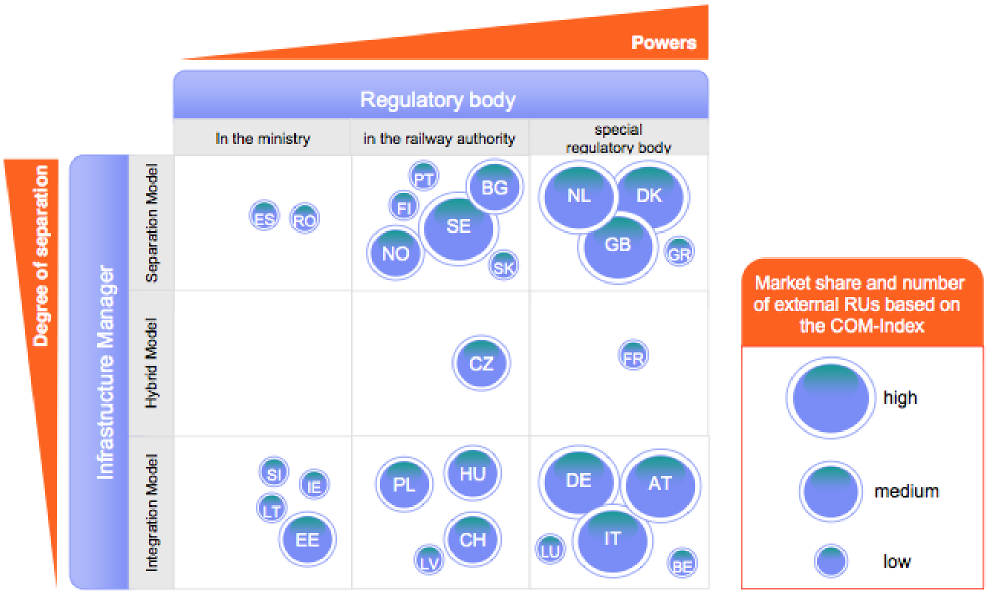

Figure 2.1 - Relationships of regulatory bodies and infrastructure managers in Europe

Source: Kirchner 2011

To open domestic passenger rail markets to competition, to reduce time-to-market of rolling stock and to improve the governance of railway infrastructure, a Fourth Railway Package was proposed. The European Parliament approved the technical pillar of the Fourth Railway Package, but the political pillar covering market opening is still under debate[5].

2.3 Lessons from other industries

Two industries are of special interest when looking at the development of the international high-speed train services market: i) the airline industry and ii) the rail freight transport industry. Some lessons can be learned from these sectors while both have gone through a comparable deregulation, liberalisation and privatization process over the last decades. The market opening for cross border passenger services by 1 January 2010 gives new opportunities to incumbent railways and new start-ups to enter this market. It seems logical that they will learn from experiences from the rail freight operators and the airlines that have already been through a process of liberalisation and consolidation.

2.3.1 Rail freight transport

The opening of the European market for rail freight transport on 1 January 2007 has given way to new open-access operators. Many new players have entered the market, but

5 Railway Gazette, 28 April 2016

accelerated by the economic downturn, volumes fell and a shake-out and consolidation has taken place where incumbent railways have acquired these new entrants. The rail freight sector in Europe was facing big challenges after the financial crisis. Besides surviving the economic crisis, inter-modality, the “last mile”, access charges, network access and capacity were major challenges to tackle (Barrow, 2009). Although the European Commission claims that the liberalisation has been a success, the open access railway operators do not fully agree. From figure 2.2, it can be seen that new open access freight operators did not survive. These are the same type of hurdles that may occur in cross-border passenger traffic.

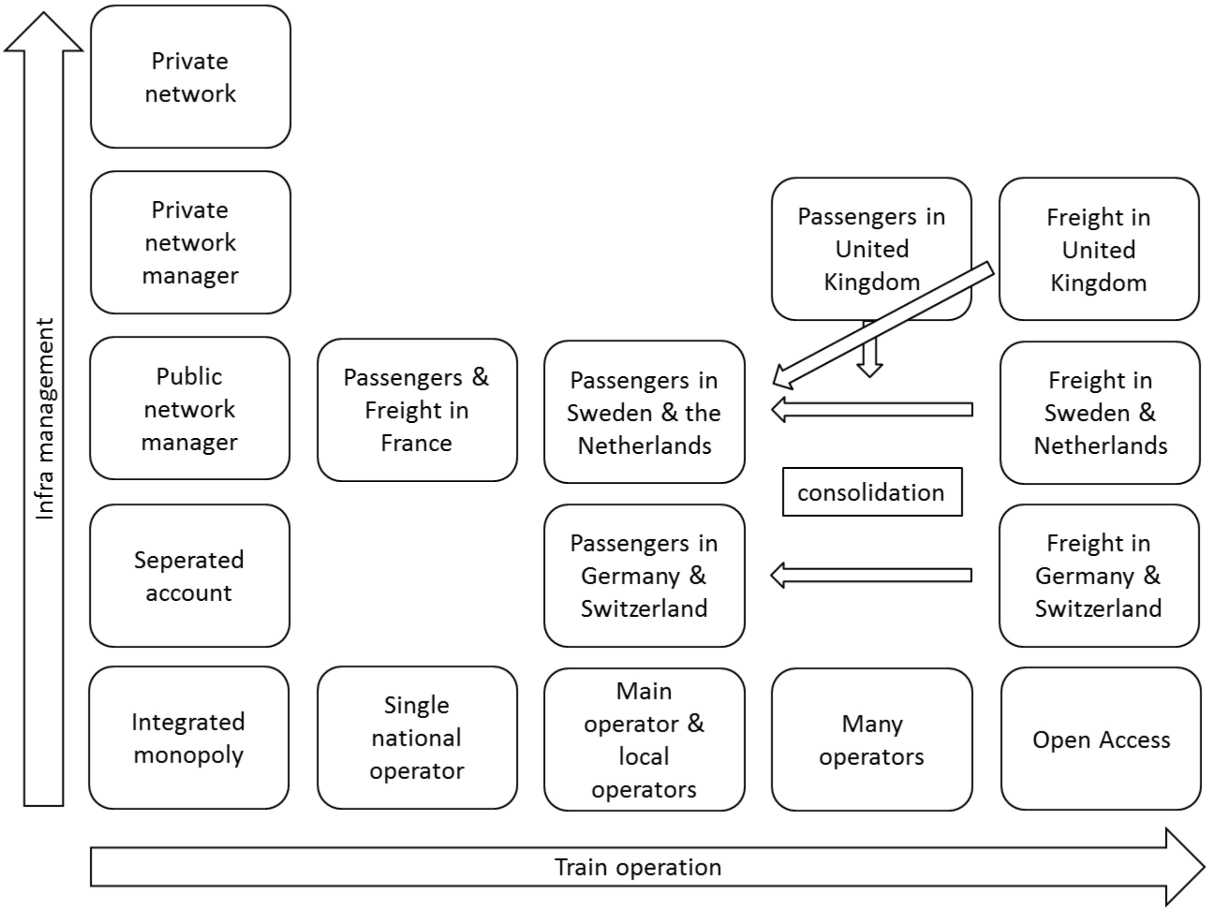

Figure 2.2 - Consolidation of freight operators in the European rail market

2.3.2 Passenger airlines

The airline industry has gone through a comparable deregulation process with the entry of no-frills carriers. Liberalisation and deregulation of the air transport market was introduced in Europe in the eighties and took about ten years. Three air measure packages were implemented which established different stages of deregulation (Valeri 2013). This sector learned that in the end there is only room for a few large cross-border operators (Ulrich et al 2009). In Europe, high–speed railways and airlines are competing for the favour of business and leisure travellers. The modal share in Europe for railways fell from 6.6 to 6.1% from 1995 to 2007, while for airlines, it grew from 6.3 to 8.6% over the same period. This might change with increasing interest in high-speed rail. While air transport demand grew at an average annual rate of 5% over the last decade, high-speed rail passenger demand has grown by 16% over the same timeframe (Janic 2003). The policy from the European Commission is to encourage travellers to change modes and move from air to rail transport

(EC 2001). When it comes to strategy, "*passenger rail companies could improve their competitive position by learning from the leading airlines' and rail providers' best practices.*" (Ulrich et al 2009). High-speed rail may not be purely viewed as a competitor to air transport. It may not only be a substitute but also a likely potential complement to air networks (Givoni 2007). Considering multi-mode trips is likely to further improve a rail operator's likelihood of success.

2.4 Conclusions and discussion

The railway market in Europe has gone through a process of liberalisation for both freight and passenger transport since the first White Paper was published by the European Commission in 1996. After two decades, the legislative framework is finished, but the liberalisation process is ongoing and not finalised yet. The historical monopolistic railway structures were reorganised by separation of rail infrastructure management from railway operations and the establishment of regulatory bodies. In the EU Member States, different organisational arrangements can be recognised to meet the requirements from the EC Railway Directives. In Europe, airlines and rail freight have gone through a comparable liberalisation process as passenger rail. In both industries, it became apparent that in the end, there is only room for a few large international operators.

With reference to the SCP model (figure 1.1), the government policy sets the direction for the market structure and the behaviour and performance of the acting firms in this market. The reform of the European railway industry has broken down the monopolistic national railway companies and has set the conditions market opening and the introduction of competition between railway operators. The goal of liberalisation is to transform and revitalise the railway market and to make railways more efficient and competitive with private cars, coaches and airlines.

The market opening gives opportunities for new high-speed rail operators to enter the international rail market. On the one hand, the European transport policy supports new entrants with a legislative framework and structures that create a level playing field. On the other hand, it is a challenge for new operators to comply with all directives and rules set by the European Commission. It will take serious time, money and effort to meet all the European and national requirements. Another major challenge is to claim a position in a market dominated by incumbent railways with a strong home base and which are already settled on the most attractive and busiest routes in Europe. During the development of the railway directives, the incumbents had the advantage to get involved in the development of European legislation and to use their experience and knowledge to influence the outcome. In the meantime, they have had enough time to adapt to all agreed developments and changes.

Before moving over to the analysis of the Structure, Conduct and Performance elements, travel demand and supply conditions for the high-speed rail market are investigated in the next chapter.

3 Demand and supply[6]

3.1 Introduction

The basic conditions regarding demand and supply are important inputs that structure the market as indicated in the conceptual research model in chapter 1. Demand depends on the mobility needs of citizens and supply is closely related to the available travel options with their specific characteristics. This chapter clarifies the need for high-speed rail traffic and the resulting high-speed travel performance. When looking at the adoption of high-speed rail transport on the world map, Europe and Asia are the two regions that have substantial experience in developing, building and operating high-speed rail networks. Although there are some good examples of countries across the world adopting new high-speed rail technology, there are in fact eight countries in the world leading: in Europe: France, Germany, Italy and Spain and in Asia: Japan, Taiwan, Korea and China. Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. This chapter outlines developments in high-speed rail networks and rolling stock and characterises the most important high-speed railway systems in Asia and in Europe. It gives an overview of the development of the world's high-speed train fleet, the networks and system performance. This chapter starts with an overview of the current high-speed rail performance of operators in Asia and Europe and outlines the future opportunities for high-speed rail transport. A forecast is made for Europe based on an analysis of demand scenarios and the development of high-speed networks and rolling stock. Finally, the European high-speed cross-border travel market is highlighted in more detail.

3.2 Market size

The market size can be investigated at aggregate level with global, regional or national network data, or at disaggregate level with a focus on individual origin-destination pairs. The aggregate data give a good overview of the current situation. Market size is normally expressed in ridership i.e. the number of passengers carried or in passenger-kilometers. The latter gives more information as it incorporates the average distance travelled by passengers.

The traffic performance delivered by high-speed rail networks in terms of ridership (number of passengers per year) is sketched in Appendix A for the four Asian (Japan, China, Taiwan, Korea) and four European countries (France, Germany, Spain, Italy) that run high-speed rail services. The data is derived from UIC data, annual reports of individual operators and national statistics.

3.2.1 Asia

Figure A.1 in appendix A shows the early start of Japanese Railways (JR) in 1964 and the steady growth and development of HSR technology in Japan over the last decades. Due to the steep growth in China since 2006, in 2010 the high-speed rail ridership has reached the same level as in Japan, reaching a travel volume of 440 million passengers in 2011. Detailed

[6] This chapter is based on the presentation at the 8th UIC Congress on High-Speed Rail in Philadelphia in July 2012 and the paper presented at the 13th World Conference on Transport Research in Rio de Janeiro in July 2013.

official ridership figures for HSR services in China are generally not available, but the World Bank reported that in 2010 about 290 million passengers (17% of the total carried in China) travelled on services operating at 200 km/h (both on dedicated high-speed lines and "speeded-up" conventional lines (World Bank 2012). Introduction of HSR led to a shift from Conventional Rail (CR) to HSR services and induced a significant amount of new traffic as can be seen from the three cases presented: Changchun – Jilin, Wuhan – Guangzhou and Beijing – Tiajing (Bullock et al 2012). These generated trips come on the one hand from competing modes like private cars, busses and airplanes and on the other hand from new travellers that enter the system caused by growing mobility needs. On 26 December 2012 China's Ministry of Railways inaugurated the world's longest HSR line which connects Beijing to Guangzhou. The 2,298 km line is covered at an average line speed of 300 km/h, which enables the journey to be completed in approximately 8 hours. As HSR operations in China have only started recently, the expectation is that the continuous growth of the network and rising incomes will lead to increasing travel demand and ridership. In Korea and Taiwan, high-speed rail developments started in 2001 and 2006 respectively. These networks are relatively small compared to Japan and China.

3.2.2 Europe

In figure A.1 in appendix A, the start of the TGV projects in Europe in 1981 can be recognized, followed by developments in Germany, Italy and Spain. In 2008, the high-speed rail traffic performance in Europe exceeded 100 billion passenger-km's (figure 3.1). More than 50% was realised in France by SNCF and 20% in Germany by DB, mainly on their national high-speed lines. Over the last 10 years, traffic volumes doubled with an average annual growth rate of 7%. This strongly correlates to the opening of new high-speed lines in the various countries. Figure 3.1 shows a growth stagnation over the last 4 to 5 years in France and Germany with a traffic performance of 54 and 25 billion pkm respectively.

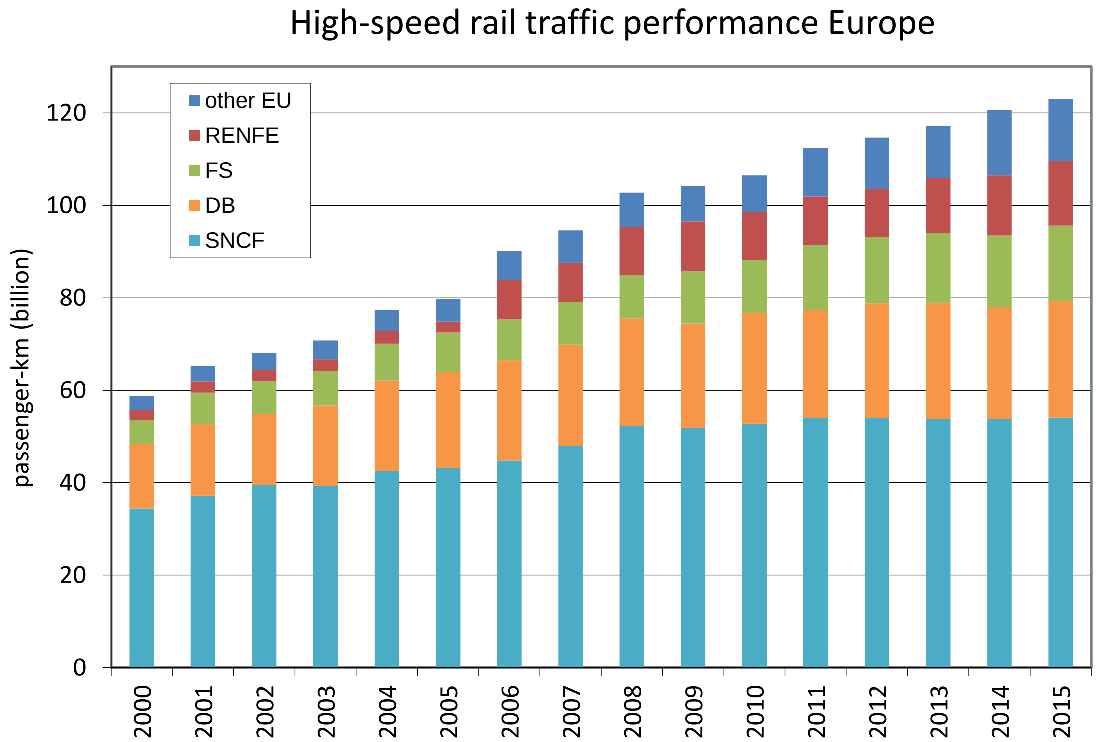

Figure 3.1 - High-speed rail traffic performance in Europe
Note: Figure by author based on data from UIC, Annual reports and National statistics

Traffic performance is the result of the number of passengers and the average distance traveled on the network. The average travel distance calculated for the 11 major networks in the world shows that travellers in Europe take longer trips than in Asia (details can be found in Appendix A). In 2015, the average trip length in Europe was 396 km compared to 241 km in Asia. There are also differences within Europe and Asia. In France and Spain, the distance is about 455 km, while in Italy and Germany, it is 350 and 320 km respectively. Travel distances in Japan, Korea and China are approximately 260 km and in Taiwan 190 km. It is remarkable to see that the trip length is relatively short for a large country like China with large distances between cities. Differences can be found between the four high-speed rail operators in Japan (JR Central, JR East, JR West and JR Kyushu).

3.3 Demand drivers for high speed

Research from Schäfer and Victor shows that rising income nearly directly leads to rising demand for mobility (Schäfer and Victor 2000). Gross Domestic Product (GDP) per capita, i.e. the total value at current prices of all final goods and services produced within a country during a specific time period divided by the average population for the same one year, strongly correlates with traffic volume in that country. Schäfer and Victor also concluded that as mobility rises, travellers shift to faster modes to remain within the fixed travel time budget of 1.1 h per person per day. The travel time budget is stable over a wide range of income levels, geographical regions and cultural settings. Residents of African villages devote similar time for travel as those of Japan, Singapore, Western Europe or North America. The results for the Travel Time Budget per capita from 36 city surveys and 20 national travel surveys and 2 data points from Africa, Tanzania and Ghana, are shown in figure 3.2 (Schäfer and Victor 2000).

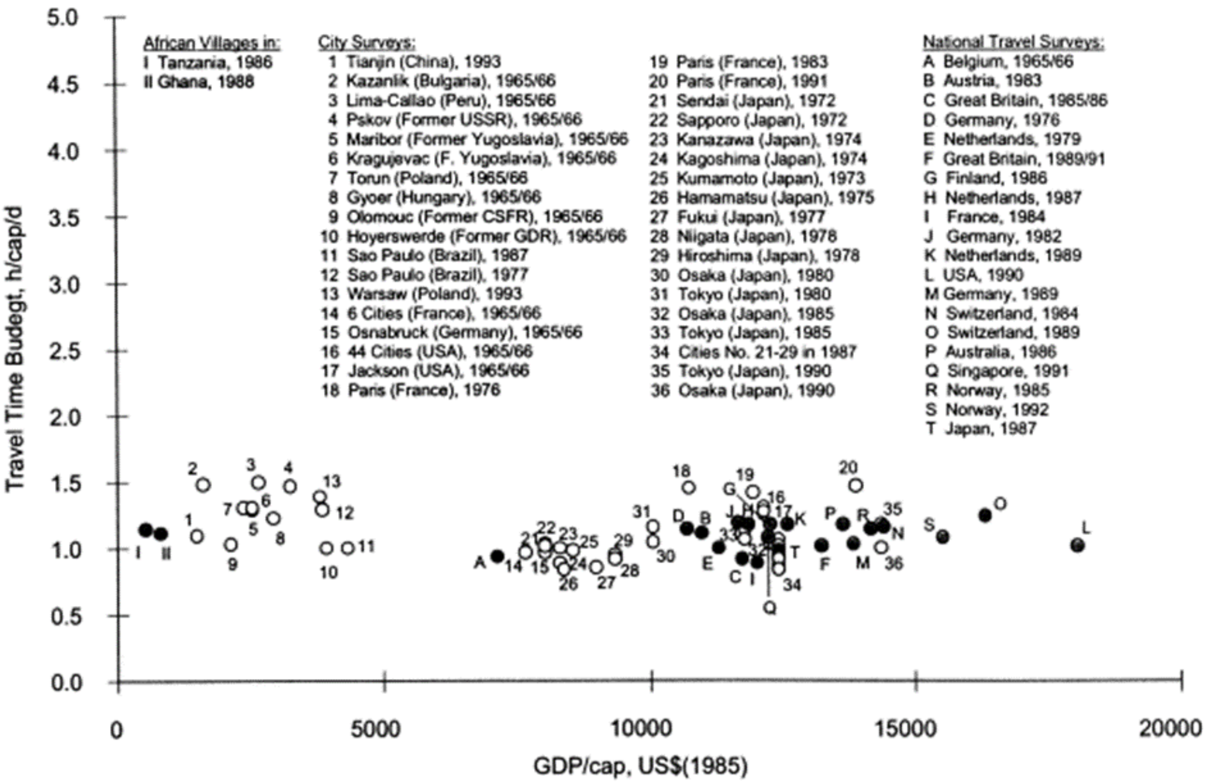

Figure 3.2 - Average per capita Travel Time Budget (TTB)
Source: Schäfer and Victor, 2000

The data used in the research of Schäfer and Victor originates from surveys between 1965 and 1992. To verify if the conclusions are still valid with a focus on the European travel market, the analysis is repeated with more recent data (1995 till 2014) for the 28 Member States in the European Union. For the EU28, the correlation between income and mobility is illustrated in figure 3.3 based on data from the European Statistical Pocketbook 2016 (EC 2016). The graph shows an exceptionally good linear fit between traffic volume and GDP indicating that mobility increases proportionally with higher income per inhabitant. This effect is stronger for high-speed modes, indicating that travellers shift to faster transport modes with rising income. In the time frame 1995 till 2014, the EU28 GDP per capita has grown by 36% (1.6% per year) and mobility expressed in traffic volume per capita for all transport modes increased accordingly by 17% (0.8% per year). Figure 3.3 also shows that the growth in traffic volume for high speed modes (air and high speed rail) between 1995 and 2014 was 79% (3.1% per year), more than six times higher compared to the low speed modes (passenger cars, powered two-wheelers, coaches, buses, tram, metro, conventional railways and sea) that grew by 12% over the same period. Since 2008, the EU28 GDP has decreased due to the financial crisis, resulting in a higher density of data points in the upper right corner of figure 3.2. In 2014, the GDP has recovered to the level before the crisis. The financial crisis had also its effect on the growth in travel volume, but less prominently.

For high-speed travel, passengers may choose between air and high-speed rail to stay within their travel time budget. Over the 1995-2014 period, high-speed rail in the EU28 has managed to exceed the growth in air transport. The high-speed rail share has grown from 8.6% to 16.6% from 1995 till 2009, but fluctuates around 16% for 2009 till 2014 (EC 2016).

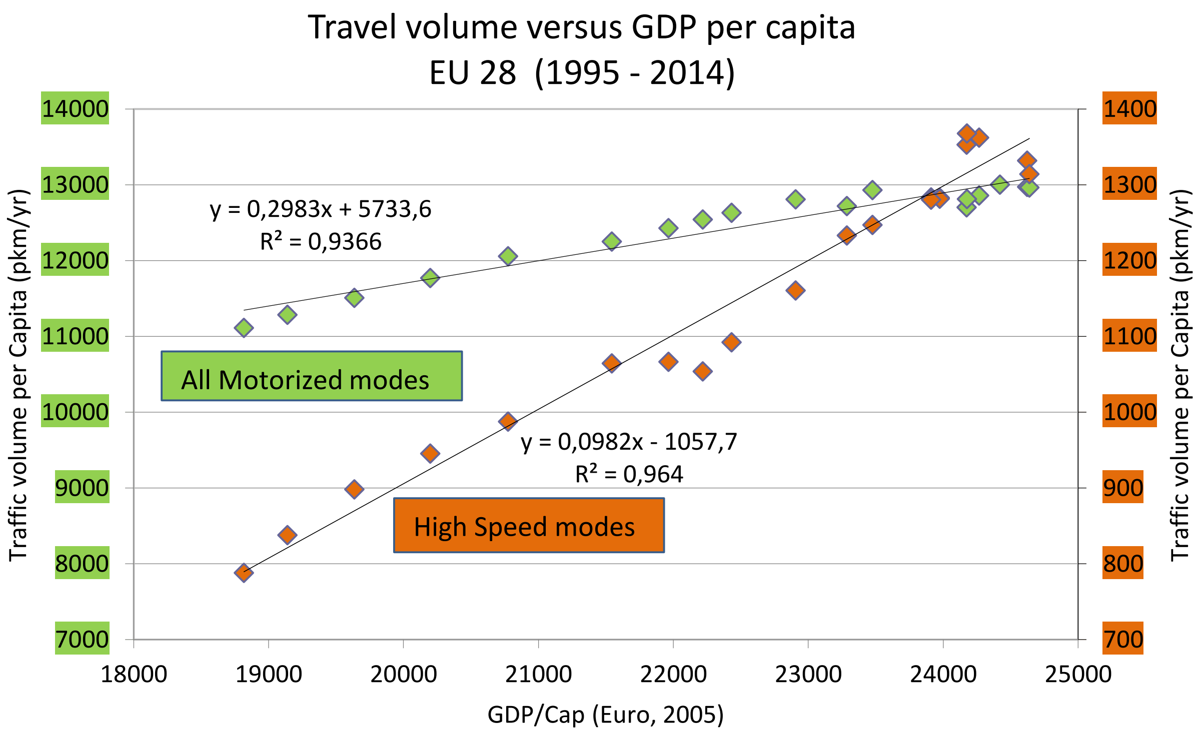

Figure 3.3 - Correlation between (high-speed) traffic volume and income for EU 28
Note: Figure by author based on data from Eurostat Statistical Pocketbook 2016 (EC 2016)

As already indicated by Schäfer and Victor (2000), GDP and GDP growth are useful indicators to predict high-speed travel demand. The IMF World Economic Outlook gives a five-year forecast of GDP developments for all countries in the world (IMF 2016). Figure 3.4 shows that leading economies with high GDP per capita and strong growth like Australia, USA, Canada, Japan and Europe give good opportunities for high-speed travel modes. Over the last 35 years (1980-2015), Europe's average growth of GDP/Cap was 3.1% from 1980 till 2015 and a steady 3.5% GDP growth is forecast for the next five years (IMF 2016). This forecast steady GDP growth may lead to a growing mobility and higher travel demand giving good opportunities for high-speed rail. The lower income per inhabitant in 2015 in the BRIC countries (1,600 US$ per capita in India and 8,500 US$ per capita for Brazil, Russian Federation and China) give questionable prospects for high-speed travel modes. In practice though, not only income per head is determining high-speed rail developments. It is evident that for example the fast development of an extensive HSR network in China has boosted the growth of high-speed train services and limited the growth of air travel. China will show continuous growth for the coming years with CRH becoming the world's largest HSR brand. Brazil, India and the Russian Federation are also planning and building new high lines to accommodate high-speed train services in the future. The forecast GDP growth in the BRIC countries, which varies between 4.8% for Brazil and 9.2% for China may accelerate this development and improve the future situation. An important condition is that governments support the development of HSR networks in their transport plans. Policy makers planning for a sustainable transport future need to take these factors into account as key drivers for mobility growth.

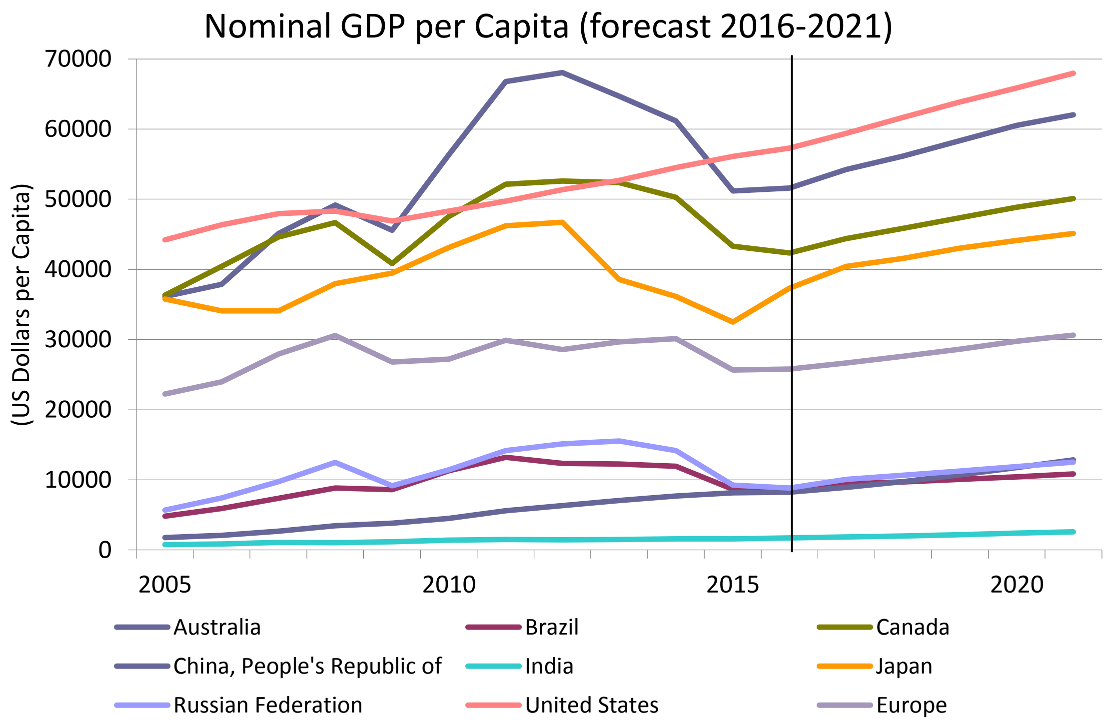

Figure 3.4 - GDP forecast from 2016 until 2021
Note: Figure by author based on data from IMF World Economic Outlook, October 2016

Besides HSR markets in Europe and Asia that will continue to grow over the next 20 years, opportunities in the US, Canada and Australia are there, but investments in HSR infrastructure are needed to challenge air transport. In the longer run, countries like Brazil, India and Russia may profit from HSR introduction in their transport policy. In these countries, plans, feasibility studies and even actual projects are built to make the first steps into the HSR future. In the US, HSR was supposed to be President Obama's signature transportation project, but despite the administration spending nearly $11 billion since 2009, the US still lags far behind Europe and Asia in HSR development (Jiang 2014).

3.3.1 Demand forecast

The way mobility in Europe will develop over the next decades is decisive for future demand for high-speed rail. In general, there are good opportunities for high-speed transportation in industrialized countries with economic growth, though competition between high-speed trains and airlines may be fierce in these markets. To explore the future opportunities, a traffic prognosis is made for till 2025. An extrapolation of the historical data given by the EC transport statistics over 1995 till 2014 (EC 2016), combined with the average forecast GDP growth for the EU 28 by IMF (IMF 2016) gives an indication of the future demand for high-speed traffic in Europe (see also figure 3.2 and 3.3). The linear trend line for Travel Volume (TV) per capita for all high speed modes and for HSR derived from an ordinary least squares estimation is given by:

All high-speed modes: $TV_{HS}/cap = 0.0982 * GDP/cap - 1058$ (pkm/yr) ($R^2 = 0.964$)

High-speed rail: $TV_{HSR}/cap = 0.0252 * GDP/cap - 411$ (pkm/yr) ($R^2 = 0.899$)

with GDP/cap given in Euro/year[7]. The resulting traffic prognosis given for 2020 and 2025 in table 3.1 is based on the actual yearly average growth in GDP/cap of 1.4% between 1995 and 2014 for EU 28 (EC 2016a) and a 3.5% forecasted GDP/cap growth for EU 28 (IMF 2016). In addition, the table is completed with a low growth (+0.8%/yr) scenario, which was the actual GDP/cap growth between 2009 and 2014, during the financial crisis.

Table 3.1 - Traffic prognosis for high speed rail travel

Scenario	Variable	Unit	2015	2020	2025
Low Growth	GDP	(€/cap)	24616	24813	25012
(GDP/cap: +0.8%/yr)	TV_{HS}	(pkm/cap)	1359	1379	1398
	TV_{HSR}	(pkm/cap)	209	214	219
	TV_{HSR}/TV_{HS}		15.4%	15.5%	15.7%
Average Growth	GDP	(€/cap)	24763	25109	25461
(GDP/cap: +1.4%/yr)	TV_{HS}	(pkm/cap)	1374	1408	1442
	TV_{HSR}	(pkm/cap)	213	222	231
	TV_{HSR}/TV_{HS}		15.5%	15.8%	16.0%
High growth	GDP	(€/cap)	25275	26160	27076
(GDP/cap: +3.5%/yr)	TV_{HS}	(pkm/cap)	1424	1511	1601
	TV_{HSR}	(pkm/cap)	226	248	271
	TV_{HSR}/TV_{HS}		15.9%	16.4%	16.9%

Note: Table by author based on data from Eurostat Statistical Pocketbook 2016 (EC 2016) and IMF data mapper (2014)

[7] The use of historical data to forecast future mobility can lead to unreliable results. For long-term predictions, the accuracy of the prognosis becomes questionable. Although, non-linear curve fitting gives slightly better R^2 values, there is no reason to assume that the relationship between travel volume and income is non-linear. A more detailed study is needed to investigate the contributing factors that shape travel demand and to model the demand curves.

Depending on their rise in income, in 2025, Europeans will approximately 16% of their high-speed travel need for high-speed rail trips. High-speed rail will benefit the most in the high-growth scenario.

Travellers can only choose between air and rail when a high-speed rail alternative is available. A high-quality railway network and rolling stock fleet are required to offer attractive high-speed train services to the public. When high-speed travel demand grows faster than the transport capability of the rail network and the train fleet, the market share for high-speed rail services will be limited as passengers may choose to travel by plane.

3.3.2 The high-speed network capability

In 35 years' time, starting in 1981, almost 8,600 km high-speed line was built in Europe (UIC 2017a). The length of new high-speed lines in Europe doubled from 2005 till 2016 (average growth of about 390 km or 6.5% per year). It is expected that this growth will continue till at least 2025 as can be seen from figure 3.5, which gives an overview of high-speed lines that are in operation, under construction, planned, listed on the long-term planning or under study. Planned means that the decision for construction is taken and that there are contracts signed and budgets available the latter. For long-term planning, projects' exact timing and financing still needs to be arranged. Projects are still on-going and the expectation is that networks will be extended for the next 10 to 15 years. The forecast is that the total length of the high-speed network in the world will exceed 70,000 km in 2025 (UIC 2017a). A detailed overview of high-speed rail projects in the world and a detailed view for Europe, Asia and the Rest of World is given in Appendix B. Countries like India, the US, Canada, Australia and Norway are investigating the feasibility of new high-speed rail networks and studying the opportunities for having high-speed rail. These plans add up to an extra estimated 10,000 km of high-speed rail network.

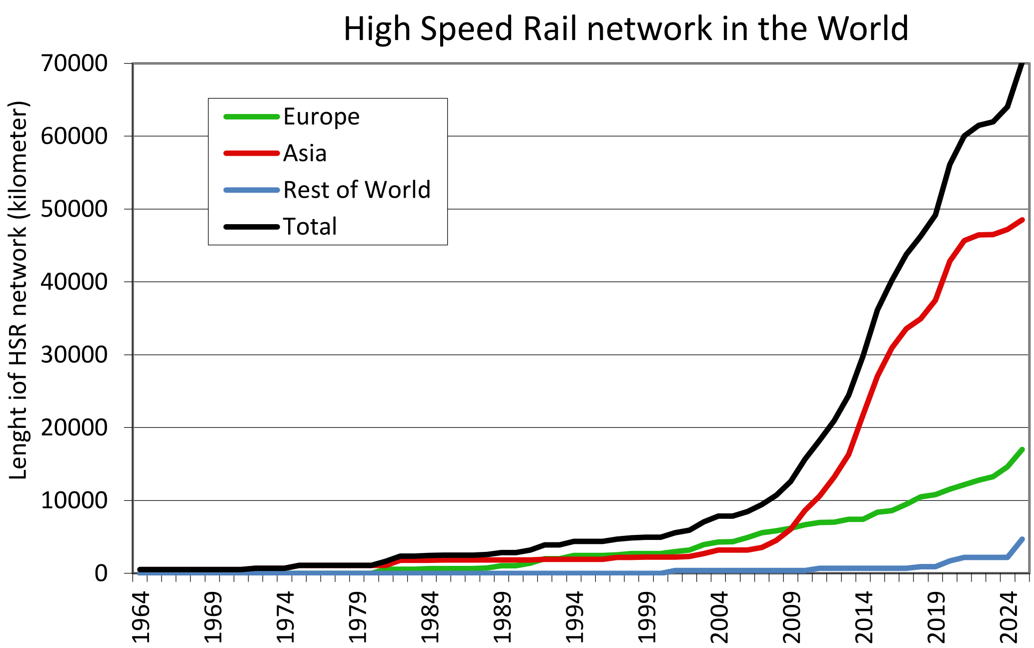

Figure 3.5 - Development of high speed rail network in the world

Note 1: Figure by author based on data from UIC High Speed Lines in the World overview (UIC 2017b)
Note 2: Projects "Under Construction "are assumed to be ready before 2022, "Planned" projects between 2022 and 2030 and "Long-term planning" projects between 2030 and 2040.

As illustrated by figure 3.5, after the opening of the first high speed line between Tokyo – Osaka in Japan in 1964, it took more than 15 years before Europe adopted the high speed rail concept starting in France with the opening of the Paris – Lyon TGV line. Also Italy was an early adopter on the Rome – Florence route, followed by Germany in de mid 80's and Spain in the early 90's. In 2009, Asia took over the lead, caused by a fast growing high-speed network in China. Based on the situation in 2016, figure 3.6 shows that in Europe (EU 28 plus Switzerland and Norway) at that time, 8,428 km was in operation, 2,346 km under construction, 7,288 km listed on the long-term planning and 380 km under study. In 2025, the total length of category I (> 250 km/h) high-speed lines will be around 17,000 km, about 25% of the world HSR network. In Asia, Japan was worldwide the high-speed rail innovator in the sixties. Korea and Taiwan introduced their HSR technology in 2004 and 2007. China was a relatively late follower, but over the last ten years a strong growth in network development and passenger traffic has taken place. In 2003, the Chinese Ministry of Railways launched their Mid to Long-Range Network Plan (MLRNP) targeting at 12,000 km's of high-speed passenger network by 2020 based on four north-south and four east-west corridors. This goal was already achieved in 2013 and in 2016 the total network length was almost 25,000 km with plans for another 10,000 km before 2030.

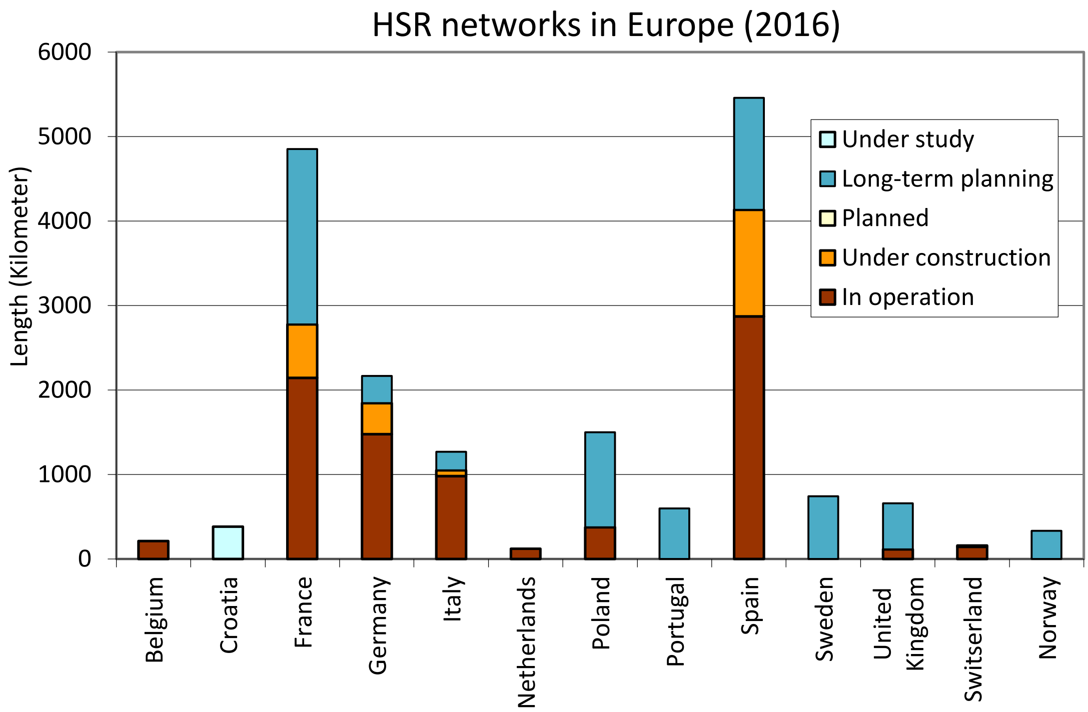

Figure 3.6 - High speed rail network in Europe in 2016

Note 1: Figure by author based on data from UIC High Speed Lines in the World overview (UIC 2017a)
Note 2: "Under study" projects added by author

Investments in HSR infrastructure vary considerably per country. Projects include both the building of new lines and improving and upgrading the existing network on important routes. The four biggest high-speed rail countries (France, Germany, Italy, Spain) are still expanding their networks as can be seen from figure 3.6. Projects that are under construction now in Spain will extend the network with over 30% in the next decade. The networks in Germany and France will grow by 20% and 23% respectively when the projects that are currently under construction will be put into operation. Building the Y-shaped line from Stockholm to Malmö and Goteborg as planned, will put Sweden on the high-speed map. The design and preparations for the HS2 project for a connection from London to Birmingham (stage 1) and Manchester and Leeds (stage 2) in the United Kingdom are in progress. Portugal and Poland have been considering new high-speed rail connections, but their plans are long-term now. In 2012, the Portuguese government has taken the decision against the construction of the high-speed link between Madrid and Lisbon[8].

Looking at the ridership in relation to the extent of the high-speed rail network as illustrated in figure 3.7, Japan accommodates approximately 350 mln. passengers per year, which is approximately the same amount as Europe (300 mln.), but on a network that is approximately one third of that of Europe. One could conclude that there is still a lot of room for growth in the number of trips in Europe on the existing HSR infrastructure, but there are many more factors of importance than just network length like the geography and network structure, the operational model, the size and characteristics of the rolling stock fleet and the maturity of the HSR system. Within Europe, large variations can be seen as well. Although the network in France is smaller than in Spain, the number of passengers in France is almost four times higher than in Spain. Of course, these results are only indicative as not only the number of passengers is of importance, but also the distance passengers travel per trip. In fact there is an indirect relationship between network length and travel volume. As the performance of the train fleet is the missing factor, it would be better to evaluate the correlation between yearly number of train kilometers and the network length. This ratio is further elaborated in a systematic benchmark approach in the next chapter. A difficulty that appears is that fleet performance is not always publicly available and is seen as confidential information from the train operators' point of view. Also the results depend for example on geography, the network's layout, the system's maturity and the operating model and the type of rolling stock operated for delivering the service.

New infrastructure boosts mobility, but the impact varies across countries and regions. This is very apparent for the evolution of the new high-speed rail networks in Europe and Asia (Figure 3.7). There is a strong correlation between the length of new high-speed lines and the traffic performance on the network. This relationship can be used to forecast the future performance through extrapolation on the basis of the future HSR network development[9]. Specifically the developments in Europe are highlighted in this case. The linear trend line for HSR Ridership (RS_{HSR}) and Travel Volume (TV_{HSR}) versus HSR Network Length (NL) in operation in the EU 28 between 1981 and 2015, derived from an ordinary least squares estimation is given by:

HSR Ridership: $RS_{HSR} = 0.0453 * NL$ (million pas/yr) ($R^2 = 0.961$)

HSR Travel Volume: $TV_{HSR} = 0.0167 * NL$ (billion pkm/yr) ($R^2 = 0.972$)

with NL in kilometers. Considering these linear equations and the development of the length of the HSR network, the future high-speed rail performance that the network can accommodate can be forecasted.

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[8] Europa Press, 22 March 2012

[9] The same remark applies here as for the forecast of future mobility that extrapolation can lead to unreliable results. For long-term predictions, the accuracy of the prognosis becomes questionable. Linearity is assumed, as there is no valid argument to argue that the relationship between travel volume and income is non-linear.

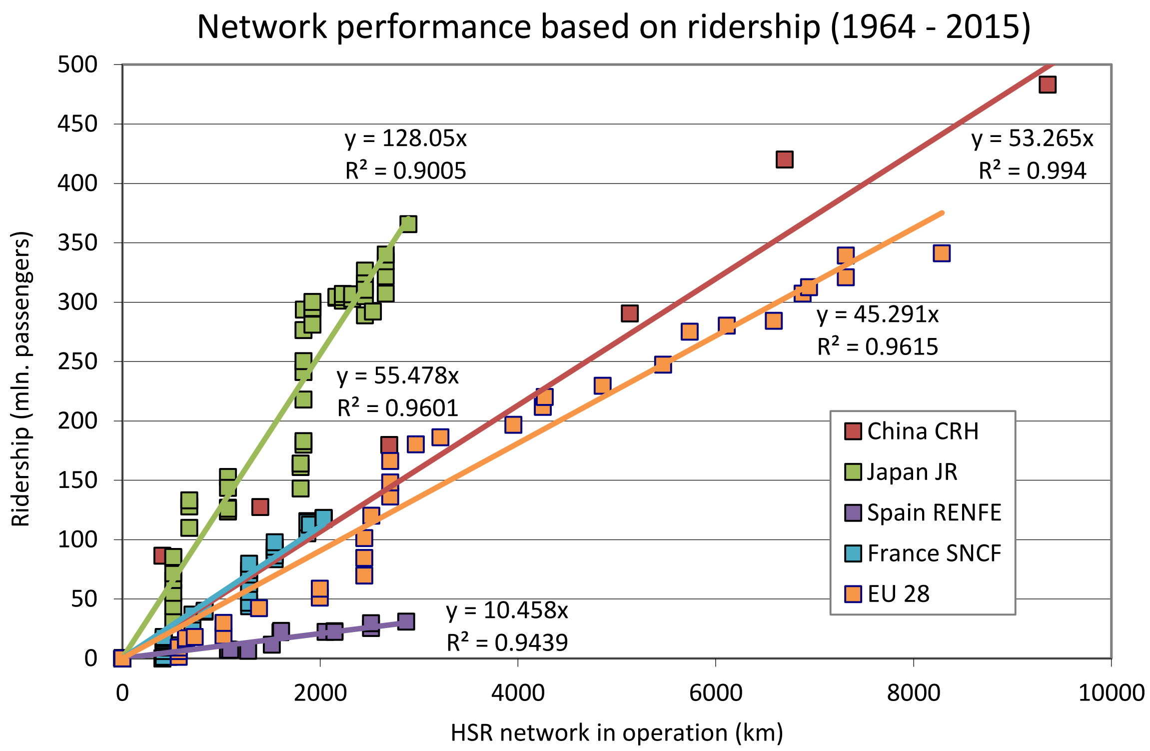

Figure 3.7 - Correlation high-speed network length and ridership

Note: Figure by author based on EC and UIC data

3.3.3 The rolling stock fleet capability

A fast growing fleet of high-speed train sets provides HSR services in the world. Figure 3.8 shows the development since 2008 in Europe and Asia and the projection made for 2025 by the UIC. The world's high-speed train fleet will double towards 2025. The rolling stock fleet in Asia is growing faster and since 2015 even bigger than in Europe. As there is a large variety in train sets, an overview and detailed analysis of the worlds' rolling stock fleet is given in Appendix C. There is a remarkable difference in capacity per train set between Asia and Europe. The average train seating capacity in Asian countries is 723 and in Europe 411 seats (figure 3.8). The reason is that in Asia, high-speed trains have train set configurations with 10 coaches on average with higher seat densities, compared to 8 coaches for European trainsets. In Europe, a tendency can be observed towards larger trainsets. Between 2007 and 2015, the average train capacity was between 400 and 430 seats, but the average seating capacity of trainsets recently ordered by the operators is about 535 seats. The new Velaro Eurostar trains, the ICE 4 trains from DB, the nine-car Hitachi trains in the UK and the new trains ordered by Renfe and Trenitalia all have above average seating capacity.

The correlation between performance and the key characteristics of the HSR system can be evaluated by combining the data of the high-speed fleet capacity and network length with the travel volume and ridership data as presented in figure 3.1 and appendix A. The correlations of ridership versus fleet capacity and travel volume with network length are investigated and figure 3.9 presents the resulting graph[10].

[10] The type of correlation is unknown, but as the results are only used for indicative purposes, a linear correlation is assumed.

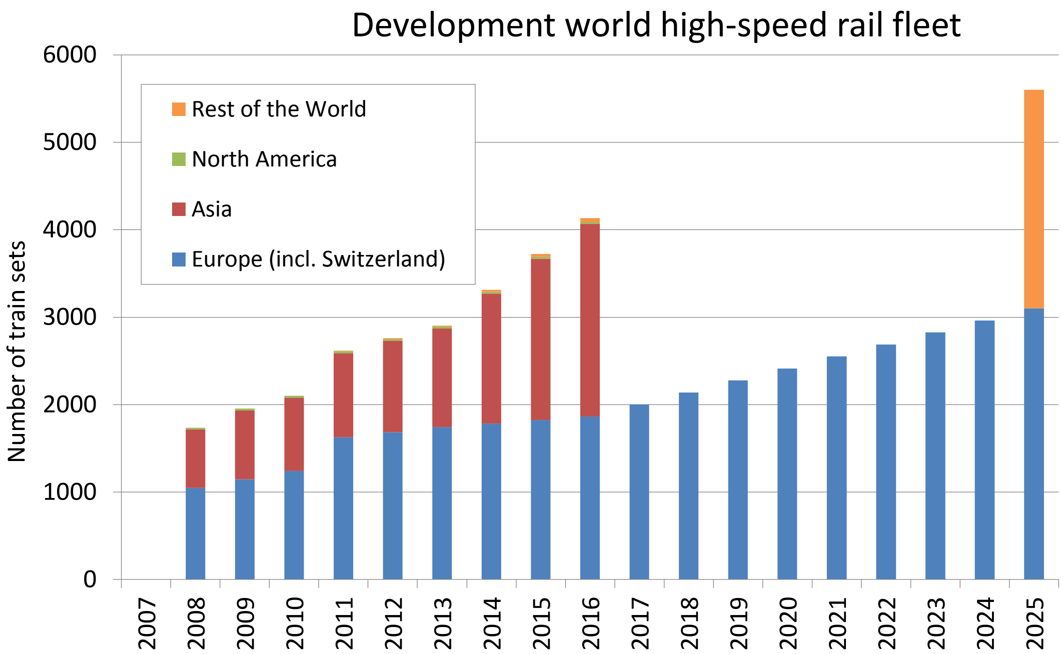

Figure 3.8 - High-speed train fleet development in the world (UIC)

Note: Figure by author based on UIC Brochures "High speed rail, Fast track to sustainable mobility", 2008, 2010, 2012 and UIC World High Speed Rolling Stock databases, 2009, 2011, 2013, 2017

For an asset like a theatre or a football stadium, it makes sense to evaluate the ratio between visitors and available seats as an efficiency indicator. As passenger's access and egress trains all the time, the situation for railways is more complicated. Trip length and duration are important variables as well that need to be taken into account. The result for the fleet capacity (figure 3.9) shows that for the same fleet capacity, ridership in Asia is twice as high as in Europe. It might be that Asian travellers take shorter trips or that trains have higher seat occupancies. To clarify the differences a more detailed benchmark is set up as presented in chapter 4.

The correlation between available seat capacity and traffic performance (ridership and travel volume) can be used to forecast the future performance through extrapolation on the basis of the development of the rolling stock fleet. Specifically, the developments in Europe are highlighted in this case. The linear trend line for HSR Ridership (RS_{HSR}) and Travel Volume (TV_{HSR}) versus Fleet Capacity (FC) in operation in the EU 28 between 2008 and 2015, derived from an ordinary least squares estimation is given by:

HSR Ridership: $RS_{HSR} = 0.1039 * FC + 261$ (million pas/yr) ($R^2 = 0.969$)

HSR Travel Volume: $TV_{HSR} = 0.0307 * FC + 99$ (billion pkm/yr) ($R^2 = 0.985$)

with FC in thousands seats.

Considering these linear equations and the development of the HSR rolling stock fleet, the future high-speed rail performance that the train fleet can accommodate can be forecasted.

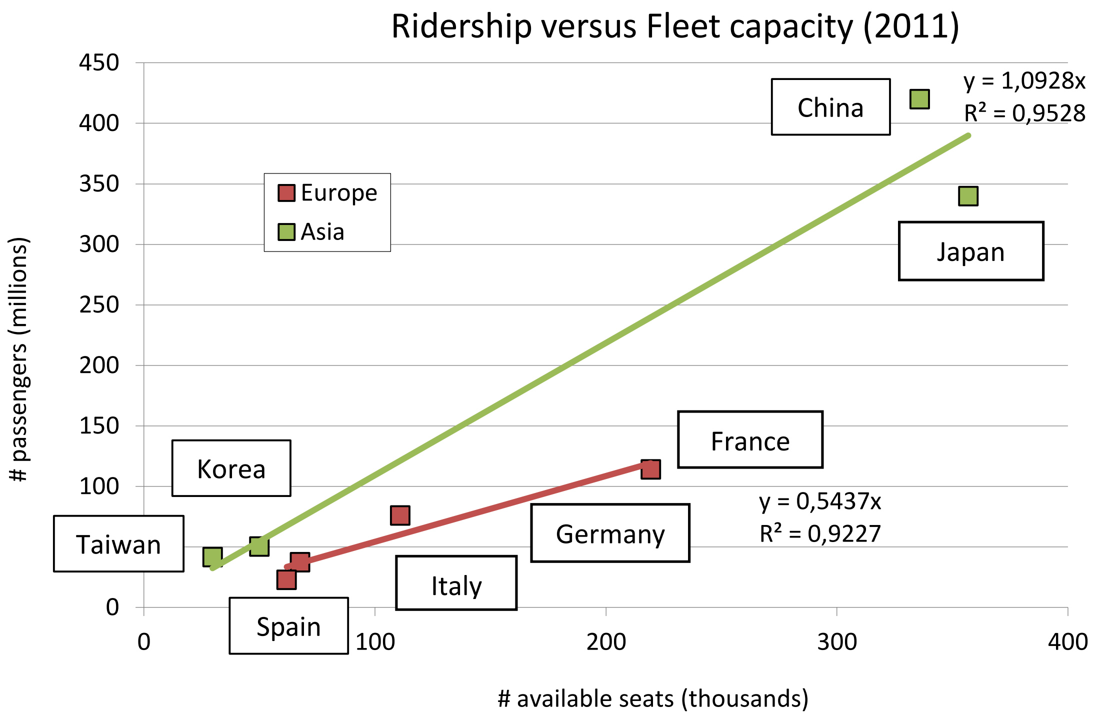

Figure 3.9 - Ridership versus fleet capacity in Europe and Asia (UIC 2011)

3.3.4 High speed rail traffic demand and supply

Growth in income will lead to extra traffic volume and a shift to faster modes like air and high-speed rail as illustrated in paragraph 3.3.1. The development of the high-speed rail network and train fleet in Europe since 1980 will continue until at least 2025 and will accommodate the growth in high-speed rail traffic. The growth and share of high-speed rail is limited by the available network and rolling stock capacity. Besides these supply limitations, HSR has to compete with air traffic to establish and defend their market position.

The relation between demand and supply can be evaluated based on extrapolation of historical data with the formulas presented earlier for traffic demand development and network and rolling stock capability. In the EU28, the actual yearly average growth in GDP/cap was 1.4% between 1995 and 2014 (EC 2016a) and IMF uses a relatively high 3.5% GDP/cap growth for their forecasts (IMF 2016). An average and high demand scenario with a growth of 1.4 and 3.5% per year is presented in figure 3.10 together with the HSR network and HSR train fleet supply curves. In addition, the figure is completed with a low growth scenario, based on the actual yearly average growth in GDP/cap of 0.8% during the financial crisis between 2009 and 2014 (EC 2016a), to account for stagnation in the demand growth.

The forecast from 2015 shows that the European high-speed rail network can accommodate a high demand growth, but not in the long run. If the network is not capable to meet the demand growth, high-speed rail will lose market share to air transport. The planned rolling stock fleet has the capability to supply the medium, but not the high demand scenario. Extra rolling stock needs to be ordered to match the high growth percentages. In the case of stagnation in demand, overcapacity in available train seats and on the network will give an opportunity for high-speed rail operators to capture market share from airlines.

The forecast demand and supply curves are based on linear extrapolation of historical data. In all cases, the linear fit is exceptionally good as can be seen from the resulting R^2-values. The assumption of linearity holds as long as there is no valid reason to argue that a non-linear approach is needed. When the assumption of linearity is rejected, and non-linear extrapolation is applied, the results can deviate considerably from our findings, especially for the longer-term predictions. For our purpose, the indicative approach as presented is sufficient to understand the way supply and demand conditions influence the market structure for high-speed rail operators, but a more detailed study is needed if a more

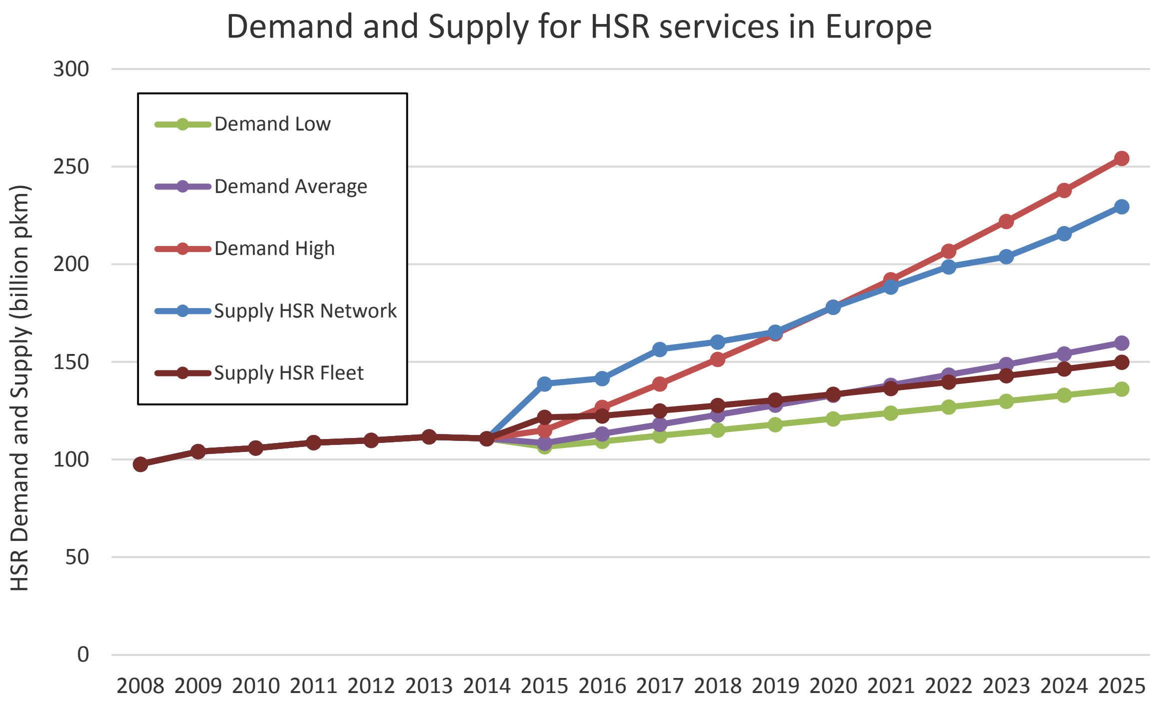

Figure 3.10 - Development of high-speed traffic demand and supply till 2025

Linear extrapolation is valid when new high-speed lines can be treated individually. In an expanding network, where in time high-speed lines will be interlinked, the supply conditions will improve and a higher performance can be expected. This “network” effect will evolve over the next 20 years.

For international train services, focusing on individual lines per country will not be sufficient, as can be seen from the recent development of rail freight corridors across Europe between important industrial areas. As travellers will favour end-to-end routes between major capital cities and airports in Europe, an international corridor approach makes more sense than focusing on individual countries. High-speed operators will fight for the most attractive routes like London-Paris, Paris-Frankfurt or Paris-Brussels-Amsterdam. Of course, the situation in the countries along the route will be of major importance regarding the development and operation of high-speed train services.

Two factors are important in determining which routes or corridors are suitable for expanding activities: i) The attractiveness of the route and the future travel demand on the route in question and ii) The accessibility and ease with which an operator can develop activities on this route. Attractiveness is linked to the quality, capacity and accessibility of the network and future investments. Due to the national orientation of railway markets, entry barriers are related to country-specific circumstances. Route attractiveness and country-specific entry barriers form the building blocks for shaping the portfolio for market participation.

3.4 Market share

The resulting market share for high-speed rail operators depends on the growth of high-speed demand and capability of the high-speed rail network and rolling stock. In some cases, with the introduction of new services in Asia and Europe, high-speed rail has gained more than 50% market share on specific corridors. “Since the appearance of high speed in railways of the world (Japan in 1964 and Europe in 1981), the experience obtained has been very significant in terms of the air-rail modal split” (Lopez-Pita 2010). A study carried out by Steer Davies Gleave for the European Commission concluded that rail travel time is the single most important factor determining market share (EC 2006b). Travel time is not only the scheduled in-vehicle time, but also access time, waiting time, egress time and taxi time in case of airplanes. Taking this into account, the choice between air and rail transport can be described with a logit model for the probability a traveller will prefer rail above air depending on the travel time difference between these modes (Tzieropuoulos 2010):

$$P_{train} = \frac{1}{1+e^{\alpha+\beta*(TT_{plane}-TT_{train})}}$$

Where α reflects an algebraic preference for the plane and β is the sensitivity to travel time gains. The logit choice model is calibrated by tuning these parameters to actual data published by the EC DG TREN (EC 2006b). The values that replicate the best the available data using a least-square regression method are α = -2.0 for and $\beta = -1.0$. The results shown in figure 3.11 show that when the high-speed train takes more than 2 hours extra travel time, air becomes the preferred travel mode. Other factors important to travellers like ticket price, service quality, reliability, punctuality and station accessibility cause deviations from the logit model. This should be taken into account when refining the model.

The Madrid-Barcelona route was in 2007 the world's busiest passenger air route in Europe with nearly 5 mln. passengers per year before the 621-kilometre Madrid-Barcelona high-speed line was inaugurated on 20 February 2008 (Lopa Pita, 2010). The line is designed for speeds of 350 km/h and is covering the distance between the two cities in just 2 hours 38 minutes. In November 2013, the extension into France was taken into operation connecting to the European high-speed rail network. After the opening of the first section Madrid-Zaragoza-Lleida in October 2003, the rail share on this route developed from 6.5% in to 9.7% in 2005 as the journey time was reduced from 6h30 to 5h30. This rose to 15.4% in 2007 when the Lleida-Taragona was put into operation. In 2010, 2 years after the completion of the route the rail share stabilized at 46%. This is illustrated in figure 3.11 with the red dots.

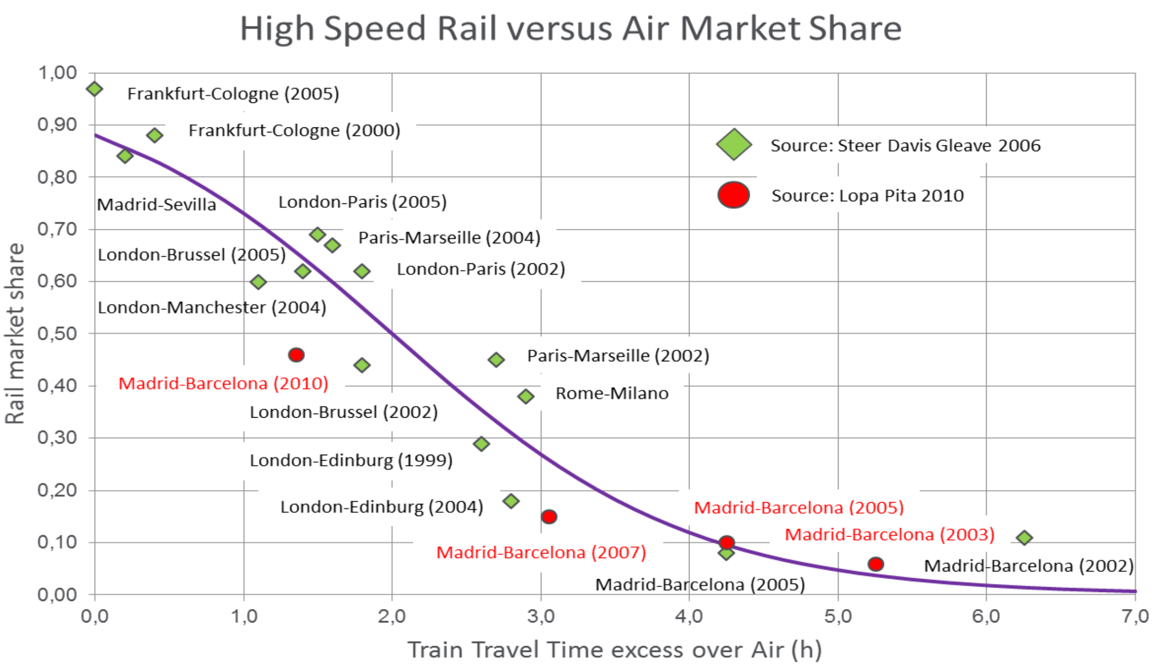

Figure 3.11 – High-speed rail market share on some routes in Europe

Note: Figure by author based on data from EC2006b and Lopa Pita 2010

3.5 The West European High-speed market

London Heathrow (LHR), Paris Charles de Gaulle (CDG), Frankfurt Airport (FRA) and Amsterdam (AMS) are the four largest airports in Europe and feature in the world's top 15 regarding number of passengers per year. In 2014, LHR handled 73 mln. passengers, CDG 62 mln., FRA 58 mln. and AMS 53 mln.[11] . Besides, London has four other airports, of which Gatwick with over 35 mln. passengers per year is the largest. Paris Orly (ORY), Paris' second airport handles about 28 mln. passengers per year. All these airports are well connected with frequent flights and within a distance of 300 and 700 km (see figure 3.12) where strong competition might be expected from high-speed rail services. As the market for international cross-border rail services is liberalised since 2010, new opportunities arise for international high-speed rail operators. To prevent competition on international routes from new entrants, national incumbent railways have built joint ventures (Thalys, Eurostar) to strengthen their position. Entry barriers for new entrants are numerous (e.g. competition from incumbent railways, compliance with European rail directives and regulations, required certified rolling stock and staff, network access etc.) and there are only few railway operators that have the resources and capabilities to provide these services. Incumbent operators profit from economies of scale and stronger buying power compared to new entrants. New players attempt to develop services on high-speed rail routes, but with little success so far. Strong positions and market power of incumbent railways hinder new entrants to be successful. Besides intra-modal competition, high-speed rail faces competition from airlines, private cars and busses. Although road transport needs to be considered, for high-speed traffic the customers' choice is mainly between plane and high-speed train.

[11] Air Transport World (ATW) and Enac Air Transport Data, July 2014

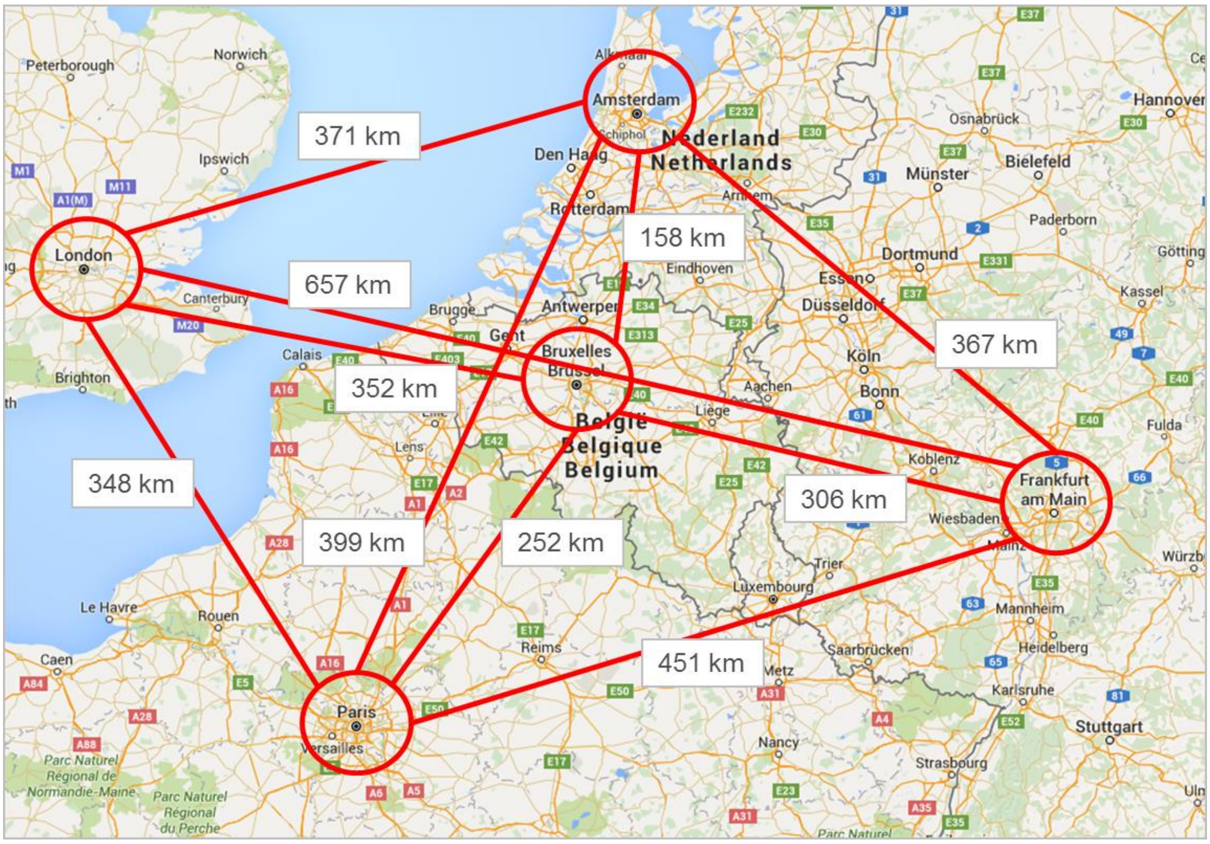

Figure 3.12 - Connecting the largest airports in Europe

Note: Great Circle Distances calculated on http://www.gcmap.com/

The network in Western Europe for high-speed rail services is presented in figure 3.13. Currently, cross-border high-speed train services in Western Europe are provided by Thalys between Paris, Brussels, Köln and Amsterdam, DB international for the route between Köln, Liège and Brussels and Eurostar for the connections between Paris, Brussels and London. Thalys is a joint venture of SNCF (62%), NMBS/SNCB (28%) and DB (10%). SNCF has a share of 55% in Eurostar together with London & Continental Railways (40%) and NMBS/SNCB (5%). The cancellation of the ordered Fyra high-speed trains for the Brussels to Amsterdam route by SNCB/NMBS and NS mid 2013 left the HSL Zuid high-speed line from Amsterdam to Antwerp underused (Abott 2013b). This gave Thalys the opportunity to run more services on this route and Eurostar to plan for a service from London to Amsterdam via Brussels. So far this service has not been established yet. Air France and Veolia have established a partnership, possibly with a view to competing with Thalys services, whilst DB are believed to be considering competing with Eurostar services (Preston 2009). DB has ordered 16 Velaro-D high-speed trains for providing services from London to Frankfurt. As approvals are running late, it is expected that DB will not be introducing a service competing with Eurostar through the Channel Tunnel until 2018 the earliest (Abott 2013a). Apart from the already established high-speed rail operators (Thalys, Eurostar, DB), no new entrants are observed, but the Italian national operator Trenitalia is holding preliminary discussions with suppliers and regulatory bodies regarding the possible launch of an open access high speed service between Paris and Brussels[12]

[12] www.railwaygazette.com, 20 October 2015

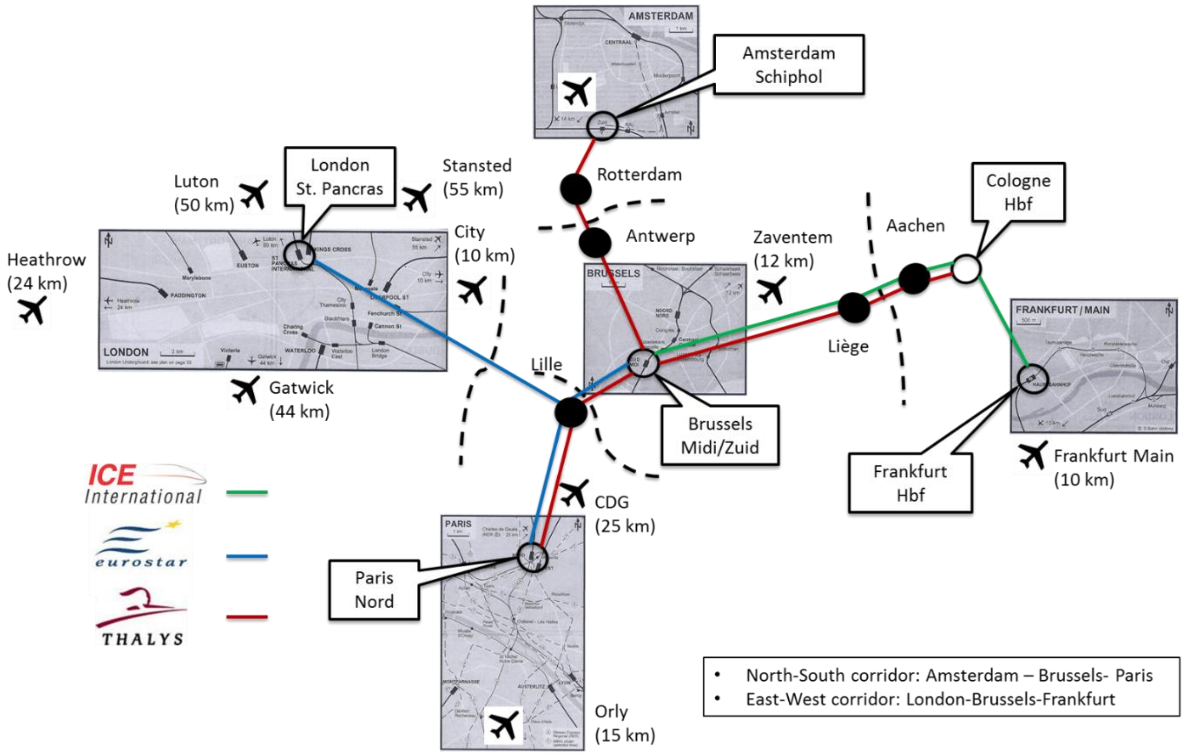

Figure 3.13 - West-European high-speed market

The observed rail-air market shares for London-Paris and London-Brussels in 2002 were 62-38% and 44-56% and increased to 69-31% and 62-38% respectively in 2005 (EC 2006). On these routes train travel time excess is between 1 and 2 hours over air, where a market share between 50 and 70% can be expected (figure 3.11). In 2008, 50% of passengers travelling from Paris to Brussels used the Thalys train services and 81% of travellers from Paris to London took Eurostar trains (UIC 2008). The correlation between rail journey time and market share is strong. Steer Davies Gleave concluded that 90% of the variation in market shares across the routes studies could be explained by the estimated generalised journey time which takes, besides the scheduled journey time, also the check-in time and an allowance for the frequency into account. Punctuality, ticket price and time/cost involved in access to terminals were other important factors mentioned by operators (EC 2006).

3.6 Conclusions and discussion

3.6.1 Conclusions

High-speed rail has started in Japan in 1964 and developed in Europe since 1981. Eleven operators in eight countries in Asia (Japan, Korea, Taiwan and China) and Europe (France, Germany, Spain and Italy) are leading its development. The rest of the world is following slowly. The high growth in China since 2007 is remarkable, resulting in more than one billion passengers in 2015[13]. Besides number of passengers, it is also important to take the trip length of passengers into account to compare the performance between operators. Asian travellers take significantly shorter trips than Europeans do. The need for high-speed transport is investigated and it is proven that there is a strong correlation between income

[13] The figures for Chinese high-speed rail performance could not be verified as to our knowledge no official China HSR statistics are available.

per head of the population and the high-speed travel demand per capita in the European travel market. The analysis also showed a shift from low-speed to high-speed travel modes in Europe as income rises. This underlines the statement that travellers want to keep their travel transport time within their travel time budget. Historic data shows that that high-speed rail grows faster than airlines. High-speed rail operators will gain market share over airlines when this trend continues. On the supply side, the available rail network and rolling stock are limiting factors for high-speed rail growth. The forecasted growth in mobility in Europe gives good opportunities for high-speed rail services. The growth for high-speed rail is limited on the demand side by economic developments and on the supply side by the available network capacity and rolling stock fleet. For Europe, evidence is found that the planned growth of the train fleet is more stringent than the growth of the HSR network. The current plans for new rolling stock can accommodate a demand growth of approximately 1.5% per year. If the demand growth is higher, travellers will shift to airlines and the high-speed rail market share will decrease. When extension of the fleet is accelerated and not limiting the demand anymore, the capacity of the network is the next boundary for growth. The new lines under construction and plans can facilitate a 3.5 % demand growth approximately. When network developments allow a 3.5% demand growth, the current 16% market share for high-speed rail in Europe will grow to 17% in 2025.

Empirically, it is found that travellers shift to faster options to limit their travel time. Train is the preferred high-speed travel mode, as total travel time does not exceed the air mode with more than two hours. In 2005, High-speed rail achieved a 60% market share on the London-Brussels connection and even 70% on the London-Paris market, illustrating the opportunities in the Western European market. High demand, an appropriate infrastructure and competitive travel times makes Western Europe an attractive market for high-speed rail operators. Currently, three operators provide cross-border services i.e. Thalys, ICE International and Eurostar in competition with airlines.

3.6.2 Discussion

The demand and supply analysis is carried out on an aggregate European level, but there are many differences among countries. The approach could also be applied on a more disaggregate level by analysing individual countries, using the data already collected. Our interest is to study high-speed rail operators’ strategies on international routes in Europe. For these cross-border markets more detailed and specific demand and supply data is needed on a route level.

Cancelling of new HSR projects or delay in planning and limited demand growth as a result of the financial crisis are expected to be the main reasons behind the observed growth stagnation in France and Germany for high-speed rail traffic. With being early adopters of high-speed rail in Europe, the main HSR lines in France and Germany are completed and the focus is more on removing bottlenecks in the HSR networks than on building new lines. The high track access charges for high-speed lines, particularly in France, may be another important contributing factor to stagnation in growth.

Railway operators need an attractive market with sufficient demand and growth to build a sustainable business case. New entrants may opt for the most attractive high-demand routes, but will encounter serious inter-modal competition from the incumbents and intra-modal competition from airlines and private cars. Connections where the total travel time of rail and car can be matched give excellent opportunities to capture a substantial market share. From the analysis, it shows that looking for international connections between countries with a high and growing GDP per capita would be a good business strategy. This makes Western Europe interesting as a target market. Market entry is easier when capacity on an HSR connection leaves room for an extra operator, than in the case of congestion on the network. From this perspective, Italy and Spain have networks that may attract new business. Having sufficient and adequate HSR rolling stock is required to enter the market. Incumbent railways already own HSR trains that can run cross-border and have ordered additional sets for future growth. For new entrants it will take a lot of money, time and effort to acquire HSR trains for international services.

After outlining the transport policy in Europe in chapter 2, in this chapter, the demand and supply conditions were studied at an aggregate level across regions and countries. This sets the scene for the structure, conduct and performance elements in the SCP model (figure 1.1). With these observations in mind, a benchmark study is presented in the next chapter to investigate the performance of high-speed rail operators. This element is important to learn more about the behaviour of individual operators.

4 Performance[14]

4.1 Introduction

Referring to the conceptual research model (figure 1.1), in Chapter 3 attention was paid to demand and supply conditions for high-speed rail markets. In this chapter, we investigate the performance in terms of ridership and travel volume of high-speed rail operations in Europe and Asia in more detail to find best practices in the world and the associated important conduct variables. In the first part, a benchmark model based on multi Partial Performance Measures (PPM) is presented to compare the performance of eight high-speed rail operations in Asia and Europe. In the second part of this chapter, a Data Envelopment Analysis (DEA) approach is applied to the same peer group to clarify their efficiency in production and marketing and sales performance.

As explained in the previous chapter, since the introduction in Japan in 1964 and in France in 1981, high-speed rail systems have been developed in various countries in Asia and Europe. Governments have created new dynamics in railway transport to cater for the rising need for high-speed travel and railways are revitalized to be able to compete better with other modes of transport. An important focus was on the development of new high-speed networks in order to facilitate growth in mobility and to limit air travel. The building of high-speed rail systems requires substantial investment in infrastructure, railway stations and rolling stock. Efficient use of these capital-intensive assets is needed to justify the investments made. In addition, identification of areas of improvement in production and marketing is important to optimize operational performance and productivity. National governments decide on the development of high-speed rail systems based on the expected future demand for high-speed travel and the social benefits for the country. Long-term performance forecasts for high-speed rail are a basic input for the decision-making process. Ex post, at the operational stage, the assumptions need to be validated based on the actual system performance.

The goal of this chapter is to clarify the operational performance and efficiency of the world's major high-speed rail systems currently in operation by comparing travel performance, ridership, train fleet and network and to identify the best high-speed rail practices. The performance and efficiency of these railway systems in Europe and Asia is benchmarked against selected key performance indicators for network, fleet and station utilization derived from the actual system characteristics and performance. It identifies the most efficient high-speed rail systems and the contributing factors in achieving high performance in production and marketing. High-speed rail system operators can use the results to adjust their strategy in order to improve their performance and process efficiency. Policy makers that are planning for a high-speed rail future may benefit from the experiences in other countries to make better decisions on the investments in infrastructure and rolling stock needed.

[14] The material of this chapter has been presented at the 13th World Conference on Transport Research in Rio de Janeiro in July 2013 and at the European Transport Conference in Frankfurt in September 2014.

This chapter is structured as follows. Section 4.2 gives a review of the development on benchmarking in the railway industry and the applied methods. The sections 4.3 to 4.6 cover the benchmark study using a multi PPM approach. Section 4.3 presents the model used to compare eight high-speed rail systems in Europe and Asia against a selection of key performance indicators. The results are given in section 4.4 and in 4.5 some explanatory factors which influence the results are discussed. Conclusions from the multi PPM benchmark are presented in section 4.6. In section 4.7 to 4.12 the same peer group is benchmarked by applying a DEA model. In section 4.7, the application of Data Envelopment Analysis (DEA) in railways is explained. The methodology and the DEA-model, variables and data used in the study are presented in section 4.8 to benchmark eight high-speed rail systems across Europe and Asia. Section 4.9 provides the results for the Malmquist Productivity Index and the efficiency and effectiveness scores. In section 4.10 some explanatory factors are discussed. The benchmark is repeated on a more disaggregate level (i.e. individual operators instead of national networks) for a subset of five Asian railway operators in section 4.11. Finally, section 4.12 presents the conclusion from the DEA benchmark and discusses the results.

4.2 Benchmarking methods and application to railways

Benchmarking is intended to compare products or services with the competition or with organisations that are recognized as leaders in their sector to find best practices and ways to grow. This implies that it does not give an answer to how industry leaders themselves can improve. The best practices can be found by comparing individual performances within a selected peer group. The main objective of benchmarking is to measure and compare the realized output of a product or service with the amount of inputs (Hansen et al 2013). Besides the uni-dimensional Ratio Analysis (RA) or multi-dimensional Partial Productivity Measures (PPM) analysis for productivity and efficiency measurement, four multi-dimensional approaches can be identified (see figure 4.1 for an overview): Total Factor Productivity (TFP), Data Envelopment Analysis (DEA), Least Squares Regression (LSR) and Stochastic Frontier Analysis (SFA) (Coelli et al, 2005, Ozcan, 2008, Merkert et al 2010).

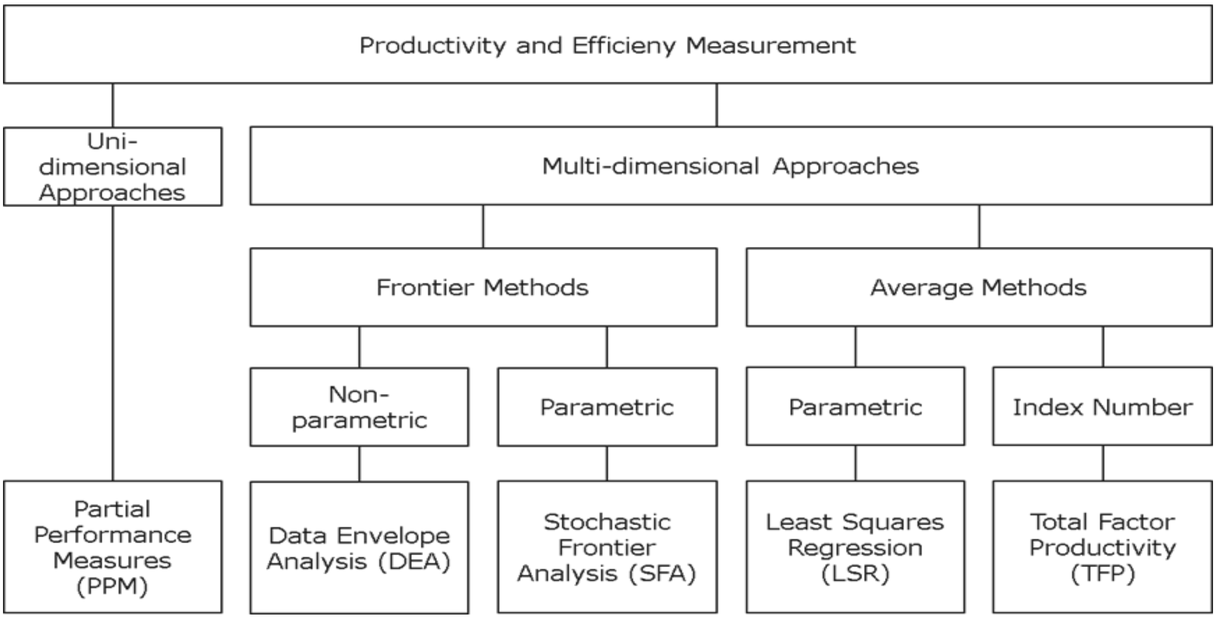

Figure 4.1 - Productivity and Efficiency Measurement methods

Source: Adopted from Laird et al, 2011

The PPM analysis, where an output variable is viewed in relation to a single input variable is a practical, easy and fast way to of comparing performance. The challenge here is to find meaningful efficiency indicators. In the more practical and technical-managerial studies like the CoMET/Nova metro railway benchmark, the European IMPROVERAIL project and the INFRACOST and LICB studies performed by the UIC to benchmark rail infrastructure companies, Key Performance Indicators were developed for the comparison (Anderson et al 2003). An application for comparing the performance of eight high-speed railways in Europe and Asia was presented by Doomernik (2013). The main disadvantage is that only one indicator at the time can be evaluated. A multi-PPM analysis, where more ratios are assessed at the same time can easily lead to misinterpretation. The benchmarks established using old analytical schemes based on various multiple ratios created more dilemmas than solutions (Ozcan 2008). The TFP analysis enables to evaluate multiple inputs and outputs simultaneously resulting in a single index for efficiency that makes it possible to rank the entities under study. DEA, LSR and SFA are more sophisticated tools that can also handle multiple inputs and outputs. All five benchmark methods can be recognized in international (mostly European) railway efficiency and productivity studies. As PPM is the most widely used measure in railways, DEA and SFA have become the most commonly applied methods in rail efficiency analysis in recent years (Merkert, 2010). A selection of recent benchmark studies presented by Hansen et al. (2013) also shows that DEA and SFA have become frequently used since about 2008. The utilization of either DEA or SFA is now one of the most defining elements of the studies, while LSR and TFP have lost importance (Laird et al 2011). The same report states that no single benchmark can be applied to all railways and several benchmarking methods should be used concurrently, since particular insight can be gained from each of them.

There have been many studies in the rail sector where DEA is used as a comparison technique. For an overview, see for example Merkert et al. (2010) and Hansen et al. (2013). To our knowledge, there are no benchmark studies for high-speed railway systems using DEA. DEA is however very suitable for the use in the rail sector, due to the highly regulated and quasi-monopolistic industry structure (Coelli & Perelman et al 2000) and where the formal link between input and output is not clear in the first instance. An important advantage of DEA is that the results are based on a relative comparison and that DEA can work with index numbers, ensuring that no sensitive information is provided to others as often desired by companies (Caldas 2013).

4.3 Multi PPM benchmark methodology

This section presents a more adequate benchmark methodology based on a system approach, taking the indicative results from chapter 3 as a starting point.

A railway system can be modelled as a Multiple Input Multiple Output (MIMO) system for efficiency, productivity and costs analyses (Cantos et al 2010, Mizutani and Uranishi 2012). A system approach with N inputs and M outputs as illustrated in figure 4.2 is the basis for the benchmark stage of this study. The first step is to define the relevant input and output variables. Choosing appropriate performance indicators for the high-speed rail system is the next step. Finally, key and additional performance indicators can be calculated using the available data.

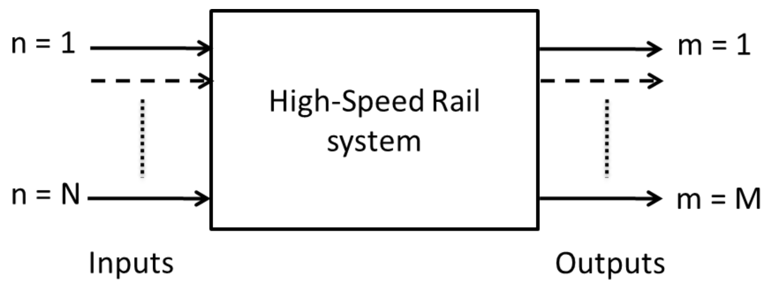

Figure 4.2 - A multiple input multiple output of a high-speed railway system

4.3.1 Variables

To provide high-speed train services in a country, three major physical assets are needed:

- A high-speed rail network
- Railway stations for access and egress of passengers
- A fleet of high-speed trains

Besides physical assets, an operational model and timetable to run the trains on the network is required to deliver the rail services. Staff on board and at the railway stations is also a production factor, but we do not consider those in this study.

The high-speed rail MIMO system is detailed in figure 4.3 with four asset-related input parameters (N=4) for the infrastructure and rolling stock and three output parameters (M=3) for the transport and travel performance. From these input and output variables three key and two additional performance indicators are derived for each asset type (network, fleet and stations) to benchmark the high-speed rail systems under study.

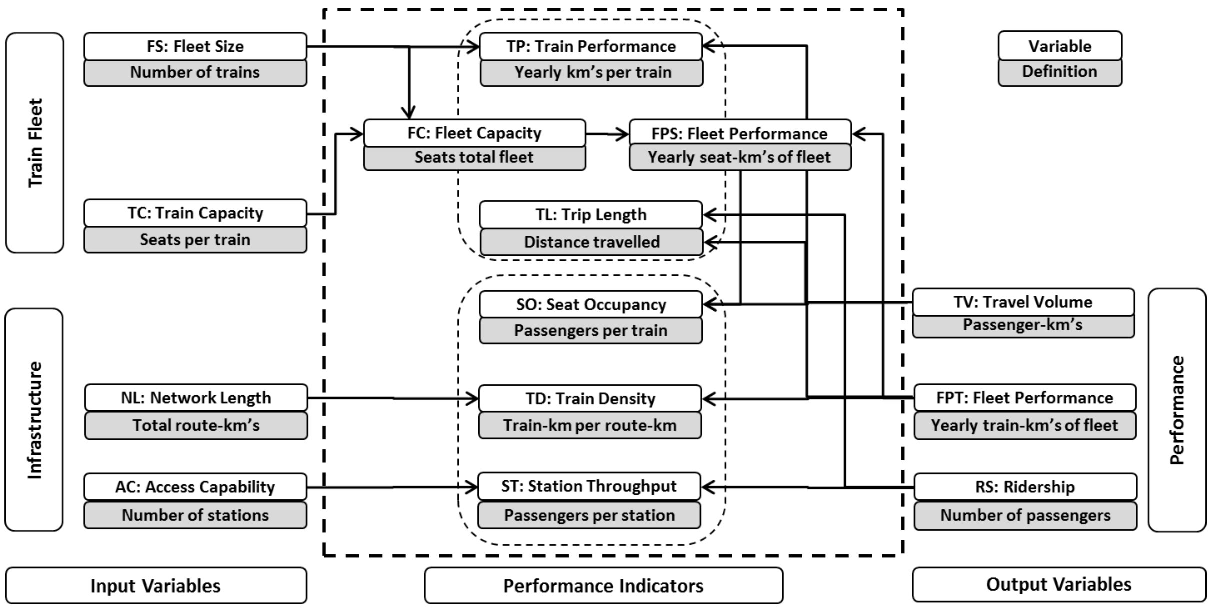

Figure 4.3 - Variables, definitions and output characteristics of a high-speed rail system

Note: Figure by Author

Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. The total length of high-speed lines in the network, the number of railway stations for access and egress of passengers, the number of available high-speed trains and their seating capacity are key parameters for the high-speed rail system performance. The final output performance can be expressed in terms of travel volume and is defined as the product of the yearly number of passengers and the average travel distance per passenger. Ridership and train or seat kilometres produced by the fleet are additional output variables indicating the railway's performance. Besides the necessary assets, an adequate operational model is needed to optimise the rail system performance.

4.3.2 Performance indicators

On the basis of the input and output variables as indicated in figure 4.3, three key performance indicators are proposed for the benchmark to quantify the efficiency. Seat occupancy SO is used as a measure for the efficiency of rolling stock, station throughput ST to express the access and egress performance of the railway stations and train density TD indicating the utilisation of the network capacity:

$$SO = \frac{TV}{FPT} \quad (1), \quad ST = \frac{RS}{AC} \quad (2) \text{ and } \quad TD = \frac{FPT}{NL} \quad (3)$$

with TV the Travel Volume in passenger kilometres per year, FPT being the Fleet Performance in Train kilometres per year, RS the annual ridership, AC the access capability in terms of number of high-speed rail stations in the network and NL the Network Length in route kilometres of high-speed track. The train seat occupancy depends on the willingness of travellers to use the offered train service. A high density of railway stations gives easy access for passengers, but can reduce the average speed along the route. A better network utilisation can be achieved by running more trains on the network leading to a higher train density.

The three key performance indicators represent the load factors for the three major assets, i.e. train fleet, railway stations and network. Two additional performance indicators are the average trip length of passengers (TL) and the yearly performance of the individual train sets (TP). These additional performance indicators are the "travel volume over ridership" ratio and "fleet performance over number of train sets" ratio:

$$TL = \frac{TV}{RS} \quad (4) \quad \text{and} \quad TP = \frac{FPT}{FS} \quad (5)$$

with RS being the ridership in number of passengers per year, TV being the Travel Volume per year, FPT being the Fleet Performance in train-kilometres per year and FS the Fleet Size in number of train sets. The three key and two additional performance indicators are the backbone for the benchmark.

4.3.3 Explanatory factors

From the evaluation of the key and additional performance indicators for the peer group, high-speed rail systems can be ranked. The benchmark results do not give any information why some operators perform better than others do and does not explain which factors influence performance. Amongst the many other factors that influence the results, the operational model, the network structure and maturity of the system are of major importance for performance

Operational model

In the analysis, the focus is on the performance of the three major railway assets: network, stations and train fleet. The operating model, timetable and scheduling of trains over the day is of major importance for the performance of the railway system. Figure 4.4 gives four basic operational models that can be recognised in various countries (Rus et al. 2009):

1. Exclusive model: Japan, Korea, Taiwan
2. Mixed high speed: France, Italy, China
3. Mixed conventional: Spain
4. Fully mixed: Germany

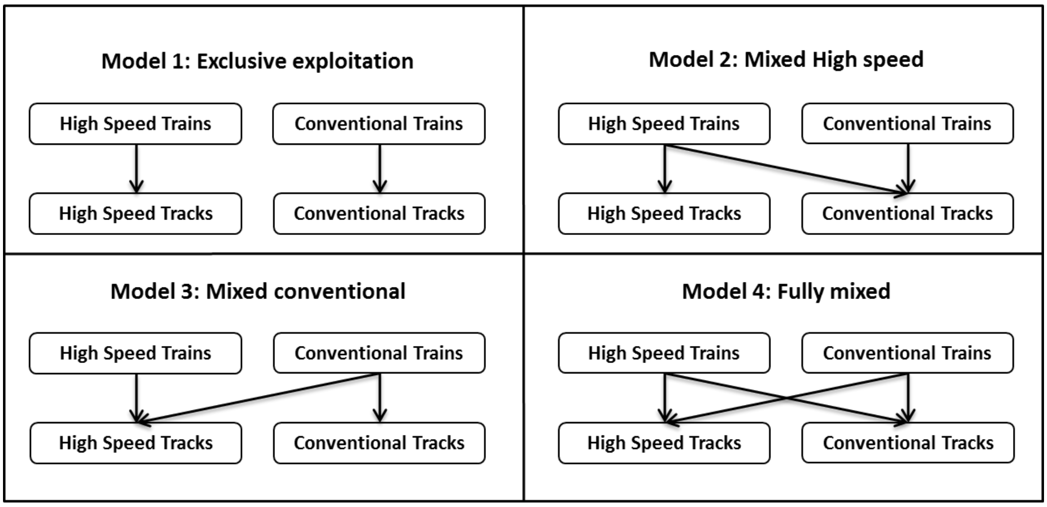

Figure 4.4 - Operational models for high-speed rail traffic (Rus et al. 2009)

An exclusive operation or a mixed operation with infrastructure sharing will give different results for the key performance indicators under study. For the interpretation of the benchmark results, the operational model needs to be taken into account, i.e. only high-speed rail systems with the same operational model will give meaningful comparisons. The assumption behind the benchmark methodology used is the exclusive model, where only high-speed trains run only on high-speed tracks like in Japan and Korea. The method will produce comparable and meaningful results in this case for all key performance indicators. For the mixed high-speed model, high-speed trains also run on conventional tracks at lower speeds. In this case, the high-speed train fleet is servicing a larger network and more railway stations. This influences the key performance indicators in the benchmark. Train density and station throughput will be overestimated as a part of the train kilometres and the number of passengers will be realised on conventional track. Seat occupancy, trip length and train performance are independent of the network length and will remain unchanged. Besides high-speed trains, conventional trains run on high-speed lines as well in the mixed conventional model. This will not affect the key performance indicators in the benchmark. In the fully mixed model, the effect on the key performance indicators will be the same as in the mixed high-speed model.

The exclusive model where high-speed trains run exclusively on high-speed track and are not hindered by conventional trains can achieve the best network utilisation. When high-speed trains may also run on conventional track, the fleet performance may increase as the high-speed network length stays the same. This leads to a higher network utilisation, but the actual high-speed network loading remains unchanged. The French and German network utilisation may therefore be overestimated. Only high-speed rail systems with the same operational model will give meaningful comparisons.

Network structure
Four different basic structures can be recognised regarding network configuration:

1. Point to point: single connection between two cities (Taiwan, Korea)
2. Linear structure: trunk line with branches (Japan, Italy)
3. Radial structure: lines departing from a capital city to various directions (France)
4. Meshed structure: a network with interconnected North-South and East-West axes (Germany, China)

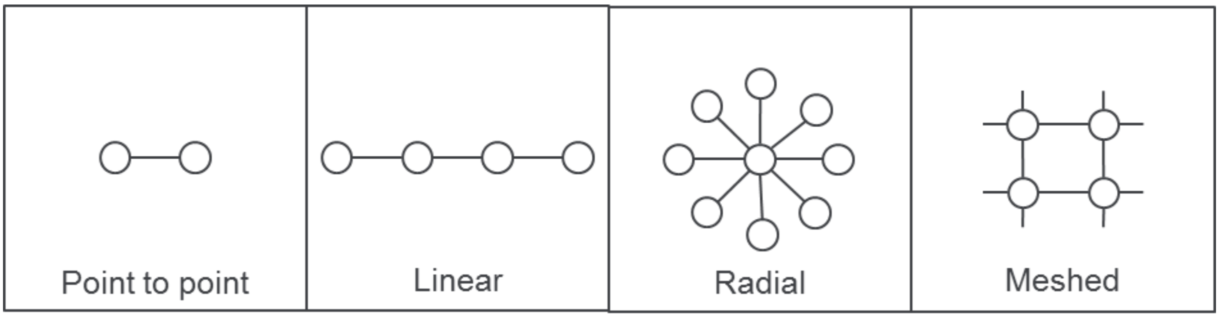

Figure 4.5 - Basic HSR network structures (figure by author)

Structures depend strongly on the country's geography and the need for high-speed rail connections. The benchmark is indifferent to the network structure, but in practice, the performance can be different due to operational limitations given by the network structure.

Besides network configuration, the spread of railway station across the network is influencing the operational performance. Frequent stops reduce the average train speed, but can improve the high-speed railway accessibility. This trade-off is country-specific.

System maturity
Early adopters of high-speed rail like Japan and France already have a well-established high-speed rail system integrated in society. The network will develop in smaller steps with new lines and further extensions. Countries that only recently have adopted high-speed rail, like China, need some time to develop and mature their high-speed services. Their score on train density and seat occupancy can gradually improve over time as travel demand grows.

4.3.4 Data

Table 4.1 shows the definition of all input and output variables used in the study with their associated values from the data collected for eight high-speed railway systems for a single year. Spain, Italy and Taiwan were eliminated from the analysis, as no reliable data on train performance was available. For China 2011, data from the World Bank is used. For all other countries, the figures are derived from UIC data for 2010.

China has the largest high-speed rail network in the world, is operating the largest fleet and is servicing the largest number of passengers yearly. Although France and China have a comparable fleet size, China's fleet capacity is larger as their train sets can carry more passengers. Japan is the outperformer regarding travel volume, although ridership is lower compared to China. This indicates that, on average, Japanese travellers take longer trips. Travel volume and seat-kilometres in Japan exceed the numbers in France with less train kilometres due to high-capacity train sets.

Table 4.1 - Variables and values for output performance calculation (2010)

	Input				Output			
	Infrastructure		Rolling Stock		Performance			
	NL	**AC**	**FS**	**TC**	**FPT**	**FPS**	**RS**	**TV**
Variable	Network Length	Access Capability	Fleet Size	Train Capacity	Fleet Performance	Fleet Performance	Ridership	Travel Volume
Definition	Total route-km	Number of stations	Number of trains	Average number of seats per train	Yearly train-km of fleet *(millions)*	Yearly seat-km of fleet *(billions)*	Yearly number of passengers *(millions)*	Yearly passenger-km *(billions)*
Unit	km	-	-	-	km	km	-	km
France	1896	24	474	450	172.2	77.5	112.6	51.9
Germany	1285	34	254	445	102.3	45.5	78.5	23.9
Italy	923	16	115	561	47.7	26.8	34.0	11.6
Spain	2056	24	184	302	57.6	17.4	22.2	10.4
Europe	**6160**	**98**	**1027**	**1758**	**379.8**	**167.2**	**247.3**	**97.8**
Japan	2534	82	356	903	116.2	104.9	292.0	77.4
Korea	412	11	46	935	20.8	19.4	41.3	10.8
China	4584	128	441	677	213.0	144.2	290.5	66.7
Taiwan	345	8	30	989	15.0	14.8	36.9	7.5
Asia	**7875**	**229**	**873**	**3504**	**365.0**	**283.4**	**660.7**	**162.4**
All	**14035**	**327**	**1900**	**5262**	**744.8**	**450.6**	**908.0**	**260.2**

Note: China data 2011, other countries 2010

The data sources used for the analysis are summarised in table 4.2. The main data comes from the UIC. UIC gives data on travel volume, number of passengers, network length, fleet performance and fleet configuration. The travel performance data for Asia is completed with information from the KTX website and from the World Bank (Bullock et al 2012) specifically for China. To fill in information gaps, additional data is used from several other sources. Missing data on annual train kilometres for the fleet in Korea and Japan are covered by expert judgements based on the operational 2012 timetables.

Table 4.2 - Major data sources for the study

Variable	**Source**	**Version**
Network Length	UIC Railway Statistics	September 2012
Access Capability	European Rail Timetable, Thomas Cook	June 2012
	www.hochgeschwindigkeitszuege.com	Viewed December 2012
Fleet Size	UIC World High Speed Rolling Stock Database	2009, 2011
Train Capacity	UIC World High Speed Rolling Stock Database	2009, 2011
Fleet Performance	UIC Railway Statistics	September 2012
	World Bank (for China)	2012
Ridership	UIC Railway Statistics	September 2012
	http://whhh.fc2web.com/ktx/hikaku.html	Update October 2012
Travel Volume	UIC Railway Synopsis	2011
	http://whhh.fc2web.com/ktx/hikaku.html	Update October 2012
All	Annual reports, Fact sheets	2010

4.4 Results from the multi-PPM benchmark

Table 4.3 shows the comparison made between Europe (France, Germany) and Asia (Japan, Korea, China) for the identified performance indicators based on the data from table 4.1.

Table 4.3 - Performance indicators of selected European and Asian HSR-networks (2010)

	(Key) Performance Indicators		(Additional) Performance Indicators		
	FPT/NL	**RS/AC**	**TV/FPS**	**FPT/FS**	**TV/RS**
Characteristic	**TD**	**ST**	**SO**	**TP**	**TL**
	Train Density	Station Throughput	Seat Occupancy	Train Performance	Trip Length
Definition	Train-km per route-km *(thousands)*	Passengers per station *(millions)*	Passengers per trainset to capacity	Yearly km per trainset *(thousands)*	Passenger distance travelled
Unit	-	-	-	km	km
France	90.8	4.69	0.67	363	461
Germany	79.6	2.31	0.53	403	304
Italy	51.7	2.13	0.43	415	341
Spain	28.0	0.93	0.60	313	468
Europe	**61.7**	**2.52**	**0.59**	**370**	**395**
Japan	45.9	3.56	0.74	326	265
Korea	50.5	3.75	0.56	452	262
China	46.5	2.27	0.46	483	230
Taiwan	43.5	4.61	0.51	500	203
Asia	**46.3**	**2.89**	**0.57**	**418**	**246**
All	**53.1**	**2.78**	**0.58**	**392**	**287**

Note: China data 2011, other countries 2010

4.4.1 Key Performance Indicators

The train densities for Europe are considerably higher than for Asia, except for Spain that runs a mixed conventional network. High-speed trains in France, Germany and Italy not exclusively run on high-speed track, but on conventional lines as well, resulting in higher train densities. Japan, Taiwan and Korea operate their high-speed trains only on high-speed lines, leading to lower train densities. Despite the exclusive operational model on the single high-speed line from Seoul to Busan, in Korea a high network utilisation is achieved by running a very intensive timetable with small headways. The fast growing high-speed network in a new and still developing high-speed rail market causes the low train density value for China.

On average, the Asian cases show somewhat higher values for station throughput than Europe. The highest value for station throughput is realised by the TGV network in France. When all railway stations on the conventional network that are also serviced by TGV trains are included, instead of only the railway stations that are part of the high-speed network, the station throughput drops considerably. The French station throughput is twice the German value, which is remarkable as in Germany the average station distance is 38 km compared to 79 km in France.

With a seat occupancy above 70%, Japan is outperforming the other networks in this respect. Compared to Japan, in Korea, seat occupancy is low and train density is high. Reducing the number of trains per day would lead to increased rolling stock efficiency. With lower frequencies, the service level decreases which will have its effect on passenger volumes. Seat occupancy in France is 14% higher than in Germany and has therefore more efficient utilisation of the train sets. With 46%, the Chinese high-speed train operations show the lowest seat occupancy among the Asian operators in the peer group. As the Chinese HSR network is still under development, seat occupancy is expected to improve in the near future. The benchmark does not confirm that trains have higher seat occupancies in Asia than in Europe as indicated in the preliminary results of Section 2. An important factor leading to higher ridership figures compared to fleet capacity in Asia is the shorter trips that travellers take.

4.4.2 Additional Performance Indicators

In 2010, for Europe, the average trip length is 395 km compared to 246 km for Asia. Differences are related to geography and the origin-destination relationships in the high-speed rail network. Comparing travel length with average station distance shows that a trip in China covers only two stops, where for the other high-speed rail systems six to eight stops are typical. The low yearly mileage of Japanese train-sets is caused by the series 800 train-sets. All train sets in the world perform in a range of 300 to 500 thousand kilometres a year.

4.5 Conclusions from the multi-PPM benchmark

Significant differences are found between Europe and Asia in the key performance indicators considered. The train densities for Europe are considerably higher than for Asia as high-speed trains in France, Germany and Italy not exclusively run on high-speed track, but on conventional lines as well. Comparing fleet performance between Europe and Asia it is found that Japan is performing best and China worst on seat occupancy. For Europe, France is giving the best results. The case for China is not assessed in full, as longer time series of data on travel volume and fleet performance is currently not available. There are significant differences between Asia and Europe regarding the infrastructure and rolling stock fleet and the way the high-speed railway is run. High-speed trains in Asia have in general larger seat capacity and equal or even better performance is achieved with less train kilometers. More passengers and shorter trips are characteristic for Asia, especially for China. Japan realises seat occupancies above 70% and is outperforming all the other networks in this respect, with China being an underperformer.

The study shows that high-speed railways can be represented as a MIMO-system with 4 input and 3 output variables for benchmark purposes. Meaningful comparisons can be made based on three key performance indicators; seat occupancy, station throughput and train density, to express the train, station and network loading. Two additional performance indicators give information on travel behaviour (trip length) and the performance of train sets (train kilometres per year). Careful interpretation of the results is needed as various operational models can be distinguished among. Train density and station throughput may be underestimated as high-speed trains run on conventional track as well (operational model 2 and 4 in figure 4.4).

The sections 4.3 to 4.6 covered the benchmark study of eight high-speed rail systems across Europe and Asia using a multi PPM approach. In the following sections the same peer group is benchmarked by applying a complementary multi-dimensional approach using a DEA model (see figure 4.1).

4.6 DEA benchmark methodology

Data Envelopment Analysis (DEA) is a non-parametric technique to compare performance between entities, normally indicated as Decision Making Units (DMU's), which allows multiple inputs and outputs. It is possible to increase the efficiency by lowering the input or increasing the output, keeping the inputs unchanged (Caldas 2013). Besides this distinction between input and output orientation, in DEA a difference can be made regarding the returns to scale. The Constant Returns to Scale (CRS) assumption implies that all DMU's operate at an optimal scale, while Variable Returns to Scale (VRS) divide the CRS-efficiency score into Technical Efficiency (TE) and Scale Efficiency (SE). The difference between CRS and VRS is that in the VRS model an additional condition on the weights is introduced. This is because the CRS model does not work properly if there is more than one optimal solution. When economies-of-scale are not changed by an increase in efficiency, CRS can be applied. If this is not the case, a VRS model is needed.

4.6.1 Malmquist Productivity Index

An interesting feature of DEA is that, by using the Malmquist Productivity Index (MPI), it can also capture the dynamics in efficiency. This index tells us how much the ratio of aggregate output to aggregate input has changed between any two time periods (Färe and Grosskopf, 2000). This is a commonly applied approach to assessing dynamic efficiency in a DEA environment, assuming constant-return-to-scale (CRS) technology. An important feature of the DEA Malmquist Index is that it can decompose the overall efficiency into two mutually exclusive components, one measuring Efficiency Change (EC) and the other measuring Technical Change (TC).

4.6.2 Network DEA

Traditional DEA (TDEA) models are based on a "black box" approach with multiple inputs and outputs. The actual transformation process is generally not modelled explicitly. TDEA reveals rather than imposes the structure of the transformation process. Network DEA (NDEA) models allow to identify components inside the box and to evaluate organizational performance and its component performance (Färe and Grosskopf 2000). This is done by splitting the model into two or more stages where an output feeds a subsequent stage. This approach can be applied to railways to assess besides the overall system efficiency, the technical efficiency and marketing and sales efficiency separately (Lan and Lin 2006, Yu 2008).

4.6.3 Performance matrix

Performance can be defined as an appropriate combination of efficiency and effectiveness. An organization can be efficient, but not effective; it can also be effective and not efficient (Ozcan 2008). Efficiency, the ratio between output and input, is a key performance parameter indicating if assets are properly used. Effectiveness indicates if the inputs are properly used to produce the best possible outcome. By plotting the efficiency and effectiveness for all DMU's in a performance matrix (see figure 4.6), best practices can be found and strategies can be proposed to improve the position of underperformers (Ozcan 2008, Lan and Lin 2006).

Besides the evaluation of performance on both dimensions, the correlation between efficiency and effectiveness can be studied as well to answer the question whether efficient organisations are also effective or not. Karlaftis and Tsamboulas (2012) found that efficiency is generally negatively related to effectiveness in their research on 15 European transit systems over a ten-year period (1990-2000). This implies that increasing efficiency may result in decreased effectiveness.

4.7 Network DEA model

A railway system can be modelled as a Multiple-Input Multiple Output (MIMO) system for efficiency, productivity and costs analyses (Cantos et al 2010, Mizutani and Uranishi 2012). A system approach with N inputs and M outputs is the basis for our DEA study. In the current study, NDEA is chosen for the high-speed rail systems' performance and efficiency assessment. As DEA can be considered a "black box" approach, we introduce a two-stage Network DEA (NDEA) model to evaluate the overall system efficiency, the technical efficiency of the production process and efficiency of the marketing and sales process simultaneously in a single model as proposed by Lin and Lan (2006) and Yu (2008).

4.7.1 Input and output variables

To provide high-speed train services in a country, two major physical assets are needed: i) A high-speed rail network and ii) A fleet of high-speed trains. For this study, we only consider the network and the rolling stock assets, being the two major production factors for railway performance. Railway stations for access and egress of passengers are left out of the equation as in most cases they are not a performance-limiting factor. Difficulties with defining meaningful parameters is another reason not to take stations into account as not only the number, but also the size, location and accessibility by other modes of transport are normative parameters.

Besides physical assets, an operational model and timetable to run the trains on the network is required to deliver the rail services. Operational expenditures and staff on board and at the railway stations are also production factors, but we do not consider these in this study, mainly because only limited data is available on operational costs and staffing levels in high-speed rail.

Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. The total length of high-speed lines in the network and the number of available high-speed trains and their seating capacity are key parameters for the high-speed rail system performance. The final output performance can be expressed in terms of travel volume and is defined as the product of the yearly number of passengers and the average travel distance per passenger. Ridership and train or seat kilometers produced by the fleet are additional output variables indicating the railway's performance.

The high-speed rail MIMO system is detailed in figure 4.7 with two asset-related input parameters (N=2) for the infrastructure and rolling stock and two output parameters (M=2) for the transport and travel performance. The overall process is split into two subsequent stages, which are both owned and managed by the operator: the production process and the marketing and sales process. The efficiency of these processes can be assessed separately. These stages are linked by the fleet performance being an output of the production process and an input for the marketing and sales process. The production process uses network length and fleet capacity to produce train-km's, who are in turn input for the marketing and sales process delivering ridership and travel performance as outputs. By plotting the results for all DMU's regarding production efficiency, marketing and sales efficiency and system efficiency in a performance matrix, best practices can be found and strategies can be proposed to improve the position of underperformers.

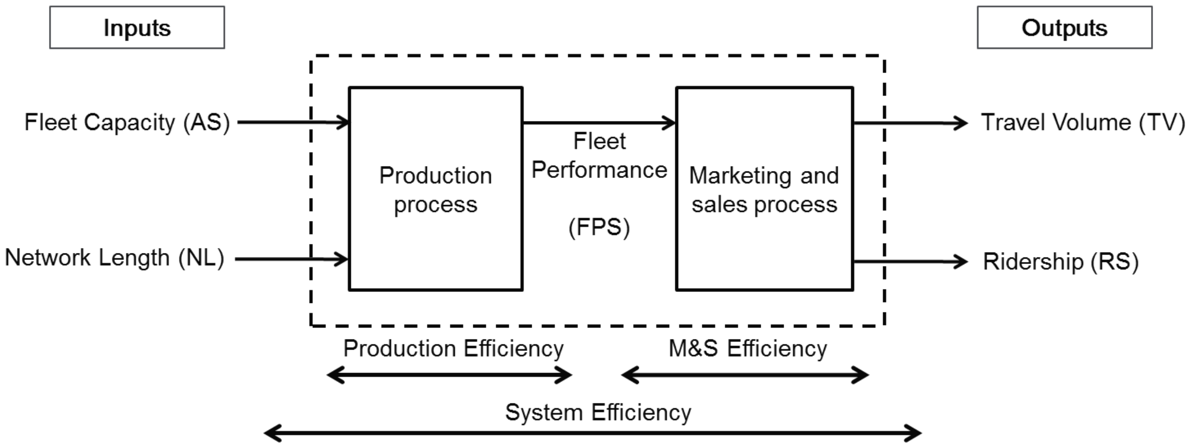

Figure 4.6 - Two-stage multiple-input multiple-output NDEA model of a HSR system

The efficiency and effectiveness scores and Malmquist productivity indices are calculated for the overall process and the two separate stages. Merkert et al (2010) use an input orientation because "it assumes that rail firms have higher influence on the inputs, since output volumes are substantially influenced by macro-economic factors and often pre-determined by long-term contracts and exogenously controlled public transport service level requirements". For this NDEA analysis model, the output orientation is applied for the overall model and the individual stages. Regarding stage 1, improving the fleet performance has a preference over decreasing the infrastructure or fleet capacity. In practice, taking out of operation and disinvestments in high-speed lines and rolling stock are very unusual to improve technical efficiency. For the effectiveness (stage 2) it is easier on the short term to influence ridership and travel performance by proper marketing and sales activities than to change the timetable. The calculated VRS efficiency is split into Technical Efficiency and Scale Efficiency scores. The Malmquist Productivity Index is decomposed to identify the Efficiency Change and Technical Change factor from the CRS results over the 2007 to 2012 period. All efficiency and effectiveness scores and Malmquist Productivity Indices are calculated by using DEAP (Data Envelopment Analysis Program) software written by Tim Coelli (2001).

4.7.2 Performance matrix for NDEA

For our purpose to capture the results from the NDEA analysis, we use a NDEA performance matrix where the efficiency of the production process is plotted against the efficiency of the marketing and sales process (figure 4.6)[15].

[15] This matrix is different from the performance matrix as suggested by Ozcan (2008) to evaluate efficiency and effectiveness of a single process. In our case, we want to evaluate the operator's performance by evaluating the efficiency of the production and marketing & sales process at the same time.

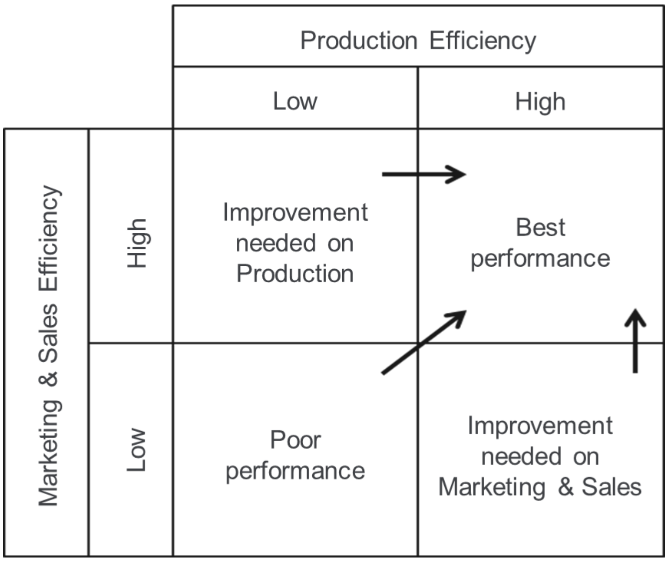

Figure 4.7 - NDEA performance matrix (adopted from Ozcan, 2008)

4.7.3 Selected high-speed rail networks

To find best practices in production and marketing in the worlds' largest high-speed rail systems, eight networks are identified; four of which can be found in Asia (Japan, Taiwan, China, Korea) and four in Europe (France, Germany, Spain, Italy). The selection was made based on actual travel volume over the selected period. The study not only compares the individual peers, but also explores the differences between two regions, Europe and Asia. From the resulting performance matrices, strategies are proposed to improve the overall efficiency.

4.7.4 System characteristics and performance data

Table 4.4 shows the descriptive statistics of the input and output variables used in the study with their associated values from the data collected for the eight high-speed railway systems over a six-year time period from 2007 till 2012 (in total 48 observations).

For all countries, the figures in table 4.4 are derived from UIC data, statistical handbooks, annual company reports and other publications. The data published by UIC is the most comprehensive and reliable, but data on fleet performance (train-km's) is not reported. Numbers on fleet performance are difficult to find as train operators only publish limited figures on their operational performance. To recover the fleet performance data, a bottom-up approach is used and combined with a top-down calculation to complete and validate the results. From the number of trainsets owned by the operator and the average mileage of individual train series as published by UIC, the performance of the complete fleet is calculated. Detailed information about the mileage of French and German high-speed trains between 2006 and 2012 is given in Appendix D. Top-down, fleet performance (in seat-km) can be calculated by dividing the travel volume by the fleet occupancy rate. Details of the train and fleet performance data can be found in Appendix D. To fill in information gaps, additional data is used from several other sources. For China, data from the World Bank (Amos et al 2010, Bullock et al 2012) and the CRH timetable is used with estimations on travel performance made by the author and input from the universities of Beijing and Shanghai, as data on China's high-speed rail programme is not made publicly available.

Table 4.4 - Descriptive statistics of inputs and outputs (N = 48, 2007-2012)

Variable		NL	FS	AS	FPT	FPS	RS	TV
		Network Length	Fleet Size	Available Seats	Fleet Performance	Fleet Performance	Ridership	Travel Volume
Indicator		Total route-(km)	Number of trains	Number of available seats (thousands)	Yearly train-km of fleet (millions km)	Yearly seat-km of fleet (billions km)	Yearly number of passengers (millions)	Yearly passenger-km (billions km)
Europe (N_E=24)	mean	1391	243	105.9	95.1	42.1	60.0	24.1
	SD	91	26	12.1	10.3	4.8	7.5	3.5
	min	562	97	37.5	45.4	13.4	11.4	8.5
	max	2056	475	216.4	182.6	83.2	115.5	54.0
Asia (N_A=24)	mean	2885	449	278.4	177.5	111.3	222.6	65.3
	SD	433	63	38.4	25.4	15.7	32.4	9.5
	min	330	30	29.7	7.9	7.8	15.6	3.5
	max	6405	632	455.4	300.0	216.2	485.5	144.6

Historically, the largest high-speed rail systems can be found in Japan, France, Germany and Spain. These countries have mature networks built gradually over decades. Heavy investments in high-speed rail over the last decade gave China the position of operating the largest high-speed rail network and fleet in the world since 2010. Train densities on the European high-speed network (ratio of FPT and NL from table 4.4) are about 10% higher than in Asia. In operational models where high-speed trains run on conventional tracks as well, train densities will be higher than in services where only high-speed tracks are used (Doomernik 2013). From 2011 on, China is the leader in ridership and travel volume and shows the fastest growth. Smaller networks can be found in Taiwan and Korea. Although France and China had a comparable fleet size in 2010, China's fleet capacity (number of available seats) is larger as their train sets can carry more passengers. This is typical for the Asian train sets (Doomernik 2013). In Asia, the average number of seats per train (ratio AS/FS from table 4.4) is 620 compared to 436 for Europe. Due to such high-capacity trains, Asia produces 170% more travel volume and 164% more seat kilometers than Europe, with only 86% more train kilometers. Large differences can also be seen regarding the average travel distance (ratio TV/RS from table 4.4). In Asia, travellers take shorter trips (293 km) than in Europe (402 km). Seat occupancy (ratio of TV and FPS from table 4.3) is comparable for Europe (57%) and Asia (59%).

4.8 Results from the DEA model

4.8.1 Malmquist Productivity Index

The results from the Malmquist Productivity Index are listed in Table 4.5 and its decomposition in Efficiency Change and Technical Change in Table 4.6 for the eight high-speed rail systems. In addition, the results are given for the regions Asia and Europe separately and together. When the values of the Malmquist index and its components are more than one in an output-oriented evaluation, they indicate progress (Ozcan and Ozgen 2004).

The MPI reflects a productivity improvement for the whole peer group of 12.5% over the five-year period from 2007 until 2012. This is caused by technical change rather than improvement of efficiency. In contrast with Europe, where the MPI was stable and close to 1 from 2007 to 2012, Asia achieved a productivity growth of 26.9% over the same time period. Europe didn´t show any productivity improvement because, despite the 16.6% technical change, efficiency dropped by 14.4%. In Asia, both technical efficiency improvements (+17.9%) and technology change (+7.6%) contributed to the overall productivity growth.

Table 4.5 - Malmquist Productivity Index (MPI)

	2008-2007	2009-2008	2010-2009	2011-2010	2012-2011	mean	2012-2007
France	1.011	0.967	0.984	0.998	0.974	0.986	0.940
Germany	1.063	0.972	1.058	0.987	1.064	1.028	1.141
Italy	0.931	1.250	1.003	1.001	1.070	1.046	1.188
Spain	0.965	1.028	0.963	0.786	1.036	0.951	0.778
Europe	0.991	1.048	1.001	0.938	1.035	1.002	0.998
Japan	0.965	0.922	1.015	1.019	0.998	0.983	0.969
Korea	1.012	0.953	1.075	1.056	1.054	1.029	1.184
China	1.252	0.663	0.832	1.201	1.200	0.999	0.878
Taiwan	1.917	1.052	1.116	1.103	1.066	1.215	2.573
Asia	1.237	0.885	1.003	1.093	1.077	1.053	1.269
Europe + Asia	1.108	0.963	1.002	1.012	1.056	1.027	1.125

Table 4.6 - Decomposition of Malmquist Productivity Index

	2008-2007		2009-2008		2010-2009		2011-2010		2012-2011		mean		2012-2007	
	EC	TC	EC	TC	EC	TC	EC	TC	EC	TC	EC	TC	EC	TC
France	1.000	1.011	1.000	0.967	1.000	0.984	0.954	1.045	0.916	0.973	1.063	1.013	0.874	1.075
Germany	1.063	1.000	0.957	1.016	1.049	1.008	0.928	1.063	0.961	0.990	1.107	1.038	0.951	1.199
Italy	0.912	1.020	1.255	0.996	1.003	1.000	0.942	1.063	0.920	0.999	1.163	1.047	0.995	1.195
Spain	0.928	1.040	1.070	0.960	0.984	0.979	0.746	1.054	0.891	0.917	1.163	1.037	0.649	1.199
Europe	0.974	1.018	1.065	0.984	1.009	0.993	0.888	1.056	0.922	0.969	1.123	1.034	0.856	1.166
Japan	0.998	0.967	0.945	0.976	1.023	0.993	1.037	0.983	0.949	0.990	1.052	0.994	0.949	1.021
Korea	1.062	0.953	0.904	1.055	1.107	0.971	1.000	1.056	1.000	1.012	1.054	1.017	1.062	1.114
China	1.000	1.252	1.000	0.663	0.840	0.990	1.115	1.077	1.067	1.000	1.125	0.999	1.000	0.878
Taiwan	1.920	0.998	1.000	1.052	1.000	1.116	1.000	1.103	1.000	1.139	1.066	1.066	1.920	1.340
Asia	1.194	1.036	0.961	0.921	0.988	1.016	1.037	1.054	1.003	1.034	1.074	1.019	1.179	1.076
Europe + Asia	1.079	1.027	1.012	0.952	0.998	1.004	0.960	1.055	0.961	1.001	1.098	1.026	1.005	1.120

Note: EC = Efficiency Change, TC = Technical Change

Looking at the individual HSR networks in Europe and Asia, the evolution of the Malmquist index is fairly stable over the years for Germany, Japan, Korea and France. Germany, Italy, Korea and Taiwan show an above-average MPI-value between 2007 and 2012. The high productivity improvement in Taiwan is remarkable (+157%). Taiwan is the only DMU that has achieved a productivity index above unity in every successive year. This is in fact from the start, as the Taiwan high-speed rail services were inaugurated in January 2007 and services were gradually increased. This also explains the high 2008-2007 MPI. Underperformers are the networks in Spain and China, but for different reasons. Efficiency in of the Spanish HSR-network dropped by 34.1% in five years' time, but this is partly compensated for by a technical improvement of 19.9%. China has achieved to keep up efficiency, but shows a decreasing technical change of 12.2%. A lot of variation can be seen in the China technical change index, making progress over the last couple of years. In this case, we have to realise that China only started their high-speed operations in 2008 and is still growing fast. The network is not fully mature yet and CRH (the Chinese national high-speed railway operator) is still optimising their operations.

In general, productivity improvement for the peer group comes from technical change, rather than from efficiency change, which is declining year-on-year. Only Taiwan was able to maintain efficiency in five successive years.

4.8.2 Production efficiency and marketing and sales efficiency

From the descriptive statistics (table 4.7) can be seen that Asian high-speed rail systems are fully efficient in the VRS-model. Scale efficiency is comparable for both Asian and European systems. The CRS and VRS models show that Asia outperforms Europe regarding production efficiency and marketing and sales efficiency.

Table 4.7 - Descriptive statistics of efficiency of eight HSR systems 2007 - 2012

Region	2007 -2012	Production efficiency			Marketing and sales efficiency			System Efficiency		
		CRS TE	VRS TE	SE	CRS TE	VRS TE	SE	CRS TE	VRS TE	SE
Europe (N=4)	mean	0.795	0.896	0.889	0.792	0.842	0.944	0.791	0.821	0.963
	SD	0.020	0.024	0.009	0.032	0.035	0.011	0.028	0.028	0.007
	min	0.542	0.591	0.796	0.504	0.522	0.783	0.555	0.579	0.856
Asia (N=4)	mean	0.936	0.985	0.949	0.877	0.977	0.897	0.958	1.000	0.958
	SD	0.025	0.011	0.021	0.027	0.012	0.025	0.020	0.000	0.020
	min	0.545	0.773	0.545	0.608	0.776	0.608	0.521	1.000	0.521

CRS TE = Technical Efficiency from CRS DEA   VRS TE = Technical Efficiency from VRS DEA   SE = Scale Efficiency

The efficiency scores for the production and marketing process for all networks and their development in time for the years 2007-2012 are reflected in the performance matrices in figures 4.8 and 4.9. Overall efficient DMU's are coloured green and inefficient ones orange (overall efficiency between 0.75 and 1.00) or red (overall efficiency between 0.50 and 0.75).

The Asian DMU's and France are the best performers in the peer group. In all years, Italy appears to be the worst performer and Germany and Spain are in the middle of the spectrum. Except for 2007, when the high-speed rail service was started, Taiwan was overall efficient and effective in production. Year-on-year, Taiwan has improved its marketing efficiency compared to others. This is in line with the MPI results shown earlier. Although the efficiency of the production process varies over the years, China was able to be fully efficient in its marketing process. The results from the Malmquist index show that technical change has been lagging behind. This indicates that improvements could be achieved in optimising the technical production process. For Korea, the opposite is the case: an efficient production process, but variation in the marketing efficiency. In Japan, we see a dip in 2008 and 2009 in marketing performance. The last three years, they have an efficient production and are improving their marketing performance, but are outperformed by Korea and Taiwan. This ranking can also be recognised by the MPI results. The evolution of the production and marketing efficiency in Italy and Germany shows the same pattern: a steady reduction in production efficiency and improving marketing performance after a light shortfall. Italy is performing a bit better in production, but this cannot compensate for their marketing inefficiency. Spain and France show fluctuating results. Their marketing is better than their production performance. France is improving and Spain is losing on production efficiency over the last years.

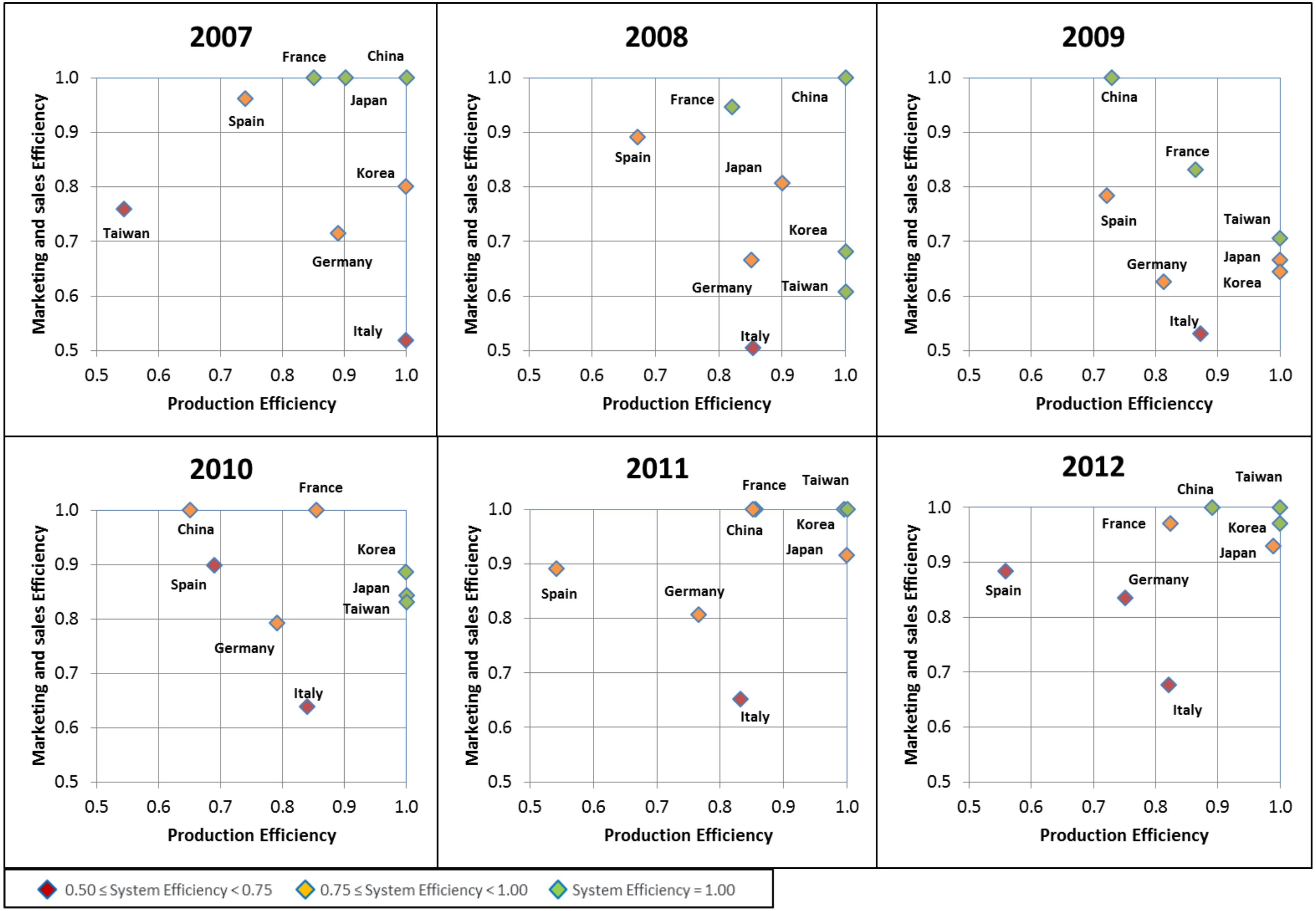

Figure 4.8 - Performance per year of HSR networks in the world (2007-2012)

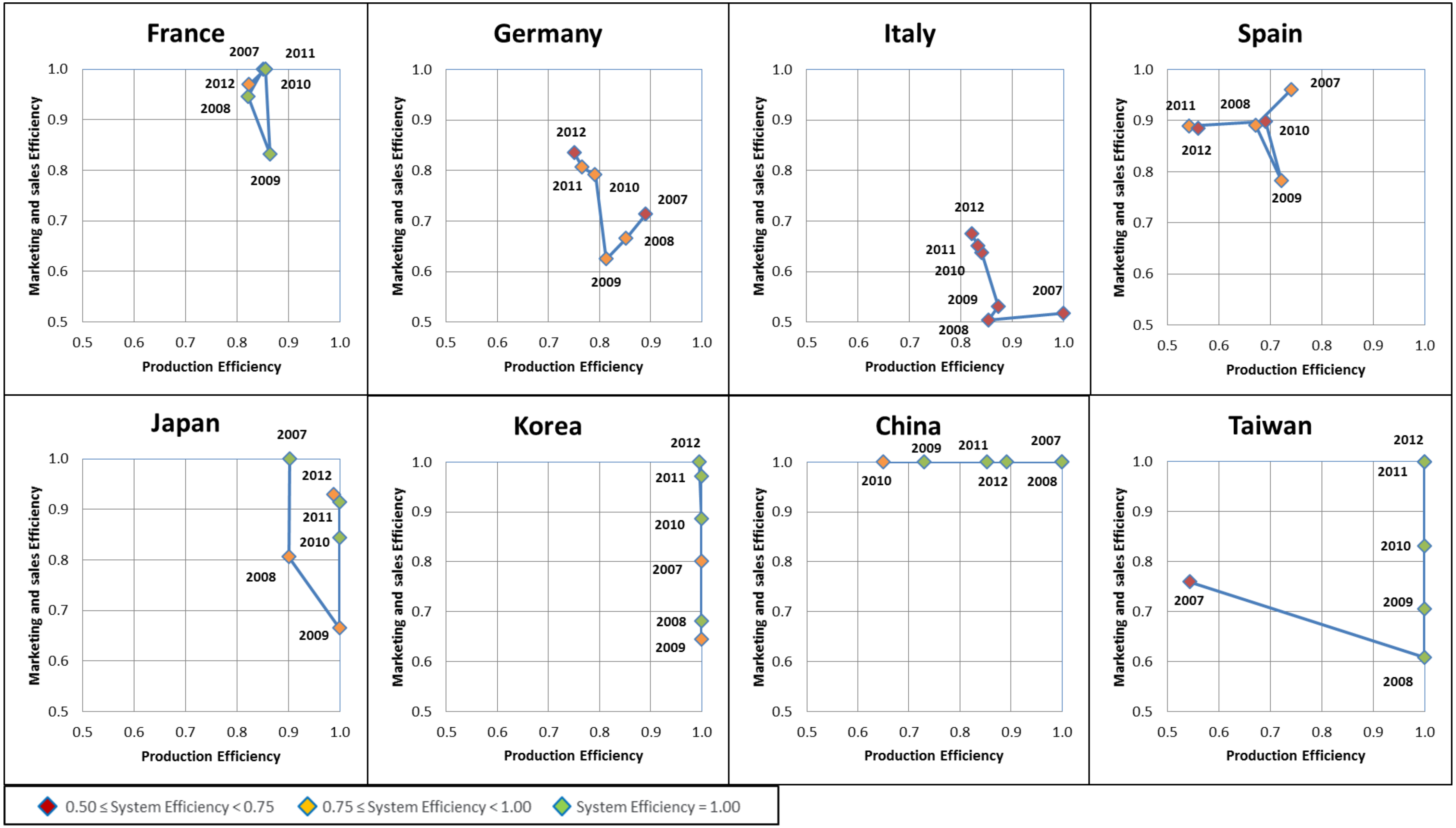

Figure 4.9 - Performance per country of HSR networks in the world (2007-2012)

The correlation coefficients between production and marketing & sales efficiency for all high-speed rail systems in the peer group over the years 2007 to 2012 are presented in table 4.8 for the CRS and VRS model (in total 48 observations from eight countries and over six years). The results indeed show a negative correlation, which implies that increased production efficiency tends to come with decreased efficiency in marketing and sales process. For Europe, this effect is much stronger than for Asia, where a 10% increase in production efficiency comes with a 7% loss in marketing & sales efficiency.

Table 4.8 - Correlation between Production Efficiency and Marketing & Sales Efficiency

	CRS Model	VRS Model
Region	M&S Efficiency / Production Efficiency	
Europe + Asia	-0.091	-0.179
Europe	-0.657	-0.661
Asia	-0.170	-0.128

4.9 Explanatory factors

The performance evaluation of high-speed rail does not explain why some high-speed systems perform better than others. The same explanatory variables as identified in the multi PPM-benchmark i.e. operational model, network structure and system maturity are evaluated against the system efficiency results and Malmquist Performance Index for 2012 in table 4.9.

Table 4.9 - Performance and explanatory factors for HSR systems in the world (2012)

2012	Performance		Explanatory factors					
Country	System Efficiency	MPI 2012-2007	Network Structure	System Maturity (yr)	Operational Model	Network Size (km)	Fleet Size (trainsets)	Train Capacity (seats)
France	0.874	0.974	Star	10 to 40	Mixed HS	1896	475	456
Germany	0.735	1.064	Meshed	10 to 40	Fully mixed	1285	246	454
Italy	0.622	1.070	Linear	10 to 40	Mixed HS	923	110	566
Spain	0.555	1.036	Meshed	10 to 40	Mixed CR	2056	193	306
Japan	0.949	0.998	Linear	> 40	Exclusive	2664	365	965
Korea	1.000	1.054	Point-point	<10	Exclusive	412	65	768
China	1.000	1.200	Meshed	<10	Exclusive	6405	632	721
Taiwan	1.000	1.066	Point-point	<10	Exclusive	345	30	989

Note: Details about explanatory factors in section 4.5

As expected, new networks with an exclusive operational model perform better than others (Korea, China and Taiwan) because operation is not disturbed by conventional trains and always uses dedicated high-speed track. It also shows that HSR-systems with larger trainsets perform better, which could indicate that economies of scale can be achieved with longer trains. For network structure and size and fleet size, no uniform conclusions can be drawn.

4.10 Asian operators

In the analysis of the eight selected high-speed rail operators, coherent national networks and operational models are assumed. In Japan, the national network consists of four sub-networks though, operated by JR East, JR Central, JR West and JR Kyushu. The analysis can be detailed by taking the individual operators as DMU's, instead of the national network as level of aggregation. This also gives the opportunity to compare competitors operating on the same network like the Italian case where in 2012 a new private operator entered the high-speed rail market (Cascetta and Coppola 2014).

A DEA benchmark exercise is conducted with the four Japanese high-speed rail operators (JR East, JR Central, JR West and JR Kyushu) and the Taiwan High Speed Rail Cooperation (THSRC). All these companies operate in an exclusive exploitation model i.e. high-speed trains only run on high-speed track and high-speed tracks are not used by conventional trains. The results can be found in Appendix E. In all years JR West appears to be the inefficient (overall efficiency between 0.75 and 1.0) and the worst performer. JR Central is the best performer in the peer group regarding production efficiency and JR East regarding service performance. Taiwan is overall efficient and efficient in production, except for 2007, when THSRC started their operation. As seen earlier, Taiwan has improved their marketing efficiency steadily compared to others. JR Kyushu performed well in the first three years (2007-2009), but from 2010 until 2012 its performance went down compared to its peers.

4.11 Conclusions and discussion

4.11.1 Conclusions from the DEA benchmark

The peer group in the DEA benchmarks consists of eight networks, which show considerable differences in operational models. The four basic operational models that can be recognised in various countries are i) the exclusive model where only HS-trains run on HS-track (Japan, Korea, Taiwan), ii) the mixed high speed model where HS-trains run on conventional track as well (France, Italy, China), iii) the mixed conventional model where also conventional trains can access the HS-network (Spain) and iv) the fully mixed model where both high-speed and conventional trains can run on high-speed and conventional tracks (Germany) (Rus et al. 2009). Although theoretically it would be better to consider different operational models, the peer group is too limited to split it into sub-groups.

Between 2007 and 2012, Asia achieved a productivity growth of 26.9%. Europe did not show any productivity improvement because, despite the 16.6% technical change, efficiency dropped with 14.4%. In Asia both technical efficiency improvements (+17.9%) and technology change (+7.6%) contributed to the overall productivity growth.

Germany, Italy, Korea and Japan show an above-average MPI-value between 2007 and 2012. The high productivity improvement in Taiwan is remarkable (+157%). Taiwan is the only DMU that has achieved a productivity index above unity in every successive year. Underperformers are the networks in Spain and China, but for different reasons. Efficiency of the Spanish HSR network dropped by 34.1% in five years' time, but this is partly compensated for by a technical improvement of 19.9%. China managed to keep up efficiency, but shows a decreasing technical change of 12.2%.

The DEA model shows that Asian HSR systems are fully efficient in the VRS model and Asia outperforms Europe regarding production efficiency and marketing and sales efficiency. The Asian DMU's and France are the best performers in the peer group. In all years, Italy appears to be the worst performer and Germany and Spain are in the middle of the spectrum.

The results show a negative correlation between production efficiency and marketing and sales efficiency. For Europe, this effect is much stronger than for Asia, where a 10% increase in production efficiency comes with a 7% loss in marketing and sales efficiency.

4.11.2 Discussion

The study shows that HSR can be represented as a MIMO-system with two input and two output variables for benchmark purposes. Meaningful comparisons can be made based on the overall efficiency and the efficiency of the production and marketing process.

A Network DEA model has proven to be very useful to analyse the differences in performance among the peer group. It gives a better view if performance differences come from the production or marketing and sales process. The performance matrices reveal typical patterns regarding production efficiency and marketing and sales efficiency. The conclusions from the Malmquist index are in line with the resulting performance matrices from the DEA model.

In the NDEA model, the number of variables is rather limited. Including extra variables will lead to a better representation and better understanding of the actual situation. For the input, one could include for example labour (number of train drivers and train assistants) and operational costs. Besides train-km's to describe the fleet performance, punctuality could also be an important intermediate variable. Client satisfaction could be added as an extra output variable. To what extent extra variables can be included depends on data availability. The model could be refined by considering shared inputs and adding environmental variables as suggested by Yu (Yu 2008).

In this chapter, a benchmark was used to investigate the performance of European and Asian high-speed rail operators between 2007 and 2012. Countries that are planning for a high-speed rail future can take lessons from existing networks. They can identify their high-speed rail peers in Asia and Europe and benchmark their plans to existing cases. The results from this study give guidance on the major identified key performance indicators and indications for scores that need to be achieved. A benchmark does not answer the question why some operators perform better than others and does not explain to what extent market structure and operators' behaviour influence their performance. It has become clear that, besides the size of the network and rolling stock fleet, the operational model, networks structure and the system maturity are of major importance for performance, but the results give no cause for decisive conclusions. Of course, many other factors influence the results. Government policies, market conditions, demand for high-speed transport, competition, economic welfare, service quality and ticket prices, track record regarding safety and reliability and branding and image all affect performance.

Operators need efficient production and marketing and sales processes to compete. This is valid for both incumbents and new entrants. In Europe, lessons can be learned from France, being the best performer in this perspective. SNCF has a strong position, operating all the national high-speed lines and is involved in several joint ventures with incumbents of neighbouring countries to run cross-border services. In Asia, the Taiwan High Speed Rail Cooperation, JR East and JR Central are interesting operators to study in more detail to find the attributes to their good performance in production and marketing and sales.

In the SCP model (figure 1.1), performance is closely related to the operators' conduct and feeds back into the demand and supply conditions and market structure. Identification of the market structure is important to learn more about the behaviour of individual operators. With this observation in mind, the market structure for international high-speed passenger transport that defines the playground and competitive environment for airlines and railway operators is analysed in the next chapter. Performance of high-speed rail operation is studied in relation to conduct and market structure in more detail for the London-Paris market for 2003 till 2015 using multi-linear regression analysis.

5 Market structure

5.1 Introduction

The conceptual research model is organised according to the Structure-Conduct-Performance paradigm as indicated in chapter 1. In this chapter, the relations between the high-speed passenger transport market structure, the conduct of airlines and high-speed rail operators that operate in this market and their performance is investigated using empirical data. Our specific interest is to find how the operators' behaviour in terms of strategic decisions concerning service characteristics and pricing is related to market structure and performance.

This chapter starts with a projection of Porter's five-forces framework for industrial analysis on the high-speed passenger transport market to identify the market structure and players. For this purpose, the model is extended to a six-forces model to capture the influence of complementors (Grant 2010). The Structure-Conduct-Performance model is used to structure relevant variables to study the relationship between the three SCP elements. After describing the London-Paris high-speed passenger transport market, the model is applied for this specific case. A multi-linear regression analysis is used to identify the importance of the conduct variables of all market players i.e. all operational airlines and Eurostar between 2003 and 2015. A second analysis is done with a specific focus on Eurostar. The results for both models are presented and discussed in section 5.7.

5.2 Industry definition

High-speed rail operators act in general in monopolistic railway markets. A duopoly develops in case a new HSR operator enters the market like for instance NTV in Italy competing with Trenitalia on the national network. Although the market for international cross-border rail services is open since 2010, there are only few railway operators that have the resources and capabilities to provide these services. Entry barriers for new entrants are numerous like market potential and competition, European rail directives and regulations, certified rolling stock and staff, network access and financial resources. Besides intra-modal competition between incumbent railways and new entrants and conventional and high-speed rail, the rail market faces inter-modal competition from airlines, private cars and busses. The market can be characterized as an oligopoly when other transport modes are taken into account.

Every industry has its own characteristics and although there are many differences across industry sectors, general observations can be made when it comes to strategy. A classical approach in the business literature, the "Five Forces" framework from Porter (2008), describes the industry from a business perspective and the viewpoint of competition. The five forces that drive industry competition are postulated as: threat of substitutes, threat of new entrants, bargaining power of suppliers, bargaining power of buyers and intensity of rivalry among competitors (Preston, Whelan & Wardman 1999). Especially in fast growing or new markets, it is important to look beyond direct competitors and take also the customers, suppliers, new entrants and substitute services into account. In general, for rail the threat of substitutes (such as car, coach and plane) and the bargaining power of suppliers (such as infra providers and rolling stock manufacturers) is high, but the bargaining power of buyers is low (Preston et al. 1999). Complementarity exists in the industry when a product or service cannot be delivered without another product or service (Grant 2010). In the railway industry, operators cannot deliver their (international) services without the infrastructure managers, which can be seen as a complementors. To include the role of the infrastructure managers, a sixth force, the bargaining power of complementors, was added to Porter's industry analysis framework (figure 5.1).

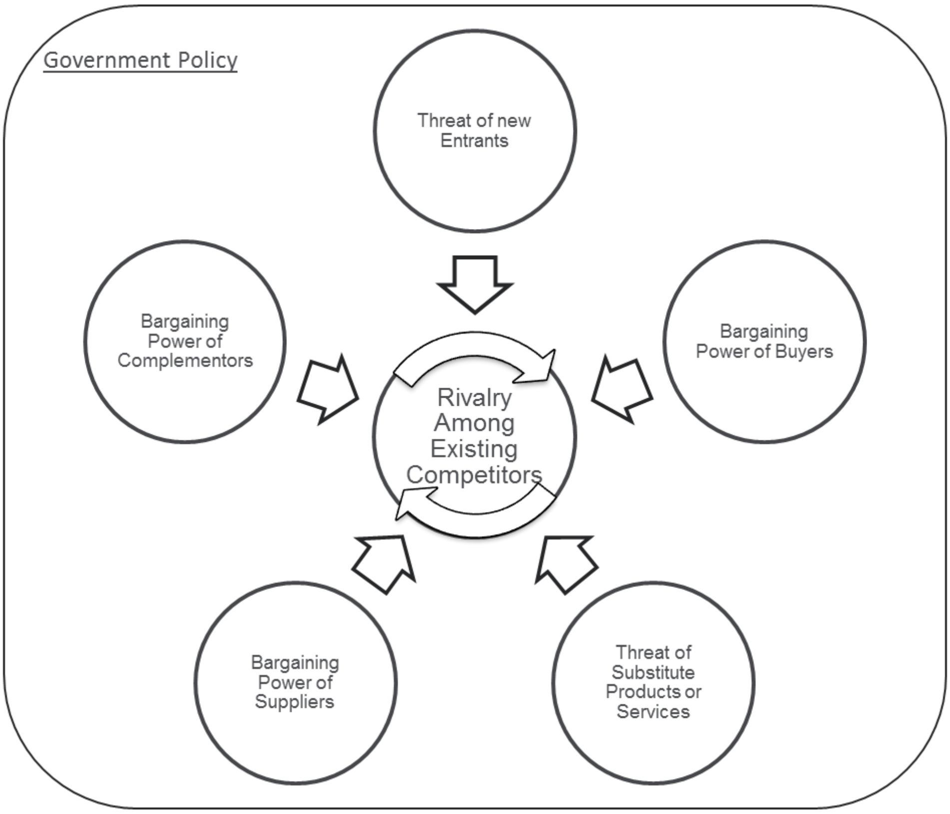

Figure 5.1 - The six forces that shape industry competition

Note: adapted from Porter 2008 and Grant 2010

5.2.1 Competitors

Considering the railway industry, established incumbent railways dominate the national markets. In most European countries, they have a monopolistic position, and even though long-term transport concessions are more and more common practice, the market is not open to competitors, at least not during the time of the concession period. Opportunities arise in national and international open access high-speed rail traffic where market power and monopolistic behaviour of incumbent railways is less. Incumbent railways have built joint ventures (e.g. Thalys, Eurostar) and positioned themselves on attractive international routes. This is a major barrier for competitors to enter the market. Railway operators not only face inter-modal rivalry, but also competition from other transport modes.

5.2.2 Buyers

Passengers cannot really choose between different operators. Even in a liberalised market, there is normally only one rail operator that runs a service to the destination of choice. The bargaining power of passengers within the rail mode is therefore non-existing. The alternative in conventional rail is to switch to another modality like coaches or private cars. For high-speed traffic, the customers' choice is between plane and high-speed train. Besides new entrants, these substitutes are serious threats for railway operators, especially on international routes.

5.2.3 Substitutes

In long-distance international travel, readily available and well-established substitutes like cars and (low-cost) airlines make it hard for train operators to grow their business and market share. Operators focus more on competition with other modes of transport than on rival railway companies. This might change when high-speed corridors prove to be better accessible for competing operators. Opening new high-speed lines or upgrading existing routes has proven to have serious effect in increasing the railways' market share. On the one hand, it will reduce conventional rail services on the same route, and on the other hand, travellers will shift from car and plane to high-speed trains. The total market will grow as new infrastructure induces extra traffic.

5.2.4 New entrants

As seen in freight transport, new players attempt to enter the European market, but with little success so far. Strong positions and market power of incumbent railways hinder new entrants in being successful. The new freight corridors in Europe may offer new opportunities and in time that might also be expected for high-speed rail traffic. So far, only NTV in Italy has managed to enter the high-speed rail market, but only on a national scale. For international connections, the market is dominated by national state-owned operators or joint ventures with national state-owned operators and no new entrants are observed.

5.2.5 Complementors

The sixth force, complementors, refers to products or services that are compatible with what a particular industry sells. In the railway industry, the operator cannot deliver its transport services without the services of the infrastructure manager. The operator's performance and profitability depends on the way train paths are provided by the infrastructure manager. If the infrastructure manager is performing well and reliable train paths are available with an acceptable price, the railway operator will benefit. On the contrary, if performance is bad or track access charges too high, the level of profit that the industry can obtain will be impacted. Although historical bonds between incumbent operators and national infrastructure managers have been relaxed during the rail liberalisation process in Europe to give opportunities to new entrants, there is a risk that incumbent operators still have a preferred position.

5.2.6 Government policy: the seventh force

Porter pays little attention to the governmental influences that can seriously affect the way markets operate. The model assumes a perfect and liberalised open market. Policy makers influence the market structure in terms of liberalisation, privatization and deregulation that will affect all market players. Competition laws, taxes and subsidies and policies on international trade, macro-economics, environment etc. will affect the behaviour of market players. The European railway directives give the framework and rules for the railway market development. The railway sector might be open from a political viewpoint, but in day-to-day practice the operators struggle with the "six" forces in a more or less closed market space.

5.3 SCP model for the high-speed passenger transport market

The neoclassical economic theory of competing firms distinguishes among four main theoretical market structures: (a) perfect competition, (b) monopolistic competition, (c) monopoly and (d) oligopoly (Lipczynski et al., 2013). In the railway industry, the number of competing firms is small. Most operators are monopolists on specific rail links like Thalys or Eurostar or have only one on-rail competitor as for example Trenitalia and NTV on the Rome – Milan corridor. As can be seen from the analysis of the "six forces", high-speed rail operators compete with substitutes such as airlines, conventional rail, coaches and private cars. This inter-modal competition can be characterised as an oligopoly where a small number of firms provide passenger transport services on a specific origin-destination pair. More precisely, a city-to-city link is an oligopoly with differentiated products as services of different modes have different quality characteristics like travel time, frequency, convenience etc.

As stated in chapter 1, the study focusses on strategies of passenger Train Operating Companies (TOC's) in the European market (EU 28) that run high-speed train services, i.e. the TOC in interaction with its environment (clients, infrastructure managers, authorities, competitors) and within the context of the EU transport policy. For the theoretical framework, the structure-conduct-performance paradigm (Lipczynski et al 2013) is used for the analysis (figure 5.2). The aim of this research is to explore the relations between the determining variables for market structure, operators' behaviour and their performance for the cross border high-speed travel market in Western Europe.

Market structure and performance are influenced by strategic decisions (Hazersloot 2013). The way operators perform in the market place depends on their proposition regarding service characteristics and prices offered. Our focus is the operators' conduct and how their behaviour influences performance and market structure. The SCP model has been applied for numerous sectors like for example non-ferrous-metal mining and refining (Slade 2003), manufacturing in Korea (Jeong and Masson 1990) and the US (Delorme et al.), international shipping (Lam et al. 2007), the Spanish hotel industry (Jorge and Suárez 2014) and accounting firms in Taiwan (Lee 2012, 2013). To our knowledge, the SCP model has never been applied to high-speed passenger transport markets.

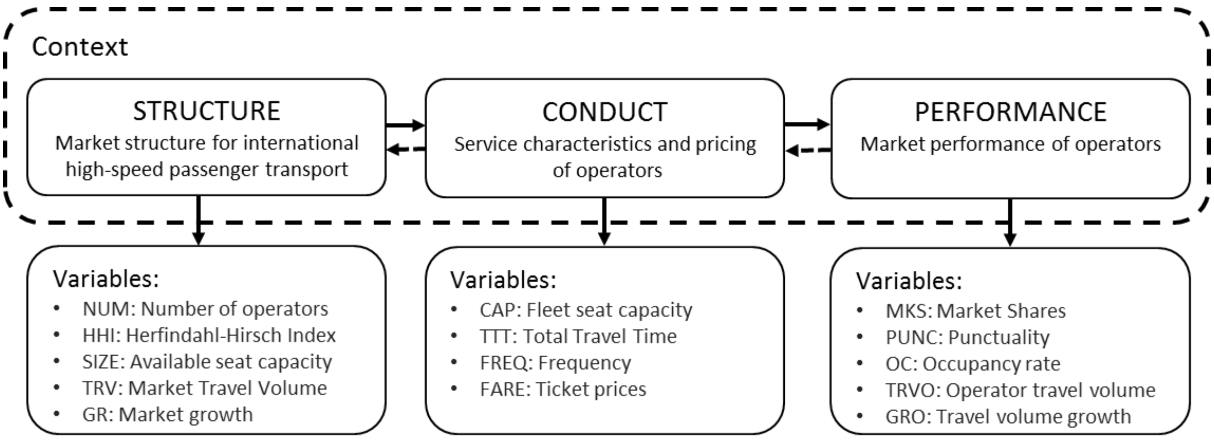

Figure 5.2 - SCP model for the high-speed transport market

Regarding the methodology, we follow the approach as developed by Lee (2012) for the accountancy industry in Taiwan. The method is based on three equations that describe the relationship between the three elements of the SCP model:

- Structure = *f* (Conduct variables, Performance variables)
- Conduct = *f* (Structure variables, Performance variables)
- Performance = *f* (Structure variables, Conduct variables)

These equations are detailed by definition and selection of adequate sets of structure, conduct and performance variables. An overview of the variables is given in table 5.1. Although it is possible to include binary predictors, we have restricted ourselves to quantitative variables.

To find the correlations between these variables, a two-step procedure is applied. In the first step, the degree to which all variables are linearly related is assessed by calculating the Pearson product-moment correlation coefficients. Combinations that are not significantly linearly related are excluded. In the second step, the coefficients are calculated by a multiple linear regression calculation.

Table 5.1 - Definition of Structure, Conduct and Performance variables

SCP element	Variable	Description
Structure	NUM	Number of operators on the Origin-Destination link
	HHI	Herfindahl-Hirschman Index for every year based on the individual market shares of all services provided on the OD-link
	SIZE	Total available seats offered by all services on the OD-link for every year
	TRV	Travel volume in each year for all services provided on the OD-link expressed in number of passengers (million)
	GR	Growth in travel volume on the OD-link compared to the year before.
Conduct	CAP	Available seats offered by each individual service on the OD link for every year
	TTT	Total Travel Time between origin and destination for each individual service (total of in-vehicle time, port processing time and delay)
	FREQ	Frequency offered per week on the OD connection for each individual service
	FARE	Mean ticket price realized by each individual service in every year in pound Sterling (£)
Performance	MKS	Travel volume of each individual service on the OD link in relation to the total travel volume of all services for every year
	PUNC	Punctuality on arrival within 15 minutes of the scheduled arrival time for each service and every year.
	OC	Occupancy rate of available seats for each service and every year.
	TRVO	Travel volume in each year for every individual service expressed in passenger-kilometers.
	GRO	Growth in travel volume for each individual service on the OD-link compared to the year before.

The empirical model consists of three sets of linear equations with 14 variables for structure, conduct and performance. Each variable per set acts as a Dependent Variable (DV) with the variables from the other two sets as Independent Variables (IV). The associated formulas are given below.

$$S_i = a_0 + (a_1 * CAP + a_2 * TTT + a_3 * FREQ + a_4 * FARE) + (a_5 * MKS + a_6 * PUNC + a_7 * OC + a_8 * TRVO + a_9 * GRO) + e_1$$

where (i = 1, 2, 3, 4, 5), S_1 = NUM, S_2 = HHI, S_3 = SIZE, S_4 = TRV, S_5 = GR,

$$C_i = b_0 + (b_1 * NUM + b_2 * HHI + b_3 * SIZE + b_4 * TRV + b_5 * GR) + (b_6 * MKS + b_7 * PUNC + b_8 * OC + b_9 * TRVO + b_9 * GRO) + e_2$$

`

where (i = 1, 2, 3, 4), C_1 = CAP, C_2 = TTT, C_3 = FREQ, C_4 = FARE,

$$P_i = c_0 + (c_1 * NUM + c_2 * HHI + c_3 * SIZE + c_4 * TRV + c_5 * GR) + (c_6 * CAP + c_7 * TTT + c_8 * FREQ + c_9 * FARE) + e_3$$

where (i = 1, 2, 3, 4, 5), P_1 = MKS, P_2 = PUNC, P_3 = OC, P_4 = TRVO, P_5 = GRO.

The coefficients a_i, b_i and c_i are to be estimated from a multi-linear regression analysis where e_1, e_2 and e_3, are the error terms. The multiple linear regression analysis is applied for all equations consecutively. Following the procedure as described by Lee (2012), each regression consists of two steps. In step 1 the significant parameters are identified. After the deletion of the unimportant and insignificant parameters, the correlation coefficients are calculated in step 2.[16]

5.4 Structure of the London – Paris market

The London-Paris link is serviced by airlines from the London area with five airports (Heathrow, Gatwick, Luton, City and Stansted) and from the Paris area with four airports (Charles de Gaulle, Orly, Le Bourget and Beauvais[17]). In 2012, airline services were offered by British Airways and Air France between Heathrow and Charles de Gaulle, British Airways between Heathrow and Paris Orly, CityJet between City Airport and Paris Orly and EasyJet between Luton and Paris CDG (figure 5.3). Eurostar operated the high-speed rail connection between the railway stations London St Pancras and Paris Nord.

On the London-Paris link, inter-modal competition can be observed between airlines, HSR (Eurostar), coaches and private cars. Intra-modal competition exists between traditional airlines (British Airways, Air France) and the Low Cost Carriers EasyJet, CityJet, VLM and BA CitiExpress. Air traffic is growing again since 2010 after a decrease between 2003 and 2010 (figure 5.4). British Airways and Air France have a dominant market share on the London Heathrow – Paris Charles de Gaulle connection, but competition from smaller airports and

[16] This approach is different from simultaneously solving a system of equations.

[17] Paris - Le Bourget is a business airport and Paris - Beavais, the original city airport used for charter flights and budget airlines. In 2012, there were no regular services to London from Le Bourget and Beauvais.

low cost carriers is growing. For an air distance of 350 km strong competition might be expected. Operators target both business and leisure travellers in this market.

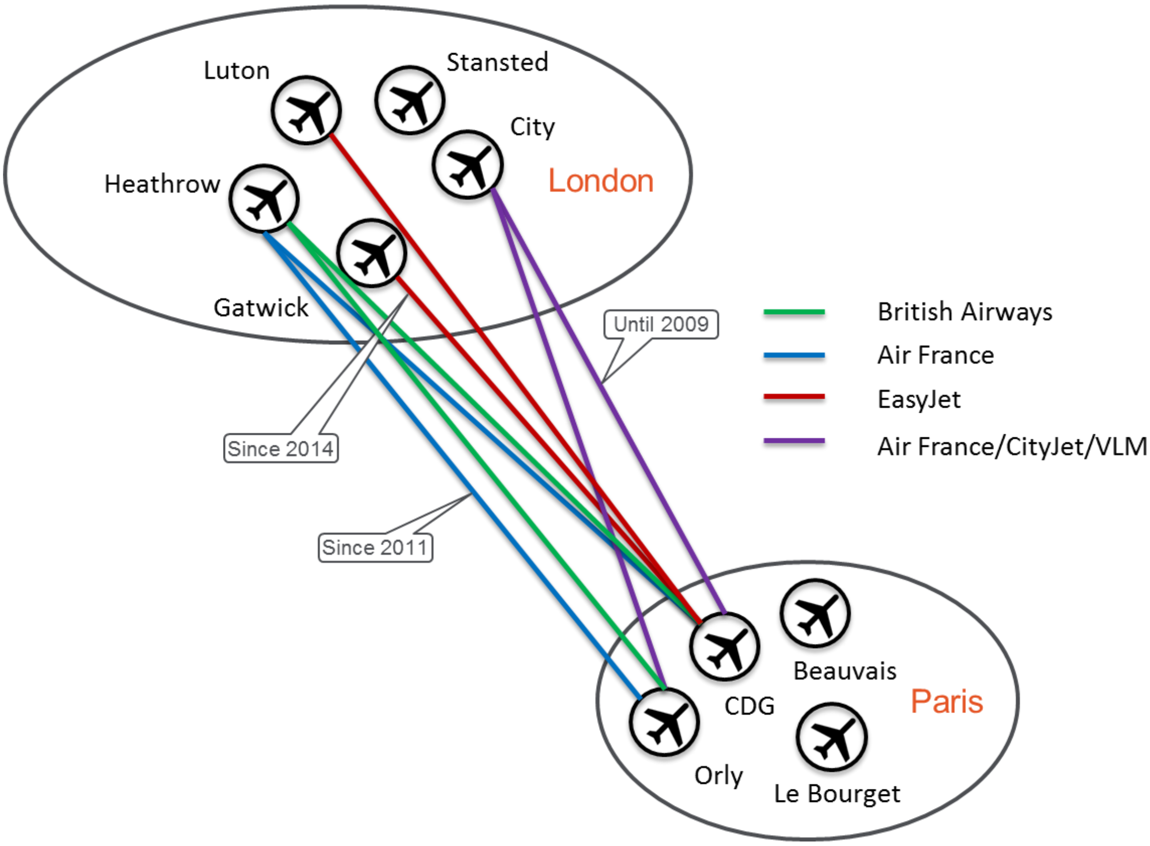

Figure 5.3 - Air traffic Paris-London market

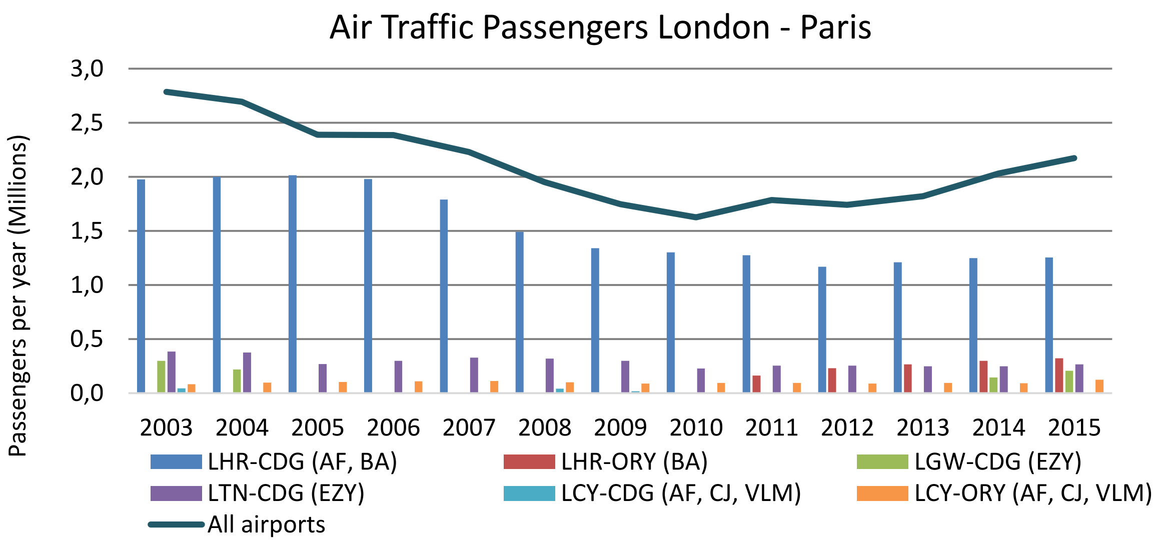

Figure 5.4 - Evolution of passenger traffic London-Paris

Note 1: Figure by author based on Eurostat data, last update 07.05.15, extracted on 14.08.15
Note 2: LHR: London Heathrow, CDG: Paris Charles de Gaulle, ORY: Paris Orly, LCY: London City, LGW: London Gatwick, LTN: London Luton, AF Air France, BA: British Airways, CJ: CityJet, EZY: EasyJet

The London-Paris air/rail market has grown by 28.7% between 2003 and 2015. Rail has gained a dominant market share which has grown from 62% in 2003 to 80% in 2012 (figure 5.5). The last couple of years, the airlines have managed to improve their market share to 23%. The indicated market shares are over-estimated when also private cars are taken into account as an alternative.

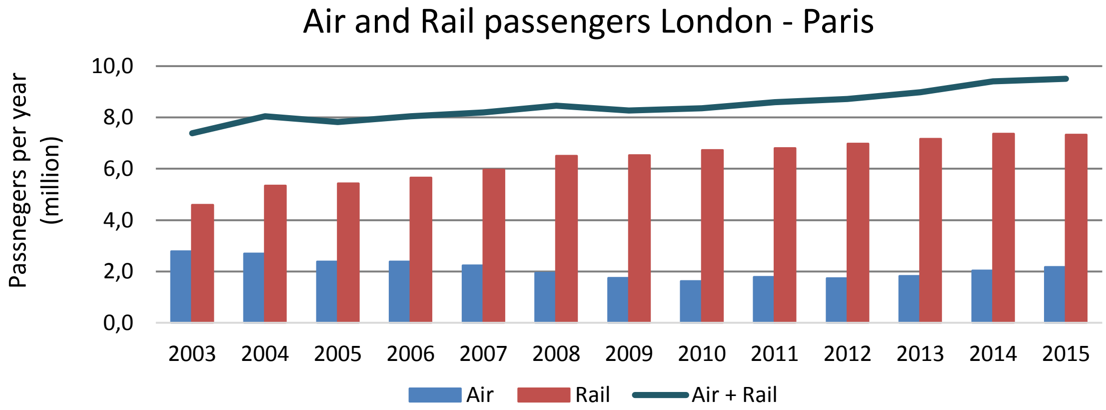

Figure 5.5 - Air and Rail traffic volumes London-Paris

Note: Figure by author based on Eurostat data, last update 07.05.15, extracted on 14.08.15

Besides using airlines or a high-speed train, travellers can also travel by coach or use their private car and ferry (DFDS Seaways, P&O Ferries) or tunnel (Eurotunnel Shuttle) between Dover and Calais to make the Channel crossing. DFDS Seaways and P&O Ferries provide the majority of ferry services. From all private cars using the Dover-Calais connection to cross the Channel, 44% takes the ferry (DFDS Seaways and P&O Ferries) and 56% use Eurotunnel (IPS 2012). For 2012, the market share for private cars on the London-Paris route is estimated at 3.6% (see Appendix H).

An analysis of the market structure variables (see Appendix J) shows a growth in travel volume from 7.2 to 9.5 million passengers between 2003 and 2015. In the same period, the total available seats have been 12 million or less. Consequently, the market in total has become more efficient with an increasing occupancy rate from 60% in 2003 to 80% in 2015. The number of operators varied between four and seven. The Herfindahl-Hirschman Index (HHI), defined as the sum of the squared market shares of all operators in the market is a measure to indicate the market concentration. The HHI can vary between 1/N (with N the number of operators) in the case of N competitors with an equal market share and 1 in case of a monopoly. The HHI increased from 0.43 to 0.66 from 2003 to 2010 and decreased again to 0.61 in 2015. An HHI in the range of 0.20 to 0.60 indicates an oligopolistic market. If the HHI is above 0.60, a monopolistic market structure exists (Besanko 2013). The London-Paris passenger market is an oligopoly with a tendency to a monopoly with Eurostar being the dominant player.

5.4.1 Suppliers

Suppliers like the train manufacturers boost prices for special requirements and due to small series of rolling stock, unit prices are still high. This will affect the competitive position of operators. Larger incumbent operators will profit from economies of scale and stronger buying power compared to smaller new entrants. The infrastructure managers, supplying train paths to operators, have their own policies regarding infrastructure charging. European regulations require a non-discriminatory access to railway networks, but for example high charges for high-speed train paths on conventional lines may favour national traffic. The rail infrastructure managers can be seen as a key supplier, but because of their market power, we prefer to position them as a complementor.

5.5 Behaviour and performance in the London – Paris market

The proposed empirical SCP-model is applied to the London-Paris link taking into account all transport providers i.e. Eurostar and the four airlines British Airways, AirFrance, BMI and EasyJet as outlined in section 5.4.

5.5.1 Input data

Data is gathered for the period 2003 until 2015 from Eurostat, UK International Passenger Surveys, timetables and flight schedules, press releases and annual reports. Cases with missing data are omitted. The descriptive statistics from the complete dataset as given in appendix J is presented in table 5.2. IBM SPSS version 24 is used for the analysis.

Table 5.2 - Descriptive statistics for all operators London-Paris market (2003-2015)

	Structure						Conduct				Performance			
	NUM	HHI	SIZE	TRV	GR	CAP	TTT	FREQ	FARE	MKS	PUNC	OC	TRVO	GRO
N Valid	75	75	75	75	75	75	75	75	75	75	75	75	75	71
N Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Mean	5.88	0.59	11.37	8.45	0.02	1.98	147.26	51.63	110.57	0.17	0.75	0.70	1.46	0.01
Median	6.00	0.61	11.39	8.45	0.03	0.77	146.00	45.00	114.94	0.06	0.74	0.70	0.58	0.01
Std. Dev.	0.770	0.071	0.500	0.652	0.031	3.011	18.244	32.393	42.364	0.269	0.105	0.106	2.291	0.172
Skewness	-0.518	-1.002	-0.915	0.060	0.393	1.725	0.332	0.693	0.698	1.737	0.087	-0.987	1.805	1.004
Kurtosis	0.244	-0.280	1.770	-0.739	0.542	1.124	0.208	-0.759	1.149	1.176	-0.693	1.119	1.509	6.781
Minimum	4	0.433	9.930	7.256	-0.029	0.041	110	4	47	0.002	0.533	0.387	0.018	-0.561
Maximum	7	0.662	12.178	9.504	0.095	9.048	194	116	266	0.805	0.950	0.868	7.370	0.779

Note 1: NUM, CAP, OC, TRVO are derived from Eurostat and Eurotunnel data
Note 2: MKS is ratio of TRVO and TRV, TRV is sum of TRVO, HHI is calculated using MKS results, SIZE is the sum of CAP, GR and GRO are calculated on TRV and TRVO data for subsequent years
Note 3: PUNC for airlines UK Civil Aviation Authority and for Eurostar from press releases and annual reports
Note 4: TTT, FREQ are deducted from Eurostat data, flight schedules (www.flightstats.com) and Eurostar timetables
Note 5: FARE data come from Behrens and Pels (2012) for 2003 till 2007 and the International Passenger Survey published by UK Office of National Statistics for 2008 till 2015

In the thirteen-year time period, four to seven airline operators were offering travel services in competition with Eurostar, resulting in 75 observations. For the period 2003 until 2007, the data is restricted to Eurostar and the four major airlines on the London-Paris route.

The resulting Pearson product-moment correlation coefficients from the analysis are displayed in table 5.3. The table highlights correlations that have a 1% and 5% significance level. None of the structure variables has a significant correlation with a reliability better than 0.01 ($p<0.01$) with the conduct and performance variables, except for correlation between HHI and PUNC. On the contrary the conduct and performance variables all have a significant correlation ($p<0.05$), except all relations with GRO. This indicates that the market structure is as characterised by the chosen variables is of little influence on the market behaviour and performance of operators in the London-Paris market, but the operators' behaviour and performance are closely related.

Table 5.3 - Results from the correlation analysis model 1: air and rail London-Paris

		Structure					Conduct				Performance				
		NUM	HHI	SIZE	TRV	GR	CAP	TTT	FREQ	FARE	MKS	PUNC	OC	TRVO	GRO
Structure	NUM	1.000	0.178	0.780	0.650	0.279	-0.082	-0.122	-0.199	0.180	-0.094	0.111	0.066	-0.062	0.093
	HHI	0.178	1.000	-0.258	0.727	-0.267	-0.023	-0.195	-0.169	0.045	-0.015	0.304	0.093	0.020	-0.069
	SIZE	0.780	-0.258	1.000	0.153	0.262	-0.061	-0.052	-0.106	0.128	-0.078	-0.046	-0.097	-0.069	0.045
	TRV	0.650	0.727	0.153	1.000	0.056	-0.053	-0.132	-0.207	0.174	-0.054	0.180	0.251	-0.007	0.123
	GR	0.279	-0.267	0.262	0.056	1.000	-0.011	0.045	0.007	0.111	-0.017	-0.138	0.005	-0.012	0.066
Conduct	CAP	-0.082	-0.023	-0.061	-0.053	-0.011	1.000	0.823	0.870	-0.302	0.999	0.592	0.236	0.994	0.105
	TTT	-0.122	-0.195	-0.052	-0.132	0.045	0.823	1.000	0.776	-0.245	0.819	0.170	0.445	0.807	0.113
	FREQ	-0.199	-0.169	-0.106	-0.207	0.007	0.870	0.776	1.000	-0.057	0.866	0.361	0.184	0.860	0.075
	FARE	0.180	0.045	0.128	0.174	0.111	-0.302	-0.245	-0.057	1.000	-0.310	-0.236	-0.409	-0.300	-0.056
Performance	MKS	-0.094	-0.015	-0.078	-0.054	-0.017	0.999	0.819	0.866	-0.310	1.000	0.594	0.251	0.996	0.110
	PUNC	0.111	0.304	-0.046	0.180	-0.138	0.592	0.170	0.361	-0.236	0.594	1.000	-0.046	0.598	0.198
	OC	0.066	0.093	-0.097	0.251	0.005	0.236	0.445	0.184	-0.409	0.251	-0.046	1.000	0.271	0.229
	TRVO	-0.062	0.020	-0.069	-0.007	-0.012	0.994	0.807	0.860	-0.300	0.996	0.598	0.271	1.000	0.105
	GRO	0.093	-0.069	0.045	0.123	0.066	0.105	0.113	0.075	-0.056	0.110	0.198	0.229	0.105	1.000

p<0.01   p<0.05   p>0.05   (1-tailed)

5.5.2 SCP model

To investigate the significance of the independent variables in more detail, a multi-linear regression analysis is used. All variables in the structure, conduct and performance set are analysed as depending on the variables from the other two sets as predictors. The results given in table 5.4 show that GR has on the one hand no significant predictive value for any of the conduct and performance variables and on the other hand have as a dependent variable no significant predictors. GR is therefore eliminated from the set of variables and the structure-conduct-performance equations presented earlier. The regression results for HHI, SIZE and GRO do not produce significant results with the predictors marked in table 5.4, so HHI, SIZE and GRO are also eliminated from the set of dependent variables, but also form the list of independent variable as HHI, SIZE and GRO are insignificant predictors ($p<0.01$). NUM is only significant for PUNC ($p<0.01$) and TRV is only significant for OC ($p < 0.01$). NUM and TRV have no predictive value for any of the other dependent variables. The analysis shows that a serious multi-collinearity exists for the performance variables MKS and TRVO causing difficulties in the interpretation of the regression coefficients. This has to do with the fact that the operators' market share is given by the operators' travel volume divided by the total travel volume of all operators together. We have chosen to keep MKS as a variable and eliminate TRVO from the model.

For the next step, referring to table 5.4, we drop all the dependent variables that produce insignificant results ($p > 0.01$) and all not significant independent variables ($p > 0.01$) to study the causality in more detail with the multiple linear regression method[18]. Remember that we have already eliminated GR from the model and have sacrificed TRVO in favour of MKS due to the existing multi-collinearity of these variables. This results in an SCP model with two equations for market structure:

$$NUM = a_0 + a_1 * CAP + a_2 * FREQ + a_3 * MKS + e_1$$

$$TRV = a_4 + a_5 * FREQ + a_6 * FARE + a_7 * MKS + a_8 * OC + e_2$$

three equations for conduct:

$$CAP = b_0 + b_1 * MKS + e_3$$

$$TTT = b_2 + b_3 * MKS + b_4 * PUNC + b_5 * OC + e_4$$

$$FARE = b_6 + b_7 * OC + e_5$$

and three equations for performance:

$$MKS = c_0 + c_1 * CAP + e_6$$

$$PUNC = c_2 + c_3 * NUM + c_4 * CAP + c_5 * TTT + e_7$$

$$OC = c_6 + c_7 * TRV + c_8 * CAP + c_9 * TTT + c_{10} * FARE + e_8$$

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[18] A probability value of 0.01 is chosen to preserve enough variables for the analysis, but not too many.

Table 5.4 - Significance of variables model 1: air and rail London-Paris

Independent Variables (IV)		Dependent Variables (DV)													
		Structure					Conduct				Performance				
		NUM***	HHI***	SIZE	TRV***	GR	CAP***	TTT***	FREQ***	FARE**	MKS***	PUNC***	OC***	TRVO***	GRO
Structure	NUM											**			
	HHI														*
	SIZE											*			
	TRV												**		*
	GR														
Conduct[1]	CAP	**		*	*						***	***	***	***	
	TTT											***	***		
	FREQ	**			***							*	*		
	FARE	*			***								***		
Performance	MKS	***		**	**		***	***							
	PUNC							***	*						
	OC				**		*	**		***					
	TRVO	*			**			*							
	GRO														

Significance level of variables: *** $p<0.001$ ** $p<0.010$ * $p<0.050$

Note 1: The Variance Inflation Factors (VIFs) are more than 10 for MKS and TRVO, meaning that no serious multi-collinearity exists among these independent variables

Table 5.5 - Regression coefficients model 1: air and rail London-Paris

		Structure	Conduct			Performance		
		TRV***	CAP***	TTT***	FARE**	MKS***	PUNC***	OC***
	Intercept	6.216 (11.50***)	0.0404 (1.784)	172.7 (16.54***)	225.1 (7.442***)	-0.003095 (-1.521)	1.492 (15.50***)	-0.4660 (-2.684**)
Structure	TRV							0.06718 (4.967***)
Conduct	CAP					0.08931 (157.3***)	0.04901 (11.59***)	-0.02153 (-4.190***)
	TTT						-0.005673 (-8.130***)	0.005184 (6.188***)
	FREQ	-0.02179 (-5.149***)						
	FARE	0.009126 (5.022***)						-0.001116 (-5.181***)
Performance	MKS	2.310 (4.345***)	11.160 (157.3***)	70.40 (17.01***)				
	PUNC			-76.06 (-7.427***)				
	OC	2.788 (4.346***)		28.140 (3.315**)	-163.8 (-3.829***)			
	R^2	0.389	0.997	0.849	0.167	0.997	0.661	0.540
	Adj. R^2	0.354	0.997	0.843	0.156	0.997	0.652	0.514
	N	75	75	75	75	75	75	75

Significance level of coefficients: *** p<0.001 ** p<0.01 t-values between brackets ( )

Note 1: The Variance Inflation Factors (VIFs) are all less than 10, meaning that no serious multi-collinearity exists among the independent variables
Note 2: NUM gives no significant results at p<0.01. For p<0.05: NUM = 6.324(31.07) + 1.252(2.368) * CAP – 0.001336(-2.503) * FREQ – 12.86(-2.220) * MKS

The first market structure equation indicates the way the number of operators in the market (NUM) is influenced by operator behaviour regarding service characteristics (CAP and FREQ) and operator performance (MKS). Operator behaviour regarding service characteristics (FREQ) and pricing (FARE) and operator performance (MKS and OC) have an effect on the total travel volume (TRV) in the market. The conduct set of equations show that operators adapt their product offering (CAP, TTT and FREQ) taking into account their own performance, but that market conditions parameters (NUM, HHI, SIZE, TRV, GR) do not play any role. Ticket prices (FARE) depend on service performance (OC). With the yield management systems operators use nowadays, ticket prices are adjusted immediately, depending on the market demand and load factors. Changing the service characteristics requires careful planning and takes more time than price changes. It can be seen from the performance set of equations that both market structure (NUM, TRV) and the behaviour of operators regarding product design (CAP, TTT) and pricing (FARE) influence their performance. Service frequency (FREQ) has no significant impact on the operators' performance.

5.5.3 Results

The estimated coefficients for these SCP equations for the London-Paris market are given in table 5.5. It can be seen from the (adjusted) R^2 values that the variables CAP and MKS show an exceptionally good fit with the selected significant predictors. A resulting R^2 of 0.167 indicates a poor linear fit for FARE with OC.

The first market structure equation shows that travel volume depends on the performance variables market share (MKS) and seat occupancy (SO) and the conduct variables service frequency offered (FREQ) and ticket prices (FARE) set by the operators. It is remarkable to see that the total travel volume increases with increasing ticket prices and decreases with higher service frequencies. This is not what might be expected. An additional analysis is needed to explain this effect. The second market structure equation for the NUM variable did not produce a significant results at $p<0.01$.

The first conduct equation shows that the number of available seats an operator offers (CAP) depends on the market share (MKS). Table 5.5 shows that MKS has a significant positive correlation with CAP. Operators will optimize their time schedule and fleet to provide for the seat capacity needed to protect their market share. The second conduct equation indicates that the total travel time (TTT) depends on three performance variables i.e. market share (MKS), punctuality (PUNC) and seat occupancy (OC). Table 5.5 shows that TTT has a significant and positive correlation with MKS and OC. Higher seat occupancy results in a larger market share and longer travel times. The reason for longer travel times can be that highly occupied planes and trains are more sensitive for delays caused by the boarding and un-boarding process. It is evident that with a better punctuality the total travel time will reduce as delays will be less. The FARE conduct variable is significantly negatively correlated to the performance variable seat occupancy (OC). A better occupancy rate will lead to lower prices as the service operation becomes more cost-efficient.

Looking at the first performance equation, we see a significantly positive correlation for seat capacity offered by the operator and market share (MKS). Operators will gain more market share when more seats offered to the London-Paris market. For punctuality (PUNC), a significant and positive correlation with the seat capacity offered by the operator (CAP) and a significant and negative correlation with the total travel time (TTT) can be recognised. Boarding is quicker and easier with more seat capacity, which will lead to less delay and better punctuality. That punctuality decreases with an increasing travel time could be the effect of the delay time component included in the total travel time. The third performance equation shows that the seat occupancy rate (OC) depends on the market's travel volume (TRV), the seat capacity (CAP), total travel time (TTT) and ticket prices (FARE). Table 5.5 shows that TRV and TTT have a significant and positive correlation with OC and CAP, while FARE has a significant negative effect on OC. TTT is the most significant predictor for OC. It is evident that seat occupancy will improve with higher demand and lower fares that attract more passengers. That more seat capacity and longer travel time will lead to higher seat occupancy is harder to explain. In the last performance equation for the operators' travel volume (TRVO), a significant and positive correlation with the seat capacity offered by the operator (CAP) can be recognised. It shows that the operators' travel volume will go up when the operator offers more available seat capacity.

5.5.4 Sensitivity analysis

To clarify the contribution of individual predictors on the dependent variables, the sensitivity is investigated by calculating the effect of an increase of the mean value of the individual predictors with 10%[19]. The results in table 5.6 and figure 5.6 show that the total travel volume in the market is only little influenced by the offered service frequencies (-1.3%), ticket prices (+1.2%) and actual seat occupancy (+2.3%) and even less by the operator's market share (+0.5%). The seat occupancy OC is highly sensitive to total travel time (+10.9%), moderately sensitive to total travel volume (+8.1%) and insensitive to ticket prices (-1.8%) and seat capacity offered (-0.6%). There appears to be an asymmetric relation between FARE and OC. If ticket prices go up with 10%, seat occupancy decreases with only 1.8%, but a seat occupancy increase of 10% leads to 10.4% lower ticket price. The conduct variables CAP and TTT appear jointly as predictors in the performance equations for PUNC and OC. The Pearson correlation matrix shows a high (>0.800) inter-correlation between CAP and TTT, indicating that these variables are not independent. The model could be simplified by leaving the least important variable (CAP in this case) out of the equations for PUNC and OC, accepting a decrease of R^2.

Table 5.6 - Sensitivity analysis model 1: air and rail London-Paris

	Dependent Variables							
	Structure	Conduct			Performance			
	TRV	CAP	TTT	FARE	MKS	PUNC	OC	TRVO
TRV+10%							8.1%	
CAP+10%					10.2%	1.3%	-0.6%	10.3%
TTT+10%						-11.1%	10.9%	
FREQ+10%	-1.3%							
FARE+10%	1.2%						-1.8%	
MKS+10%	0.5%	9.8%	0.8%					
PUNC+10%			-3.9%					
OC+10%	2.3%		1.3%	-10.4%				

[19] The individual importance of variables can also be evaluated from the standardized coefficients produced by SPSS, but interpretation of the results is more difficult.

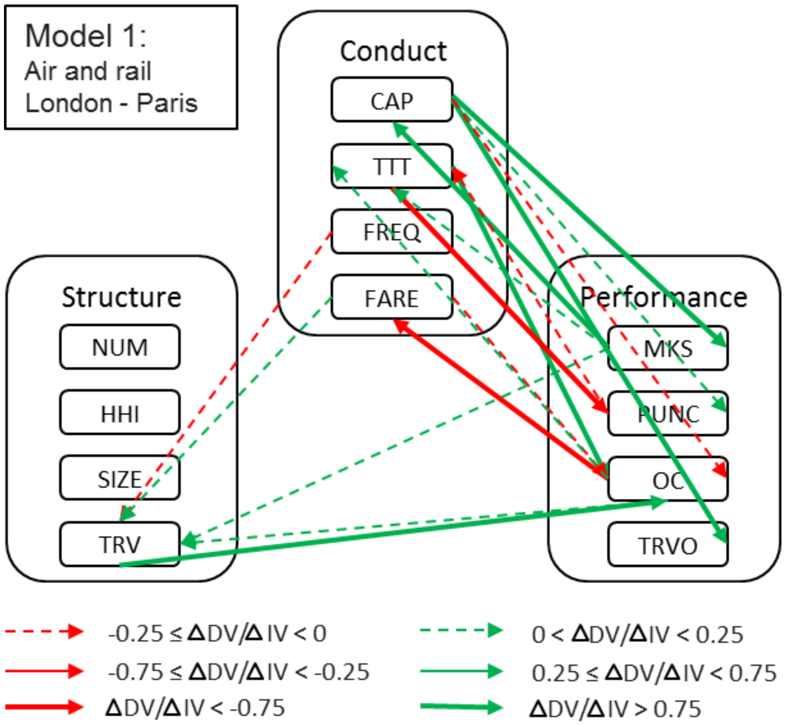

Figure 5.6 - Sensitivity analysis model 1: air and rail London-Paris

Although the results are significant, the fit is not good in all cases as can be seen from the R^2 figures in table 5.5. The equations for CAP and MKS show proper results, but the other variables are less well predicted. More observations would be beneficial, but the number of market players and the limited length of the time series limit this.

The sign of the coefficients for the predictors is not always easy to explain. Especially the positive signs for FARE as a predictor for TRV and for TTT as a predictor for OC. This may be caused by the fact that although serving the same market, high-speed trains and aeroplanes are different transport modes with heterogeneous products.

5.6 Eurostar behaviour and performance

The dominant share of Eurostar is specific for the London-Paris market, which is in fact a rail monopoly within an oligopolistic market structure for the competing airlines. To investigate the behaviour of Eurostar in more detail, we have repeated the analysis by splitting off the Eurostar data from the airlines data.

5.6.1 Input data

For the analysis, the same dataset is used, but only selecting the 13 observations for Eurostar of the period 2003 until 2015. The descriptive statistics are presented in table 5.7. The London-Paris market is unchanged, so the data for the market structure variables remain the same[20]. The standard deviation of the conduct and performance variables is reduced, as the spread in the Eurostar data is smaller.

[20] Small differences can be found between the value of the market structure variables for all operators and Eurostar only. This has to do with the fact that the market share in the second case was calculated using the actual travel volumes instead of an estimate based on the revealed travel behaviour from the UK International Passenger Survey.

Table 5.7 - Descriptive statistics Eurostar London-Paris (2003-2015)

	Structure					Conduct				Performance				
	NUM	HHI	SIZE	TRV	GR	CAP	TTT	FREQ	FARE	MKS	PUNC	OC	TRVO	GRO
N Valid	13	13	13	13	13	13	13	13	13	13	13	13	13	13
N Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean	5.77	0.586	11.306	8.397	0.024	8.451	179	108	79	0.752	0.897	0.748	6.338	0.056
Median	6.00	0.609	11.381	8.355	0.028	8.580	176	110	75	0.771	0.915	0.738	6.526	0.029
Std. Dev.	0.832	0.073	0.557	0.650	0.032	0.482	6	6	12	0.055	0.043	0.071	0.867	0.070
Skewness	-0.528	-1.015	-0.999	0.204	0.401	-0.556	1.705	-0.577	0.897	-1.075	-1.670	-1.304	-0.650	0.718
Kurtosis	0.519	-0.029	2.366	-0.315	1.207	-0.898	3.704	-0.890	-0.200	0.134	3.601	2.372	-0.538	-0.628
Minimum	4	0.433	9.930	7.256	-0.029	7.644	172	98	65	0.634	0.783	0.567	4.597	-0.044
Maximum	7	0.662	12.178	9.504	0.095	9.048	194	116	104	0.805	0.950	0.820	7.370	0.181

The Pearson product-moment correlation coefficients for Eurostar on the London-Paris connection are displayed in table 5.8. The table highlights correlations that have 1% and 5% significance level. From the structure variables, only HHI and SIZE have a correlation with the conduct and performance variables with more than 1% significance. In addition, the correlation with FARE and GRO is insignificant ($p<0.01$). It is remarkable that ticket prices set by Eurostar are hardly influenced by the market conditions and are not correlated to their performance in the London-Paris market. This underlines that price sensitivity is low for a dominant market player like Eurostar.

5.6.2 SCP model

To investigate Eurostar behaviour in more detail, a multi-linear regression analysis is used. As done for all operators earlier, all variables in the structure, conduct and performance set are analysed as depending on the variables from the other two sets as predictors. The results from step 1: identification of significant variables, given in table 5.9 show that NUM, SIZE, GR, FARE and GRO have on the one hand no significant predictive value for any of the conduct and performance variables and on the other hand have as a dependent variable no significant predictors. NUM, SIZE, GR, FARE and GRO are therefore eliminated from the set of variables and the structure-conduct-performance equations presented earlier. From the market structure variable set, only HHI and TRV are significant predictors for the performance variables MKS, OC and TRVO, but for none of the conduct variables. The analysis shows that in some cases, serious multi-collinearity exists for the performance variables MKS, OC and TRVO, causing difficulties in the interpretation of the regression coefficients. We choose to keep the variables from the model that have a Variance Inflation Factor (VIF) less than 10.

Table 5.8 - Pearson correlation model 2: Eurostar London-Paris

		Structure					Conduct				Performance				
		NUM	HHI	SIZE	TRV	GR	CAP	TTT	FREQ	FARE	MKS	PUNC	OC	TRVO	GRO
Structure	NUM	1.000	0.165	0.806	0.623	0.309	0.576	-0.030	0.571	0.315	0.188	0.048	0.305	0.459	-0.393
	HHI	0.165	1.000	-0.231	0.733	-0.229	0.765	-0.648	0.767	0.114	0.999	0.653	0.881	0.913	-0.254
	SIZE	0.806	-0.231	1.000	0.160	0.279	0.309	0.315	0.306	0.153	-0.216	-0.304	-0.207	-0.003	-0.407
	TRV	0.623	0.733	0.160	1.000	0.089	0.801	-0.485	0.797	0.590	0.755	0.485	0.889	0.946	-0.283
	GR	0.309	-0.229	0.279	0.089	1.000	-0.099	-0.033	-0.105	0.060	-0.218	0.051	-0.035	-0.059	0.193
Conduct	CAP	0.576	0.765	0.309	0.801	-0.099	1.000	-0.407	1.000	0.233	0.771	0.406	0.633	0.847	-0.561
	TTT	-0.030	-0.648	0.315	-0.485	-0.033	-0.407	1.000	-0.405	0.002	-0.658	-0.998	-0.629	-0.589	-0.176
	FREQ	0.571	0.767	0.306	0.797	-0.105	1.000	-0.405	1.000	0.229	0.773	0.405	0.631	0.846	-0.563
	FARE	0.315	0.114	0.153	0.590	0.060	0.233	0.002	0.229	1.000	0.140	-0.023	0.433	0.406	-0.097
Performance	MKS	0.188	0.999	-0.216	0.755	-0.218	0.771	-0.658	0.773	0.140	1.000	0.663	0.895	0.926	-0.248
	PUNC	0.048	0.653	-0.304	0.485	0.051	0.406	-0.998	0.405	-0.023	0.663	1.000	0.633	0.592	0.165
	OC	0.305	0.881	-0.207	0.889	-0.035	0.633	-0.629	0.631	0.433	0.895	0.633	1.000	0.947	-0.096
	TRVO	0.459	0.913	-0.003	0.946	-0.059	0.847	-0.589	0.846	0.406	0.926	0.592	0.947	1.000	-0.303
	GRO	-0.393	-0.254	-0.407	-0.283	0.193	-0.561	-0.176	-0.563	-0.097	-0.248	0.165	-0.096	-0.303	1.000

p<0.01 p<0.05 p>0.05 (1-tailed)

Following the procedure as described by Lee (2012), for the next step, referring to table 5.9, we drop all the dependent variables that produce insignificant results ($p > 0.01$) and all not significant independent variables ($p> 0.01$) and the independent variables with multi-collinearity issues to study the causality in more detail with the multiple linear regression method. This results in an SCP-model for Eurostar with two equations for market structure:

$$HHI = a_0 + a_1 * MKS + e_1$$

$$TRV = a_2 + a_3 * OC + e_2$$

two equations for conduct:

$$CAP = b_0 + b_1 * OC + b_2 * TRVO + e_3$$

$$TTT = b_3 + b_4 * PUNC + e_4$$

and four equations for performance:

$$MKS = c_0 + c_1 * HHI + c_2 * TRV + e_5$$

$$PUNC = c_3 + c_4 * TTT + e_6$$

$$OC = c_5 + c_6 * HHI + c_7 * TRV + e_7$$

$$TRVO = c_8 + c_9 * HHI + c_{10} * TRV + e_8$$

5.6.3 Results

Table 5.10 presents the regression coefficients and the corresponding t-values resulting from the multi-linear regression analysis. It can be seen from the (adjusted) R^2 values that all the variables show a good to exceptionally good fit with the selected significant predictors.

The market structure equations are simple and self-explaining as a higher market share for Eurostar directly improves the Herfindahl-Hirschman Index, and a better seat occupancy supports a higher travel volume. Looking at the conduct equations, the analysis shows no significant results for Eurostar's service frequency FREQ and ticket prices FARE. Except from TTT and PUNC, no conduct variables of Eurostar appear to be of significance for the performance. This is against the expectation that Eurostar's behaviour regarding pricing and service characteristics would influence their performance, but can be explained by Eurostar's dominant market position. The market structure variables HHI and TRV can be recognised as positive predictors in the three performance equations for MKS, OC and TRVO. The Pearson correlation matrix shows a high (>0.700) inter-correlation between HHI and TRV, indicating that these variables are not independent, which is evident as TRV is one of the inputs for calculating HHI. The model could be modified by leaving one of the two predictors out of the equations.

Table 5.9 - Significance of variables model 2: Eurostar London-Paris

		Dependent Variables													
		Structure					Conduct				Performance				
Predictors		NUM	HHI***	SIZE	TRV***	GR	CAP***	TTT***	FREQ***	FARE	MKS***	PUNC***	OC***	TRVO***	GRO
Structure	NUM							*							
	HHI										***		***	***	
	SIZE														
	TRV										*		**	**	
	GR														
Conduct[1]	CAP														
	TTT										*	***			
	FREQ														
	FARE														
Performance	MKS		***		***										
	PUNC							***							
	OC				***		***		***						
	TRVO						*								
	GRO														

Significance level of variables: *** p<0.001 ** p<0.010 * p<0.050

Table 5.10 - Regression coefficients model 2: Eurostar London-Paris

		Dependent Variables															
		Structure				Conduct				Performance							
		HHI***		TRV***		CAP***		TTT***		MKS***		PUNC***		OC***		TRVO***	
	Intercept	-0.409	(-35.13***)	2.334	(2.463*)	8.306	(80.48***)	297.6	(149.8***)	0.2911	(63.63***)	2.243	(99.74***)	-0.02035	(0.2216)	-3.686	(-50.85***)
Structure	HHI									0.7272	(103.0***)			0.4863	(3.432**)	5.656	(50.57**)
	TRV									0.004101	(5.196***)			0.05751	(3.630**)	0.7990	(63.90***)
Conduct	TTT											-0.007529	(-59.87***)				
Performance	MKS	1.324	(85.65***)														
	PUNC							-132.4	(-59.87***)								
	OC			8.109	(6.424***)	-11.15	(-32.98***)										
	TRVO					1.338	(48.18***)										
	R^2	0.999		0.790		0.997		0.997		1.000		0.998		0.950		1.000	
	Adj. R^2	0.998		0.770		0.997		0.997		1.000		0.997		0.903		1.000	
	N	13		13		13		13		13		13		13		13	

Significance level of coefficients: *** $p<0.001$ ** $p<0.01$

Note: The Variance Inflation Factors (VIFs) are all less than 10, meaning that no serious multi-collinearity exists among the independent variables

5.6.4 Sensitivity analysis

The sensitivity analysis (table 5.11 and figure 5.7) shows that HHI is highly sensitive to MKS. Eurostar already has a dominant market share, which is reflected in the Herfindahl-Hirschman Index in a quadratic form. Punctuality (PUNC) is highly sensitive to total travel time (TTT). With a 10% travel time increase, punctuality drops by 15%. Punctuality is 100% when trains arrive within 15 minutes of the scheduled timetable and 0% when the delay is more than 15 minutes. By definition, punctuality drops rapidly when with extra delays. The reverse effect is also observed, where a 10% better punctuality results in a 6.6% decreased travel time. This effect is less prominent as delay is only one of the components of total travel time.

Table 5.11 - Sensitivity analysis model 2: Eurostar London-Paris

	Dependent Variables							
	Structure		Conduct		Performance			
	HHI	TRV	CAP	TTT	MKS	PUNC	OC	TRVO
HHI+10%					5.7%		3.8%	5.2%
TRV+10%					0.5%		6.5%	10.6%
TTT+10%						-15.0%		
MKS+10%	17.0%							
PUNC+10%				-6.6%				
OC+10%		7.2%	-9.9%					
TRVO+10%			10.0%					

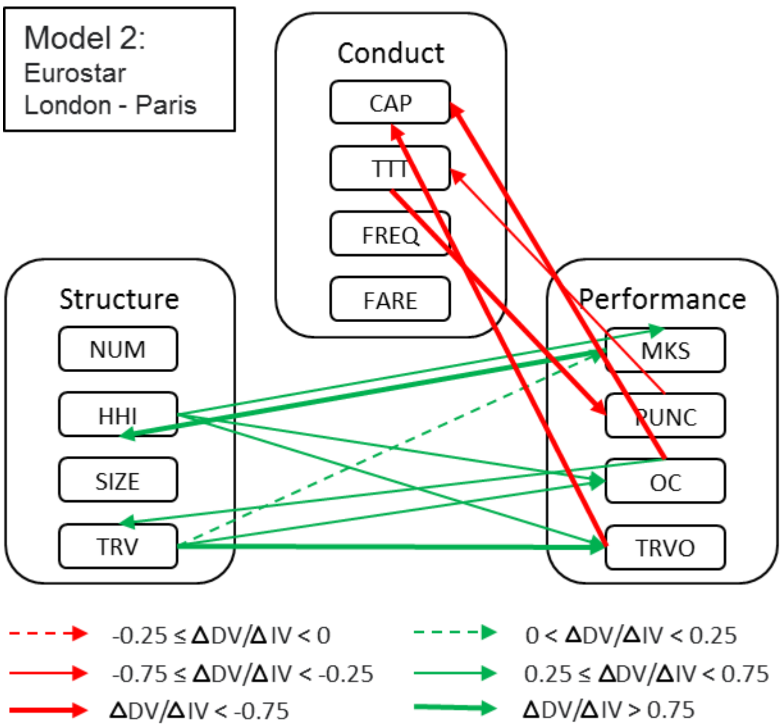

Figure 5.7 - Sensitivity analysis model 2: Eurostar London-Paris

5.7 Conclusion and discussion

5.7.1 Conclusions

The goal of this exercise was to identify the market structure and importance of the conduct variables of all market players (operational airlines and Eurostar) on the performance and the structure of the London-Paris passenger market. Although only qualitative, the “Six Forces” framework proves to be a suitable way to describe the international passenger rail services market.

To explore the relations between the determining variables for market structure, operators’ behaviour and their performance for the cross border high-speed travel market in Western Europe, an SCP model was defined with three sets of linear equations for structure, conduct and performance with 14 variables in total. Two situations were tested: model 1 with all market players (Eurostar and airlines) and model 2 with Eurostar only. A two-step approach was used to find the significant predictors for each of the variables and their associated coefficients by applying a multiple linear regression analysis. In addition, the sensitivity of the dependent variables for the resulting predictors was calculated.

Both for model 1 (rail and air) and model 2 (only Eurostar), it is remarkable to see that ticket prices are of little or no influence on any of the other variables. Looking at the development of the HHI for the London-Paris passenger market between 2003 and 2015, the market structure can be characterised as an oligopoly with a tendency to a monopoly with Eurostar being the dominant player, indicating a less intense price competition.
Comparing the results, we find some bidirectional dependencies for model 1 (CAP-MKS, TRV-OC, PUNC-TTT, OC-TTT and OC-FARE) and model 2 (PUNC-TTT, HHI-MKS and OC-TRV). As expected, the sign in both directions are the same. In both models, a two-way dependency between punctuality (PUNC) and Total Travel Time (TTT) is observed. Punctuality is highly sensitive to total travel time. With a 10% travel time increase, punctuality drops by 11% in model 1 and with 15% in model 2. Punctuality is 100% when all trains or planes arrive within 15 minutes of the scheduled timetable and 0% when the delay is more than 15 minutes. By definition, punctuality drops rapidly when with extra delays. The reverse effect is also observed, where a 10% better punctuality results in a 4% decreased travel time in model 1 and 7% in model 2. This effect is less prominent, as delay is only one of the components of total travel time. In model 2, Total Travel Time has, besides the effect on punctuality as mentioned earlier, a significant and positive effect on seat occupancy (OC), which is not recognised in model 1. That a longer travel time will lead to higher seat occupancy is difficult to explain.

For the other service characteristics, service frequency (FREQ) and fleet capacity (CAP), the models do not produce uniform results. The fleet capacity (CAP) has a direct effect on the performance variables market share (MKS) and the operators travel volume (TRVO) in model 1. This indicates that operators will gain more travel volume and market share when more seats are offered in the London-Paris market. This requires of course more rolling stock or aircraft and comes with additional investments. In model 2, both FREQ and CAP are no significant parameters for any of the market structure or performance variables.

5.7.2 Discussion

The operators' behaviour is characterised by the strategic decisions taken regarding service characteristics and pricing. It is important that these conduct variables are independent and that decisions about each of them can be taken separately and can be changed over time. From the analysis, not all independent variables for structure and performance prove to be independent. For example the market share (MKS) is calculated by taking the ratio of the travel volume of each individual operator (TRVO) and the sum of all travel volumes (TRV). All these variables have been taken into account to see what predictor fits best.
In the approach, no distinction was made between business and leisure travellers. Leisure travellers are more price-sensitive and a market segmentation with a separate analysis for both groups could possibly reveal a more significant influence of pricing on performance and market structure.

The results from the SCP analysis give little lessons for the market strategy of existing and new HSR operators. Caused by the dominant position of Eurostar and the unique tunnel operations between France and the UK to cross the Channel, the London-Paris market is a special case and the results are not easily transferable to other cases. To get more confidence and to cancel out the special features associated with the France-UK border crossing, the SCP approach should be applied to other international routes as well.

To improve the model, one could consider a time delay for the conduct and structure variables as applied for example by Jeong (1990) and Delorme et al (2002). The ratio behind this is that profits in year t-1 can be used to revise strategic decisions and change market behaviour in year t that will lead to a new market structure in year t+1. Appropriate time delays can be built in for each of the variables. In our case, where data is used over the 2005-2013 period, this means that the time series data needs to be shifted according to the time delay that is required.

Lee (2013) and De Jorge and Suárez (2014) demonstrate an SCP model with the integration of Data Envelopment Analysis (DEA) and multiple regression methods. DEA is used to include technical and scale efficiency as performance variables in the model. Combining the SCP-model in this chapter with the DEA approach demonstrated in chapter 4, could give additional insight about the interaction between conduct and performance.
So far, only operational and no financial variables like revenues and profitability have been considered in the SCP approach to model the operators' performance. The consequence is that it remains unclear to what extent financial performance affects the operators' behaviour and market structure. Depending on data availability, an extension with financial parameters could be considered.

From the results given by the SCP model, it is difficult to drill down to individual operator's behaviour. Although the SCP paradigm is suitable to capture long-term market developments, it is an empirical approach for Industrial Organisations (IO) with no rigorous theoretical modelling behind it and has virtually disappeared from mainstream IO research. With the SCP analysis, it is difficult to capture the market dynamics. This is the main reason not to look for further optimization of the SCP-model, but to take a different angle. Simulations using a system dynamics approach has become more popular are to capture the dynamic market processes. Over the last 20 years, techniques like game theory and transaction costs have superseded the SCP paradigm (Slade 2004). This opens the opportunity to incorporate travellers' behaviour to predict the behaviour and performance of high-speed rail operators. In the next chapter, behaviour of operators and competition is investigated using game theory in addition to the SCP approach as presented in this chapter.

6 Competition in Western Europe[21]

6.1 Introduction

The goal of this chapter is to clarify the inter- and intra-modal competition in the Western European cross-border high-speed railway market and to analyse the market effect of rail policies and strategic behaviour of high-speed rail operators. A game theory model with multiple players is applied to evaluate the dynamics and interaction of operators and the effect of decisions taken on future scenarios. The success of TOC strategies is evaluated to gain market understanding and predict possible outcomes for the future. To this purpose, we first describe what the European high-speed transport market looks like, then present the model that is used for the market evaluation and finally show the results for the London-Paris case, as outlined in chapter 5.

This chapter is structured as follows. In paragraph 6.2, the econometric competition model and the methodology are presented for calibration and simulation to evaluate the market share of high-speed rail operators. Section 6.3 presents the model and input data for the London-Paris link as a specific case studied in detail. Section 6.4 presents the calculated market equilibrium for the London-Paris transport market and the simulation results for three different scenarios. Finally, section 6.5 presents the conclusion from the study and discusses the results.

6.2 Competition model

An open market with free competition will find in time its equilibrium between demand and supply. This also goes for transport markets, where regulators set the environment and rules for network access and competition, operators strategically decide on product design and set prices for the type of services they provide and travellers choose a transport mode and an operator to travel on a given city-pair. In practice, the free market axiom is not fully valid for the high-speed market. Incumbent railways act as monopolistic or oligopolistic market players making it hard for new entrants and competitors to gain market share. Our interest is to find a method to evaluate market shares in an oligopolistic market where train operators compete with each other (intra-modal) and with airlines and private cars (inter-modal) by offering distinctive train services to potential travellers with an attractive price setting. The aggregation level on the supply side needs to be on transport modes and operators to capture operators' strategic behaviour. On the demand side, a distinction between business and leisure market segments is necessary to meet differences in travellers' behaviour and requirements concerning service and pricing. The goal is to simulate different market scenarios after the recovery of the equilibrium outcome and to incorporate governmental policies. It is required that the model can be applied to specific Origin-Destination pairs with the use of limited data requirements.

Berry presented an econometric supply and demand model for oligopolistic markets with differentiated products (Berry 1994). A discrete-choice model for consumer behaviour is adapted to model market demand, where the consumers' utility depends on the product

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[21] The material of this chapter has been presented at the 14th World Congress on Transport Research, 10-15 July 2016, Shanghai, China.

characteristics. Regarding the supply side, firms, in our case train operators, are modelled as price-setting oligopolists. The model gives an approach to find the market equilibrium between supply and demand. Ivaldi and Vibes (2008) give an application of the game theory model as described by Berry to the competition in the intercity passenger transport market. In this game, consumers choose a mode and an operator to travel on a given city-pair and firms decide on service quality and prices. The model is used to evaluate inter- and intra-modal competition for business and leisure travellers on the 475 km Berlin-Cologne link between airlines, rail operators and private cars. Specific cases are presented to study the effect of LCC airlines entering the market, higher kerosene taxation and the entrance of a new low-cost rail operator. The same methodology has been elaborated by Prady and Ullrich and applied to the competition between road and rail in the freight transport market between Italy and France (Prady and Ullrich 2010). They analyse the effect of building a rail tunnel between Lyon and Turin on the market shares of freight shippers. De Rus et al (2009) give the same model theory and some indicative results for the Paris-Amsterdam link, with the remark that the presented economic model is quite relevant to describe the strategic interaction between transport operators of the same or different modes. Adler et al. (2010) use the economic model to calculate social welfare from market share evaluations in 27 European Union countries for four Trans-European network scenarios with competing high-speed rail operators, hub-and-spoke legacy airlines and regional low-cost carriers. More recently, this discrete choice model was used to evaluate the market shares on the Milan-Rome intercity transport link, where the entry of new rail and air operators in 2012 was simulated (Mancuso 2014).

6.2.1 Demand: travellers choice set

We consider the transport between a city-pair as one market where travellers can choose to travel from origin to destination between distinctive transport modes and competing operators. We assume that travellers first choose between the possible transport modes before selecting their preferred operator. This discrete-choice structure can be presented as a nested logit model where one can choose from three alternative transport modes (figure 6.1). In the market, travellers can choose from J competitive alternatives consisting of m railway operators, n airlines and the private car[22]. There is an outside alternative considered as potential consumers may choose not to travel.

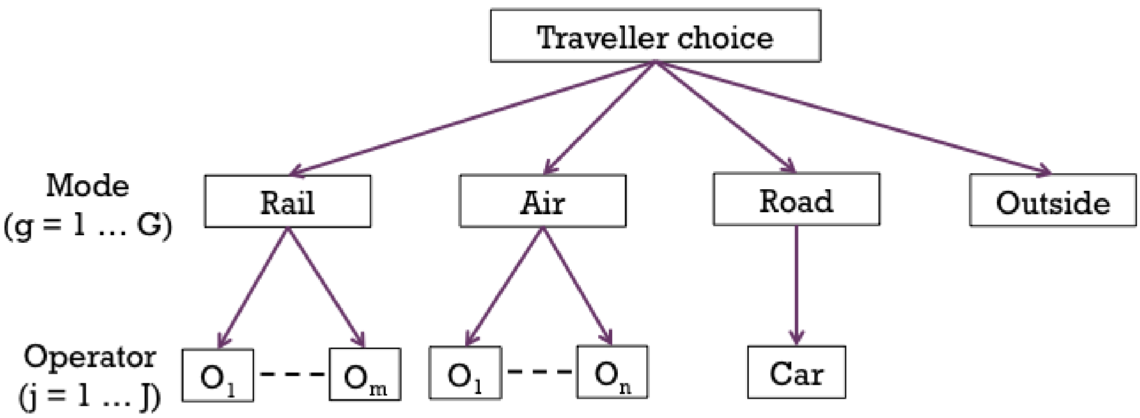

Figure 6.1 - Discrete-choice mode for travellers

[22] “Private car” is seen as being offered by an operator competing with the other alternatives.

The utility of traveller i from alternative j can be written as follows:

$$U_{ij} = V_j + \varepsilon_{ij}$$

Where V_j represents the mean utility level common to all travellers and εij the unknown random part of traveller's *i* preferences for service *j*. The traveller chooses the utility-maximising alternative:

$$U_{ij} \geq U_{ij'}, \ \forall j' \neq j$$

The mean utility of alternative *j* depends on the service quality Ψ_j and price p_j offered.

$$V_j = \Psi_j - h * p_j$$

The parameter h represents the utilities' sensitivity to price.

Ψ_j can be expressed as a linear combination of K quality parameters assigned to the service alternative *j*:

$$\Psi_j = \sum_{k=1}^{K} Q_{jk} \cdot \alpha_j$$

Traveller i will choose the alternative j that maximises his utility. In the nested logit specification, alternatives within the same mode g are closer to each other than between transport modes. The random part of travellers' i preferences for service j can be split into two random components for intra- and intergroup correlation:

$$\varepsilon_{ij} = \nu_{ig} + (1-\sigma) * \nu_{ij}, \quad \forall i = 1, \dots N$$

The parameter σ represents the correlation between alternatives within the same group and must lie between 0 and 1. If $\sigma = 1$, there is a perfect correlation of preferences for products within the same group; so these products are perceived as perfect substitutes. If $\sigma = 0$ there is no correlation of preferences: consumers are equally likely to switch to products in a different group as to products in the same group in response to a price increase (Ivaldi and Verboven 2005).

The probability of choosing alternative j is the product of the two sequential discrete choices for the transport mode *g* and the operator *j* within this mode:

$$s_j = s_{j|g} * s_g$$

Where $s_{j|g}$ is defined as:

$$s_{j|g} = e^{V_j/(1-\sigma)/D_g}$$

and the probability of choosing mode *g*,

$$s_g = D_g^{(1-\sigma)} \Big/ \sum D_g^{(1-\sigma)} \quad \text{, with} \quad D_g = \sum_{j \in g} e^{V_j/(1-\sigma)}$$

Actual market shares are the observed outcome of aggregated travellers' choices. Expressing the mean utility level as a function of observed market shares as stated by Berry (1994):

$$V_j = \ln(s_j) - \ln(s_o) - \sigma * \ln(s_{j|g})$$

With $s_j = q_j/N$ and $s_{j|g} = q_j/N_g$ and q_j being the number of travellers with alternative j and N the total number of travellers. S_0 is the market share for non-travellers. From these formulas, the own price elasticity of demand and cross price elasticity can be derived as elaborated by Ivaldi and Vibes (2008):

Own Price elasticity:
$$\eta_j = \frac{dq_j}{dp_j} \times \frac{p_j}{q_j} = h \cdot p_j \cdot \left(s_j - \frac{1}{1-\sigma} + \frac{\sigma}{1-\sigma} s_{j|g} \right) \quad \forall j$$

Intra modal price elasticity:
$$\eta_{j,k} = \frac{dq_j}{dp_k} \times \frac{p_k}{q_j} = h \cdot p_k \cdot s_k \quad if\ j \neq k, k \notin g, j \in g$$

Inter modal price elasticity:
$$\eta_{j,k} = \frac{dq_j}{dp_k} \times \frac{p_k}{q_j} = h \cdot p_k \cdot s_k \cdot \left(\frac{\sigma}{1-\sigma} \cdot \frac{s_{k|g}}{s_k} + 1 \right) \quad if\ j \neq k, j,k \in g$$

The consumer surplus, the expected value of the maximum of utilities, can be computed as:

$$CS = \frac{1}{h} \cdot \ln \left[1 + \sum_{g=1}^{G} D_g^{1-\sigma} \right]$$

The net consumer surplus CS measures the attractiveness of the set of J+1 products in monetary terms, after subtracting the price consumers have to pay (Ivaldi and Verboven 2005).

6.2.2 Supply: operators and pricing

Airline and train operators provide a single origin-destination transport service. In the framework, the transport mode "Road" is considered to be offered by a competing "operator". The profit function of operator *j* can be expressed by the fixed costs K_j, the marginal costs c_j and the price of the transport service p_j:

$$\pi_j = (p_j - c_j) \cdot q_j - K_j$$

It is assumed that all operators strive to maximise their profit. The price of service j is equal to the marginal costs plus a mark-up term:

$$p_j = c_j + \frac{1-\sigma}{h \cdot (1-\sigma \cdot s_{j|g} - (1-\sigma) \cdot s_j)}$$

Each operator trades off two effects when considering an increase in price by one unit: i) it increases profits proportional to the current sales level of the firm, ii) it reduces sales, which lowers profits proportional to the current mark-up (Ivaldi and Verboven 2005).The producer surplus is simply the sum of these profits across operators:

$$PS = \sum_{j=1}^{K} \pi_j$$

Total welfare is the sum of producer surplus and consumer surplus as defined earlier.

6.2.3 Market equilibrium

As stated by Ivaldi and Vibes (2008) Bertrand-Nash competition is assumed, where the Nash equilibrium is defined by a set of J necessary first-order conditions:

$$\ln(s_j) - \ln(s_0) = \psi_j - hp_j + \sigma \cdot \ln(s_{j|g})$$

$$p_j = c_j + \frac{1-\sigma}{h \cdot (1-\sigma \cdot s_{j|g} - (1-\sigma) \cdot s_j)}$$

The equilibrium is fully characterised by the demand and supply-side equations above, leading to a unique solution (Ivaldi and Vibes 2008). The model parameters h, σ, quality indices ψ_j and the associated coefficients of the quality attributes, the own, inter-modal and intra-modal price elasticities and the consumer and producer surplus can be computed for the equilibrium situation.

6.2.4 Calibration and simulation

Before market scenarios can be assessed, the market equilibrium of the economic model presented needs to be calculated. Ivaldi and Vibes (2008) describe a calibration procedure that is applied to the Cologne-Berlin transport market. The observed variables taken as input are prices p_j, market shares s_j, the marginal cost c_j and the service characteristics Q_{jk} for all J alternatives. From the equilibrium, values for the parameters h and σ are recovered as well as the weight factors α_j for the quality attributes. The detailed calibration algorithm is presented in appendix D.

Once the equilibrium and the associated calibration parameters are known, simulations can be run for specific cases. The impact of changes in pricing, marginal costs, the operators' service offering and new entrants in the transport market under study can be assessed. Ivaldi and Vibes (2008) present the results of four different simulations in detail.

6.2.5 Validation

The model is validated based on the data given by Ivaldi & Vibes (2008). Calculations were done in Excel and Visual Basic and the results for the equilibrium outcomes and the simulation describing the entrance of a low-cost train on the Cologne-Berlin market show good conformity with the findings from Ivaldi & Vibes. As marginal costs for the business market are not available, the demand parameters for this segment are recovered by running a Monte Carlo simulation as described by Ivaldi (2008). The mean values for the elasticity distribution for the three modalities were set according to the average values as given by Oum et al (1990): -0.65 for Rail, -0.80 for Air and -0.60 for Car and the standard deviation was set to 2.8 to fit the results obtained by Ivaldi (2008). The same mean elasticity values are used for the Rome-Milan route, but with a standard deviation of 4.0 (Mancuso 2014).

6.3 Discrete choice model London-Paris

Applying the discrete choice model as presented in figure 6.1 to the London-Paris market (see chapter 3 for a detailed market description), four nests with one rail operator, five airlines and two car alternatives can be recognised (figure 6.2). The air mode has been split into a Full Service Carrier (FSC) and a Low Cost Carrier (LCC) nest with three and two airlines respectively. CityJet and EasyJet fly from secondary airports with a low cost business model. The market shares are calculated by using data from Eurostat, the UK Civil Aviation Authority (CAA), the UK Office for National Statistics (ONS) and Eurotunnel. A distinction is made between the business and leisure market. There are almost three times more leisure passengers than business travellers on the London-Paris route. Private car and to a lesser extent the high-speed train are preferred transport modes for leisure travellers. EasyJet is the preferred airline for leisure travellers. For the outside alternative, we assume 15% for the business market and 30% for the leisure market. Leisure passengers have a higher probability not to travel than business travellers do.

6.4 Input data

For the simulations, data is collected for all operators and the business and leisure markets on the London-Paris link. For this purpose, various sources are used which are listed in Table 6.1. The International Passenger Survey (IPS) is a survey of international passengers conducted by the UK Office for National Statistics. Details about this survey and the data analysis process and assumptions made can be found in Appendix H. For the Total Travel Time access/egress time to/from airport/train station/terminal, take-off/taxi time, port processing time, expected delay and landing/taxi time are taken into account besides the scheduled in-vehicle time (train, plane, ferry and shuttle). Marginal costs cannot be observed directly (Prady and Ulrich 2010). “Marginal costs are the additional costs a firm incurs in order to produce one additional unit of output.” (Lipczynski et al, 2013). In passenger transport, a unit of output can be an extra flight, train, seat or passenger. In our model, the marginal costs are estimated at the actual load factor (81% in 2012 for London-Paris) and associated with carrying extra passengers, within the existing trainsets and scheduled timetable. Marginal costs are derived from the cost functions related to the specific transport modes on the London-Paris link. For road and rail transport, marginal costs include costs of infrastructure use such as road, rail and tunnel fees and fuel costs (Prady and Ulrich 2010).

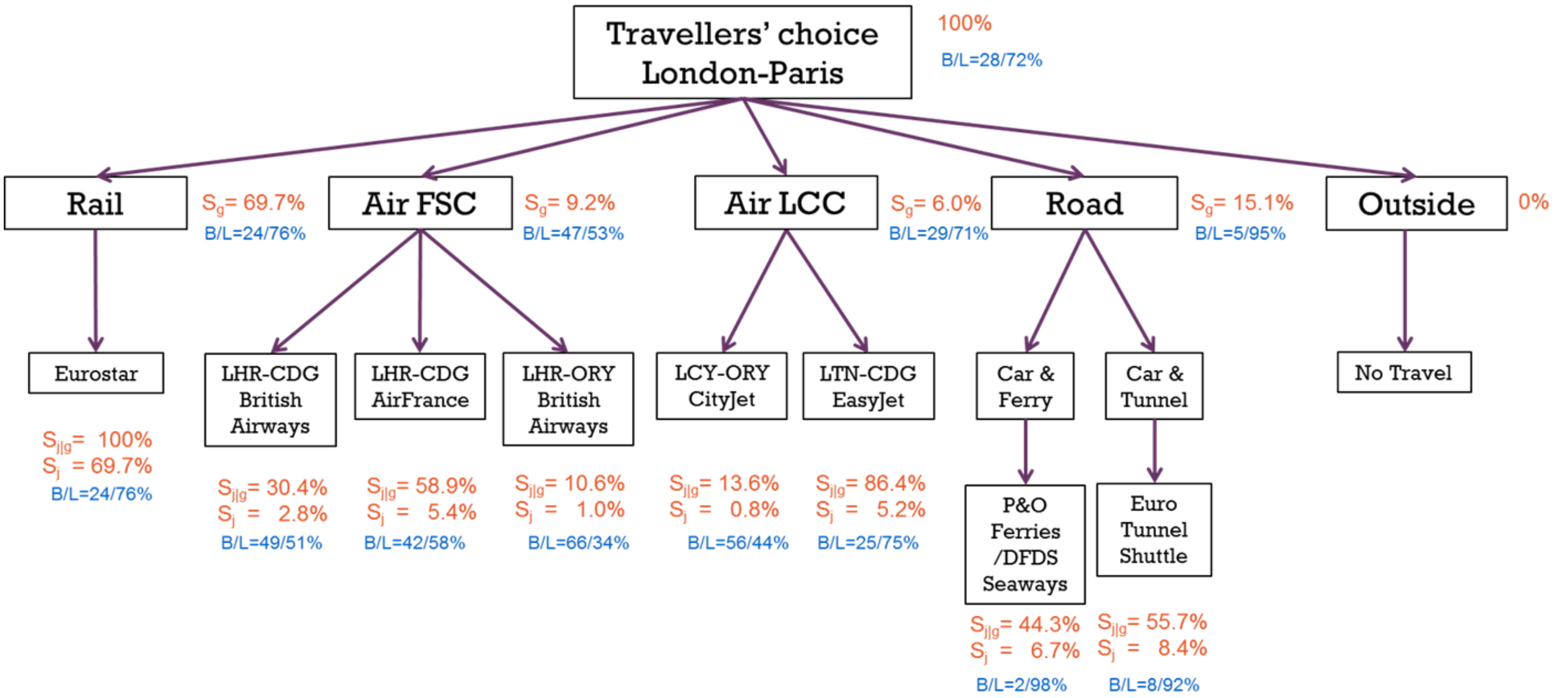

Figure 6.2 - Nested logit model for London-Paris

Note 1: Market shares calculated from IPS 2012 data
Note 2: In the first instance, "Air" was considered as one nest. In this revised model a split is made into two nests: Air FSC and Air LCC to account for the differences in business model
Note 3: In our model CityJet is considered as a Low Cost Carrier as only secondary airports are used. From the perspective of the airline operating costs (table K4), CityJet's business model is not low-cost.

Table 6.1 - Data sources used

Parameter	Sources
Traffic volume and market shares	Eurostat, Civil Aviation Authority (CAA), UK Office for National Statistics (ONS), Eurotunnel Registration documents
Load factors	Eurostat, International Passenger Survey (IPS) UK ONS
Service characteristics and attributes:	
Total Travel Time	Timetables (Thomas Cook for rail) , flight schedules, own calculations
Service frequency	Timetables (Thomas Cook for rail), flight schedules
Seat capacity	Eurostat, Swan and Adler, 2006 (aircraft), UIC HS rolling stock database (train)
Delay on arrival (punctuality)	CAA (air), press releases Eurostar (rail)
Prices and fares	International Passenger Survey (IPS) UK ONS, own calculations (car)
Marginal cost	UIC cost model, Froïdh 2006, European Commission 2006, Alvarez 2010 (rail), Swan and Adler 2006, Givoni 2005, (aircraft), own calculations (car)

Table 6.2 - Input data (2012)

			Traffic modal	Alternatives shares (%)		Prices (Euro)		Marginal costs		Travel time (minutes)		Frequency	Punctuality	Capacity
Mode	Connection	Carrier	shares (%)	Business	Leisure	Business	Leisure	Business	Leisure	Business	Leisure	trips/week	(%)	(seats)
Rail	QQS - XPG	Eurostar	69.7	71.1	69.2	117	73	NA	42	177	187	119	92.1	750
Air FSC	LHR - CDG	British Airways	2.8	5.8	1.9	279	117	NA	43	212	242	48	77.0	166
	LHR - CDG	Air France	5.4	9.7	4.1	291	123	NA	43	220	250	51	67.4	166
	LHR - ORY	British Airways	1.0	2.7	0.4	259	123	NA	50	226	256	27	77.6	136
Air LCC	LCY - ORY	CityJet	0.8	2.0	0.5	202	103	NA	40	227	227	30	90.7	50
	LTN - CDG	EasyJet	5.2	5.4	5.1	99	64	NA	23	221	221	18	83.4	158
Car	LDN - PAR	Eurotunnel	8.4	2.7	10.2	127	82	53	28	299	299	252	75.0	5
	LDN - PAR	P&O/DFDS	6.7	0.6	8.6	105	80	51	24	359	359	221	85.0	5

6.5 Results for the London-Paris route

6.5.1 Market equilibrium

The Paris-London market equilibrium for 2012 is calculated for business and leisure travellers with outside shares of 15, 30 and 60%. The upper part of table 6.3 presents the associated market shares and the demand parameters calculated from the input data (table 6.2). The marginal utility of income is higher for leisure (h=0.025) than for business (h=0.013), indicating that leisure travellers are more price sensitive. This is also found in other studies (see table 6.4). For the London-Paris link, the correlation of alternatives within the same mode is significantly less than unity in both markets, which indicates that the hypothesis that operators in the same group are perfect substitutes can be rejected. This result is comparable with the findings from the Cologne-Berlin (Ivaldi 2008) and Milan-Rome study (Mancuso 2014). Business passengers on the London-Paris route value particular providers to the same extent as leisure passengers (σ=0.35 for business 15 and σ=0.34 for leisure 30). Results from Ivaldi (2008) and Mancuso (2014) show clearer differences between preferences for leisure and business travellers (table 6.5).

Table 6.3 - Equilibrium outcomes for the Paris-London market (2012)

			Business			Leisure		
Share outside alternative (%)			15	30	60	15	30	60
Market shares (%)								
Rail	QQS - XPG	Eurostar	60.4	49.8	28.4	58.8	48.4	27.7
Air FSC	LHR - CDG	British Airways	4.9	4.1	2.3	1.6	1.3	0.8
	LHR - CDG	Air France	8.2	6.8	3.9	3.5	2.9	1.6
	LHR - ORY	British Airways	2.3	1.9	1.1	0.3	0.3	0.2
Air LCC	LCY - ORY	CityJet	1.7	1.4	0.8	0.4	0.4	0.2
	LTN - CDG	EasyJet	4.6	3.8	2.2	4.3	3.6	2.0
Car	LDN - PAR	Eurotunnel	2.3	1.9	1.1	8.7	7.1	4.1
	LDN - PAR	P&O/DFDS	0.5	0.4	0.2	7.3	6.0	3.4
Marginal utility of income:			0.013	0.013	0.013	0.025	0.025	0.024
Within group correlation coefficient:			0.35	0.32	0.32	0.34	0.34	0.34
Own price elasticities[23]								
Rail	QQS - XPG	Eurostar	-0.61	-0.78	-1.11	-0.74	-0.93	-1.29
Air FSC	LHR - CDG	British Airways	-4.82	-4.78	-4.78	-3.88	-3.94	-3.88
	LHR - CDG	Air France	-4.46	-4.48	-4.54	-3.49	-3.54	-3.51
	LHR - ORY	British Airways	-4.87	-4.80	-4.75	-4.48	-4.55	-4.46
Air LCC	LCY - ORY	CityJet	-3.64	-3.60	-3.56	-3.72	-3.77	-3.70
	LTN - CDG	EasyJet	-1.43	-1.44	-1.45	-1.58	-1.61	-1.60
Car	LDN - PAR	Eurotunnel	-1.79	-1.81	-1.81	-2.32	-2.38	-2.39
	LDN - PAR	P&O/DFDS	-1.97	-1.94	-1.91	-2.38	-2.43	-2.44
Consumer surplus:			144.4	90.3	38.6	76.9	48.5	20.9

[23] The own price elasticities are calculated from the recovered system parameters h and σ from the calibration procedure (Appendix F) and can deviate from the actual values.

The lower part of table 6.3 shows that the own price elasticities for Eurostar are the lowest, which means that Eurostar's market share is relatively insensitive to price. Own price elasticities for FSC airlines are higher in the business market, whereas they are higher for Eurostar in the leisure market. The consumer surplus decreases with higher outside shares. By comparing these results with other studies, it can be observed that rail has in all cases the lowest price elasticity compared to other modes (table 6.5).

Table 6.4 - Demand parameters from different HSR studies

Link	Business 15		Leisure 15		Source
	h	σ	h	σ	
Cologne-Berlin	0.023	0.15	0.040	0.20	Ivaldi and Vibes, 2003
Paris-Amsterdam	-	-	-	-	De Rus et al, 2009
Milan-Rome	0.011	0.41	0.043	0.34	Mancuso, 2014
Paris-London	0.013	0.35	0.025	0.34	

Table 6.5 - Own price elasticities from different HSR studies

	Business 15				Leisure 15				
Link	Rail	Air LCC	Air FSC	Road	Rail	Air LCC	Air FSC	Road	Source
Cologne-Berlin	1.77	3.77 to 4.13	5.39	2.10	1.25	2.11 to 2.29	2.40	2.67	Ivaldi and Vibes, 2003
Paris-Amsterdam	-	-	-	-	-	-	-	-	De Rus et al, 2009
Milan-Rome	1.15		2.66 to 3.17	2.29	0.75	-	3.18 to 4.36	3.18	Mancuso, 2014
Paris-London	0.63	1.45 to 3.63	4.49 to 4.83	1.92 to 2.60	0.86	1.74 to 2.74	1.50 to 1.73	1.67 to 1.73	Doomernik, 2014

Note: All elasticity values have negative signs

The cross price elasticities at the market equilibrium are presented in table 6.6 for the business market (with a 15% outside alternative) and in table 6.7 for the leisure market (with a 30% outside alternative). The high cross price elasticities for Eurostar in the business and leisure market indicate that price changes of this operator have a strong effect on market shares of others. In the business market, private car prices have little influence on market shares of other modes. Eurostar's market share is most influenced by the pricing of British Airways and Air France. In the leisure market, Eurostar's market share is most affected by price changes in private car travel (Eurotunnel and P&O/DFDS). Airlines have no significant effect on the London-Paris leisure travel market.

Table 6.6 - Cross price elasticities London-Paris business market (2012)

Share outside alternative (%)			Business 15							
Cross price elasticities:			ES	BA	AF	BA	WX	U2	ET	PD
Rail	QQS - XPG	ES	-0.61	0.18	0.32	0.08	0.05	0.06	0.04	0.01
Air FSC	LHR - CDG	BA	0.93	-4.82	1.40	0.35	0.05	0.06	0.04	0.01
	LHR - CDG	AF	0.93	0.80	-4.46	0.35	0.05	0.06	0.04	0.01
	LHR - ORY	BA	0.93	0.80	1.40	-4.87	0.05	0.06	0.04	0.01
Air LCC	LCY - ORY	WX	0.93	0.18	0.32	0.08	-3.64	0.57	0.04	0.01
	LTN - CDG	U2	0.93	0.18	0.32	0.08	0.43	-1.43	0.04	0.01
Car	LDN - PAR	ET	0.93	0.18	0.32	0.08	0.05	0.06	-1.79	0.14
	LDN - PAR	PD	0.93	0.18	0.32	0.08	0.05	0.06	0.77	-1.97

Note: ES: Eurostar, BA: British Airways, AF: Air France, WX: CityJet, U2: EasyJet, ET: EuroTunnel, PD: P&O/DFDS

Table 6.7 - Cross price elasticities London-Paris leisure market (2012)

Share outside alternative (%)			Leisure 30							
Cross price elasticities:			ES	BA	AF	BA	WX	U2	ET	PD
Rail	QQS - XPG	ES	-0.93	0.05	0.11	0.01	0.01	0.07	0.18	0.15
Air FSC	LHR - CDG	BA	1.07	-3.94	1.13	0.11	0.01	0.07	0.18	0.15
	LHR - CDG	AF	1.07	0.50	-3.54	0.11	0.01	0.07	0.18	0.15
	LHR - ORY	BA	1.07	0.50	1.13	-4.55	0.01	0.07	0.18	0.15
Air LCC	LCY - ORY	WX	1.07	0.05	0.11	0.01	-3.77	0.83	0.18	0.15
	LTN - CDG	U2	1.07	0.05	0.11	0.01	0.13	-1.61	0.18	0.15
Car	LDN - PAR	ET	1.07	0.05	0.11	0.01	0.01	0.07	-2.38	0.62
	LDN - PAR	PD	1.07	0.05	0.11	0.01	0.01	0.07	0.76	-2.43

Note: ES: Eurostar, BA: British Airways, AF: Air France, WX: CityJet, U2: EasyJet, ET: EuroTunnel, PD: P&O/DFDS

The quality indices show that business passengers value services provided by Air France between Heathrow airport and Paris CDG the best (table 6.8), followed by British Airways on the same route and Eurostar. Flights to and or from secondary airports are less valued, especialy when operated by LCC carriers. Private car options have the lowest quality index where the train shuttle is perceived better than the ferry. Leisure passengers value Eurostar the best. Private car and flights with Air France between LHR and CDG are more valued than other flights. The quality attributes for the leisure and business market show the expected signs (table 6.9). Longer travel time has a negative effect, while higher frequency, punctuality and capacity have a positive effect on quality. The quality parameter values can be evaluated in monetary terms using the utilities' sensitivity to price (h). For an outside alternative of 15% for the business market (h = 0.0131), a travel time reduction of 10 minutes is equivalent to a price increase of €34.97. Five extra trips per week is equivalent to €3.21, while 1% better punctuality is equivalent to €11.02 and 10 extra seats are equivalent to €1.27. For the leisure market with a 30% outside alternative share (h=0.0248), the values are €6.53, €4.01, €0.96 and €3.25 respectively. Travel time appears to be the most valuable quality factor for both business and leisure travellers. Business travellers value punctuality better than frequency, whereas it is the opposite for leisure travellers. The value of an extra seat is higher for leisure and business travellers.

Table 6.8 - Quality indices for the London-Paris transport market (2012)

Quality, mode ranking			Business			Leisure		
Share outside alternative (%):			15	30	60	15	30	60
Rail	QQS - XPG	Eurostar	2.93	2.07	0.80	3.17	2.29	1.01
Air FSC	LHR - CDG	British Airways	2.95	2.09	0.80	1.07	0.21	-1.10
	LHR - CDG	Air France	3.44	2.60	1.32	1.72	0.86	-0.45
	LHR - ORY	British Airways	2.19	1.31	0.02	0.19	-0.67	-1.98
Air LCC	LCY - ORY	CityJet	0.93	0.05	-1.23	-0.20	-1.06	-2.36
	LTN - CDG	EasyJet	0.23	-0.65	-1.91	0.37	-0.51	-1.79
Car	LDN - PAR	Eurotunnel	-0.14	-1.01	-2.27	1.68	0.81	-0.48
	LDN - PAR	P&O/DFDS	-1.41	-2.32	-3.59	1.52	0.65	-0.64

Table 6.9 - Quality parameters for the London-Paris transport market (2012)

Quality characteristics	Business			Leisure		
Share outside alternative (%):	15	30	60	15	30	60
Eurostar Dummy	-5.67	-5.39	-4.78	-5.79	-5.29	-4.71
AF Dummy	2.29	2.24	2.11	1.03	0.95	0.82
LCC Dummy	-3.04	-2.99	-2.86	-0.56	-0.55	-0.44
Car/Shuttle Dummy	-0.13	-0.26	-0.44	-1.08	-1.19	-1.38
Travel time	-0.045	-0.046	-0.047	-0.016	-0.016	-0.017
Frequency	0.008	0.008	0.009	0.020	0.020	0.020
Punctuality	0.152	0.145	0.131	0.032	0.024	0.010
Capacity	0.002	0.002	0.001	0.009	0.008	0.007

6.5.2 Market simulations

With the model, simulations can be run in order to better understand the situation on the London-Paris transport market. The model is capable of simulating any changes in pricing, service quality or marginal costs after the market equilibrium is calculated. Even the entry or exit of a competitor can be measured in terms of variations in other firms' prices and market shares (Ivaldi 2008). Three situations are further elaborated for the London-Paris market. First, the effect of increasing the infrastructure charges is examined. The Investment Recovery Charge (IRC) for the high-speed link between the Channel tunnel and London (HS-1) was reduced by 80% from £10,937 per train to £2,150 per train at the end of 2009 to help Eurostar to turn-around their loss-making operation. The reduction in the IRC had the desired effect and Eurostar UK made its first profits in 2009 (NAO 2015). Charges levied by Eurotunnel for the Channel tunnel are perceived to be high and are part of a debate around infrastructure and track access charges in Europe. Eurostar has a dominant share on the London-Paris market despite the high Channel tunnel charges. In the first simulation, the effect of raising the infrastructure charges is explored.

Eurostar has ordered 17 new international passenger trains, the first of which came into service at the end of 2015. The new e320 trains have higher seating capacity (around 20% more), allowing for more passengers per train. New trains are forecast to increase revenue due to an increase in the number of passengers, while many of the costs will stay (for example track access costs per train) or fall (more cost-efficient trains) (NAO 2015). The expected effect of these new trains is that service quality will improve, operating costs per seat will go down and Eurostar's market share will increase. The second simulation is aimed at exploring the effect of improving the service characteristics of Eurostar and reducing the marginal costs.

The third case has to do with the entry of a new rail competitor. International rail passenger services have been liberalised since 1 January 2010. The assumption is that an operator offering competing rail service between Paris and London would significantly reduce Eurostar's market share. In 2010, the German train operator Deutsche Bahn (DB) announced that it planned to offer cross-Channel services from London by 2013. In 2014, it announced that its plans were on hold due to operational challenges (NOA 2015). As there is still an opportunity for a new high-speed rail operator to enter the London-Paris market, a simulation is run where a competitor is offering the same type of service as Eurostar but with 25% lower marginal cost.

6.5.3 Increase of infrastructure charges

The 80% charge reduction for HS-1 is equivalent with a decrease in cost of approximately €18 per passenger (at 81% load factor, 1.23 Euro/Sterling exchange rate). Increasing the rail infrastructure charges again between London and Paris results in higher marginal costs. For the simulation, we assume a €18 per passenger increase in marginal costs. The effect is that Eurostar increases the ticket price, but they are losing market share to the air and car modes, as might be expected (table 6.10 and 6.11). The effect on the consumer surplus is limited.

Table 6.10 - Results for increased infra charges (Paris-London business market 2012)

Share outside alternative (%):			Business 15		Business 30		Business 60	
Prices (€):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	235.2	101.0%	126.3	8.0%	130.2	11.3%
Air FSC	LHR - CDG	British Airways	280.1	0.4%	279.1	0.0%	279.1	0.0%
	LHR - CDG	Air France	293.5	0.9%	291.2	0.1%	291.1	0.0%
	LHR - ORY	British Airways	259.4	0.2%	259.1	0.0%	259.0	0.0%
Air LCC	LCY - ORY	CityJet	202.4	0.2%	202.0	0.0%	202.0	0.0%
	LTN - CDG	EasyJet	100.4	1.4%	99.1	0.1%	99.1	0.1%
Car	LDN - PAR	Eurotunnel	127.6	0.5%	127.1	0.1%	127.0	0.0%
	LDN - PAR	P&O/DFDS	105.1	0.1%	105.0	0.0%	105.0	0.0%
Market shares (%):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	43.4	-28.1%	46.7	-6.2%	25.0	-12.0%
Air FSC	LHR - CDG	British Airways	7.0	41.5%	4.3	6.1%	2.4	4.7%
	LHR - CDG	Air France	12.1	46.6%	7.2	5.9%	4.1	4.6%
	LHR - ORY	British Airways	3.2	40.6%	2.0	6.2%	1.1	4.8%
Air LCC	LCY - ORY	CityJet	2.4	40.5%	1.5	6.2%	0.8	4.8%
	LTN - CDG	EasyJet	6.6	44.6%	4.0	6.0%	2.3	4.7%
Car	LDN - PAR	Eurotunnel	3.3	43.1%	2.0	6.2%	1.1	4.7%
	LDN - PAR	P&O/DFDS	0.7	41.0%	0.4	6.2%	0.3	4.8%
Outside alternative			21.3	41.7%	31.9	6.2%	62.9	4.8%
Consumer surplus:			145.9	1.0%	85.8	-5.0%	35.0	-9.2%

Note: For "Business 15" we found oscillations in the iteration results for price and market share. The figures presented are average values.

Table 6.11 - Results for increased infra charges (Paris-London Leisure market 2012)

Share outside alternative (%):			Leisure 15		Leisure 30		Leisure 60	
Prices (€):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	107.8	47.6%	82.8	13.5%	86.6	18.6%
Air FSC	LHR - CDG	British Airways	117.1	0.1%	117.0	0.0%	117.0	0.0%
	LHR - CDG	Air France	123.4	0.3%	123.1	0.1%	123.0	0.0%
	LHR - ORY	British Airways	123.0	0.0%	123.0	0.0%	123.0	0.0%
Air LCC	LCY - ORY	CityJet	103.0	0.0%	103.0	0.0%	103.0	0.0%
	LTN - CDG	EasyJet	64.7	1.1%	64.2	0.2%	64.1	0.1%
Car	LDN - PAR	Eurotunnel	83.2	1.4%	82.3	0.3%	82.1	0.1%
	LDN - PAR	P&O/DFDS	80.9	1.1%	80.2	0.2%	80.1	0.1%
Market shares (%):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	43.8	-25.5%	42.4	-12.4%	21.6	-22.1%
Air FSC	LHR - CDG	British Airways	2.2	35.5%	1.5	11.8%	0.8	8.5%
	LHR - CDG	Air France	4.8	36.7%	3.2	11.5%	1.8	8.4%
	LHR - ORY	British Airways	0.5	35.5%	0.3	11.9%	0.2	8.5%
Air LCC	LCY - ORY	CityJet	0.6	35.2%	0.4	12.0%	0.2	8.6%
	LTN - CDG	EasyJet	5.9	36.9%	4.0	11.4%	2.2	8.3%
Car	LDN - PAR	Eurotunnel	11.9	37.6%	8.0	11.6%	4.4	8.2%
	LDN - PAR	P&O/DFDS	9.9	36.0%	6.7	11.3%	3.7	8.3%
Outside alternative			20.4	35.8%	33.5	11.8%	65.1	8.5%
Consumer surplus:			73.3	-4.7%	44.0	-9.3%	17.6	-16.0%

Note: For “Leisure 15” we found oscillations in the iteration results for price and market share. The figures presented are average values.

6.5.4 New Eurostar trains

In this case, we assume the capacity to increase by 20% as soon as e320 trains with 900 seats replace the current TGV trains with 750 seats. This results in 20% lower operational costs per available seat. The marginal cost will decrease as well, but less than 20% as charges for the Channel tunnel (€17 per passenger in 2012) will remain the same. Assumed is that a 20% higher train capacity leads to a 10% decrease in marginal costs. The results are presented in table 6.12 for the business market and 6.13 for the leisure market.

Product quality improvement of Eurostar (translated into lower marginal costs) results into an even more dominant market position. The business market is more sensitive to Eurostar’s service level than the leisure market as illustrated by the extra seat capacity offering. Consumer surplus increases slightly, but the decrease in the outside alternative indicates that no extra traffic is induced.

Table 6.12 - Results for new Eurostar trains (Paris-London Business market 2012)

Share outside alternative (%):			Business 15		Business 30		Business 60	
Prices (€):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	108.6	-7.2%	113.4	-3.1%	115.9	-1.0%
Air FSC	LHR - CDG	British Airways	278.9	-0.1%	279.0	0.0%	279.0	0.0%
	LHR - CDG	Air France	290.7	-0.1%	290.9	0.0%	291.0	0.0%
	LHR - ORY	British Airways	258.9	0.0%	259.0	0.0%	259.0	0.0%
Air LCC	LCY - ORY	CityJet	201.9	0.0%	202.0	0.0%	202.0	0.0%
	LTN - CDG	EasyJet	98.8	-0.2%	98.9	-0.1%	99.0	0.0%
Car	LDN - PAR	Eurotunnel	126.9	-0.1%	127.0	0.0%	127.0	0.0%
	LDN - PAR	P&O/DFDS	105.0	0.0%	105.0	0.0%	105.0	0.0%
Market shares (%):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	63.0	4.2%	51.0	2.4%	28.8	1.1%
Air FSC	LHR - CDG	British Airways	4.6	-6.5%	4.0	-2.3%	2.3	-0.4%
	LHR - CDG	Air France	7.7	-6.2%	6.6	-2.3%	3.9	-0.4%
	LHR - ORY	British Airways	2.1	-6.6%	1.8	-2.4%	1.1	-0.4%
Air LCC	LCY - ORY	CityJet	1.6	-6.6%	1.4	-2.4%	0.8	-0.4%
	LTN - CDG	EasyJet	4.3	-6.4%	3.7	-2.3%	2.2	-0.4%
Car	LDN - PAR	Eurotunnel	2.1	-6.5%	1.8	-2.4%	1.1	-0.4%
	LDN - PAR	P&O/DFDS	0.5	-6.6%	0.4	-2.4%	0.2	-0.4%
Outside alternative			14.0	-6.6%	29.3	-2.4%	59.7	-0.4%
Consumer surplus:			149.6	3.6%	92.2	2.0%	38.9	0.9%

Table 6.13 - Results for new Eurostar trains (Paris-London Leisure market 2012)

Share outside alternative (%):			Leisure 15		Leisure 30		Leisure 60	
Prices (€):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	70.2	-3.9%	72.4	-0.8%	71.4	-2.2%
Air FSC	LHR - CDG	British Airways	117.0	0.0%	117.0	0.0%	117.0	0.0%
	LHR - CDG	Air France	123.0	0.0%	123.0	0.0%	123.0	0.0%
	LHR - ORY	British Airways	123.0	0.0%	123.0	0.0%	123.0	0.0%
Air LCC	LCY - ORY	CityJet	103.0	0.0%	103.0	0.0%	103.0	0.0%
	LTN - CDG	EasyJet	63.9	-0.1%	64.0	0.0%	64.0	0.0%
Car	LDN - PAR	Eurotunnel	81.9	-0.1%	82.0	0.0%	82.0	0.0%
	LDN - PAR	P&O/DFDS	79.9	-0.1%	80.0	0.0%	80.0	0.0%
Market shares (%):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	60.5	2.8%	48.8	0.7%	28.5	2.9%
Air FSC	LHR - CDG	British Airways	1.5	-4.1%	1.3	-0.7%	0.8	-1.1%
	LHR - CDG	Air France	3.3	-4.0%	2.9	-0.7%	1.6	-1.1%
	LHR - ORY	British Airways	0.3	-4.1%	0.3	-0.7%	0.2	-1.1%
Air LCC	LCY - ORY	CityJet	0.4	-4.2%	0.3	-0.7%	0.2	-1.1%
	LTN - CDG	EasyJet	4.2	-4.0%	3.5	-0.7%	2.0	-1.1%
Car	LDN - PAR	Eurotunnel	8.3	-3.9%	7.1	-0.7%	4.0	-1.1%
	LDN - PAR	P&O/DFDS	7.0	-3.9%	6.0	-0.7%	3.4	-1.1%
Outside alternative			14.4	-4.1%	29.8	-0.7%	59.3	-1.1%
Consumer surplus:			78.6	2.2%	48.7	0.6%	21.4	2.2%

6.5.5 Entrance of a new high-speed rail operator with low-cost trains

A new rail operator introduces a structural change in the transport system. Eurostar's market share would be halved when a new operator would offer the same quality characteristics (travel time, frequency, punctuality, capacity) and prices. In this case, we assume a new operator with marginal costs that are 75% of Eurostar's cost level. The results of this simulation for the business and leisure market is presented in tables 6.14 and 6.15.

In the case of a new high-speed train operator entering the London-Paris market, the shares of the air and car mode are decreasing by 30 to 75% depending on the share of the outside alternative, while keeping the same price level. Eurostar is losing 15 to 25% of its market share as well in favour of the new operator resulting in an almost equal share for both rail operators, but with slightly lower prices for the new entrant due to the lower marginal costs. The outside alternative is decreasing which means that the new market situation attracts extra travellers. The consumer surplus is higher in all cases. The market share losses for the incumbent operators are about the same for the leisure and business market.

Table 6.14 - Results for a new HSR operator (Paris-London business market 2012)

			Business 15		Business 30		Business 60	
Prices (€):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	361.1	208.7%	167.8	43.4%	87.4	-25.3%
		LCC Train	297.6	0.0%	162.6	0.0%	85.7	0.0%
Air FSC	LHR - CDG	British Airways	277.3	-0.6%	277.9	-0.4%	278.7	-0.1%
	LHR - CDG	Air France	287.9	-1.1%	289.0	-0.7%	290.4	-0.2%
	LHR - ORY	British Airways	258.3	-0.3%	258.5	-0.2%	258.9	-0.1%
Air LCC	LCY - ORY	CityJet	201.4	-0.3%	201.6	-0.2%	201.9	-0.1%
	LTN - CDG	EasyJet	97.0	-2.0%	97.8	-1.3%	98.6	-0.4%
Car	LDN - PAR	Eurotunnel	125.9	-0.8%	116.2	-8.5%	126.8	-0.1%
	LDN - PAR	P&O/DFDS	104.8	-0.2%	112.8	7.5%	105.0	0.0%
Market shares (%):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	45.4	-24.9%	39.5	-20.7%	24.0	-15.5%
		LCC Train	44.2	0.0%	38.6	0.0%	24.8	0.0%
Air FSC	LHR - CDG	British Airways	1.4	-70.7%	1.9	-53.1%	1.7	-28.3%
	LHR - CDG	Air France	2.5	-69.9%	3.2	-52.2%	2.8	-28.0%
	LHR - ORY	British Airways	0.7	-71.3%	0.9	-53.6%	0.8	-28.6%
Air LCC	LCY - ORY	CityJet	0.5	-71.2%	0.7	-53.6%	0.6	-28.5%
	LTN - CDG	EasyJet	1.4	-70.4%	1.8	-52.8%	1.6	-28.2%
Car	LDN - PAR	Eurotunnel	0.7	-70.8%	0.2	-89.2%	0.8	-28.4%
	LDN - PAR	P&O/DFDS	0.1	-71.3%	0.3	-40.1%	0.2	-28.6%
Outside alternative			4.3	-71.3%	13.9	-53.6%	42.9	-28.6%
Consumer surplus:			239.4	65.7%	148.0	63.8%	64.0	65.9%

Note: For "Business 15 and 30" we found oscillations in the iteration results for price and market share. The figures presented are average values.

Table 6.15 - Results for a new HSR operator (Paris-London leisure market 2012)

Share outside alternative (%)			Leisure 15		Leisure 30		Leisure 60	
Prices (€):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	174.5	139.0%	102.9	40.9%	55.8	-23.6%
		LCC Train	156.5	0.0%	101.9	0.0%	53.4	0.0%
Air FSC	LHR - CDG	British Airways	116.7	-0.2%	116.8	-0.1%	116.9	0.0%
	LHR - CDG	Air France	122.3	-0.5%	122.6	-0.3%	122.9	-0.1%
	LHR - ORY	British Airways	122.9	0.0%	123.0	0.0%	123.0	0.0%
Air LCC	LCY - ORY	CityJet	102.9	-0.1%	102.9	-0.1%	103.0	0.0%
	LTN - CDG	EasyJet	62.9	-1.7%	63.3	-1.1%	63.8	-0.3%
Car	LDN - PAR	Eurotunnel	80.3	-2.1%	75.7	-7.7%	81.7	-0.4%
	LDN - PAR	P&O/DFDS	78.6	-1.7%	85.1	6.4%	79.7	-0.3%
Market shares (%):			Value	Change	Value	Change	Value	Change
Rail	QQS - XPG	Eurostar	44.6	-24.2%	39.5	-18.4%	23.2	-16.0%
		LCC Train	43.8	0.0%	39.3	0.0%	25.4	0.0%
Air FSC	LHR - CDG	British Airways	0.4	-74.0%	0.6	-54.7%	0.5	-28.9%
	LHR - CDG	Air France	0.9	-73.6%	1.3	-54.3%	1.2	-28.7%
	LHR - ORY	British Airways	0.1	-74.2%	0.1	-54.9%	0.1	-29.1%
Air LCC	LCY - ORY	CityJet	0.1	-74.4%	0.2	-55.1%	0.1	-29.1%
	LTN - CDG	EasyJet	1.2	-73.4%	1.6	-54.0%	1.5	-28.6%
Car	LDN - PAR	Eurotunnel	2.3	-73.0%	0.6	-91.6%	2.9	-28.4%
	LDN - PAR	P&O/DFDS	2.0	-73.3%	2.9	-51.2%	2.5	-28.6%
Outside alternative			3.9	-74.1%	13.6	-54.8%	42.6	-29.0%
Consumer surplus:			131.8	71.3%	80.4	65.9%	35.0	67.0%

Note: For "Leisure 15 and 30" we found oscillations in the iteration results for price and market share. The figures presented are average values.

6.6 Conclusions and discussion

6.6.1 Conclusions

The calculated system parameters of the model presented shows that leisure travellers for the London-Paris link are more price sensitive than business passengers, as can be expected. This is also found in other studies on the Cologne-Berlin and Milan-Rome routes.

Eurostar has a dominant market share of about 70% (2012) on the London-Paris market compared to 30% for airlines and private car. On the one hand, price changes of Eurostar in the business and leisure market strongly influence the shares of other market players. On the other side, Eurostar's market share is most influenced by the pricing of British Airways and Air France. In the business market, private car prices have little influence on market shares of other modes. In the leisure market, Eurostar's market share is most affected by price changes in private car travel using the Channel tunnel or ferry.

The calculated quality indices show that business passengers value Eurostar and airline services provided by full-service carriers between major airports the best, with AirFrance being the best performer. Flights to and or from secondary airports are less valued, especially when operated by LCC carriers. Leisure passengers value Eurostar the best. The use of private cars is a low quality option, where the train shuttle is perceived better than the ferry.

Eurostar's market share is sensitive to changes in infrastructure charges. If charges would be increased again, after the 80% reduction in 2009 for HS-1, Eurostar's market share will initially go down in favour of air and road traffic and, depending on the strategic actions taken by Eurostar and its competitors, the market will adapt to the new situation. Introduction of new Velaro trainsets with more seat capacity will make Eurostar's market position even more dominant. A new high-speed rail entrant would completely change the competitive landscape. With the same pricing and quality characteristics, Eurostar's market share will be halved. If the new entrant is capable of reducing its marginal costs, the effect will even be bigger and drive airlines and private cars out of the market. The business market is less sensitive to prices, but more sensitive to the service level offering.

6.6.2 Discussion

The econometric supply and demand model for oligopolistic markets with differentiated products as used in this study has proven to be a valuable tool to study competition in transport markets. The application on the London-Paris passenger link gives valuable information on the effect of marginal costs and quality attributes on the competitive position of operators. The results are well in line with comparable studies on the Cologne-Berlin, Amsterdam-Paris and Rome-Milano markets. For the future, the London-Paris case can be studied in more detail with the statistical data available from the UK International Passenger Survey for subsequent years. Further application of the methodology on other links will contribute to capturing the competitive position of operators in the West European market in more detail.

Application of a game theory model with multiple players to the London-Paris link revealed the effect of rail policies and strategic decisions of high-speed rail operators on future developments. The strategic behaviour and performance of operators is core to the SCP model and shapes the market (figure 1.1). The London-Paris case shows that the Eurostar's market share grows with quality improvement (higher train capacity) and that higher rail infra charges set by the government and entry of a new operator completely change the competitive landscape.

The dominant position of Eurostar and the unique tunnel operations between France and the UK to cross the Channel makes the London-Paris market a special case. The results are not easily transferable to other cases. To get more confidence and to cancel out the special features associated with the France-UK border crossing by train, the discrete choice model could be applied to other international routes as well. The challenge is to find reliable data to support these cases.

In the next chapter, we will have a closer look at the state-of-play of high-speed rail on international routes in Europe, before investigating market entry strategies and access barriers that may hinder new entrants. The progress of the railway liberalisation process and the developments in infrastructure management and pricing will be highlighted as well.

7 Market entry

7.1 Introduction

The former chapter on competition gives an indication of how government policy and strategic decisions from high-speed rail operators affect performance and influence the market structure. It illustrates for the London-Paris market the effect of increasing infra charges, the introduction of new rolling stock and the entrance of a new competitor in an existing market. The goal of this chapter is to explore the experiences of open access rail operators in the European high-speed market to learn about their business strategies. We also give an overview of possible entrance strategies and access barriers that new entrants have to face. The progress of the rail liberalisation process in Europe and the way rail infrastructure is managed are analysed to find the most attractive routes for market entrance.

This chapter is structured as follows. Section 7.2 presents an overview of the current cross-border operations to illustrate what initiatives already have been taken in the European market. Section 7.3 describes the developments in international coach services that provide a new competing mode for the railways. The view of the European Commission on the desired market developments is presented in section 7.4 and the view from the operators' perspective and the possible entrance and deterrence strategies are given in section 7.5 and 7.6. The market, administrative, technological, operational and financial barriers that need to be overcome are collected in the MATOF framework presented in section 7.7. The progress of the rail liberalisation process in the EU 15 Member States to eliminate these barriers is illustrated in section 7.8. Section 7.9 presents the role and importance of rail infrastructure managers in cross-border operations. Finally, section 7.10 presents the conclusions and discussion.

7.2 Current cross-border high-speed rail operations

Starting in the 80's with a 300 km/h line between Paris and Lyon, high-speed train services in Europe were developed on a national basis in specific countries like France, Germany, Spain, Italy, UK and Belgium over the last decades. Cross-border high-speed train services are in operation in several countries, like the Thalys train service between Paris, Brussels, Köln, Amsterdam, the Eurostar (Paris-Brussels-London), Lyria between France and Switzerland and services between France and Spain (Perpignan-Figueres) operated by SNCF and Renfe. At the moment, 50% of passengers travelling from Paris to Brussels use the Thalys train services and 81% of travellers from Paris to London take Eurostar trains (UIC 2008). New cross-border connections are planned or under construction between France and Italy (Lyon-Turin) and Germany and Switzerland (Karlsruhe-Basel). The plans to build a high-speed connection between Portugal and Spain (Lisbon-Madrid) was abandoned in 2012[24]. New cross-border links will give opportunities for new high-speed traffic services. Extra growth can be established from the "network" effect and might shift the modal split to high-speed train services.

[24] Railway Gazette International, 23 March 2012

Table 7.1 shows that four different types can be distinguished among operators based on ownership. It is generally assumed that an open international rail passenger market with lower entry barriers will lead to more competition with a stronger involvement of private parties and less dominant positions of state-owned operators.

Table 7.1 - Overview of high-speed cross-border operators in Europe (2016)

Category	Operator	Ownership	Cross-border routes
I. National State-owned operators	Deutsche Bahn	Germany	Frankfurt-Vienna, Frankfurt-Brussels, Amsterdam-Frankfurt-Basel
	SJ	Sweden	Stockholm/Malmö-Copenhagen
II. Joint Ventures of State-owned operators	Thalys	SNCF (62%), NMBS/SNCB (28%), DB (10%)	Paris-Brussels-Amsterdam
	TGV Lyria	SNCF (74%), CFF/SBB (26%)	Paris-Lausanne/ Geneva, Paris-Bern /Basel/Zürich
	Elipsos International	SNCF (50%), Renfe (50%)	Toulouse/Marseille/Lyon-Barcelona-Madrid
	Alleo	SNCF (50%), DB (50%)	Paris-Frankfurt /Stuttgart
III. Joint Ventures of State-owned operators and private owners	Eurostar International	SNCF (55%), NMBS/SNCB (5%), LCR (40%)	Paris-Brussels-London
	High Speed Alliance	NS (90%), KLM (10%)	Amsterdam-Brussels (liquidated 2015)
	Thello[25]	Trenitalia (67%), TransDev (33%)	Paris-Venice, Milan-Marseille
IV. Private operators	NTV	SNCF (20%), private (80%)	North Italy – Munich, Vienna (under consideration)

In most countries incumbent state-owned railways like SNCF, DB, Renfe, NMBS/SNCB and Trenitalia run high-speed operations. These (public) companies look for international expansion of their business by setting up new train services abroad. Sometimes they act on their own, like DB with their ICE International brand and in other cases they look for joint ventures and cooperation with other state-owned operators like Thalys (62% SNCF, 28% NMBS/SNCB, 10% DB), Lyria (SNCF 74%, CFF 26%), Elipsos SNCF, Renfe) and Alleo (DB, SNCF) and. There were also public-private joint venture initiatives like Eurostar (SNCF, SNCB, London & Continental Railways) and High Speed Alliance (NS, KLM), where private parties team up with state-owned operators. In the light of the opening of the cross-border rail market in 2010, in 2008 a joint venture between Veolia and Air France-KLM was launched to operate high-speed train services in Europe, but this cooperation ended in 2009.

TGV Lyria was initially launched as an economic interest group (GEIE) between SNCF and SBB in 1993 and converted into a Societé par Actions Simplifiée (SAS) under French law responsible for the commercial management of TGV services between Paris and Lausanne, Brig and Bern. Since 2005, it operates high-speed rail services between Paris and Geneva and

[25] Thello runs cross-border high-speed trains on conventional track. Thello is now fully owned by Trenitalia, following Transdev's decision to relinquish its one-third stake (Hughes 2017b).

after the opening of TGV Est it also serves the Paris-Basel-Zürich route[26]. The jointly-owned subsidiary by SNCF and SBB runs a fleet of 19 dedicated TGV POS trainsets[27].

Elipsos International is a subsidiary holded by Renfe and SNCF with a capital contribution of 50% each. Since December 2013, Elipsos runs train services connecting major Spanish and French cities like Barcelona, Madrid, Marseille, Lyon and Toulouse.

As such, Elipsos has been appointed to coordinate the international high-speed railways project linking Spain and France. Since December 2010, date of commissioning of the Perpignan-Figueras Perthus tunnel under the Eastern Pyrenees, Elipsos manages the marketing of high-speed trains under the "Renfe-SNCF en Cooperación" trademark.

The joint venture Alleo between DB and SNCF has transported over 10 million passengers on the cross-border link between Frankfurt/Main and Stuttgart and Paris since 2007[28]. Alleo realised a 66% share on the Stuttgart-Paris connection (four trains daily in both directions) and a 27% share on the Frankfurt-Paris link (five trains daily in both directions). With a 3:50h travel time, Alleo is a serious competitor for air travel[29]. The existing fleet of TGV 2N2-Euroduplex trains will be extended with the newest generation of ICE 3 trains.

Thello is an open access long-distance operator that has started to run night trains between Paris and Venice via Switzerland. This is the first service in the long-distance passenger market in France which is not operated by or in cooperation with SNCF (EC 2013a). In 2014 Thello introduced a daytime new train service between Milan and Marseille running Italian Frecciabianca high-speed trains (ETR460/470) on conventional track[30]. In fact, Thello is a cross-border, but currently not a high-speed rail operator.

In 2011, Nuovo Trasporti Viaggiatori (NTV) started high-speed services in the Italian market. NTV (with a 20% SNCF share) claims to be Europe’s first private open access operator for high-speed services, competing with Trenitalia in their home market. “*The mission of NTV is to offer passenger services on high-speed lines, presenting innovative features and value traveling time by: complete customized services; comfortable technologically advanced surroundings, top quality and competitive prices*” (Ripa, 2010). NTV set out plans in December 2012 to introduce its first service beyond Italy's core high-speed network. It wanted to start a service between Milan and Ancona using the high-speed line as far as Bologna, but the plan was abandoned after a conflict with RFI, the Italian infrastructure manager. In 2015, NTV has purchased eight Pendolino high-speed trains to expand the operator’s existing fleet and offer additional high speed journeys to its passengers[31]. The Pendolino fleet is due to be delivered by December 2017, with entry into service planned for March 2018[32].

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[26] Railway Gazette, 19 February 2008

[27] Railway Gazette, 17 February 2011

[28] SCI Raildata Newsletter 40/2014, 6 October 2014

[29] Deutsche Bahn Press release, 29 August 2014

[30] Thello Press release, 2 September 2014

[31] Alstom Press release, 29 October 2015

[32] Railway Gazette, 15 December 2016

The High Speed Alliance (HSA) case shows that airlines keep an eye on the high-speed rail market. HSA (90% NS, 10% KLM) was founded in 1993 to run high-speed trains from Amsterdam to Brussels and Paris. HSA started to run Fyra trains on 9 December 2012, but after 40 days, the service between Amsterdam and Brussels was stopped after technical difficulties and disappointing results. At the beginning of 2013, the average occupancy rate was around 22% and 33% during peak times between Amsterdam and Rotterdam. After a political debate in the Dutch parliament, the concession to run high-speed trains was transferred to NS (Dutch Railways) and HSA is liquidated by 2015. The 19 delivered trainsets were handed back to the manufacturer in Italy.

It is remarkable to see that SNCF is involved in many joint-ventures (Thalys, TGV Lyria, Alleo, Eurostar, NTV) with a considerable stake. Adding the cooperation with Renfe on the Perpignan-Barcelona link to the list, gives SNCF a strong strategic position in the European market. In May 2015, the European Commission announced the conditional approval for the SNCF acquisition of Eurostar after the sale of the UK government stake to a private company[33]. SNCF can be considered the European market leader in high-speed rail traffic, currently accountable for almost 50% of all high-speed rail traffic in Europe. The most attractive routes are currently operated by consortia involving both SNCF and DB.

An interesting initiative launched by SNCF in 2013 is the low-cost high-speed train OIUGO on their national network with less comfort and flexibility and no food or drinks sold on-board. To allow for low fares, a budget travel model is adopted as offered by low-cost airlines like EasyJet and Ryanair. Although an interesting option, there are to our knowledge no plans to operate this model on cross-border services. In 2016, Thalys has introduced a low-cost train service specially designed for the leisure travellers between Paris and Brussels using two TGV high-speed trainsets leased from SNCF. The train carries fewer members of staff, who are tasked with basic maintenance of the train besides serving passengers[34].

Various European train companies have initiated a cooperation to provide seamless services for long distance passenger transport on the high-speed train infrastructure (Friederiszick et al 2009). The Railteam alliance is the answer of the high-speed railway operators to the competition of airline alliances like Oneworld and Star Alliance. Railteam has seven full members (DB, SNCF, Eurostar, NS HiSpeed, OBB and CFF/SBB) and two associated members (Thalys and TGV Lyria). *"Railteam is dedicated to making international high-speed travel across Europe simple, seamless and sustainable by combining and extending the services of its members."* (Railteam 2011). One could expect that cooperation between incumbent rail companies hinders effective competition (Friederiszick et al 2009). The Railteam cooperation makes it more difficult for new operators to enter the market.
The association of European Passenger train Operators (EPTO) coordinates the interests of private transport operators in Europe. Members are Arriva, FirstGroup, Veolia, Go Ahead, Grupo Barraqueiro, Keolis, National Express, Stagecoach, Transdev and Transdev-Connexxion. Their focus is currently more on regional and national transport contracts than on high-speed rail opportunities.

[33] European Railway Review, Volume 21, Issue 3, 2015

[34] Press release Thalys, 3 April 2016

7.3 Inter-modal competition

In 2011, the coach and bus market has been liberalised by Regulation 1073/2009. A recent study by the European Commission estimated that international coach passenger numbers grew by 40-60%, and international coach passenger-kilometres grew by 0-40%, between 2009 and 2014 (EC 2016d). Over longer distances, in the international passenger transport market, coach services compete on price with railways and airlines, which offer better journey time, seating capacity and service frequency. For example, the Paris-Milan corridor is well connected by air, with 18 flights per day in each direction and rail, with three direct TGV train services per day and a daily sleeper service provided by Thello. Before 2011, only the incumbent international coach operator Eurolines, established in 1985, provided regular coach services restricted to cross-border traffic. After Regulation 1073/2009 came into force in 2011, Eurolines became the first international operator to receive permission to operate long-distance regular coach services within France competing with French domestic rail services. In July 2012 SNCF, established a coach subsidiary iDBUS (now Ouibus) and began commercial services. In December 2012, it began to operate three Paris-Lyon-Milan services a day. In July 2015, in anticipation of this liberalisation of the French domestic market, two new operators started services on the Paris to Milan corridor, Megabus, a subsidiary of British operator Stagecoach and FlixBus, a privately owned German company.

To illustrate inter-modal competition on five international connections in Western Europe that are connected by high-speed rail links, a comparison is made regarding price and service quality across travel modes including coach services (figure 7.1). Although large discounts are possible for advance bookings, the fares used in the analysis are ticket prices for a single trip on the day of travel and total travel time is used as an indicator for service quality. As illustrated in figure 7.1, the routes served by Eurostar (Brussel-London and Paris-London) are the most expensive, but the service is much faster than by air or road. Brussels-Paris by Thalys proves to be good value for money, but also a coach service is attractive if time is not an issue. Paris-Frankfurt by air is a less attractive option compared to high-speed rail provided by Alleo and private car. For London-Köln, it is cheaper and faster to take a plane than the high-speed train. Coach services offering an average speed between 60 and 80 km/h deliver high value to the leisure market characterised by price-sensitive passengers.

A more meaningful comparison can be made based on generalised cost, by adding a monetary valuation of travel time to the fares paid by the traveller. Travel time is measured in time units and the value of travel time is the exchange rate to convert these into money units (Wardman et al 2012). The Value of Travel Time (VOT) depends on many variables like income per capita, transport mode, journey purpose and travel distance (EIB 2013). Wardman et al. (2012) have developed a model based on a meta-analysis that enables to calculate values of time considering these variables. The equation for Value of In-Vehicle Time (VoIVT) is given by:

$$VoIVT = e^{-10.060+0.150C+0.245EBTU-0.307BU+0.244AU-0.061TV+0.520AV} \times D^{0.188-0.048CV} \times GDP^{0.681+0.128EB+0.039CU}$$

This is expressed in € per minute in 2010 incomes and prices. C denotes commuting, EB is employer’s business, EBTU denotes employer’s business for train users, TU, BU, AU and CU are train user, bus user, air user and car user respectively, TV, CV and AV are train valued, car valued and air valued respectively whilst D is distance in kilometres and GDP is gross domestic product per capita. The results for the five selected international routes given in table 7.2 show large differences between leisure and business travellers and between travel modes. The in-vehicle time value is the lowest for coaches and the highest for airlines for both leisure and business trips. Car and rail travel have comparable values, but for leisure the car is slightly better valued than the train, which is the other way around for business. There are only small differences between the five routes.

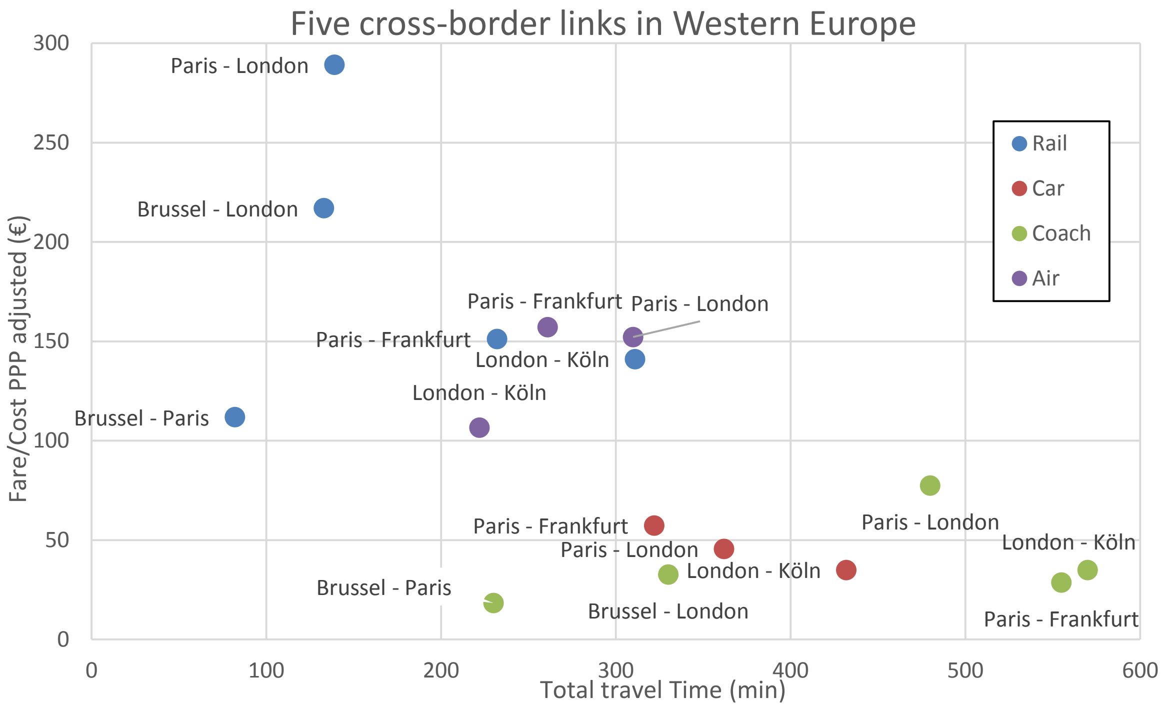


Figure 7.1 - Fares and Total Travel Time on five European cross-border links

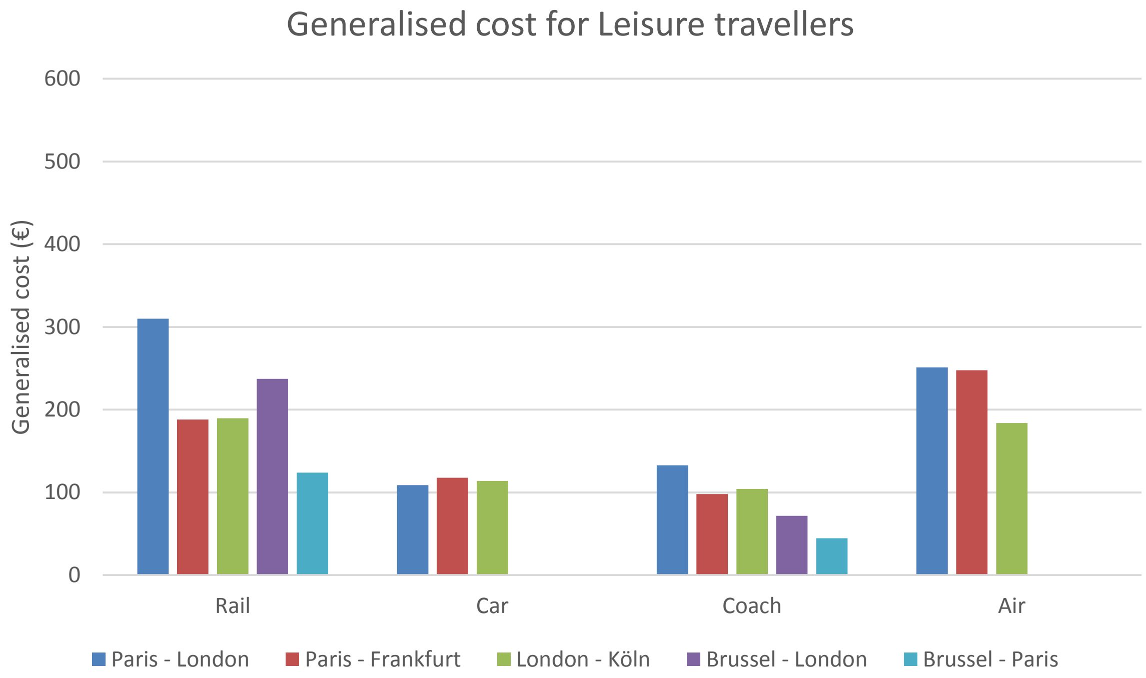
Source: Study on the prices and quality of rail passenger service (EC 2016b)
Note: Average speed recalculated with corrected distances between origin and destination. For Air great circle distance calculated at www.dices.net/airport/distances, for Car and Coach, road distance from city centre to city centre at www.viamichelin.nl/web/Routes . The fares used are peak single trip on day of travel and PPP adjusted.

Table 7.2 - Value of In Vehicle Time for five European cross-border links (2010)

Value of IVT (€/h)	Leisure				Business			
Route	Rail	Car	Coach	Air	Rail	Car	Coach	Air
Paris - London	8.96	10.48	6.90	19.13	43.08	39.44	10.34	72.02
Paris - Frankfurt	9.55	11.23	7.47	20.81	46.26	42.56	11.21	78.86
London - Köln	9.33	10.91	7.27	20.88	44.95	41.14	10.90	78.69
Brussel - London	9.03	10.82	7.03	20.35	43.93	41.20	10.56	77.49
Brussel - Paris	8.82	10.56	6.80	19.13	42.91	40.21	10.22	72.84

Note 1: Monetary values expressed in euros per hour in 2010 prices
Note 2: For GDP, the average GDP for 2010 is taken from the origin and destination country. GDP values per country as given by Wardman et al. (2012)

The time valuations from table 7.2 are used to calculate the generalised cost for leisure and business travellers for the different travel options on the five international routes identified and presented in figure 7.2. Leisure travellers prefer car and coach services, indicating that for this market segment, they do not really compete with high-speed rail and airlines on cross-border links in Western Europe. With an average speed between 60 and 80 km/h, they deliver high value to price-sensitive passengers in the leisure market, but apparently, coach services and high-speed rail serve different market segments. Coach services may compete with domestic rail, but their value proposition characterised by low-cost and low-speed proves to be different from high-speed rail.



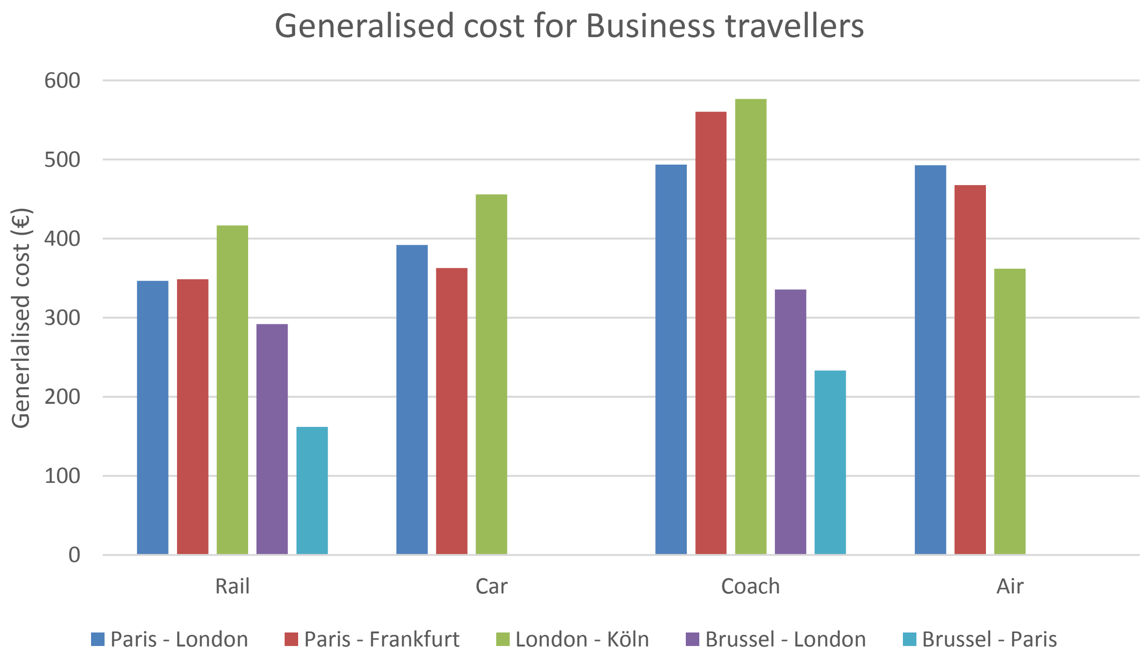


Figure 7.2 - Generalised costs for leisure and business travellers

Rail travel is favoured by business travellers, followed by private car and airlines. Coach services have the highest generalised cost and cannot be considered as an alternative for business trips. In contrast to the Paris-London and Paris-Frankfurt connections, due to lower fares and less travel time, the generalised cost for air travel is lower than for rail on the

London-Köln connection. On the Paris-London link, the higher ticket prices are compensated by shorter travel time. The lower fares and shorter travel time makes Paris-Frankfurt by rail attractive for business purposes.

For the calculations, the value of in-vehicle time (VoIVT) is used. A door-to-door trip consists of several legs with different time valuations. The valuation of attributes as walk time, wait time, parking space search time, waiting at interchange locations, access to public transport time and headways may be different from in-vehicle time. The in-vehicle time valuation for car travel is different for free flow and congested trips. Wardman et al. (2012) report a series of multipliers for valuations of attributes other than in-vehicle time. As there is no distinction made between leisure and business travellers in the available data, fares used for the calculations are the same for leisure and business trips. In practice, ticket prices can vary considerably for different classes. The VOT for rail does not account for differences in conventional rail and high-speed rail. It is expected that international high-speed rail travel will have higher valuations of time than conventional rail.

Different time valuations during the trip, different fares for leisure and business travellers and differences in valuation of time for conventional and high-speed rail should be taken into account for a more detailed assessment of generalised cost.

7.4 The European Commission's perspective

The potential of high-speed rail is recognized by the European Commission and the ambitions are formulated in the EC Transport White Paper "Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system".
One of the objectives is the creation of a single European Railway Area by "*eliminating all the residual barriers between modes and national systems, easing the process of integration and the emergence of multinational and multimodal operators.*" (EC 2011 p. 36). The removal of regulatory, administrative and technical barriers is essential to create a competitive railway market. The market opening process is still ongoing and needs completion, as *"The lack of competition to incumbent operators, which enjoy a defacto monopoly situation on the national market, is one of the reasons explaining low quality and efficiency of services."* (EC 2011, p. 37). Entrance of new operators reduces the incumbent's market power and increases the variety of services and enhances the consumer surplus. However, if entry costs are non-negligible, then social welfare might not always be improved by entry (Villemeur et al. 2003).

A study on regulatory options on further market opening in rail passenger transport for the European Commission indicates that, although easy to implement and minimum public funding, full open access[35] is not the preferred option for high-speed rail to increase modal share and keep socially necessary services. The recommendation is to opt for a model of open access with public funding for unremunerative corridors or services. (Everis 2010)

[35] Open access means that high-speed rail operators compete with other railway undertakings for traffic on the same link. Open access competition can appear in two forms: direct on-track competition between two or more operators or potential competition where the service is still operated by the incumbent, but with the threat of another operator that may enter.

The textboxes below give the relevant sections for high-speed rail from the latest EC White Paper.

High-speed services are operated on a commercial basis and new entrants are expected to take a share of this market in the future. At the same time, there are signs that the incumbent state-owned operators, which have hitherto cooperated in the running of international services, are beginning to compete with each other as well. Where they run services jointly, there is a trend towards doing this through a separate jointly owned subsidiary company (rather than through jointly operated services). This concept is believed to lead to better marketing and a more flexible approach to market developments. Increased competition and the completion of new infrastructure will facilitate further strong growth; any implementation of transport policy measures aiming to internalise the external costs of the airline industry could enhance this growth even further. (EC 2010, p. 37)

The market entry of new entities into the railway passenger market is complicated because of the existing railways as service providers, the characteristics of the railway market and the type of services provided. One special characteristic of the railway market is that new companies will always have to deal with the scarcity dilemmas that the infrastructure imposes on the market. Two decades ago, all railways were fully government-owned and national governments still have an influence on the openness of the market for new entrants. In addition, despite the best efforts of the EU to remove such barriers, many regulations remain that can form entry barriers regarding the qualifications of personnel or the technical requirements for train operation. Whilst legislation from the European Commission is liberalising and opening up the rail market for competitors step by step, this leaves room for each country to decide on the speed and degree of market opening. (EC 2010, p.54).

If the most common market entry strategies do not apply, then depending on the organisation of the market, there are several options for entry, as follows:

- *Acquiring a company that is active in that specific country.*
- *Bidding for a concession in that specific country.*
- *Forming an alliance with a company active in that specific country.*
- *Producing a competitive bid to a government for a concession that the government wants to award directly.*

All these options require in-depth knowledge of both the EU regulations and the legislation in the specific country concerned. (EC 2010, p.55).

7.5 The operator’s perspective

An open market with free competition will find in time its equilibrium between demand and supply. This also goes for transport markets, but in practice the free market axiom is not valid for the high-speed rail market. Incumbent railways act as monopolistic or oligopolistic market players making it hard for new entrants and competitors to gain market share.

For international train services, focusing on individual lines per country will not be sufficient, as can be seen from the developments of rail freight corridors across Europe between important industrial areas. As travellers will favour end-to-end routes between major capital cities and airports in Europe, an international corridor approach makes more sense than focusing on individual countries. High-speed operators will fight for the most attractive routes like London-Paris, Paris-Frankfurt or Paris-Brussels-Amsterdam. Of course, the situation in the countries along the route will be of major importance regarding the development and operation of high-speed train services.

Two factors are important in determining which routes or corridors are suitable for expanding activities: i) the attractiveness of the route and the future travel demand on the route in question and ii) the accessibility and ease with which an operator can develop activities on this route. Attractiveness is linked to the quality, capacity and accessibility of the network and future investments. Due to the national orientation of railway markets, entry barriers are related to country-specific circumstances. Route attractiveness and country-specific entry barriers form the building blocks to shape the portfolio for market participation.

The aim of railway operators is to achieve growth and profitability by obtaining a sustainable competitive advantage in the market. They will position themselves, trying to be different from the competitors, developing market strategies and value propositions that will attract new customers. Attributes in their service offering need to be well balanced and deliver value. Historically, railways have concentrated on production (Ulrich et al 2009). With a focus on operational excellence, optimising operational processes and fine-tuning routes and network access, the customer-orientation was weak. Orientation of incumbent railways was national and single-mode. For the future, an international and more customer-focused strategy will be needed to meet the passengers' needs. Growing by differentiation, upgrading offerings to develop loyalty, enhancing branding to strengthen the business, competing across borders and competing across modes (Ulrich et al 2009) are key elements to be included in the strategy. Competition will be fierce on attractive profitable international routes and entry barriers need to be taken into account.

Entry by a new operator on an existing market is a dynamic process and strategic game between the entrant and the incumbent(s). If the market potential is good, it depends on the incumbent's reputation and strength whether an operator decides to enter the market or not. After market entry, the response of the incumbents can be strong or weak, which in turn will lead to a decision of the entrant to stay in or quit the market. The dynamics and outcome of this game depend on the strategies, decisions and responses of the entrant and incumbents based on the assumptions concerning the competitors' reactions and their attitudes to risk. The number of possible entry scenarios depends on the number of players in the game and the number of periods it takes to for a definite competitive outcome (Preston et al., 1999).

The incumbent may operate more routes on the high-speed rail network and not just a single service between two cities. In this case, the operator may benefit from substitutabilities and complementarities between the different services (Villemeur et al., 2003). With multiple services, the operator has the possibility to adapt its strategy to each individual route. The incumbent can withdraw its service on a specific route when a new entrant offers a substitute service. In case a complementary service is launched on a route not operated by the incumbent, the incumbent may benefit on other parts of the network through spillover effects. The competitive outcome depends on the demand pattern, network layout and the operators' service offering and cost structure.

7.6 Entrance strategies

There are numerous strategic frameworks developed for companies to achieve profitable growth with a focus on competition (Porter 1996, 2008), competencies (Hamel & Prahalad 1985, 1994), new uncontested markets (Kim and Mauborgne, 2004, 2005) and customers (Hax 2010, Osterwalder and Pigneur 2011). Viewpoints may be different, but all frameworks pay attention to the dimensions 'market', 'customers', 'competencies' and 'competition'. These four elements are the main building blocks for the strategic decision-making of high-speed rail operators.

The theory on market entry and exit is well explained in the economics books, for example by Besanko et al (2013) and Lipczynski (2013). A theoretical investigation on entry in the passenger railway industry can be found in for example the IDEI Reports (Seabright 2003, Villemeur et al. 2003). There are no single or simple answers to the complex question of entry in the railway industry. The theoretical discussion must be completed with an empirical approach (Villemeur et al. 2003).

There is a number of strategies a new entrant may follow, like targeting only the most profitable services ("cherry picking"), head-on competition without or with price competition ("price war"), differentiation in products or market segments ("vertical" or "horizontal" differentiation in the product-market matrix) or niche market entry (Preston et al. 1999). Product differentiation and/or niche market entry may be more sustainable scenarios (Tomes et al 2016). Competitors use differentiation strategically in order to avoid a fierce price competition (Villemeur, Ivaldi and Pouyet, 2003). In response, the incumbents may use their first mover advantages and develop entry deterrence strategies to prevent new operators to enter the market. An analysis of various entry strategies conducted by Friederiszick et al (2009) indicated that entrance with inferior technology is the most profitable strategy for newcomers.

7.6.1 Cream skimming

In this strategy, the new entrant opts for the most profitable services during peak hours and avoids loss-making off-peak services. The new entrant can provide additional peak services if the capacity is not constraint. If there are no train paths left during peak hours, the new services of the entrant will replace the incumbents' services.

7.6.2 Head-on competition

Head-on competition occurs where the entrant matches the incumbent's quality and service level. Were the products of the different competitors not differentiated, price competition would trigger vigorous price wars and would erode the profits of operators (Villemeur et al., 2003). The operator with a cost leadership advantage can offer lower fares while remaining profitable. The competitor trying to match prices will lose its margin and will be forced out of business in the end.

7.6.3 Product and market differentiation

Operators can differentiate their products depending on the preferences of passengers and heterogeneity of the passenger population. Since passengers' willingness-to-pay decreases with travel time, the incumbent may offer low travel time (i.e. high speed) in order to raise the price of train services (Villemeur et al. 2003). Besides price and ticket conditions, product differentiation by changing the service characteristics can give a competitive advantage. Factors that can be used by high-speed rail operators to design their product are journey time and access to terminals, frequency and check-in time, reliability and punctuality and service quality on-board and at terminals (Duarte 2008).

Heterogeneity refers to the willingness-to-pay for train services across different types of passengers. For instance, business passengers have a larger valuation of travel time than leisure passengers do. Excluding passengers with lower valuations of time enables the incumbent to target its most profitable passengers (i.e. those with the highest willingness-to-pay) (Villemeur et al. 2003).

7.6.4 Niche market entry

A niche market is an uncontested open space to offer services that fulfil customer needs that are not satisfied by existing operators yet. By nature, the first entrant will initially face no competition. If the niche appears to be successful, attractive and profitable, others may follow, but they have to bridge the first mover advantage.

7.6.5 Deterrence strategies

Three types of strategies are available for the incumbent threatened by entry: blockading entry, preventing entry or adapting to entry (Lipczynski 2013). In the first case, the market is unattractive to an entrant and the incumbent does not have to change its behaviour. In the second case, the incumbent changes its behaviour and raises the barriers for competitors. In the third case, the incumbent finds it preferable to let the potential competitors enter the market rather than to build costly entry barriers to prevent entry (Villemeur et al. 2003).

Incumbents may actively respond in the price dimension by reducing their fares and in the quality dimension by offering higher frequencies, better journey times, extra on-board services and loyalty schemes to hinder entrance. The competitive battle may end up in predatory behaviour from the incumbent and a vigorous price war (Preston et al 1999).

7.7 Access barriers

Structural barriers exist when the incumbent has control over essential resources, a natural cost or marketing advantage or benefits from favourable regulations. Beside structural barriers, incumbents can take aggressive actions that threaten new entrants to deter entry. The economics literature indicates that barriers to entry may arise from economies of scale, incumbents' brand reputation, an absolute cost advantage held by an incumbent over an entrant or from product differentiation (Besanko 2013, Lipczynski 2013). In consumer marketing, it is common practice to use Country Portfolio Analyses (CPA) to map out the attractiveness of a geographical market. Entry barriers and distances that determine the accessibility of a country need to be included in the analysis (Ghemawat, 2001). For the same reasons, it is not sufficient that international train operators make decisions on the basis of route attractiveness. The accessibility of the national networks involved and the cross-border hurdles need to be taken into account.

The CAGE model (Ghemawat 2001), in which aside from the geographic distance, the cultural, administrative and economic differences in relation to the home base are taken into account, can be adapted to evaluate the entry barriers for high-speed cross-border traffic. In the development of international rail passenger services, the nature of the hurdles to be taken can be evaluated from a market, administrative, technological, operational and financial perspective. The MATOF barrier framework for high-speed operators is given in figure 7.1. For each country linked to the preferred route, these entry barriers need to be addressed and measures need to be taken to manage and overcome them, leading to profitable business.

7.7.1 Market barriers

The high-speed rail cross-border market will not grow when the market demand and conditions are insufficient, and the expected growth and profitability for operators is poor. The market remains unattractive as no economically viable services can be launched. Market conditions for HSR operators depend on the degree of on-track competition with other open access rail operators and with inter-modal competition from airlines, private cars and coaches. The number of obstacles for new international services are increasing the more borders are crossed and countries are involved along the route.

To run a successful high-speed rail service, there needs to be a positive market perspective regarding volume and growth that can be expected. Strong competition from other (incumbent) operators and (low cost) air carriers can prevent operators from achieving the desired market share. Experience and proven track record in railway operations and high-speed train operations will reduce the risk of setting up a new service. Starting an operation outside the home country will require overcoming the natural distance, other languages and cultural differences.

7.7.2 Administrative barriers

The opening of the European market for international rail passenger transport on 1 January 2010 has given way to new open-access operators. It is important though not to look primarily at the “law in books” but to evaluate the “law in action”, considering the actual market condition and the entry options and obstacles that exist in reality (Eisenkopf 2006). The Rail Liberalization Index (Kirchner 2007) gives an overview per Member State regarding the implementation status of the Railway Packages. Following earlier reports from 2002, 2004 and 2007, this study was carried out in 2011 for the fourth time in succession. These results can be used to analyse the administrative distance. Besides the implementation status of the European Rail Directives, national politics and the relationship between government and incumbent railway operators play an important role.

Table 7.3 - The MATOF barrier framework for high-speed operators

Market barriers	Administrative barriers	Technological barriers	Operational barriers	Financial barriers
Insufficient high speed market demand and growth	Non-compliance with European Rail Directives regarding safety certificates and vehicle authorisation	No certified multi-system locomotives for the whole corridor	International train paths and platform and station capacity not secured and aligned with domestic time tables	Negative business case to start a new international service
Strong competition from established (incumbent) operators and (low cost) air carriers	Not meeting additional national law, regulations and access rules in Member States along the route	Non-compliance to route specification (track profile, tunnels)	Non-licensed train drivers and untrained stewards and ground staff, not speaking all official languages along the route	High and volatile track access charges and other costs and differences in neighbouring charging systems
Distant foreign market, other languages and cultural differences	Poor information on administrative procedures and failing non-discriminatory network access	Non-compliance with European and national technical systems (signalling, traction power supply, ICT)	Missing license to operate train services (safety certificate)	Not enough financial resources, investors
Insufficient experience and track record in railway operation and high speed services	Missing strong and independent rail regulatory body and long and costly administrative procedures	Exceeding noise and wear limits	No access to qualified maintenance and cleaning workshops and parking facilities	Poor internalisation of external costs for air and road travel
Exit of EU Member States like Great Britain	Extra border regulations and controls for cross border traffic		No access to facilities for ticket sales and traffic information	Negative economic climate

7.7.3 Technological barriers

Historically, European rail markets have been developed from a national perspective. The result is that there is a large variety in network layout, systems and operational rules. The EU Directive 2008/58 that covers the interoperability of the conventional and high speed network across Europe is set up for harmonizing the technical and operational differences across European member states. All newly built high-speed lines comply with the new European standards, but for the conventional network this is hardly the case. For the time being, train operators that run cross-border services rely on multi-system locomotives and trainsets that can run in the various countries to cover this gap. Further standardization and harmonization across Europe will help the railways compete with other modes.

7.7.4 Operational barriers

To run a train service, the infrastructure manager has to secure the route and platform capacity and fit it with the existing timetable. The European railway interoperability directives state that network access and capacity allocation has to be done in a non-discriminatory way. The national rail regulatory body will supervise this. The Rail Liberalization Index study shows that not all European countries have already strong and independent regulatory bodies in place (Kirchner 2011). Operators need to have a safety certificate and licensed drivers to get network access. Well-trained staff in the trains, at stations and in the back-office is required to run an attractive train service. Accessible facilities are needed for parking trains at night and execution of maintenance activities by well-equipped workshops.

7.7.5 Financial barriers

High capital cost prevents entry within the high-speed market segment of the market (Friederiszick et al 2009). Rail infrastructure managers charge operators to use their network. One of the challenges of increasing international traffic is the difference between neighboring charging systems. There is a considerable variation in infra charges across countries for the use of high-speed lines (UIC 2012). For 2008, Spain charged 3 Euro/km for high-speed passenger trains, while France charged 14 Euro/km for their TGV-lines (CER 2009). As illustrated for the London-Paris market, the 80% reduction in infra charges for HS1 in the UK end of 2009 turned Eurostar around from a loss-making to a profitable operation (NAO 2015).

Social welfare of high-speed rail is much greater if marginal cost pricing is used instead of high infra-charging (Adler et al. 2008, Álvarez-SanJaime et al 2016). High charges lead to lower operator profits and less attractive and poorer utilisation of the infrastructure capacity.

Internalisation of external costs for air and road transport will promote fair competition between air, road and rail. The priviliged position of air and road transport not paying for externalities that are internalised in the rail system leads to unfair competition. Modal shift towards rail transport will be promoted in countries where airline, private cars and coaches are charged for external cost according to the polluter pays principle.

7.8 Rail liberalisation

The Rail Liberalization Index (LIB Index) presented in figure 7.2, compares the status of the relative degree of market opening in the EU 15 Member States. The LIB index is a benchmark of the legal barriers to market access from the perspective of a potential new entrant. Legal access conditions, such as the powers of the regulatory body and the market access regime, are contained in the LEX sub-index (“law in books”). The access conditions, such as barriers to information, administrative and operational barriers, and the share of the market that is accessible to new entrants, are included by the ACCESS sub-index ("law in action"). The results included in the LEX Index account for 20 percent of the LIB Index, with 80 percent accounted for by the results included in the ACCESS Index. Both the legal (LEX Index) and the de facto access conditions (ACCESS Index) of these countries offer the best conditions in Europe for newcomers (Kirchner 2011).

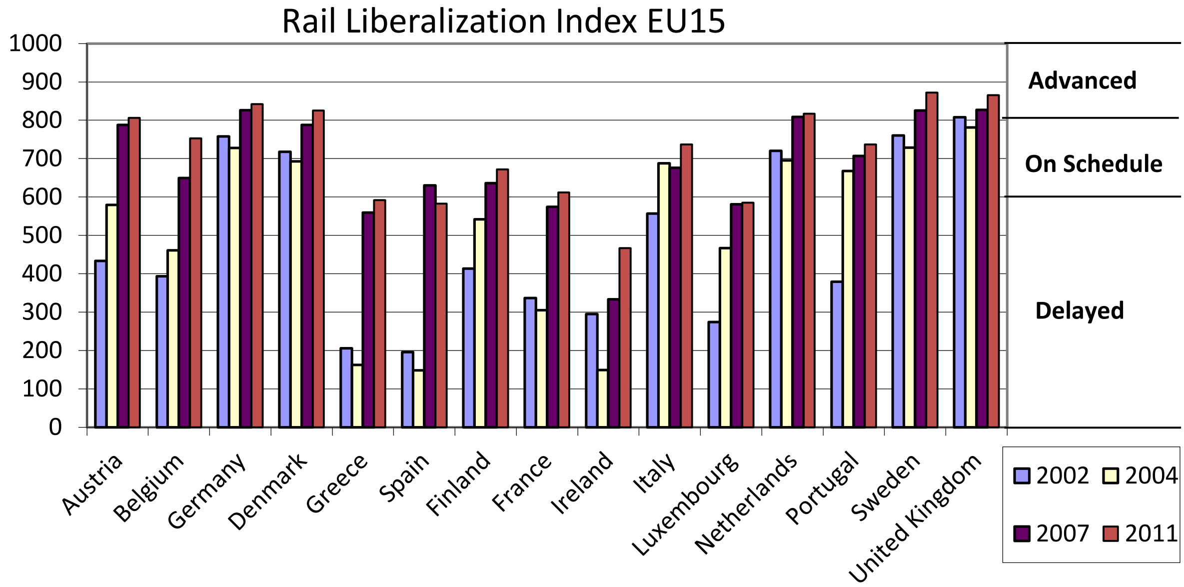


Figure 7.3 - Rail Liberalization Index in EU 15 (Kirchner 2002, 2004, 2007, 2011)

The results show that the average rail liberalisation has progressed considerably in ten years' time, from an average from 483 in 2002 to 718 in 2011, but large variations can be seen. From one side, Austria, Germany, Denmark, The Netherlands, Sweden and the United Kingdom have reached an advanced stage of rail liberalisation, but on the other hand, Greece, Spain, Ireland and Luxemburg are delayed in their liberalisation process. Considering that the liberalisation index is still increasing, there is still room for improvement as none of the EU15 Member States have reached a stable institutional state yet (Finger 2014).

7.9 Infrastructure management and charges

In Europe, domestic rail operators have to deal with five key stakeholders in their country: the government, the rail regulator, the infrastructure manager, the competition authority and their passengers. In cross-border operations, the number of stakeholders multiplies with the number of countries involved and a railway operator has to make arrangements with all infrastructure managers on the route separately. Incumbent infrastructure managers, responsible for the development, operation and maintenance of their railway network, manage the core national rail network in each Member State. Infrastructure managers have to run railway operations in an optimised, efficient and non-discriminatory manner. A key operational task is the production, allocation and pricing of train paths to guarantee access to the network for all railway operators on an equal footing. Difficulties for international train services arise from a bias towards domestic traffic and the needs of the incumbent operator and from differences in pricing principles and charging policies across countries (UIC 2012). As infrastructure managers play an increasing role in the functioning of the EU transport network, cooperation among infrastructure managers across borders becomes more important (EC 2013c). The national rail infrastructure managers are members of the

European Rail Infrastructure Managers (EIM), established in 2002 following the liberalisation of the EU railway market to promote the interests of all rail infrastructure managers in the EU and the EEA. EIM currently has 12 full and 3 associate members which accounts for 11 European countries[36].

Most of the EU Member States have unbundled their national railways as mandated by Directive 91/440/EC. Independence of the infrastructure manager from the railway holding and the incumbent rail transport operators was one of the goals of rail liberalisation and reform. Railways have implemented various governance structures where infrastructure management is more or less separated from the rail transport operators as illustrated in table 7.2 (EC 2016c). The evidence so far shows that separated and liberalised networks have experienced a greater level of new entry than networks that have retained a more integrated industry structure (EC 2012). Railway governance is still developing and there is no "one-size-fits-all" model available, nor is there clear proof that one particular institutional arrangement is performing better than others (Finger 2014).

Table 7.4 - Infrastructure Management and rail liberalisation in EU15 (2015)

	Rail Liberalisation		
Infrastructure Management	**Advanced**	**On Schedule**	**Delayed**
Complete separation (Swedish model)	Denmark Great Britain Netherlands Sweden	Belgium	Finland Greece Portugal Spain
Holding company (German model)	Austria Germany	Italy	
Separation of key powers (French model)		France	Luxembourg

Source: Table by author based on data from Finger 2015, the fifth report on monitoring development of the rail market (EC 2016c) and the Rail Liberalization Index (Kirchner 2011)
Note: In Great Britain services and networks are fully privatized. This "British Model" is one of a kind and not adopted in any other Member State. Ireland remains vertically integrated as their railway system is not connected with any other network in Europe (Bergantino et al. 2015)

With the separation of rail infrastructure management from train operations, new rail infrastructure pricing systems have been introduced in Europe. Every national infrastructure manager has defined its own tariff system to charge the use of infrastructure to the railway operators. For international train services, rail operators have to pay fees to all infrastructure managers along the route for the facilities used. Infra charges directly affect the market share, pricing and profitability of high-speed rail operators as illustrated for the London-Paris case in chapter 6. Figure 7.3 presents the calculated infra charges for a "standard" high-speed train on 52 origin-destination pairs with one or more border crossings (UIC 2012). The highest infra charges occur on four connections using the Channel tunnel.

[36] www.eimrail.org

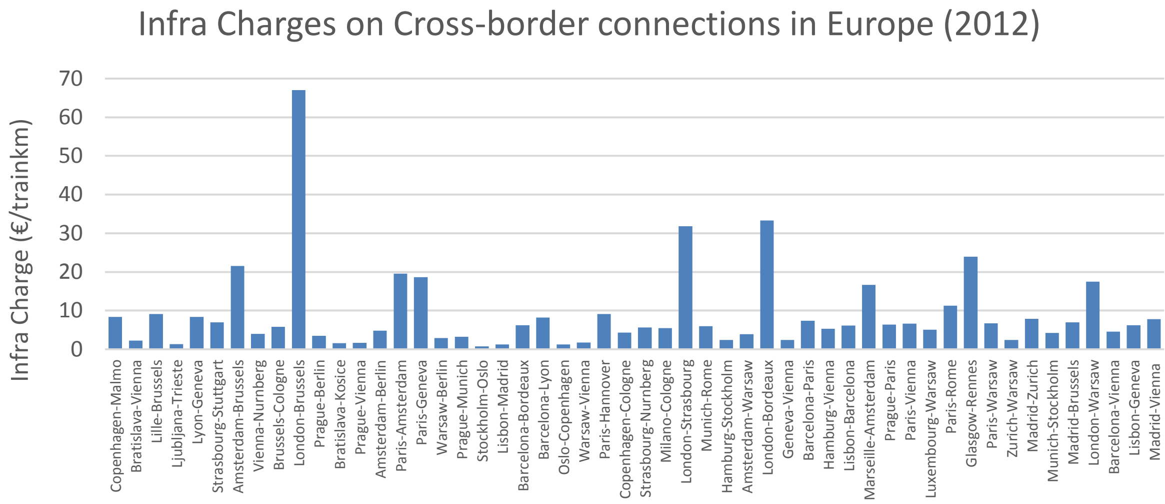


Figure 7.4 - Infra Charges on international Origin-Destination pairs in Europe

Note 1: Figure by author based on data from UIC 2012)
Note 2: Infra charges calculated for a ten-car high-speed train, weighing 430 tons, with a length of 200 meters and a capacity of 500 seats.

Looking in detail at the infra charges on the London-Brussels-Paris connection, the high fee for using the Channel tunnel is obvious (figure 7.4). It is also apparent the using the HS-1 rail link between London and the Channel tunnel is more expensive than the using the tracks in France and Belgium.

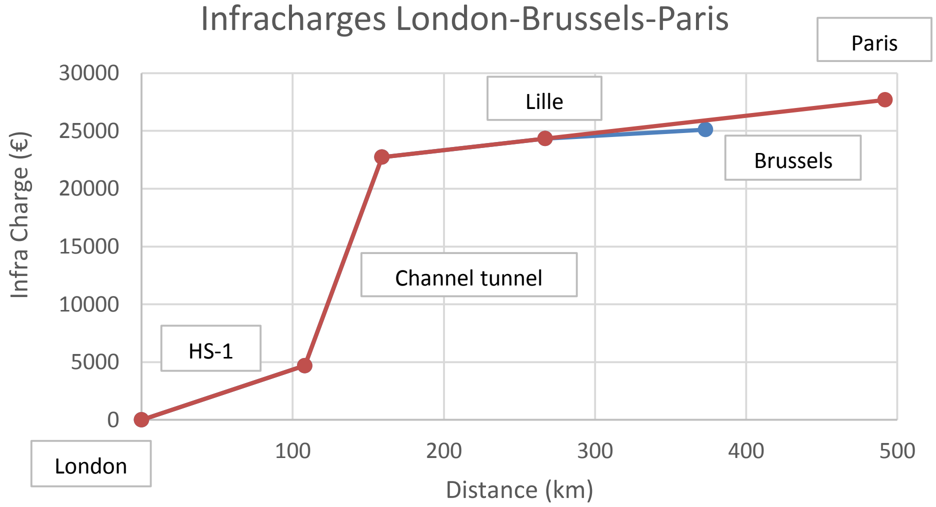


Figure 7.5 - Infra charge on the London-Brussels-Paris connection

Note 1: Figure by author based on data from UIC 2012)
Note 2: Infra charges calculated for a ten-car high-speed train, weighing 430 tons, with a length of 200 meters and a capacity of 500 seats.

There exist many differences in the structure, pricing principles and pricing level of tariff systems, which affect the fares, and market competitiveness of high-speed rail operators. For intra-modal competition, the way infrastructure costs and the external costs are incorporated in the tariff system should be balanced with other modalities. The creation of a level playing field across modalities is an issue that should be dealt with by the European

Commission and the PRIME platform (Platform of Rail Infrastructure Managers in Europe) that was established to improve cross-border cooperation between infrastructure managers.

7.10 Conclusions and discussion

7.10.1 Conclusions

The EC transport policy strongly supports the high-speed rail developments to build a sustainable future and has put a regulatory framework in place to remove barriers for competition. Rail liberalisation in Europe has progressed well since 2002. A greater level of new entry can be observed in liberalised networks with separated infrastructure managers than in integrated organisational structures. National state-owned operators provide cross-border high-speed rail traffic solely or in joint ventures with other public or private partners.

Although the cross-border market is open since 2010, no private operators have entered this market yet. Early joint ventures that run cross-border services like Thalys and Eurostar have established a solid market position. Also new initiatives like the DB-SNCF joint venture Alleo are gaining market share in competition with airlines. There are no attempts of entrance by new private operators in the high-speed rail cross-border market, except for the HSA joint venture for an international service between Amsterdam and Brussels that was abolished after 40 days of operation. Up until now, the European high-speed rail market is dominated by SNCF. Besides being the biggest national high-speed operator, SNCF has several stakes in key cross-border joint ventures with other incumbents. The DB plan, being the second largest high-speed operator in Europe, to run services between Frankfurt and London and Amsterdam have not materialised yet.

Coach and bus services grow as a new travel mode on international routes in Europe. Evaluation of value to travellers, by trading off fare and speed across modes, revealed that although more expensive, high-speed rail has the competitive advantage of shorter travel times on some important origin-destination pairs. The value proposition of coach services (low-cost and low-speed) proves to be different from high-speed rail and cannot be considered as a strong challenger in the high-speed passenger market.

The hurdles to be taken by new entrants come from market, administrative, technological, operational and financial obstacles and can be identified using the MATOF framework. In cross-border traffic, these barriers exist on all separate national parts of the route. Owning adequate rolling stock that can cross borders is an important competitive advantage for operators. From this viewpoint, SNCF, DB, Thalys and Eurostar seem to have the best position to grow their market share, but also NTV has the ability to expand their services abroad with the recent extension of their train fleet. The Railteam cooperation between incumbent railways is an extra barrier for new entrants.

Rail liberalisation has progressed considerably in ten years’ time, but large variations can be seen across Member States. Railway governance is still developing and there is still room for improvement. For international train services, difficulties arise from a bias of national infrastructure managers towards domestic traffic and the needs of the incumbent operator and from differences in pricing principles, charging policies and tariff systems across countries.

7.10.2 Discussion

The open access competition on international cross-border routes gives the opportunity for existing operators to reposition themselves and for new ventures to enter the market. An apparent strategy by incumbents is to expand their activities from their home base into neighbouring countries by establishing joint ventures. So far, only head-on competition in high-speed rail can be recognized in Italy between Trenitalia and NTV, but not yet on cross-border connections. No competition from private companies can be observed. Although the opportunity is there, head-on competition on attractive routes like the HSL South between Amsterdam and Brussels and the connection London-Brussels-Paris is not observed yet. Operators that own adequate rolling stock that can run cross-border have a strong competitive advantage. This puts incumbents like SNCF and DB and joint ventures like Thalys and Eurostar in a powerful market position. A product differentiation strategy can be recognized by the introduction of low-cost high-speed trains like Ouigo on the French network and Izy on the cross-border connection Paris-Brussels. SNCF uses refurbished trainsets withdrawn from their existing fleet for these services. This underlines the thesis that owning appropriate rolling stock is a key factor in market positioning. Countries in an advanced stage of liberalisation and with separated infrastructure management will give the best opportunities for new operators. From this perspective, Scandinavia and Western Europe may expect a higher level of entry. On paper, the EC legislation supports the creation of a level playing field in the on-rail open access competition and with other modes, but in practice, the incumbents have already secured their market positions in the European market with a dominant role for SNCF.

8 Future expectations

8.1 Introduction

The former chapter presented the current state of play for HSR operators providing international services. Market entry is clarified from the viewpoint of the European Commission as outlined in their EU Transport White Paper and from the operators' perspective. It gives an overview of possible market strategies operators may adopt, the hurdles to be taken when entering the market and the incumbents' response after entry. Rail liberalisation is still developing, but it has become clear that the market developments servicing cross-border rail links in Europe started long before the relevant legislative framework was implemented in the EU Member States. International traffic has to deal with many differences in pricing principles and charging policies across European Member States.

This chapter explores the implications for the future regarding market developments. The goal of this chapter is to outline the most likely developments in the European high-speed rail market, based on the strategies of the most important stakeholders that can shape the market, i.e. the trinity of the European Commission, the national rail infrastructure managers and the high-speed rail operators. It discusses possible scenarios and expectations for the future based on potential market strategies high-speed rail operators may adopt within the context of the European liberalisation of the railway market. Lessons are taken from experiences with open access competition in the domestic market in various European Member States. It is not the ambition to give a complete overview of all possible scenarios taking into account all possible stakeholders.

This chapter is structured according to the elements of the Structure-Conduct-Performance model (figure 1.2), taking into account the government policy and the supply and demand conditions. In section 8.2, the effect of the European transport policy is outlined. Market demand and supply conditions for cross-border HSR are reviewed in section 8.3. An outline of the developments in market structure are given in section 8.4. Section 8.5 on conduct, describes the strategies HSR operators can adopt and their market behaviour and section 8.6 is linked to their performance. Conclusions and discussion are summarised in section 8.7.

8.2 Government policy

Over the past two decades, the European Commission has made an effort to open the market and encourage competition to make the rail sector more efficient and customer-responsive (EC 2016c). Since 1 January 2010, railway undertakings have been granted right for infrastructure access for operating international passenger services including cabotage, according to Directive 2007/58/EC. This was preceded by Directive 2004/51/EC, where rail freight in Europe was liberalised (Finger 2014). The legislative framework for the creation of a Single European Railway Area is completed by the adoption of the Fourth Railway Package, which supports the opening of the domestic railway markets (EC 2013b). A fifth railway package might be necessary one day if, despite the legislative framework already in place, the railway business fails to materialise as expected (Hughes 2017a). The changing institutional railway environment offers new opportunities for railway operators to grow their business. Despite 20 years of regulations and rule changes to harmonise standards and procedures, cross-border traffic between EU states is still hampered by complex technical and bureaucratic barriers. The EC will focus in the coming years on further implementation of the existing legislative framework in cooperation with the European Railway Agency (ERA), Member States, national regulatory bodies and stakeholders in the railway sector. Amongst others, multi-modality, a level playing field across transport modes and application of polluter pays principles will be areas of attention. The European Commission's 2011 Transport White Paper ambition was to establish a Single European Railway Area (SERA) for the development of a competitive and environment-friendly EU transport system, capable of dealing with the expected growth. A 6.5% rail share in Europe's passenger transport system is still very low and no modal shift towards rail can be observed (Hughes 2017b). High-speed rail has developed gradually over the last 35 years, has gained market share over air transport, and has become the preferred passenger choice on certain routes. For the period 2020-2035, it is expected that the increase in high-speed rail demand will exceed the growth of all other transport modes (EC 2013). Although the direction is set, the pace of development is too slow to reach the objective of the 2011 Transport White Paper that in 2030 the majority of medium distance passenger transport in Europe is served by rail (EC 2016c, Hughes 2017b).

8.3 Demand and supply conditions

A key market condition is that traffic demand is high enough to introduce economically sound new train services. Open access operators will look for viable markets in which revenues exceed costs. Routes with high and fast growing traffic demand and little inter- and intra-modal competition will attract the attention of potential new entrants. Non-congested routes with spare capacity and low infra charges are conditions to offer a profitable service. Competitive entry is a dynamic game though, where the outcome depends on the market conditions and the individual behaviour of the actors. The incumbent faced with the threat of open access can respond by offering lower fares, increasing its efficiency, improving the service quality or withdraw its service partly or completely from the market (EC 2012). The incumbents have a solid high-speed home base and have already positioned themselves on the most attractive international high-speed routes, mainly through joint ventures and partnerships.

8.3.1 Rolling stock

Non-discriminatory access to suitable rolling stock is a major constraint for new entrants (EC 2013). In the high-speed rail sector, an owner of suitable rolling stock (Everis 2010) can only introduce an expansion strategy. Operators owning multi-system high-speed trains that can run cross-border have a clear competitive advantage. In addition, low access charges and spare infrastructure capacity and availability of paths are in favour of new entrants (CERRE 2016). In many cases, incumbent railway undertakings own suitable trains, but are unable or unwilling to make them available for new market entrants on a fair commercial basis (EC 2013). The second-hand market for high-speed trains is non-existing. Trainsets from the early days of high speed rail have reached their end-of-life, but are refurbished (TGV PSE), scrapped (ETR 450) or used for other (low-cost) services (TGV PSE trainsets are now used for TGV Lyria services to Switzerland, Ouigo runs refurbished TGV Duplex trains) by the owner. There is also currently no well-functioning European leasing market for high-speed rolling stock. Interoperability of trainsets is not always guaranteed as technical and operational standards are different in various European countries. When the incumbent is not able or willing to make a move, a new entrant has no other choice than to buy its own trains with the consequence of creating a high barrier to exit. This does not only require large investments, but will also take several years and much effort from the operator to specify, procure and test the new trainsets on functionality and for homologation before the operation can start. Although Bombardier, Siemens and Alstom are the key manufacturers of high-speed rolling stock for the European market, Japanese or Chinese competitors will move towards Europe with their high-speed rail experience from the Asian market. For the domestic market this is already noticed in the UK (Hitachi) and Czech Republic, where the new open access entrant LEO Express has ordered three multi-system trainsets from CRRC Zuzhou Locomotive for future cross-border operation to Slovakia (Hughes 2017b).

8.3.2 Rail infrastructure

Operators planning to run international train services have to apply for train paths at the rail infrastructure managers along the route. The infra manager charges the operator for the availability and usage of railway capacity. Large differences in pricing principles and infra charges are observed across infra managers in Europe (UIC 2012). High track access charges, exceeding marginal infrastructure costs in order to contribute to the fixed costs, are major entry barriers (CERRE 2012) and make open access operators become less profitable unless they raise their ticket fares. Too high access charges weaken the competitive position of rail towards other transport modes. Congestion may arise when demand for train paths is higher than the available capacity. None of the infrastructure managers has reported congestion so far, but on the busiest routes, capacity limits have been reached. In a congested situation (e.g. Paris-Lyon), the operator may increase its transport capacity to fit double-decker trains in the train path.

8.4 Market structure

Most of the commercial cross-border high-speed services are currently operated by subsidiaries of SNCF like Thalys (Paris-Brussel-Amsterdam) and Eurostar (London-Brussels-Paris) or in cooperation with SBB (Lyria on Paris-Lausanne/ Geneva and Paris-Bern /Basel/Zürich routes), DB (Alleo on the Paris-Frankfurt connection) and Renfe (Perpignan-Barcelona). Even SNCF's competitors seem to prefer cooperation, sharing benefits of a profitable activity, rather than competition when it comes to HSR (CERRE 2016a). Like the airlines did before, SNCF and Thalys have developed the low-cost train services Ouigo and Izy. These low-cost services will hinder the entry of new competitors and are increasing the number of passengers, but not necessarily the revenues (CERRE 2016).

8.4.1 Existing operators

Thalys and Eurostar on the cross-border routes between major cities are success stories, but the international high-speed train services on these high demand origin-destination pairs were already in place before the EU Directive 2007/58 regarding market opening for international passenger services came into force. Practically, very few new cross-border services have been launched since 2010. It seems that, besides a proper legislative framework, additional administrative, technological, operational and financial barriers are present in the market that prevent new entrants to launch new international services. The experience from the rail freight market is that new operators prefer entering into domestic rather than international services. The main reasons are higher transport demand, less organisational difficulties and lower financial risk (EC 2013a). The same developments can be recognized in domestic passenger transport. Although new open access operators have entered the national markets in the UK, Italy, Sweden, Czech Republic, Slovakia, Austria and Germany, the number of new cross-border initiatives is still limited.

8.4.2 New entrants

Access barriers for new entrants, long and costly procedures and different market access rules in Member States lead to a suboptimal structure of the rail passenger market, market distortion and a low degree of competition. This results in low operational efficiency and poor service quality (CERRE 2012). Open access entry in the passenger rail market on cross-border routes is more complex than in domestic markets and open access operators are facing more barriers than operators that run a public service contract where rolling stock and personnel is transferred from its predecessor. The nature of access barriers are administrative, technical, operational and financial. Insufficient independence and limited administrative capacity of national railway institutions lead to unclear procedures and may cause conflicts of interest and discrimination against new entrants. Incomplete implementation of legislation across Member States and lack of financial transparency of the incumbent railway may induce cross-subsidisation and will raise extra institutional barriers. In addition, vague rules on the access to rail-related services like stations and platforms, travel information and ticketing will hinder new entrants (EC 2016b). Technically, limited access to rolling stock is a major constraint for new entrants. Extra operational barriers arise regarding access to station facilities, depots, maintenance and cleaning facilities, ticket sales and traffic information systems. Sufficient, skilled and trained staff is a key success factor for operators. A commercial open access operator is free to recruit its own staff and setting own terms and conditions (Johnson and Nash 2012). This can bring a considerable reduction in cost, giving the new entrant a competitive advantage over the incumbent. Even in the case when all barriers are removed, it is unlikely that the high-speed rail cross-border market will grow rapidly when the market conditions are insufficient and the expected profitability for operators is poor. The market remains unattractive as no economically viable services can be launched.

8.4.3 Lessons from rail freight

Some lessons can be learned from the rail freight sector. The European Court of Auditors concluded that rail freight transport in the EU is still not on the right track and has failed over the last 15 years to respond effectively to the competition by road transport. Shippers clearly prefer road to rail for transporting goods (RCA 2016). Rail competition is not a goal in itself, but an enabler to make the rail sector perform better and become more efficient, reliable and customer-focussed. In cross-border passenger transport, high-speed rail has to compete with airlines, private cars and coaches on price and service quality. New entrants look for niches, product differentiation and innovation of services to relax price competition and use modern yield management techniques to maximize profitability. Cheap air travel across Europe has a serious impact on the rail business. If HSR operators only focus on on-track competition with their rivals, they will end up in a zero or even a negative sum game for the railway sector as has for example been observed in the rail freight sector in France (CERRE 2016a).

8.4.4 Lessons from HSR in Italy

Italy is currently the only European country, which is experiencing intra-modal competition on their HSR network. NTV was established in 2006 and has entered the Italian HSR market in 2012 as a new open access competitor to the incumbent Trenitalia on the Milan-Rome-Naples corridor (Cascetta and Coppola 2014, Bergantino et al 2015). Bergantino et al found that Trenitalia has not reduced its supply, but on the contrary, increased the daily frequencies with 30%, after the market entry of NTV. The overall capacity on the Rome-Milan city pair has increased by 56% resulting in an improved network utilization. NTV's market share in 2013, calculated on the service frequency offered on regular working days, was 27% across three selected HSR lines (Rome-Milan, Rome-Venice and Rome-Turin) and 73% for Trenitalia. The analysis shows that Trenitalia and NTV adopt a strategic pricing behaviour, but that there was no evidence of price leadership or predatory pricing. In 2013, Trenitalia's fares prove to be 30-35% higher than NTV's. HSR competition in Italy resulted in an increasing supply of train services (i.e. more capacity, frequency and connections), lower prices and better services (Desmaris et al 2016). Besides the effect on the railway services, the entrance of NTV led to a significant reduction of fares in the airline market (Bergantino et al 2015).

NTV entered the market at the time of a negative European macro-economic situation and a declining Italian railway demand (Desmaris et al 2016). NTV's strategy is based on an entrance with a significant impact on the supply side of the market, a distinctive customer value proposition with a focus on high service quality, a modern image and a new business model. NTV's business model, inspired by low-cost airlines, with ticket sales through the internet, pricing based on yield management, outsourcing of rolling stock maintenance, catering, security and the call centre and an incentive-based remuneration model is the fundamental innovation (Desmaris et al 2016).

NTV has experienced many barriers to entry, resulting in claims to the Italian Antitrust Authority (AGCM) about the incomplete separation between the infrastructure manager (RFI) and Trenitalia, the high track access charges for high-speed paths, the extremely long rolling stock authorization procedure and the incumbent's influence during the authorization process (Desmaris et al 2016).

Excessive access charges mean higher cost for the operator when using the infrastructure and consequently higher ticket prices for rail passengers. The chances for a profitable entry decrease with higher track access charges. The access charge for the use of the Italian High Speed rail infrastructure were estimated around 13.4 €/trainkm (Arrigo and Di Foggia 2013) and has been changed significantly over the last years. The Italian regulator decided to reduce the HSR access charges with 15% in 2014 and in 2015 an additional reduction of approximately 35%, from 12.8 €/trainkm to 8.2 €/trainkm, was realized (Desmaris et al 2016). Lower track access charges may have a negative effect on the financial balance of the Italian rail infrastructure manager RFI, but the evidence collected by Desmaris et al (2016) suggest that higher traffic volumes compensate for the lower fees. CERRE (2016a) concludes "*the reduction in rail access charges has been only partially compensated for by a higher volume of traffic.*"

On-track competition on the Italian HSR network has proven to be technically feasible and social desirable with positive effects on passengers, but NTV's financial results in the first 3 years of operation up until 2014 are too far from an economic equilibrium to label it as a real commercial success (Desmaris et al 2016). In 2015, NTV generated a gross operating surplus for the first time with more than 9 million passenger per year and a load factor exceeding 70% (CERRE 2016a).

8.4.5 Lessons from HSR in Asia

A single operator runs all high-speed rail services in China. This is also the case in Taiwan. They compete with airlines, but on-rail competition is not a part of the transport policy. In Japan, currently five operators are providing high-speed rail services (JR East, JR West, JR Central, JR Kyushu and JR Hokkaido), but there operation is restricted to dedicated lines in the various regions. Although a vertical separation model applies to the Shinkansen high-speed lines, the train operator is also responsible for the infrastructure management to reduce coordination problems. Japanese railways do not have lines, which operate under on-rail competition, but arrangements are in place for through-train services on neighbouring networks (Kurosaki and Okua 2013). Two operators serve the same railway station at the border where separate lines connect to guarantee a seamless travel for passengers. Arrangements are in place about the way the railway station is used by both operators to prevent competition and to serve the traveller.

South Korea is the only country outside Europe where open access on-track competition is introduced. The South Korean government has reformed the railway in 2005 through vertical separation and studied on-rail competition for some time to make the incumbent Korail more efficient and profitable (Kurosaki and Okua 2013). In December 2016, drawing on the experience of NTV, Supreme Railways (SR) started a rail service on the new Sudokwon high-speed line competing with Korail's KTX services (Hughes 2017b). A 10% reduction on Korail's KTX cheaper ticket prices have resulted in passenger numbers reaching 99% of the forecasted loading in February 2017[37]. The SR service offers shorter travel times, more legroom than standard KTX trains, free Wi-Fi, power sockets, USB ports and the ability to call the train attendant by using an app on your smartphone. SR has just started their operation and it is too early to see the results of introduction of high-speed rail competition in Korea on efficiency, profitability and social welfare. Expansion of the SR service to other parts of the country is not yet determined.

8.4.6 Lessons from domestic passenger transport

As there is very little experience so far, lessons that can be learned from open access competition on international high-speed services are limited. In the domestic passenger transport market, examples can be found in the UK, Italy, Sweden, Czech Republic, Austria, Slovakia and Germany regarding the behaviour of new entrants and incumbent operators in open access competition (EC 2016b, Tomes et al 2016). In the UK, Hull Trains and Grand Central operate open access services on the East Coast Main Line; in Italy, NTV operates high-speed services on the Turin-Naples corridor (Bergantino et al 2015, Cascetta and Coppola 2014); in Sweden, the operators Blå Tåget, Öresundtåg (Veolia) and MTR Express have entered the market (Froïdh and Nelldal 2015). In addition, new services are introduced

[37] International Railway Journal, Volume 57, Issue 4, April 2017

by RegioJet and LEO Express in Czech Republic (Tomes et al 2016) by WestBahn in Austria and by and Hamburg-Köln Express (HKX), InterConnex (operation ended in December 2014) and in Locomore, who started a new service between Stuttgart and Berlin in December 2016, in Germany.

With market shares of 10% (Hull Trains, Grand Central), 25-30% (NTV, MTR Express, LEO Express) and 45% (RegioJet), new services have been introduced on a moderate scale with a relatively small fleet of new-build or leased rolling stock to minimise financing need and risk. From the experience in the UK and Italy, it is observed that the market share appears to be broadly consistent with the share of supply (EC 2016b). The incumbents responded by moving resources to the services where they face competition, by increasing the service frequency to deter entry (Trenitalia) or to concentrate on peak times and main stations (Czech Railways). The rivalry between Czech Railways CD and the new entrants Leo Express and RegioJet on the Prague-Ostrava route resulted in a vigorous price war. Tomes et al (2016) calculated that the weighted average of fares the most common ticket from of all three competitors in the Czech Republic decreased by 46% between September 2011 and September 2014. In 2012 and 2013, the new entrants RegioJet and LEO Express have been unprofitable operating the Prague-Ostrava route. For 2013, the estimated market shares are 25% for CD, 45% for RegioJet and 30% for LEO Express. In Italy, fares fell by approximately 25% and remained low with NTV's entrance. The Austrian Federal Railways ÖBB, threatened by competition from WestBahn, lowered their fares on the Vienna-Salzburg route. The entrance of MTR Express on the Stockholm-Gothenburg connection with ticket prices 20 to 25% lower than the incumbent, led to a 13% reduction in the fares of the Swedish national train operator SJ, but did not lead to aggressive pricing (Barrow 2015, Hughes 2017b).

Introduction of extra services on routes with competition leads to growth of overall ridership as long as the available capacity is not constrained. Although none of the infrastructure managers has reported congestion on their network, service frequencies have reached the maximum capacity on the most attractive routes.

8.4.7 Competition from other transport modes

The NTV case shows that HSR competition has a significant impact on the market share and fares in the airline market (Bergantino 2015). Modal share of HSR passengers increased from 27% in 2009 to 39% in 2012 (from 39 to 55% in terms of passenger-km) on the core HSR network. In the same time-period, highway modal share decreased from 56% to 48% (28% to 21% in terms of passenger-km) and air modal share from 10 to 8.5% (26% to 21% in terms of passenger-km) (Cascetta and Coppola 2014).

The passenger transport market also faces more competition from coach and bus services since this international market has been liberalised by Regulation 1073/2009 (EC 2016b). International coach services are growing their business on city-to-city connections in Europe, but it is still unclear to what extent will affect the passenger rail market. They deliver high value for money for price-sensitive leisure travellers.

8.5 Conduct

8.5.1 Existing operators

Since HSA has stopped its high-speed rail service between Amsterdam and Brussels at the beginning of 2013, Thalys has increased its service frequency from 11 to 14 trains per day by the end of 2015 on this connection. Thalys is planning a further increase to 16 trains per day by the end of 2017, growing their service offering by 45% on this connection in four years' time. In addition, to grow their existing services, Thalys has developed services to new destinations and introduced the low-cost alternative Izy. Thalys Soleil is a new weekly service during the summer period (June-August) to take passengers to the south of France. Thalys Neige is a comparable service offered during winter (December-March) with destination French Alps. In 2016, Thalys began its own low-cost service Izy between Paris and Brussels using high-speed trains on the existing conventional track to reduce infrastructure costs. The purpose is to compete with increasingly popular international coach services such as Eurolines, Flixbus, Ouibus and Megabus, and car-pooling services such as BlaBlaCar.

Eurostar's principal goal was to add new trains to their fleet to update the service on the London-Paris route, but it will also give an opportunity to expand services into France, Germany, the UK and The Netherlands. Intentions for introducing through-services between London and Amsterdam with the new e320 Velaro multi-system trainsets were already made public in 2013[38]. The London-Amsterdam connection is an attractive market for Eurostar and the HSL-South line between Amsterdam and Brussels leaves an opportunity after the cancellation of the introduction of the Fyra high-speed trains. Thalys has partly filled this gap by running more services on the Amsterdam-Brussels route[39]. This strengthens Thalys' market position and reduces the risk that operators like Eurostar and ICE introduce their services on this route. Eurostar is offering new destinations from London in partnership with other Railteam members, like Geneva with TGV Lyria, six German cities with DB and to the South of France during summer or the French Alps in winter with Thalys. Detailed planning is undertaken for a London-Amsterdam service late 2017 with stops in Antwerp, Rotterdam and Schiphol[40] [41]. A service London-Bordeaux is under consideration following the opening of LGV Sud Europe Atlantique in July 2017. In 2014, Eurostar has together with Keolis, a French company 70% owned by SNCF, applied to operate an open access service on the UK's East Coast Main Line. The bid was lost to Intercity East Coast, a consortium of Virgin Trains and Stagecoach, but indicates Eurostar's interest to expand their business to domestic markets. Eurostar is also well-positioned for the future operation of UK's HS2-line between London and Birmingham which is currently under construction. It is unclear how the upcoming Brexit will affect Eurostar's strategy.

DB has made plans to extend its ICE service to Brussels through the Channel tunnel to London, competing with Eurostar. The new Siemens class 407 trainsets, which are technically similar to the Eurostar Velaro e320 trains, ordered for this purpose are compatible with the European traction and signalling systems and have the capability to run

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[38] European Railway Review, Volume 19, Issue 6, 2013

[39] European Railway Review, Volume 19, Issue 4, 2013

[40] Railway Gazette, 26 April 2016

[41] European Railway Review, Volume 21, Issue 1, 2015

cross-border services to London, Paris and Amsterdam. Approvals for these trainsets are running late and DB's focus is to run these trains in Germany first, before making them available for cross-border operation. DB is still interested in operating an ICE service between Frankfurt and London, but no definite start date has been announced[42]. It is expected that the service is unlikely to be launched before the end of the decade[43]. Eurotunnel, the Channel tunnel manager, claims that the tunnel has almost 30% spare capacity and is keen on attracting some extra traffic. Deutsche Bahn is also gradually pulling out of Thalys, a venture with SNCF and its Belgian and Dutch counterparts, in preparation for competing with them on those routes[44].

Trenitalia is investigating the opportunity to start a new open access high-speed rail service between Paris and Brussels using V300 Zefiro trainsets, which are equipped with EU compliant safety and train control systems for operation in France and Belgium[45]. It is reported that Trenitalia has applied for four paths on the Paris-Milan route, and consequently could compete in the Paris-Lyon market.

In 2015, NTV has purchased eight Pendolino high-speed trains to expand the existing fleet and offer additional high-speed journeys to its passengers[46]. The Pendolino fleet is due to be delivered by December 2017, with entry into service planned for March 2018[47]. NTV is considering cross-border services to Munich or Vienna[48], but we have found no details regarding these developments.

In the past, incumbent operators have settled their market position by early involvement in the development of the high-speed network in Europe, in the first instance in their home countries and in the second instance on international routes. On cross-border high-speed lines under construction or planned, the incumbents make bilateral agreements and ordering appropriate rolling stock to run these new services as soon as the line is handed over for operation. Incumbents protect and strengthen their market position on cross-border routes by continuation of the current practice. There is little room for new entrants to position themselves as long as no public service contracts are tendered for these lines.

The market power on cross-border routes is strongly related to the number of multi-system trainsets owned by the operator, capable of running these services. Currently, SNCF and DB own the most multi-system trainsets that can run cross-border, followed by Trenitalia and ÖBB. Other incumbents that own suitable rolling stock, but in less quantities are Renfe, SBB, PKP, SNCB, CD and NS.

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[42] International Railway Journal, Volume 57, Issue 4, April 2017

[43] International Railway Journal, 19 February 2014

[44] The Economist, 10 January 2015

[45] Railway Gazette, 28 October 2015

[46] Alstom Press release, 29 October 2015

[47] Railway Gazette, 15 December 2016

[48] SCI Raildata Newsletter 12/2012, 26 March 2012

8.5.2 New entrants

Market entrance can come from privately owned operators, incumbent railways extending their services across the border or joint ventures of incumbent or private operators. Besides competition for the track on international routes, these operators also have to deal with inter-modal competition from airlines, coaches and private cars.
According to Directive 2007/58/EC, all railway undertakings having a valid licence and the required safety certificates were given the right to operate international rail passenger services, including the possibility of carrying passengers on national sub-routes (cabotage) as from January 2010. Although delayed, transposition of this directive into national law in the Member States is arranged (EC 2013a). In 2014, Thello, which started a daytime service between Marseille and Milano, is in fact the only new operator that has entered the high-speed rail cross-border market since the opening in 2010. Thello might be a future new entrant when upgrading and expanding their services by applying for high-speed train slots. Trenitalia is currently 100% shareholder of Thello after TransDev decided in 2016 to relinquish their 33% holding in Thello. Alleo, a cooperation between SNCF and DB, started their operation between Frankfurt/Stuttgart and Paris in 2007 and is a relatively new player as well. The other operators Thalys, Eurostar, TGV Lyria and ICE International, have been in the market long before liberalisation of the rail market took off.

So far, no consolidation or withdrawals from the market like in the airline or rail freight industry can be observed, except for HSA in the Netherlands, which stopped its new service between Amsterdam and Brussels with Fyra trainsets in January 2013 after 40 days due to technical difficulties and disappointing results. The invested capital in rolling stock is a large exit barrier, but as long as revenues from ticket sales cover the operating costs, there is no urgency to exit the market. Withdrawal from the market leaves the operators with a train fleet, which is hard to sell as there is not an established second-hand market for used high-speed trainsets. In the case of HSA, the Fyra trainsets were handed back to the manufacturer.

In the domestic market, both public service contracts (competing for the tracks) and open access entry on national routes (competing on the tracks) is recognised. For cross-border connections, only the open access option is viable, as long as infrastructure is managed at a national scale. As, to our knowledge, the legal European railway framework does not foresee in the foundation of a pan-European rail infrastructure manager for international routes, scheduling of train services needs to be coordinated by the national infra managers and tendering of international public service contracts is only possible when all infra managers involved agree to do so[49]. A complication for new entrants is that preparations for market entry will not remain unnoticed, which would give incumbents the opportunity to deter entry. Planning and preparation will take several years and orders for new rolling stock can hardly be kept secret and will soon be known in public as many stakeholders are involved. Before the operation can start, on-track testing of the trainsets’ performance and interoperability is needed and acquisition of the required train paths from the national infra managers involved is a necessity.

[49] To our knowledge, only the high-speed train service between Amsterdam and the Belgian border was tendered publicly. The preferred bidder HSA, a joint venture between NS and KLM, won the tender. The Fyra train service between Amsterdam and Brussels was executed in cooperation by HSA and SNCB.

8.5.3 Head-on competition

The likelihood of strong intra-modal competition is low, as high capital costs prevent entry within the high-speed segment of the market (Friederiszick et al 2009). In addition, joint ventures between incumbent national high-speed rail operators prevent entry of third parties. An aggressive entry strategy in the market of another incumbent railway undertaking could jeopardise any international cooperation between them (Everis 2010). Between incumbent operators, cooperation is more likely than competition. An aggressive entry strategy by a non-incumbent operator is more likely. New entrants (CERRE 2016) favour a route with an inefficient existing operator with little customer focus. Operators with the same service quality (or better) than the incumbent, but with lower cost and prices can acquire a solid market position on the most attractive routes if capacity is not restricted. In this case, passengers will benefit from higher service frequencies and a wider choice of departure times. If network and station capacity is limited during peak hours, on-track competition will result in a zero-sum game for society and passengers because slots awarded to the new entrant decrease the available slots of the incumbent (CERRE 2016a). During off-peak hours, the new entrant can claim the spare train paths, but has to accept less seat occupancy caused by overcapacity. Evidence from the domestic market shows that new entrants offer lower frequencies, higher service quality and lower fares than the incumbent on the same route (EC 2016b, Tomes et al 2016). It is not unlikely that future competition will come from new Asian entrants. For example, MTR already has won concessions in Europe to operate metro operations for London Crossrail and Stockholm and has introduced the MTR Express in 2015 between Stockholm and Gothenburg in competition with the Swedish national rail operator SJ. MTR is currently building the 26 km new high-speed line from Hong Kong into mainland China that is planned to be put into operation in 2018 with the Chinese CRH380A trainsets. With the support of the Chinese government, the operational experience of CRH and the access to two large high-speed train builders (CNR and CSR[50]), important hurdles can be taken. Of course, the barriers as listed in the MATOF framework still apply.

Another option is that new entrants start competing on profitable domestic routes and then expand from the home base into neighbouring countries with cross-border services if the financial position is secured. An example can be found in Czech Republic, where RegioJet and LEO Express have expanded their services into Slovakia and RegioJet is planning a service between Praha and Wien (Hughes 2017b). Private companies such as Veolia and Arriva might be interested to explore the opportunities based on their experience in running concessions in Germany.

When no direct entry is permitted in a foreign domestic market, Johnson and Nash (2012) present a strategy where a new entrant on a long-distance international route with low frequency attacks an attractive and profitable foreign domestic market, exercising the right of cabotage. No empirical evidence is presented, but case simulations point out that this is a viable scenario where the international service loses money, but the domestic market is highly profitable.

[50] In 2015, the CNR merged with CSR Corporation to form CRRC Corporation.

8.5.4 Product and market differentiation

The introduction of low-cost high-speed trains and high-speed night trains are two interesting developments where operators try to differentiate their services and spread their portfolio of value propositions.

Airlines like Southwest airlines in the USA and Ryanair in Europe have successfully entered the market by offering low-cost solutions to travellers. An analogy can be observed in the railway market when SNCF launched their Ouigo high-speed rail service in 2013 with features comparable to low-cost airlines like long operating days, single class, high seating density, minimal catering and on-board staff, serving secondary stations and only online sales and ticketing. Ouigo offers a service that is different from the core TGV high-speed services. Although not high speed, more recent, the cross-border low-cost formula Izy was launched by Thalys between Paris and Brussels using the existing conventional track to reduce infrastructure costs. A passenger seat is not guaranteed (EC 2016b). Low-cost high-speed rail operations target price-sensitive leisure passengers and compete on the one hand with low-cost air carriers and on the other hand with a growing number of international coach services like Eurolines, Ouibus (formerly iDBUS), Flixbus and Megabus. These initiatives can also win some market share from private cars and car-pooling services such as BlaBlaCar. Low-cost HSR services result in increasing passenger numbers, but not necessarily higher profits. The impact of experiments like Ouigo and Izy is not clear yet, but at least they contribute to the learning curve of SNCF and Thalys in the supply of HSR-services to retain their competitive advantage and to develop a strategy to prevent any potential price war from new entrants (CERRE 2016a).

Many of Europe's long-distance overnight trains have disappeared in recent years due to increasing competition from high-speed rail services and low cost airlines. Recent research demonstrates that there is some potential for operating Very Long Distance Night Train (VLDNT) services on high-speed networks using high-speed rolling stock (UIC 2013a). This VLDNT service could provide comfortable, high-quality night train service on corridors over 2,000 km long, like for example London-Madrid in 12 hours with night-time between Paris and Barcelona. Today, travel over these distances is dominated by air transport. Estimated fare for London-Madrid would be €361 per trip, compared to €118 for an EasyJet flight. The differentiator is the very high quality service, where the train ride itself is an important and memorable part of the whole experience. The major obstacle for VLDNT are track access charges, which are by far the largest cost driver for the proposed service. These infrastructure charges are estimated at around 40% of the total cost for routes in continental Europe, but can add up to 55-60% on the routes connecting London. Besides, infra charges, limited capacity at major nodes (stations), rolling stock requirements and interoperability, overnight HSR line maintenance and freight train conflicts and security measures are hurdles to be taken. A new initiative is the Thello night service, leaving at 7 pm in Paris or Venice and arriving around 9 am the next morning after a 1,100 km journey via Switzerland. In 2003-2004, DB has invested in 42 new sleeping cars and their City Night Line brand has now 29 services operating in nine countries, giving DB a strong basis for future expansion.[51]

[51] M. Hughes, Railway Gazette, 19 February 2008

Regarding travel purpose, it makes sense to make a distinction between business and leisure travellers. This market segmentation gives transport operators the opportunity to position themselves adequately and to develop suitable value propositions to target their customers. Business travellers on the London-Paris connection account for around 25% of Eurostar's ridership. For the full service air carriers British Airways and KLM-AirFrance, there is a 50/50% split between leisure and business travellers, while it is estimated that only 5% of car drivers have business purposes on this route. High-speed rail operators try to attract business travellers to offer first and premium class seats. The number of first class seats in a traditional high-speed train is in the range 25-35% and reflects approximately the number of time-sensitive business class travellers. Low-cost train formulas like Ouigo and Izy offer less comfort and longer journey times, targeting passengers with less willingness to pay for luxury and speed.

Railway companies like NTV, DB, ÖBB and SNCF move into international bus services as well, since the market for coach and bus services has been liberalised. Although they cannot match the journey time, seating capacity and service frequencies offered by airlines and railways, this market is growing fast. Operators like Eurolines, Ouibus (owned by SNCF), Megabus and Flixbus compete on price on cross-border routes. They target price-sensitive market segments like leisure travellers and grow their business on city-to-city connections in Europe. Currently, it is still unclear to what extent these market developments will affect the passenger rail market. It is expected that the coming years will be characterised by expansion, withdrawal and consolidation of coach operations.

8.5.5 Niche market entry

Entry may be focused on a particular market niche not satisfied by other existing operators (Preston 1999). Tomes et al. (2014) make the distinction between head-on competition with the incumbent on principal railway routes as can be observed in Austria, Czech Republic, Italy, Sweden and Slovakia and the niche entry on connections that were previously lacking like some direct feeder connections into London and regional services in Germany.

With services the TGV Neige and Soleil services, Thalys is targeting the niche of leisure travellers to the south coast of France in summer and the French Alps in winter, mainly for holidays. In cooperation with the Railteam members, Eurostar offers new destinations into Europe from London to Geneva with TGV Lyria and to six German cities with DB. The introduction of night trains on the Paris-Geneva route by Thello and services provided by Ouigo and Izy can also be considered niche entries.

8.6 Performance

There is no empirical evidence on competition of open access operators on international routes. In the domestic passenger transport market, NTV is the only high-speed rail operator that has entered into a head-on open access competition with the incumbent Trenitalia on principal railway routes in Italy. Some other open access cases with conventional speed, can be found in the UK, Italy, Sweden, Czech Republic, Austria, Slovakia and Germany, but only RegioJet in Czech Republic is running cross-border services towards Slovakia and planning for a connection to Vienna.

Johnson and Nash (2012) simulate a strategy where an operator starts a low-frequency service on an international route to attack an attractive and profitable foreign domestic market, exercising the right of cabotage. No empirical evidence is presented, but from case simulations profitability is proven, where the international service loses money, but the domestic market is highly profitable.

8.6.1 Fares

After an increase in average HSR single-ticket prices from €44 to €49 between 2009 and 2011, fares dropped with 31% in 2012 to €34 because of a new pricing structure and availability of promotional offers (Cascetta and Coppola 2014). No evidence was found of predatory pricing by the incumbent. On the contrary, Trenitalia charged 30 to 35% higher fares than NTV in 2013 (Bergantino et al 2015). In the Czech Republic, the incumbent CD entered into a vigorous price war with the two new competitors resulting in 46% lower fares on the Prague-Ostrava route. In other domestic open access market cases, the fares from new entrants are 15-50% lower than those from the incumbent (2016b).

8.6.2 Service frequency and quality

Trenitalia has increased its HSR service frequencies by 30% in the year before NTV entry. In 2013, the distribution of daily HSR services between Trenitalia and NTV is 70-30% on the Rome-Milan route, 77-23% on Rome-Venice route and 74-26% on the Rome-Turin route. The entrance of NTV has led to a 56% overall increase in service frequency on the Rome-Milan connection (Bergantino et al 2015). This corresponds with the finding in the domestic open access market that the service frequency from new entrants is 10-40% from the incumbent's daily services and that the overall service frequency increases (2016b). The realised growth of overall service frequency and ridership indicates that the available capacity on the core HSR network in Italy was not constrained before NTV's entry.

8.6.3 Demand and market shares

In the Italian HSR market, from 2009 until 2012, passenger numbers have increased by 52% and passenger-km's by 79%. In addition to the 2 mln. passengers carried by NTV in 2012, Trenitalia managed to attract 5 mln. more passengers in the HSR core area compared to 2009. This growth comes from diverted demand from other modes, economy-based demand from higher income per capita and induced demand from new travellers and existing travellers using the HSR services more intensely. The modal share on the HSR core network increased from 27% in 2009 to 39% in 2012 (Cascetta and Coppola 2014).

8.6.4 Profitability

The profitability of incumbents is difficult to trace as in general no separate accounts are published on specific routes. NTV claims to have achieved an EBITDA of around 19% in 2015 (Hughes 2017b), but RegioJet and LEO Express have been unprofitable operating the Prague-Ostrava route (Tomes et al 2016). From a simulation case study it is concluded that on-track competition reduces the profitability of the incumbent and that the entrant can only be profitable as costs are significantly lower than those of the incumbent (Johnson and Nash 2012).

8.7 Expectations for the future

In the European travel market, there is a strong correlation between income per head of the population and the high-speed travel demand per capita and travellers shift from low-speed to high-speed travel modes in Europe as income rises. Under the assumption that there is a growing income and associated demand for fast international passenger transport, the establishment and growth of high-speed railway services require on the one hand a suitable network and on the other side an appropriate fleet of rolling stock. The development of the rolling stock fleet and the high-speed rail network are important predictors for the future of high-speed rail in Europe. For the short term, already ordered trainsets and cross-border projects under construction will be leading in the development of new services. Medium and long-term developments are driven by planned projects to be completed by 2030 and 2050 as part of the Trans-European Network for Transport (TEN-T).

Operators need interoperable trainsets to run services on international routes. In total, 333 trainsets of the European rolling stock fleet (18% of total 1850 trainsets) have multi-system traction drives[52] and the appropriate signalling systems, required to run cross-border services (UIC 2017a). From figure 8.1, it can be seen that SNCF owns in total 122 interoperable trainsets (95 SNCF, 15 Thalys, 12 Eurostar) to serve all five neighbouring countries (Belgium, Germany, Italy, Spain, Switzerland) and three corridors (Atlantic, Mediterranean, North Sea -Mediterranean). ÖBB in Austria has a fleet of 69 RailJet trains that run into Czech Republic, Germany and Hungary and by the end of 2017 into Italy. In addition, CD in Czech Republic owns RailJet trains for services to Austria, Germany and Slovakia. In total 155 new interoperable trainsets are ordered and to be delivered over the next five years by Eurostar (e320), DB AG in Germany (ICE 4), Trenitalia (ETR 1000), Renfe in Spain (S122) and SBB in Switzerland (Giruno). It is most likely that these operators will use these new trains to expand their services abroad. For example, after delivery of the e320 trains, Eurostar will, in addition to their services between London, Paris and Brussels, start a new service to Amsterdam in 2017 and is planning to connect to Cologne and Frankfurt. Figure 8.1 does not reflect the eight new Pendolino trainsets to be delivered to NTV in Italy by the end of 2017, as it is still unclear what their technical specifications regarding traction and signalling will be. NTV states that the objective is to strengthen their service offering in the busy north-east and north-west corridor of Italy[53]. Appendix C gives an overview of all interoperable trainsets currently in operation.

Cross-border railway operation is not a goal in itself, but is a consequence of connecting larger European cities by appropriate transport modes. The European parliament has agreed on nine international corridors forming the core of the Trans-European Network for Transport (TEN-T). The Connecting Europe Facility for Transport (CEF Transport) is a key EU funding instrument investments in the trans-European transport network to complete the TEN-T core network and its corridors by 2030. The focus is on removing bottlenecks, building missing cross-border connections and promoting modal integration and interoperability. To secure interoperability and to guarantee seamless cross-border transport, the high-speed rail corridors in Europe need to meet the Technical Standards for Interoperability (TSI's).

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[52] A multi-system traction drive is not needed when neighbouring countries operate the same power supply system like for example between Germany, Austria and Switzerland.

[53] Press release, Alstom and NTV unveil the design and technology of the Pendolino, 17 December 2015.

New opportunities arise where new high-speed lines are opened in the trans-European railway network like for example in Eastern Europe, Berlin-Warsaw and Rail Baltica (Talinn-Riga-Kaunas-Warsaw) as part of the North Sea-Baltic corridor, Madrid-Lisbon and Bordeaux-Madrid on the Atlantic corridor, Lyon-Turin on the Mediterranean corridor, Prague-Dresden on the Orient/East-med corridor, Ostrava-Katowice and Ostrave-Wroclaw on the Baltic-Adriatic corridor, Prague-Plzen-Nurnberg on the Rhine-Danube corridor and Frankfurt-Karlsruhe-Basel on the Rhine-Alpine corridor. With the exception of the Karlsruhe-Basel section, which is currently under construction, all these projects have a long-term planning horizon with commissioning and start of operation not expected before 2025 (UIC 2017b).

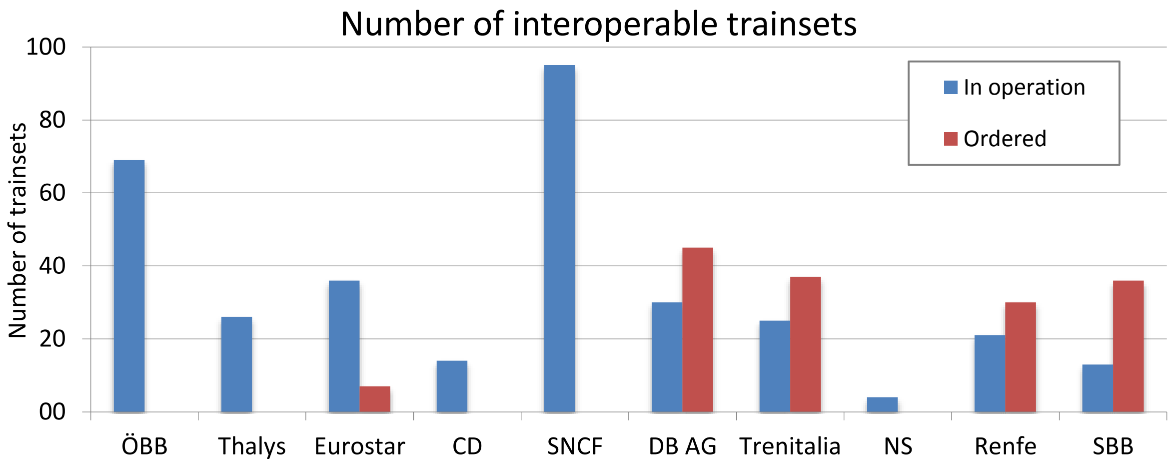

Figure 8.1 - European interoperable rolling stock fleet (UIC 2017)

Note 1: Thalys fleet consists of 15 trainsets from SNCF, 7 trainsets of NMBS and 4 trainsets of NS.
Note 2: 12 Eurostar trainsets are owned by SNCF, 3 by NMBS and 21 by Eurostar UK. The new Eurostar trains are ordered by Eurostar UK.
Note 3: Details about interoperable trains can be found in Appendix C.

The most likely short-term scenario is that SNCF will defend its market share on the existing cross-border links to the neighbouring countries and will expand their business through Eurostar. DB AG has withdrawn from Thalys and will focus on their ICE product. The new ICE 4 fleet gives DB AG the opportunity to compete on the routes Frankfurt-Paris and Frankfurt-Brussel-London. In addition, Trenitalia might be an operator looking for opportunities outside Italy, using the new ETR 1000 trainsets. For Renfe, the most likely strategy is that following the first cross-border operation from Barcelona to Perpignan, they will explore new opportunities across the French border. As all high-speed rail projects in Portugal have been abandoned, there are no opportunities in the near future for Renfe towards the West. With the Giruno trainsets delivered starting 2016, SBB might take the opportunity to grow their market share on routes to France, Germany and Italy, but will have to compete with SNCF, DB AG and Trenitalia. Switzerland may take advantage of their central position in Europe and not being an EU Member State, to strengthen their position.

In addition to the existing HSR operators, it is unlikely that new open access operators will enter the European market in the near future. For the medium term, new entrants on domestic open markets like NTV in Italy, Virgin in the UK, LEO Express and RegioJet in Czech Republic, WestBahn in Austria and MTR in Sweden, may expand their business across borders after their domestic position is established. Besides HSA, Arriva, Veolia, SJ

International, CGEA-Connex and StageCoach have bid in 2001 for the public tender for the 15 year HSL-South concession between Amsterdam and the Belgian border, indicating that tendering of high-speed rail services attract not only the usual incumbent suspects. That a new operator without any rail track record will enter the market unexpectedly is the least probable option for the near future. The barriers regarding the required investments, the associated risk and the long lead times to acquire the necessary interoperable trainsets to launch a new service are hard to overcome. Preparations will not stay unnoticed, giving the incumbents the opportunity to build barriers to prevent entry.

8.8 Conclusions and discussion

8.8.1 Conclusions

The legislative framework for railway liberalisation is completed by the release of the fourth Railway package, but implementation still needs attention for the coming years. The direction is set, but the pace is too slow to meet the objectives of the European transport white paper in 2030.

Incumbents have settled on the most attractive, busiest routes with high traffic demand between Paris, Frankfurt, London, Brussels and Amsterdam, long before the finalisation of the railway legislative framework. Although international traffic has been liberalised since 2010, no high-speed open access entry can be observed, except for the Thello service competing in France with SNCF on the Paris-Lyon route. Besides competition for the track on international routes, high-speed operators have to deal with inter-modal competition from airlines and private cars, but also form rapidly developing international coach and bus services. Rail competition is not a goal in itself, but an enabler to make the rail sector perform better and become more efficient, reliable and customer-focussed.

Interoperable trains are of major importance to run an international high-speed rail service. As there is no second-hand or lease market for high-speed trains that can run cross-border services, new entrants are obliged to buy trainsets from the rolling stock manufacturers resulting in long lead times and creating high barriers to exit. Entry in the domestic market is less complicated and gives better opportunities for a profitable business. There is a wider choice in conventional trainsets from the existing European rolling stock fleet with more trains end-of-life and interoperability is not an issue, as no borders need to be crossed.

Although product and market differentiation and niche market entry are the most sustainable strategies, examples of head-on competition in the domestic market can be found in the UK, Germany, Italy, Sweden, Czech Republic and Slovakia. Entry of new operators in the domestic markets have resulted in lower fares and extra services benefitting passengers and growth of overall ridership as long as the available route capacity is not constrained. Low-cost high-speed train services and high-speed night trains are innovative services developed by incumbents to grow their business.

SNCF has a broad range of service offerings and shareholdings to tap into opportunities in new and existing transport markets. SNCF's dominant position in France is at stake, when the delayed liberalisation process of the French rail market moves forward. Foreign operators like DB, Trenitalia, SBB and Renfe will enter the French market and threaten SNCF's position.

The future of the European high-speed rail market depends on the one hand on the growth in travel demand and on the other hand on the development of the core high-speed rail network and the interoperable rolling stock fleet. The way Eurostar, DB, Trenitalia, SBB and Renfe will exploit the 155 interoperable trains already ordered over the coming years will determine the short-term market developments. For the medium and long term, the development of the TEN-T network towards 2030 and 2050 will give opportunities to introduce new international services. Incumbent railways have the advantage to get involved in an early stage in the infrastructure developments, making it hard for new entrants to position themselves in the market. Entrance might be expected from NTV, Virgin, LEO Express, RegioJet, WestBahn and MTR if they take the opportunity to expand their business across borders after they have established their domestic market position. Public tendering of high-speed rail services may reveal new interested parties besides the usual incumbent suspects. A new entrant without any railway experience trying to compete on international routes is the least probable scenario.

8.8.2 Discussion

It proves to be hard to transform national rail monopolies into a pan-European market in which operators compete across borders. The incumbent operators have already settled in the European railway market and have marked their positions. A fifth railway package might be necessary one day if, despite the legislative framework already in place, the international railway business fails to materialise as expected.

It is expected that open access competition will grow faster in domestic markets than on international routes. National business is less complex and fewer and lower access barriers reduce the financial risk for new entrants. If incumbents enter into a price war with new entrants to defend their market position on attractive routes, this might end up in a bloodbath. Served with higher frequencies, better service and lower ticket prices, travellers will benefit from this situation, but operators will lose their profitability and in the end one of the competitors has to withdraw from the market, which as a negative effect on social welfare.

Open access entry is a strategic game between operators with dynamics and an outcome that are not easy to predict. There are no simple answers to complex market situations related to railway competition. Studying empirical evidence from domestic markets and adequate simulation models will help to obtain a better understanding of the actual situation and to give a better prediction of the future developments.

A pan-European rail infrastructure manager will open up the opportunity to tender for European public service contracts as an alternative to open access on international routes. Although it would make the market more competitive, there are to our knowledge, no plans to institutionalise international railway traffic governance like in air traffic.

Influence of Asia in the European market can come from operators that enter into open access competition and from Japanese, Korean or Chinese manufacturers selling their high-speed technology to Western operators. Some signals can be seen, but at the moment it is hard to predict if these incidents will expand in the future. The lessons to be learned from Asia regarding on-rail competition are limited, as only Korea has introduced competition on their high-speed rail network by the end of 2016.

9 Conclusions and recommendations

9.1 Introduction

The conclusions are organised in line with the research questions as listed and the associated chapters in this thesis (see figure 1.2). Before answering the main research question “*What market strategies will train operators develop to run international high-speed rail services in response to the railway market liberalisation in Europe?*“, in section 9.2, we answer the sub-questions individually using the empirical results from the research (chapter 2 to 8). The chapter ends with recommendations and suggestions for further research (section 9.3).

9.2 Answers to the research questions

9.2.1 Transport policy

Research question: What are the long-term objectives for the European passenger transport market?

Over the last two decades, the expanding European Union (EU) has developed its own transport policy based on the four freedoms of movement (goods, services, capital and labour) as declared in the Treaty of Rome in 1957. The long-term objectives for the European market are defined in the latest White Paper “Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system” that outlines the transport policy of the European Commission until 2050. It aims at “*seeking a deep transformation of the transport system, promoting independence from oil, the creation of modern infrastructure and multimodal mobility assisted by smart management and information systems.*” Ten ambitious goals are defined for a competitive and resource-efficient transport system. Specifically for high-speed rail traffic, the objectives are to triple the length of the existing high-speed rail network by 2030 and that all important airports should to be connected to the core rail network, preferably high-speed, by 2050. A tripling of the network size in 2030 is challenging, as some planned projects are cancelled or postponed during the financial crisis. Although the direction is set, the pace of development is too slow to reach the objective of the 2011 Transport White Paper that in 2030 the majority of medium distance passenger transport in Europe is served by rail.

Rail liberalisation has progressed considerably in ten years’ time, but large variations can be seen between different EU15 Member States. On the one side, Austria, Germany, Denmark, The Netherlands, Sweden and the United Kingdom have reached an advanced stage of rail liberalisation, but on the other hand, Greece, Spain, Ireland and Luxemburg are delayed in their transformation process. Considering that the liberalisation index is still increasing, there is still room for improvement as none of the EU15 Member States have reached a stable institutional state yet.

Since 1 January 2010, railway undertakings have been granted right for infrastructure access for operating international passenger services including cabotage, according to Directive 2007/58/EC. The legislative framework for the creation of a Single European Railway Area is completed by the adoption of the Fourth Railway Package, which supports the opening of the domestic railway markets. Despite 20 years of regulations and rule changes to harmonise standards and procedures, cross-border traffic between EU states is still hampered by complex technical and bureaucratic barriers. The EC will focus in the coming years on further implementation of the existing legislative framework in cooperation with the European Railway Agency (ERA), Member States, national regulatory bodies and stakeholders in the railway sector. A fifth railway package might be necessary one day if, despite the legislative framework already in place, the railway business fails to materialise as expected. The legal European railway framework does not foresee in the foundation of a pan-European rail infrastructure manager, thereby blocking the opportunity to tender international public service contracts for international routes.

9.2.2 Demand and supply

Research question: What is the need for high-speed rail transport and what can be accommodated?

The basic conditions regarding demand and supply are important inputs that structure the market as indicted in the SCP-model (figure 1.1). Demand depends on the mobility needs of citizens and supply is closely related to the available travel options with their specific characteristics. There is a strong correlation between income per head of the population and the high-speed travel demand per capita in the European travel market and travellers shift from low-speed to high-speed travel modes as income rises. Historic data shows that in Europe, high-speed rail grows faster than air traffic, resulting in a larger market share for high-speed rail operators compared to airlines when this trend continues. Growth for high-speed rail comes from diverted demand from other modes, economy-based demand from higher income per capita and induced demand from new travellers and existing travellers using the HSR services more intense.

Appropriate infrastructure and rolling stock are needed for supplying high-speed train services. For Europe, evidence is found that the available rail network and rolling stock are limiting the medium and high growth demand scenarios, where the planned growth of the train fleet is more stringent than the growth of the high-speed rail network. Introduction of extra services on a route leads to growth of overall ridership as long as the available capacity is not constrained and service frequencies have not reached the maximum route capacity. In a congested situation, the operator may increase its transport capacity to fit double-decker trains in the train path. With restrictive supply limits, travellers will shift to airlines and the high-speed rail market share will decrease.

In the high-speed rail sector, traffic growth can only be realised by extension of the rolling stock fleet. Operators owning multi-system high-speed trains that can run cross-border have a clear competitive advantage. Although Bombardier, Siemens and Alstom are the key manufacturers of high-speed rolling stock for the European market, Japanese or Chinese competitors will move towards Europe with their high-speed rail experience.

9.2.3 Performance

Research question: How do current high-speed rail operators perform?

To optimise the deployment and utilisation of high-speed rail systems, governments and railway companies may benefit from good practices in the rest of the world. A benchmark of the eight largest high-speed railway systems in the world revealed significant differences between Europe and Asia in the key performance indicators considered. The train densities for Europe are considerably higher than for Asia as high-speed trains in Europe not exclusively run on high-speed track, but on conventional lines as well. By comparing the fleet performance between Europe and Asia, it is found that Japan is performing best and China worst on seat occupancy. For Europe, France is giving the best results. High-speed railways in Asia operate trains with larger seat capacity and equal or even better performance is achieved with less train kilometres. More passengers and shorter trips are also characteristic for Asia, especially for China. Japan realises seat occupancies above 70% and is outperforming all the other networks, with China being an underperformer, bearing in mind that China's network is still under development and not fully matured yet.

A Data Envelopment Analysis (DEA) revealed that between 2007 and 2012, Asia achieved a productivity growth of 26.9%. Europe didn´t show any productivity improvement in that period because, despite the 16.6% technical change, efficiency dropped by 14.4%. In Asia, both technical efficiency improvements (+17.9%) and technology change (+7.6%) contributed to the overall productivity growth.

Germany, Italy, Korea and Japan show an above-average productivity index between 2007 and 2012. The high productivity improvement in Taiwan is remarkable (+157%). Taiwan is the only railway that has achieved a productivity index above unity in every successive year. Underperformers are the networks in Spain and China, but for different reasons. Efficiency of the Spanish HSR-network dropped by 34.1% in five years' time, but this is partly compensated for by a technical improvement by 19.9%. China has achieved to keep up efficiency, but shows a decreasing technical change of 12.2%.

Asia outperforms Europe regarding production efficiency and marketing and sales efficiency. The Asian HSR operators and SNCF are the best performers in the peer group. In all years, Italy appears to be the worst performer and Germany and Spain are in the middle of the spectrum. The results show a negative correlation between production efficiency and marketing and sales efficiency. For Europe, this effect is much stronger than for Asia, where a 10% increase in production efficiency comes with a 7% loss in marketing and sales efficiency.

There is limited empirical evidence on competition of open access high-speed rail operators on international routes in Europe. In the domestic passenger transport market, NTV is the only high-speed rail operator that has entered into a head-on open access competition with the incumbent Trenitalia on principal railway routes in Italy. Some other open access cases with conventional speed can be found in UK, Italy, Sweden, Czech Republic, Austria, Slovakia and Germany, but only RegioJet in Czech Republic is running cross-border services. From the experiences in the domestic open access market, it is observed that the fares from new entrants are 15-50% lower than those from the incumbent and that the service frequency offered by new entrants is 10-40% from the incumbent's daily services. No evidence was found of predatory pricing by the incumbents, except for CD in Czech Republic that entered into a vigorous price war resulting in 46% lower fares on the Prague-Ostrava route. On routes with no capacity constraints, open access competition results in higher service frequencies, more passengers and a wider choice of departure times. The profitability of incumbents is difficult to trace, as in general no separate accounts are published on specific routes. NTV claims to have achieved an EBITDA of around 19% in 2015, but in RegioJet and LEO Express have been unprofitable operating the Prague-Ostrava route.

9.2.4 Market structure

Research question: What is the market structure for high-speed rail operations?

In the railway industry, the number of competing firms is small. Railways operate in monopolistic, duopolistic or oligopolistic markets. Besides intra-modal competition between incumbent railways and new entrants and conventional and high-speed rail, the rail market faces inter-modal competition from airlines, private cars and busses. The market structure on a specific origin-destination pair can be characterised as an oligopoly with differentiated products, as services of different modes have different quality characteristics like travel time, service frequency and on-board services.

The relations between the high-speed passenger transport market structure, the conduct of airlines and high-speed rail operators that operate in this market and their performance is investigated using the structure-conduct-performance paradigm, applied to the London-Paris link. The London-Paris passenger market structure between 2003 and 2015 can be characterised as an oligopoly with a tendency to a monopoly with Eurostar being the dominant player, indicating a less intense price competition. The analysis revealed that ticket prices are of little of no influence on any of market structure or performance variables. The offered total travel time by the operators has a strong correlation with performance variable punctuality i.e. arrival within 15 minutes of the scheduled time table. For the other service characteristics, service frequency and fleet capacity, the models did not produce uniform results for any of the market structure or performance variables.

Incumbents have settled on the most attractive, busiest routes with high traffic demand between Paris, Frankfurt, London, Brussels and Amsterdam, long before the finalisation of the railway legislative framework. Most of the commercial cross-border high-speed services are currently operated by subsidiaries of SNCF like Thalys (Paris-Brussel-Amsterdam) and Eurostar (London-Brussels-Paris) or in cooperation with SBB (Lyria on Paris-Lausanne/ Geneva and Paris-Bern /Basel/Zürich routes), DB (Alleo on the Paris-Frankfurt connection) and Renfe (Perpignan-Barcelona). Even SNCF's competitors seem to prefer cooperation, sharing benefits of a profitable activity, rather than competition when it comes to HSR. As the airlines did before, SNCF and Thalys have developed the low-cost train services Ouigo and Izy. These low-cost services will hinder the entry of new competitors and will increase the number of passengers, but not necessarily the revenues.

Besides competition with airlines, the passenger transport market also faces more competition from liberalised international coach services that are growing their business on city-to-city connections in Europe, but it is still unclear to what extent they will affect the passenger rail market.

9.2.5 Competition

Research question: What is the influence of service quality and pricing in competition?

The changing institutional railway environment offers new opportunities for railway operators to grow their business. For international open access high-speed rail services, competition can come from privately owned operators, incumbent railways extending their services across the border or joint ventures of incumbent or private operators. Besides competition on the track on international routes, these operators also have to deal with inter-modal competition from airlines, coaches and private cars. Rail competition is not a goal in itself, but an enabler to make the rail sector perform better and become more efficient, reliable and customer-focussed.

To identify the chances for operators to successfully run high-speed services on international routes, the case for the London-Paris route is studied in detail. For this purpose, simulations are carried out using a calibrated game theory model for competition on city-to-city routes in an oligopolistic market. The effect of higher infrastructure charges, higher service quality and the entrance of a new high-speed rail operator on the London-Paris route is analysed with data from the actual operational and business performance.

The findings show that Eurostar has a dominant market share of about 70% (2012) on the London-Paris market compared to airlines and private car. This share is sensitive to changes in infrastructure charges. Introduction of new Velaro trainsets with more seat capacity will make Eurostar's market position even more dominant. A new high-speed rail entrant would completely change the competitive landscape. If the new entrant is capable of reducing its marginal costs, it will capture more than half of Eurostar's market share.

9.2.6 Market entry

Research question: What market entry strategies can be recognized and which access barriers need to be overcome?

There is a number of strategies a new entrant may follow, like targeting only the most profitable services ("cherry picking"), head-on competition without or with price competition ("price war"), differentiation in products or market segments ("vertical" or "horizontal" differentiation in the product-market matrix) or niche market entry.

Although the market for international cross-border rail services is open since 2010, there are only few railway operators that have the resources and capabilities to provide these services. Entry barriers for new entrants are numerous like market demand, competition, European rail directives and regulations, certified rolling stock and staff, network access and financial resources. In the development of international rail passenger services, the nature of the hurdles to be taken can be evaluated from a market, administrative, technological, operational and financial perspective. The barriers that high-speed rail operators can encounter are collected in the MATOF framework. For each country linked to the preferred route, these entry barriers need to be addressed and measures need to be taken to manage and overcome them.

Up till now, the European high-speed rail market is dominated by SNCF. Besides being the biggest national high-speed operator, SNCF has several stakes in key cross-border joint ventures. The plans from DB, being the second largest high-speed operator in Europe, to run services between Frankfurt and London and Amsterdam have not materialised yet. The Railteam cooperation between incumbent railways is an extra barrier for new entrants. Attempts of entrance by new private operators are limited and failed. Owning adequate rolling stock that can cross borders is an important competitive advantage for operators.

9.2.7 Market strategies

Research question: What market strategies will train operators develop to run international high-speed rail services in response to the railway market liberalisation in Europe?

Incumbent operators have settled their market position by early involvement in the development of the high-speed rail network in Europe. For new cross-border high-speed links, the incumbents make bilateral agreements and order appropriate rolling stock to run these new services as soon as the line is handed over for operation. Incumbents protect and strengthen their market position on cross-border routes by continuation of the current practice. The market power on cross-border routes is strongly related to the number of multi-system interoperable trainsets owned by the operator, capable to run these services. Currently, SNCF owns the most multi-system trainsets that have cross-border functionality, but Eurostar, Trenitalia, Renfe and DB have placed large orders for interoperable rolling stock that enables these incumbents to grow their business internationally. Despite the progress in rail liberalisation, there is little room for new entrants to position themselves as long as no public service contracts are tendered for these lines.

The incumbent railways dominate the international high-speed rail market and it is expected that this situation will remain for the short and medium term. For new entrants, only the open access option is viable, as long as infrastructure is managed at a national scale. As the legal European railway framework does not foresee in the erection of a pan-European rail infrastructure manager for international routes, scheduling of train services needs to be coordinated by the national infra managers and tendering of international public service contracts is only possible when all infra managers involved agree to do so. A complication for new entrants is that preparations for market entry will not remain unnoticed, which would give incumbents the opportunity to deter entry.

For attractive and busy routes, head-on competition with product differentiation and lower prices seems to be the only viable strategy to enter the market for new players. A new entrant can realise a substantial market share depending on the service frequency it can provide. Product differentiation with better service quality or low-cost services is needed to prevent a price war. Advanced yield management techniques will contribute to the entrants' profitability. On-track competition reduces the profitability of the incumbent and the entrant can only be profitable as costs are significantly lower than those of the incumbent.

Experiences regarding head-on competition in the domestic market indicate that passengers benefit from lower prices, higher service frequencies, wider choice in departure times and better on-board services, but that social welfare may not increase when the competitors' profitability is not sufficient. Entrance into niche markets like holiday destinations or night train services could be an alternative strategy to build a sustainable market position, but incumbents like Thalys and DB have already established their market position.

New entrants may start competing on profitable domestic routes and then expand into neighbouring countries with cross-border services if the financial position is secured, which will probably take at least five years as indicated by the experiences so far. When no direct entry is permitted in a foreign domestic market, an incumbent or new entrant can start servicing a long-distance international route with low frequency attacking an attractive and profitable foreign domestic market, exercising the right of cabotage. So far, no examples of this strategy are recognised.

9.3 Recommendations

The European Commission, the national rail infrastructure managers and the international high-speed rail operators are the most important stakeholders forming a trinity that can shape the market. With the introduction of the four railway packages by the European Commission, the legislative framework is defined for the moment. Non-discriminatory network access and use and pricing of tracks and stations are in the hands of the rail infrastructure managers. Their policies and cooperation across Europe are key to the success of high-speed rail. The existing HSR operators decide on moving their business according to their strategy and new entrants are looking for opportunities to build a business. No new market developments will take place when operators do not take action. Of course, national governments, railway regulators, competitive airlines, collaborative organizations etc. play their role as well, but are outside our scope.

9.3.1 European Commission

In the first place, it is recommended to complete the implementation of the agreed four railway packages and to speed up the liberalisation process in countries that are lagging behind. In the second place, introduction of a Fifth Railway Package may be considered to remove the remaining barriers for open access, based on the lessons learned from opening the domestic markets.

A single European railway area would benefit from an independent pan-European rail infrastructure manager for international routes. Lessons can be learned from the management and control of international air traffic. Introduction of a pan-European transparent and fair tariff system for rail infrastructure charges on international routes could be part of this development.

Tendering of Public Service Contracts for international routes, in analogy to the approach in domestic railway markets, creates a level playing field for all interested parties. To our knowledge, so far only the concession HSL-South in the Netherlands has been tendered publicly and revealed six parties to run the high-speed services on this line. Public tendering creates a level-playing field giving all interested parties, and not only the usual suspects, fair opportunities to bid.

9.3.2 Rail infrastructure managers

In the realisation of a Single European Railway Area, difficulties in managing cross-border operations and infrastructure interoperability barriers need to be overcome. As there exist many differences in the structure, pricing principles and levels of tariff systems that impact the fares and market competitiveness of high-speed rail operators, harmonisation of the national tariff systems across international routes would be beneficial to ease cross-border traffic. To create a level playing field across modalities the actual infrastructure costs and external costs should be incorporated in the tariff system and balanced with other modalities. The PRIME platform (Platform of Rail Infrastructure Managers in Europe) that was established to improve cross-border cooperation between infrastructure managers could play an important role in the harmonisation of tariff systems and fair allocation of external costs across modalities.

9.3.3 High-speed rail operators

To start on profitable national routes before operating cross-border, will reduce the overall risk for entering the high-speed railway market. In the open access model, head-on competition with product differentiation on high-demand connections gives the best opportunities to capture a fair share of the market. The market share on a specific route depends in the first place on the capacity and service frequency that can be offered relative to the competitors and in the second place on the price and service quality. The challenge is to get access to the needed amount of interoperable trainsets for service delivery. For the domestic market, lower speeds (160 - 200 km/h) may be acceptable on shorter distances (100 to 300 km) if combined with better service characteristics and superb service to customers.

Buying second-hand trains or leasing existing rolling stock to start the operation, will lower the risk profile for the operator considerably. Acquisition of trainsets that are already approved on the targeted networks will give a competitive advantage as it reduces the time-to-market. Modification of existing trainsets is an option if interoperable trains are not available in the market, but will come with extra investments and longer lead times.

9.3.4 Further research

There remain some open questions regarding competition and strategies for international high-speed operators is Europe.

From the start of high-speed rail in Europe, the national railway companies SNCF, DB, Trenitalia and Renfe have successfully developed their own high-speed rail markets. To get a better grip on their international strategies it would be useful to investigate in more detail and quantitatively the stakes they have in other transport ventures. As, SNCF is involved in Eurostar, Thalys, Keolis, Ouibus, WestBahn etc., DB in Grand Central and Arriva UK Trains and Trenitalia in Thello, it would be good to measure their market power.

The EC railway legislation regulated the establishment of the European Railway Agency (ERA), but no directions were given for a European Rail Infrastructure Manager to open the possibility to publicly tender international routes. It would be beneficial to study the options for a European Rail Infrastructure Manager.

Ownership of rolling stock and high-speed rail operation have currently a one-to-one relationship. The option of unbundling ownership and operation and of building a lease pool for standardized and interoperable high-speed trains would be beneficial for new entrants. It would be interesting to investigate the pros and cons of this option.

Over the last couple of years, competition in the domestic markets by new entrants has developed, but is still in an early stage. The cases presented in literature are descriptive and application of simulation of interesting cases is limited. To gain better insight in order to predict the future, it would be beneficial to use the theoretical competition models to build refined and powerful dynamic simulation software that can explain the strategic games in domestic and international rail and forecast the outcome.

Profitability is key to build a sustainable business. Recent experiences in the domestic markets show that operators are at least not profitability in the first years of their operation and it is too early to see what will happen on the longer run. In the international high-speed rail market, some initiatives for low-cost train services are launched, but offering less service quality. A more detailed study regarding cost structures and service quality would help identify opportunities to build sustainable business cases.

Tariff systems with different structure, pricing principles and fee levels affect the fares and market competitiveness of high-speed rail operators on international routes. To create a level playing field across modalities the actual infrastructure costs and external costs should be incorporated in the tariff system and balanced with other modalities. More research is needed to design a pan-European transparent and fair tariff system for rail infrastructure charges on international routes.

The MATOF framework as presented is qualitative. Quantification of the barriers from the operators' perspective and applied to international routes would even better explain the challenges new entrants face in practice.

Europe and Asia seem to be separate worlds when it comes to high-speed rail. Experiences are shared, but there is little interference between these regions. To study the options of Asian manufacturers and operators entering the European market and vice versa would clarify Europe's competitive position in the high-speed rail world.

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Appendices

Appendix A: High Speed Rail traffic performance in Europe and Asia

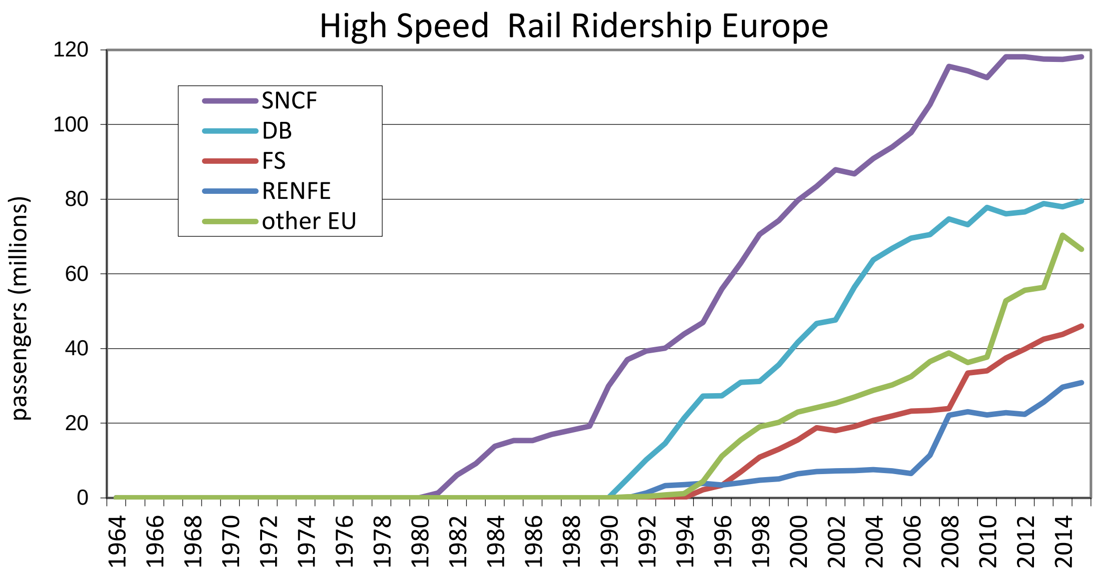

Figure A.1 - Development of High-Speed Rail traffic in Europe

Note 1: SNCF: Society National de Chemin de Fer (France), DB: Deutsche Bahn (Germany), FS: Ferrovie dello Stato (Italy), Renfe (Spain), Other EU: SJ (Sweden), SNCB (Belgium), Eurostar (UK)
Note 2: Figure based on data from UIC, Annual reports, National statistics

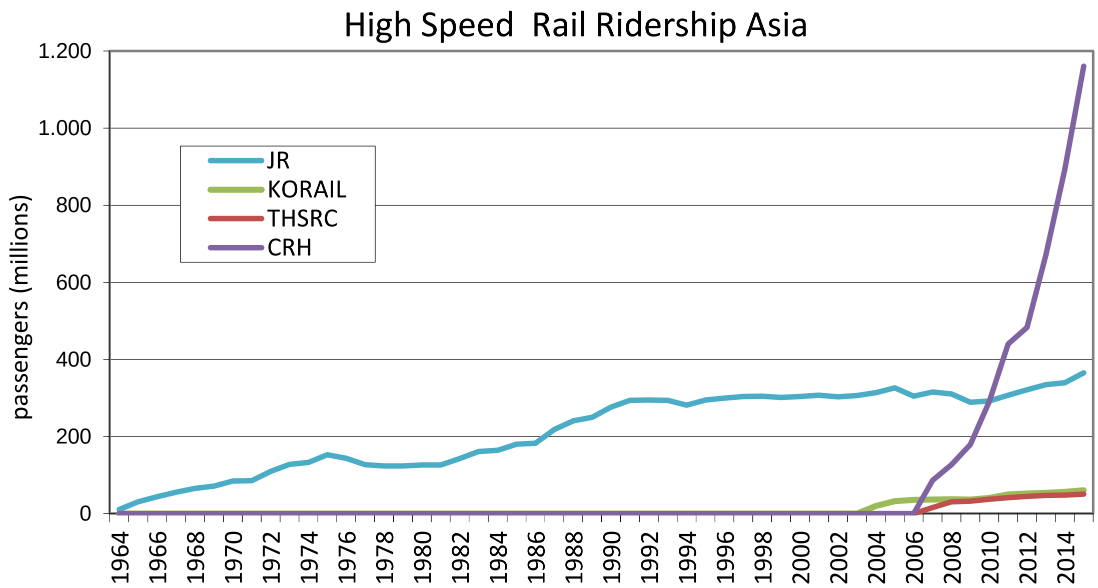

Figure A.2 - Development of High-Speed Rail traffic in Asia

Note 1: JR: Japan Rail, KORAIL: Korean Railroad, THSRC: Taiwan High Speed Railway Company, CRH: China High-speed Rail
Note 2: Figure based on data from UIC, Annual reports, National statistics

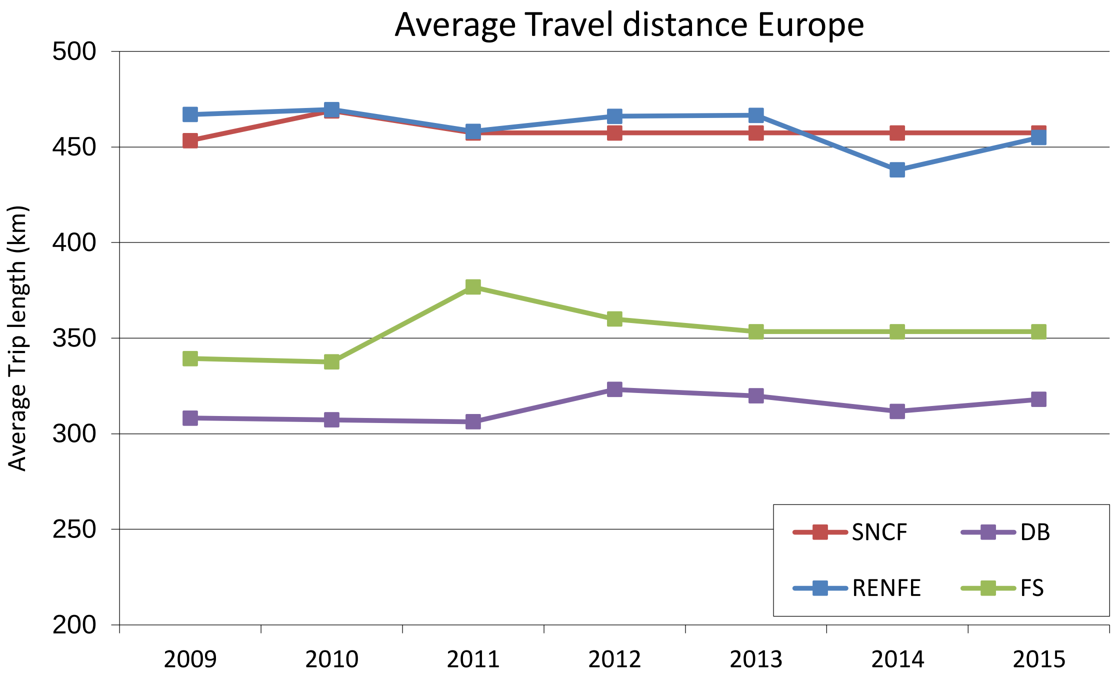

Figure A.3 - Average Travel distance in Europe

Note: Figure based on data from UIC, Annual reports, National statistics

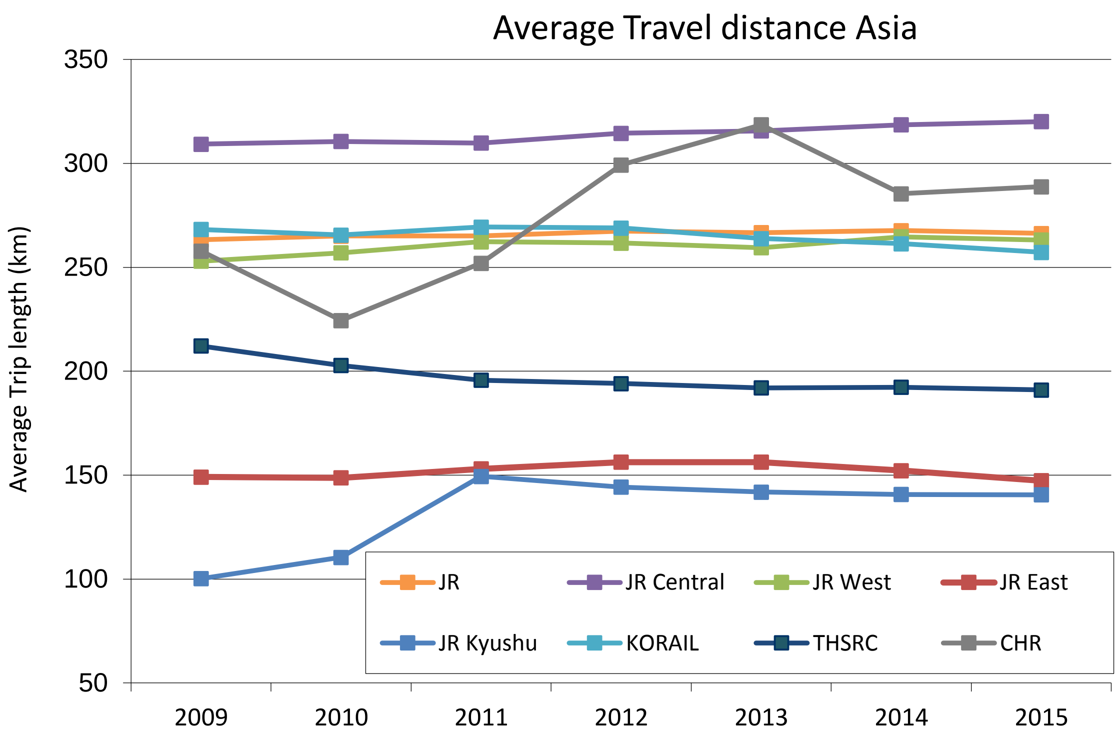

Figure A.4 - Average Travel distance in Asia

Note: Figure based on data from UIC, Annual reports, National statistics

Sources:

- Asia: website http://whhh.fc2web.com/ktx/hikaku.html
- Europe: UIC Synopses accessible at www.uic.org
- SNCF: Annual reports accessible at www.statistiques.developpement-durable.gouv.fr and INSEE database accessible at www.bdm.insee.fr
- DB: Deutsche Bahn Facts and Figures accessible at www1.deutschebahn.com
- FS: Financial reports and financial statements accessible at www.fsitaliane.it
- Renfe: Annual Financial and Management reports accessible at www.renfe.com
- JR: Annual rail traffic performance reports accessible at http://www.mit.go.jp
- KORAIL: Korea Statistical Yearbook of Railroad 2014 and websites www.korail.com and www.kric.or.kr
- THSRC: THSRC Annual reports accessible at www.thsrc.com.tw
- CRH: UIC Synopses accessible at www.uic.org and https://en.wikipedia.org/wiki/High-speed_rail_in_China

Table A.1 - High-speed rail ridership in the world

Passengers (thousands)													
Year	JR Central	JR West	JR East	JR Kyushu	JR	KORAIL	THSRC	CRH	SNCF	DB	FS	Renfe	Rest of EU
1964	11,018	0	0	0	11,018	0	0	0	0	0	0	0	0
1965	30,967	0	0	0	30,967	0	0	0	0	0	0	0	0
1966	43,784	0	0	0	43,784	0	0	0	0	0	0	0	0
1967	55,250	0	0	0	55,250	0	0	0	0	0	0	0	0
1968	65,903	0	0	0	65,903	0	0	0	0	0	0	0	0
1969	71,574	0	0	0	71,574	0	0	0	0	0	0	0	0
1970	84,627	0	0	0	84,627	0	0	0	0	0	0	0	0
1971	85,354	0	0	0	85,354	0	0	0	0	0	0	0	0
1972	109,854	0	0	0	109,854	0	0	0	0	0	0	0	0
1973	128,080	0	0	0	128,080	0	0	0	0	0	0	0	0
1974	133,195	0	0	0	133,195	0	0	0	0	0	0	0	0
1975	152,718	0	0	0	152,718	0	0	0	0	0	0	0	0
1976	143,465	0	0	0	143,465	0	0	0	0	0	0	0	0
1977	126,796	0	0	0	126,796	0	0	0	0	0	0	0	0
1978	123,690	0	0	0	123,690	0	0	0	0	0	0	0	0
1979	124,000	0	0	0	124,000	0	0	0	0	0	0	0	0
1980	126,000	0	0	0	126,000	0	0	0	0	0	0	0	0
1981	126,000	0	0	0	126,000	0	0	0	1,260	0	0	0	0
1982	125,000	0	18,077	0	143,000	0	0	0	6,080	0	0	0	0
1983	128,000	0	33,736	0	161,000	0	0	0	9,200	0	0	0	0
1984	129,000	0	35,427	0	164,000	0	0	0	13,770	0	0	0	0
1985	133,000	0	46,715	0	180,000	0	0	0	15,380	0	0	0	0
1986	135,000	0	47,959	0	183,000	0	0	0	15,370	0	0	0	0
1987	102,000	54,000	62,020	0	218,020	0	0	0	16,970	0	0	0	0
1988	112,000	61,000	68,007	0	241,010	0	0	0	18,100	0	0	0	0
1989	117,304	62,202	71,308	0	250,310	0	0	0	19,160	0	0	0	0
1990	130,000	66,000	80,480	0	276,480	0	0	0	29,930	0	0	0	15
1991	134,000	68,000	91,620	0	293,620	0	0	0	37,000	5,100	0	0	235
1992	132,000	68,000	95,050	0	295,050	0	0	0	39,300	10,200	0	1,314	392
1993	132,000	67,000	95,260	0	294,260	0	0	0	40,120	14,600	0	3,256	799

1994	128,000	57,000	96,130	0	281,130	0	0	0	43,910	21,300	0	3,554	1,099
1995	132,770	63,498	98,919	0	294,920	0	0	0	46,950	27,259	2,190	3,862	4,409
1996	134,226	64,400	102,096	0	300,100	0	0	0	55,915	27,363	3,348	3,415	11,151
1997	134,351	62,841	112,395	0	303,670	0	0	0	62,861	30,947	6,917	4,032	15,477
1998	130,343	60,226	123,656	0	304,570	0	0	0	70,575	31,201	10,897	4,694	19,047
1999	128,359	58,539	124,385	0	301,140	0	0	0	74,258	35,642	13,050	5,093	20,197
2000	130,478	58,414	125,642	0	304,210	0	0	0	79,685	41,610	15,510	6,425	22,970
2001	132,264	58,229	126,455	0	306,840	0	0	0	83,481	46,668	18,785	6,998	24,201
2002	129,616	56,593	126,388	0	302,800	0	0	0	87,860	47,636	18,010	7,208	25,353
2003	132,111	57,483	127,254	0	306,510	0	0	0	86,742	56,480	19,092	7,334	26,987
2004	136,548	58,649	125,296	3,848	313,970	19,882	0	0	90,890	63,705	20,712	7,560	28,796
2005	143,504	60,569	128,049	3,966	326,450	32,370	0	0	94,019	66,819	21,906	7,176	30,281
2006	145,269	61,104	130,056	4,045	305,094	36,017	0	0	97,861	69,533	23,236	6,518	32,488
2007	151,320	63,432	133,262	4,184	315,846	36,709	15,556	86,505	105,365	70,531	23,430	11,409	36,476
2008	138,849	57,400	129,568	4,162	310,290	37,417	30,581	127,385	115,529	74,700	23,882	22,098	38,780
2009	138,029	58,576	121,727	3,843	288,880	36,823	32,349	179,580	114,396	73,200	33,377	23,098	36,206
2010	140,833	60,503	118,698	4,462	292,094	40,765	36,939	290,540	112,557	77,800	33,993	22,193	37,668
2011	143,015	64,355	120,428	12,143	307,046	49,646	41,629	440,000	118,142	76,100	37,406	22,831	52,817
2012	149,227	65,618	128,718	12,299	321,619	52,362	44,526	483,160	118,136	76,600	39,838	22,349	55,609
2013	154,817	67,898	133,525	12,786	334,337	54,100	47,490	672,000	117,554	78,800	42,512	25,602	56,368
2014	157,369	68,109	138,005	13,103	339,928	56,295	48,020	893,200	117,451	78,000	43,743	29,685	70,305
2015	162,968	72,059	165,254	13,648	365,705	60,535	50,560	1,161,000	118,173	79,500	46,027	30,819	66,595

Note 1: SNCF: Society National de Chemin de Fer (France), DB: Deutsche Bahn (Germany), FS: Ferrovie dello Stato (Italy), Renfe (Spain), Rest of EU: SJ (Sweden), SNCB (Belgium), Eurostar (UK), JR: Japan Rail, KORAIL: Korean Railroad, THSRC: Taiwan High Speed Railway Company, CRH: China High-speed Rail

Note 2: Table based on data from UIC, Annual reports, National statistics

Note 3: Passenger volume estimated as ratio of passenger-km and average travel distance in preceding four years marked in grey.

Table A.2 - High-speed rail traffic performance in the world

Passenger-kilometers (millions)													
Year	JR Central	JR West	JR East	JR Kyushu	JR	KORAIL	THSRC	CRH	SNCF	DB	FS	Renfe	Rest of EU
1964	3,912	0	0	0	3,912	0	0	0	0	0	0	0	0
1965	10,651	0	0	0	10,651	0	0	0	0	0	0	0	0
1966	14,489	0	0	0	14,489	0	0	0	0	0	0	0	0
1967	17,911	0	0	0	17,911	0	0	0	0	0	0	0	0
1968	21,027	0	0	0	21,027	0	0	0	0	0	0	0	0
1969	22,816	0	0	0	22,816	0	0	0	0	0	0	0	0
1970	27,890	0	0	0	27,890	0	0	0	0	0	0	0	0
1971	26,795	0	0	0	26,795	0	0	0	0	0	0	0	0
1972	33,835	260	0	0	34,095	0	0	0	0	0	0	0	0
1973	38,989	0	0	0	38,989	0	0	0	0	0	0	0	0
1974	40,671	0	0	0	40,671	0	0	0	0	0	0	0	0
1975	53,317	0	0	0	53,317	0	0	0	0	0	0	0	0
1976	48,147	0	0	0	48,147	0	0	0	0	0	0	0	0
1977	42,187	0	0	0	42,187	0	0	0	0	0	0	0	0
1978	41,074	0	0	0	41,074	0	0	0	0	0	0	0	0
1979	40,985	0	0	0	40,985	0	0	0	0	0	0	0	0
1980	41,790	0	0	0	41,790	0	0	0	0	0	0	0	0
1981	41,717	0	0	0	41,717	0	0	0	700	0	0	0	0
1982	41,489	0	4,619	0	46,108	0	0	0	3,600	0	0	0	0
1983	42,186	0	8,254	0	50,440	0	0	0	5,700	0	0	0	0
1984	42,197	0	11,559	0	53,756	0	0	0	8,300	0	0	0	0
1985	43,864	0	11,643	0	55,507	0	0	0	9,300	0	0	0	0
1986	44,300	0	12,138	0	56,438	0	0	0	9,400	0	0	0	0
1987	32,123	13,153	12,138	0	57,413	0	0	0	10,400	0	0	0	0
1988	36,299	14,792	13,260	0	64,350	0	0	0	11,200	0	0	0	0
1989	37,404	15,002	13,558	0	65,965	0	0	0	12,200	0	0	0	0
1990	41,341	16,064	14,767	0	72,173	0	0	0	14,900	0	0	0	6
1991	41,841	16,278	16,102	0	74,220	0	0	0	17,900	2,000	400	0	94
1992	40,655	16,161	16,245	0	73,060	0	0	0	19,000	5,200	400	400	154
1993	40,504	16,026	16,034	0	72,564	0	0	0	18,900	7,000	500	900	272

1994	38,907	13,311	16,031	0	68,249	0	0	0	20,500	8,200	800	900	330
1995	39,817	14,759	16,251	0	70,826	0	0	0	21,430	8,700	1,100	1,200	770
1996	40,973	15,456	16,519	0	72,948	0	0	0	24,787	8,850	1,300	1,100	1,476
1997	41,090	14,976	16,750	0	72,816	0	0	0	27,600	10,073	2,400	1,300	2,009
1998	39,407	14,157	17,455	0	71,019	0	0	0	30,619	10,155	3,638	1,516	2,539
1999	38,878	13,623	16,734	0	69,236	0	0	0	32,192	11,591	4,464	1,674	2,770
2000	39,670	13,805	17,679	0	71,154	0	0	0	34,457	13,925	5,086	2,210	3,096
2001	40,573	14,003	17,741	0	72,317	0	0	0	37,200	15,515	6,763	2,409	3,367
2002	39,589	13,672	18,276	0	71,538	0	0	0	39,561	15,255	7,078	2,506	3,635
2003	40,317	13,911	18,747	30	73,006	0	0	0	39,255	17,457	7,431	2,531	4,099
2004	41,556	14,107	18,391	406	74,461	5,551	0	0	42,518	19,604	7,925	2,747	4,618
2005	43,777	14,849	18,874	409	77,908	8,862	0	0	43,130	20,853	8,550	2,325	4,806
2006	44,487	15,164	19,375	413	79,439	9,782	0	0	44,817	21,635	8,912	8,468	6,218
2007	46,540	15,932	19,925	430	82,826	9,854	3,520	13,000	47,963	21,919	9,248	8,466	6,958
2008	46,044	15,887	19,302	426	81,659	9,994	6,566	25,500	52,225	23,333	9,313	10,491	7,354
2009	42,685	14,818	18,152	385	76,040	9,876	6,864	46,300	51,865	22,561	11,327	10,788	7,613
2010	43,741	15,547	17,651	493	77,431	10,823	7,491	65,200	52,784	23,903	11,476	10,423	7,924
2011	44,303	16,878	18,425	1,814	81,420	13,375	8,148	105,842	54,038	23,306	14,093	10,462	10,577
2012	46,930	17,171	20,119	1,774	85,994	14,083	8,642	144,600	54,035	24,753	14,341	10,416	11,136
2013	48,873	17,618	20,863	1,814	89,168	14,272	9,118	214,100	53,769	25,200	15,025	11,947	11,288
2014	50,134	18,025	20,999	1,844	91,002	14,713	9,235	254,880	53,722	24,316	15,460	13,003	14,079
2015	52,167	18,960	24,353	1,919	97,398	15,569	9,655	335,309	54,052	25,280	16,267	14,021	13,336

Note 1: SNCF: Society National de Chemin de Fer (France), DB: Deutsche Bahn (Germany), FS: Ferrovie dello Stato (Italy), Renfe (Spain), Rest of EU: SJ (Sweden), SNCB (Belgium), Eurostar (UK), JR: Japan Rail, KORAIL: Korean Railroad, THSRC: Taiwan High Speed Railway Company, CRH: China High-speed Rail

Note 2: Table based on data from UIC, Annual reports, National statistics

Note 3: Passengers-km estimated as product of number of passengers and average travel distance in preceding four years marked in grey.

Appendix B: High Speed Rail network in the world

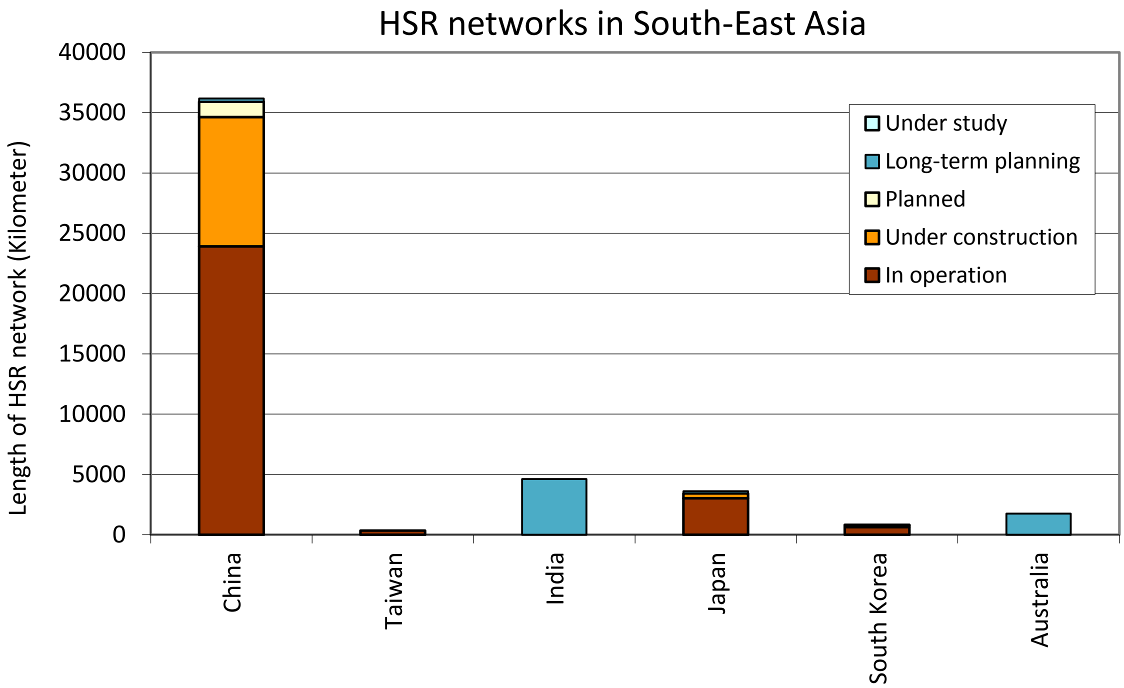

Figure A.5 - Development of High-Speed Rail networks in Asia

Note: Figure based on data from: "High speed lines in the world" overview, UIC, 1 February 2017 (UIC 2017b)

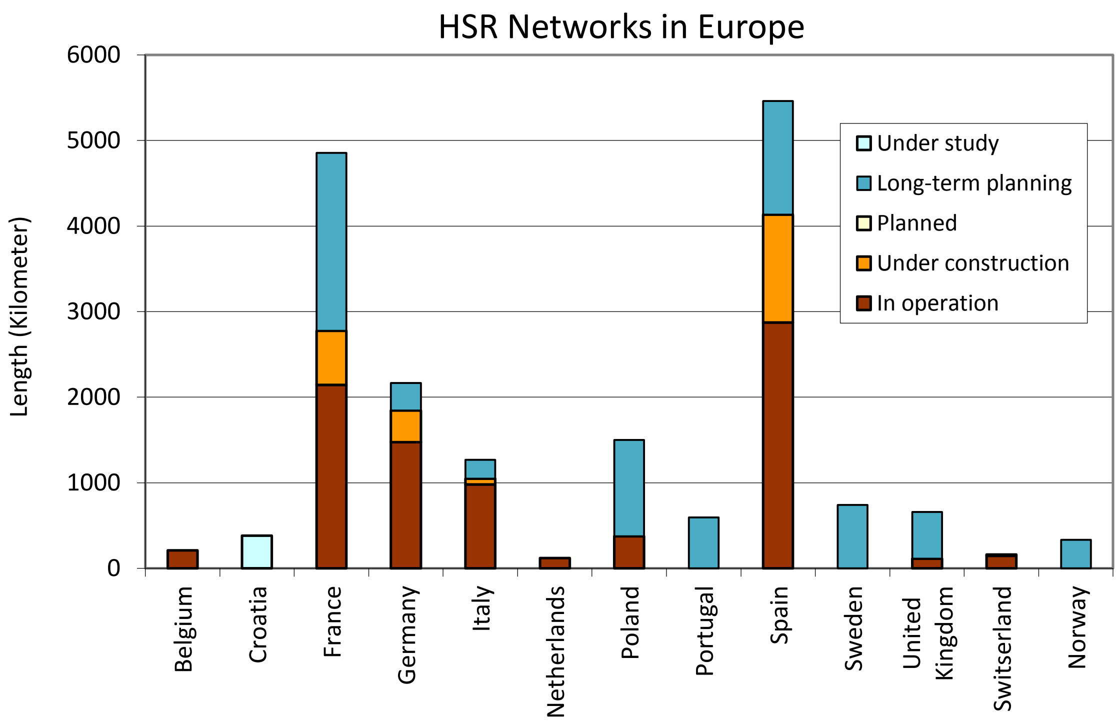

Figure A.6 - Development of High-Speed Rail networks in Europe

Note: Figure based on data from: "High speed lines in the world" overview, UIC, 1 February 2017 (UIC 2017b)

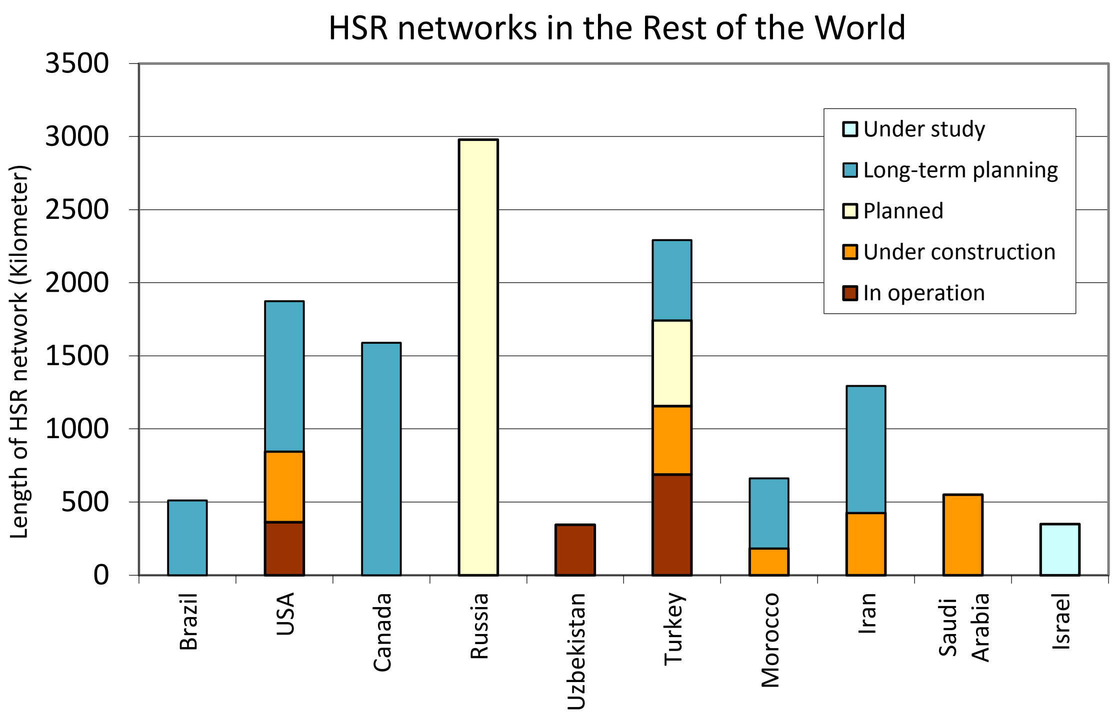

Figure A.7 - Development of High-Speed Rail networks in the Rest of World

Note: Figure based on data from: "High speed lines in the world" overview, UIC, 1 February 2017 (UIC 2017b)

Table A.3 - High-speed rail projects in the world

Line	Country	Length	Status
Doha - Manama	Bahrain and Qatar	180	Long-term planning
Qinhuangdao – Shenyang	China	405	In operation
Beijing – Tianjing	China	118	In operation
Jinan – Qingdao	China	393	In operation
Nanjing – Hefei	China	149	In operation
Hefei – Wuhan	China	331	In operation
Shijiazhuang – Taiyuan	China	224	In operation
Wuhan – Guangzhou	China	1079	In operation
Changchun – Jilin	China	111	In operation
Chengdu – Dujiangyan	China	65	In operation
Hainan East Circle	China	308	In operation
Nanchang – Jiujiang	China	119	In operation
Ningbo – Wenzhou - Fuzhou - Xiamen	China	837	In operation
Shanghai – Hangzhou	China	147	In operation
Shanghai – Nanjing	China	324	In operation
Zhengzhou – Xi'an	China	523	In operation
Beijing – Shanghai	China	1318	In operation
Guangzhou – ShenZhen (Hong Kong))	China	102	In operation
Guangzhou – Zhuhai North	China	143	In operation
Beijing - Zhengzhou	China	676	In operation
Harbin – Dalian	China	921	In operation
Hefei – Bengbu	China	131	In operation
Longyan - Zhangzhou	China	114	In operation
Wuhan – Yichang	China	292	In operation
Zhengzhou - Wuhan	China	526	In operation
Hangzhou– Ningbo	China	144	In operation
Nanjing – Hangzhou	China	256	In operation
Nanning - Liuzhou	China	221	In operation

Panjin - Yingkou	China	98	In operation
Tianjin – Qinhuangdao	China	265	In operation
Xi'an – Baoji	China	148	In operation
Xiamen – Shenzhen	China	468	In operation
Liuzhou - Hengyang	China	497	In operation
Nanchang - Fuzhou	China	632	In operation
Wuhan - Xianning	China	76	In operation
Qinzhou - Beihai	China	100	In operation
Nanning - Qinzhou	China	99	In operation
Qinzhou - Fangchenggang	China	63	In operation
Taiyuan - Xi'an	China	570	In operation
Zhengzhou - Kaifeng	China	50	In operation
Guiyang - Guangzhou	China	857	In operation
Nanning - Guangzhou	China	577	In operation
Lanzhou - Urumqi	China	1776	In operation
Hangzhou - Changsha	China	933	In operation
Changsha - Xinhuang	China	420	In operation
Hefei - Fuzhou	China	806	In operation
Jilin - Huichun	China	361	In operation
Harbin - Qiqihaer	China	279	In operation
Shenyang - Dandong	China	206	In operation
Hainan West Circle(Haikou-Sanya)	China	345	In operation
Zhengzhou - Jiaozuo	China	78	In operation
Tianjin - Yujiapu	China	45	In operation
Nanjing - An'qing	China	258	In operation
Dandong - Dalian	China	292	In operation
Chengdu - Chongqing	China	308	In operation
Jinhua - Wenzhou	China	188	In operation
Tianjin - Baoding	China	157	In operation
Nanning - Baise	China	223	In operation
Xinhuang - Guiyang	China	286	In operation
Ganzhou - Longyan	China	250	In operation
Zhengzhou - Xuzhou	China	362	In operation
Qingdao - Rongcheng	China	299	In operation
Chongqing - Wanzhou	China	247	In operation
Wuhan - Xiaogan	China	62	In operation
Changsha - Zhuzhou - Xiangtan	China	96	In operation
Kunming - Baise	China	486	In operation
Guiyang - Kunming	China	463	In operation
Dongguan - Huizhou	China	100	In operation
Guangzhou - Zhaoqing	China	111	In operation
Datong - Taiyuan	China	289	Under construction
Xuzhou - Zhengzhou	China	362	Under construction
Shijiazhuang - Ji'nan	China	323	Under construction
Baoji - Lanzhou	China	401	Under construction
Xi'an - Chengdu	China	509	Under construction
Zhangjiakou - Hohhot	China	287	Under construction
Beijing - Shenyang	China	697	Under construction
Harbin - Jiamusi	China	343	Under construction
Jinan - Qingdao	China	308	Under construction
Harbin - Mudanjiang	China	293	Under construction
Beijing - Zhangjiakou	China	174	Under construction
Shangqiu - Hangzhou (via Hefei)	China	770	Under construction
Beijing - Tangshan	China	149	Under construction
Chengdu - Guiyang	China	633	Under construction
Nanchang - Ganzhou	China	420	Under construction
Wuhan - Huangshi	China	96	Under construction
Zhengzhou - Wanzhou	China	785	Under construction
Huangshi - Jiujiang	China	112	Under construction
Fuzhou - Xiamen(Zhanzhou)	China	297	Under construction
Xuzhou - Yancheng	China	316	Under construction
Zhengzhou - Fuyang	China	277	Under construction
Ganzhou - Shenzhen	China	432	Under construction

Mudanjiang - Jiamusi	China	375	Under construction
Zhangjiajie - Huaihua	China	247	Under construction
Zhongwei - Lanzhou	China	218	Under construction
Nanning - Guiyang	China	482	Under construction
Lianyungang -	China	180	Under construction
Beijing - Xuzhou	China	78	Under construction
Beijing - Tianjin Binhal New Area	China	98	Under construction
Chongli Railway	China	67	Under construction
Lanfang - Zhuozhou	China	65	Under construction
Capital Airport - Beijing New Airport	China	160	Under construction
Pinggu section - Ring Line Langfang	China	88	Under construction
Gu'an - Baoding	China	106	Under construction
Beijing - Shijiazhuang	China	293	Under construction
Chongqing - Kunming	China	720	Planned
Chifeng - Kazuo	China	157	Planned
Guangzhou - Shantou	China	194	Planned
Tongliao - Xinmin	China	197	Planned
Zhangjiakou - Datong	China	137	Long-term planning
Meizhou - Shantou	China	120	Long-term planning
Mumbai – Amehdabad	India	495	Long-term planning
Chennai-Banalore-Coimbatore-Ernakulam-Thiruvananthapuram	India	1080	Long-term planning
Delhi - (Agra - Lucknow - Varanasi -) Patna.	India	1000	Long-term planning
Delhi-Chandigarh-Amritsar	India	480	Long-term planning
Howrah - Kolkata - Haldia	India	140	Long-term planning
Hyderabad - (Dornakal - Vijaywada -) Chennai	India	720	Long-term planning
Dehli - Jodhpur	India	530	Long-term planning
Mumbai - Pune	India	185	Long-term planning
Bandung - Surabaya	Indonesia	570	Long-term planning
Jakarta - Bandung	Indonesia	160	Planned
Teheran - Mashad	Iran	870	Long-term planning
Tehran – Qum	Iran	150	Under construction
Qum – Esfahan	Iran	275	Under construction
Tokyo – Shin Osaka (Tokaido line, JR Central)	Japan	515	In operation
Shin Osaka – Okayama (Sanyo line, JR West)	Japan	161	In operation
Okayama – Hakata (Sanyo line, JR West)	Japan	393	In operation
Omiya – Morioka (Tohoku line, JR East)	Japan	465	In operation
Omiya – Niigata (Joetsu line, JR East)	Japan	270	In operation
Ueno – Omiya (Tohoku line, JR East)	Japan	27	In operation
Tokyo – Ueno (Tohoku line JR East)	Japan	4	In operation
Fukushima – Yamagata (Yamagata line, Tohoku line, JR East)	Japan	87	In operation
Morioka – Akita (Tohoku line, JR East)	Japan	127	In operation
Takasaki – Nagano (Nagano line, JR East)	Japan	117	In operation
Yamagata – Shinjo (Yamagata line,Tohoku line, JR East)	Japan	62	In operation
Morioka – Hachinohe (Tohoku line, JR East)	Japan	97	In operation
Shin Yatsuhiro – Kagoshima Chuo (JR Kyushu)	Japan	127	In operation
Hachinohe – Shin Aomori (Tohoku line, JR East)	Japan	82	In operation
Hakata – Shin Yatsuhiro (JR Kyushu)	Japan	130	In operation
Nagano – Kanazawa (Hokuriku line, JR West)	Japan	228	In operation
Shin Aomori – Shin Hakodate (Hokkaido line, JR Hokkaido)	Japan	149	In operation
Tsuruga - Osaka (Hokuriku line, JR West)	Japan	128	Long-term planning
Shin Tosu - Takeo Onsen (JR Kyushu)	Japan	51	Long-term planning
Isahaya – Nagasaki (JR Kyushu)	Japan	21	Under construction
Kanazawa – Tsuruga (Hokuriku line, JR West)	Japan	125	Under construction
Shin Hakodate – Sapporo (Hokkaido line, JR Hokkaido)	Japan	211	Under construction
Takeo Onsen – Isahaya (JR Kyushu)	Japan	45	Under construction
Astana - Almaty	Kazakhstan	1011	Planned
Kuala Lumpur - Johor Bahru - Singapore	Malaysia and Singapore	350	Long-term planning
Medina – Jeddah – Mecca	Saudi Arabia	550	Under construction
Seoul – Dongdaegu	South Korea	330	In operation
Dongdaegu – Busan	South Korea	82	In operation
Osong – Gwangju	South Korea	184	In operation
Suseo - Pyoengtaek	South Korea	61	In operation

Gwangju – Mokpo	South Korea	49	Planned
Wonju-Gangneung	South Korea	120	Under construction
Taipei – Kaohsiung	Taiwan	345	In operation
Taipei – Nangang	Taiwan	9	In operation
Bangkok - Chiang Mai	Thailand	745	Long-term planning
Ayuthaya - Nakhon Ratchasima - Nong Kai	Thailand	615	Long-term planning
Bangkok - Rayong	Thailand	221	Long-term planning
Bangkok - Hai Yai - Padang Desar	Thailand	982	Long-term planning
Nakhon Ratchasima - Ubon Ratchasima	Thailand	314	Long-term planning
(Ankara-) Sinkan - Eskisehir	Turkey	232	In operation
Polatli-Konya	Turkey	212	In operation
Eskisehir- Izmit	Turkey	188	In operation
Izmit - Pendik	Turkey	56	In operation
Ankara-Kayseri	Turkey	175	Long-term planning
Halkai-Bulgaria border	Turkey	230	Long-term planning
Gebze-Istanbul	Turkey	43	Long-term planning
Gaziantep-Cobanbey-Halep	Turkey	100	Long-term planning
Kayseri kuzey gecisi	Turkey	23	Planned
Bandırma-Bursa	Turkey	100	Planned
Yenisehir-Osmaneli	Turkey	30	Planned
Sivas-Erzincan	Turkey	235	Planned
Nusaybin-Cizre-Habur hatti	Turkey	135	Planned
Mürsitpinar-Urfar	Turkey	63	Planned
Bursa - Yenisehir	Turkey	75	Under construction
Yerköy - Sivas	Turkey	292	Under construction
Konya - Karaman	Turkey	102	Under construction
Hanoi - Ho Chi Minh	Vietnam	1600	Long-term planning
Vienna-St. Polten	Austria	48	In operation
Gloggnitz-Mürzzuschlag (Sermmering Basistunnel)	Austria	27	Under construction
Graz-Klagenfurt (Koralmtunnel)	Austria	110	Under construction
Brennerachse	Austria	64	Under construction
Kaunas - Border with Poland (Rail Baltica I)	Balic States	119	In operation
Tallin - Riga - Kaunas (Rai Baltica II)	Balic States	621	Long-term planning
Brussels – French Border (L1)	Belgium	72	In operation
Leuven – Liège (L2)	Belgium	65	In operation
Antwerp – Dutch border (L4)	Belgium	36	In operation
Liège – German Border (L3)	Belgium	36	In operation
Vranovice - Breclav (Border Austria to Wien, Border Slovakia to Bratislava)	Czech Republic	40	Long-term planning
Brno - Prov	Czech Republic	70	Long-term planning
Praha - Lovosice	Czech Republic	55	Long-term planning
Brno - Vranovice	Czech Republic	30	Long-term planning
Ostrava - Border Poland to Katowice	Czech Republic	10	Long-term planning
Praha - Plzen	Czech Republic	75	Long-term planning
Plzen - Border Germany to Nurnberg	Czech Republic	55	Long-term planning
Praha - Border Poland to Wroclaw	Czech Republic	150	Long-term planning
Lovosice - Border Germany to Dresden	Czech Republic	40	Long-term planning
Praha - Brno	Czech Republic	205	Long-term planning
Prerov - Ostrava	Czech Republic	80	Long-term planning
Copenhagen - Ringsted	Denmark	56	Under construction
LGV Méditerranée (LN5)	France	259	In operation
LGV Est Europe (First phase) (LN6)	France	332	In operation
(Figueres -) Frontière – Perpignan	France	24	In operation
LGV Rhin – Rhône Branche Est (First phase) (LN7)	France	140	In operation
LGV Est – Européenne (Second phase) (LN6)	France	106	In operation
LGV Paris Sud-Est (LN1)	France	419	In operation
LGV Atlantique (LN2)	France	291	In operation
LGV Rhône-Alpes (Contournement Lyon) (LN4)	France	121	In operation
LGV Interconnexion IDF (LN3 bis)	France	104	In operation
LGV Nord – Europe (LN3)	France	346	In operation
LGV Bordeaux – Dax - Espagne (GPSO)	France	205	Long-term planning
LGV Bordeaux – Toulouse (GPSO)	France	250	Long-term planning
Liaison Roissy - Picardie	France	7	Long-term planning

Ligne Nouvelle Paris-Normandie (LN PN), zone Paris-Mantes, phase 1	France	59	Long-term planning
Interconnexion Sud en Île-de-France (IDF)	France	31	Long-term planning
LGV Paris-Orléans-Clermont-Ferrand (Coeur de France) (POCL)	France	540	Long-term planning
LGV Access Alpins Lyon – Chambery - Turin	France	291	Long-term planning
LGV Montpellier – Perpignan (LN MP)	France	155	Long-term planning
LGV Provence Côte d'Azur (LN PCA)	France	189	Long-term planning
Ligne Nouvelle Ouest Bretagne - Pays de la Loire (LN OBPL)	France	300	Long-term planning
LGV Rhin – Rhône Branche Est (Second phase)	France	50	Long-term planning
LGV Bretagne – Pays de la Loire (BPL)	France	214	Under construction
LGV Sud Europe Atlantique (SEA Tours-Bordeaux)	France	340	Under construction
Contournement Nîmes – Montpellier (CNM)	France	80	Under construction
Fulda – Würzburg	Germany	90	In operation
Hannover – Fulda	Germany	248	In operation
Mannheim – Stuttgart	Germany	109	In operation
Hannover (Wolfsburg) – Berlin	Germany	189	In operation
Köln – Frankfurt	Germany	184	In operation
Köln – Düren	Germany	42	In operation
Leipzig – Gröbers (- Erfurt)	Germany	24	In operation
(Karlsruhe -) Rastatt – Offenburg	Germany	44	In operation
Hamburg – Berlin	Germany	253	In operation
Nürenberg – Ingolstadt	Germany	89	In operation
München - Augsburg	Germany	62	In operation
(Karlsruhe) Katzenberg Tunnel - Basel	Germany	18	In operation
(Leipzig/Halle -) Gröbers – Erfurt	Germany	123	In operation
Frankfurt – Mannheim	Germany	84	Long-term planning
(Frankfurt -) Hanau – Fulda/Würzburg	Germany	126	Long-term planning
Hamburg/Bremen – Hannover	Germany	114	Long-term planning
Ebensfeld – Erfurt	Germany	100	Under construction
Nürnberg – Ebensfeld	Germany	83	Under construction
(Karlsruhe-) Buggingen Katzenberg Tunnel - (Basel)	Germany	12	Under construction
Stuttgart – Wendlingen	Germany	57	Under construction
Wendlingen – Ulm	Germany	60	Under construction
Tunnel Rastatt	Germany	17	Under construction
(Karlsruhe -) Offenburg – Riegel - (Basel)	Germany	39	Under construction
Rome – Florence (First section)	Italy	150	In operation
Rome – Florence (Second section)	Italy	74	In operation
Rome – Florence (Third section)	Italy	24	In operation
Rome – Naples	Italy	220	In operation
Turin – Novara	Italy	94	In operation
Milan – Bologna	Italy	182	In operation
Florence – Bologna	Italy	77	In operation
Naples - Salerno	Italy	47	In operation
Novara – Milan	Italy	55	In operation
Milan (Treviglio) – Brescia	Italy	58	In operation
Brescia - Verona	Italy	139	Long-term planning
Verona - Padova	Italy	82	Long-term planning
Genoa – Milan (Tortona)	Italy	67	Under construction
Sandbukta-Frederikstad (Oslo-Göteborg)	Norway	34	Long-term planning
Gardermoen-Hamar (Oslo-Trondheim)	Norway	74	Long-term planning
Drammen-Tønsberg (Oslo-Kristiansand-Stavanger)	Norway	60	Long-term planning
Frederikstad-Halden (Oslo-Göteborg)	Norway	39	Long-term planning
Hamar-Lillehammer (Oslo-Trondheim)	Norway	54	Long-term planning
Tønsberg-Skien (Oslo-Kristiansand-Stavanger)	Norway	72	Long-term planning
Grodzisk Maz - Opoczno - Zawiercie	Poland	373	In operation
Wroclaw - Border Czech Republic	Poland	120	Long-term planning
Poznan - Border Germany	Poland	150	Long-term planning
Warsaw – Katowice / Krakow	Poland	373	Long-term planning
Warsaw – Lodz – Wroclaw – Poznan	Poland	484	Long-term planning
Lisboa – Caia (- Madrid)	Portugal	206	Long-term planning
Lisboa – Porto	Portugal	290	Long-term planning
Porto – Valença (- Vigo) first phase	Portugal	55	Long-term planning
Porto – Valença (- Vigo) second phase	Portugal	45	Long-term planning
Moscow – Kaza	Russia	770	Planned

Moscow – St. Petersburg VSZM-1	Russia	659	Planned
Moscow - Adler (Sochi)	Russia	1549	Planned
Madrid – Seville	Spain	471	In operation
Madrid – Lleida	Spain	519	In operation
Zaragoza – Huesca	Spain	79	In operation
(Madrid -) La Sagra – Toledo	Spain	21	In operation
Córdoba – Antequera	Spain	100	In operation
Lleida – Camp de Tarragona	Spain	82	In operation
Antequera – Málaga	Spain	55	In operation
Madrid – Segovia – Valladolid	Spain	184	In operation
Camp de Tarragona – Barcelona	Spain	88	In operation
By pass Madrid	Spain	5	In operation
Figueres – Frontera (- Perpignan)	Spain	20	In operation
Madrid-Valencia / Albacete	Spain	432	In operation
Ourense – Santiago	Spain	88	In operation
Abacete - Alicante	Spain	239	In operation
Barcelona – Figueres	Spain	132	In operation
Olmedo – Zamora	Spain	99	In operation
Santiago – Vigo	Spain	94	In operation
Valladolid – León	Spain	163	In operation
Almería – Murcia	Spain	190	Long-term planning
Castejón – Pamplona	Spain	75	Long-term planning
Madrid – Navalmoral de la Mata	Spain	191	Long-term planning
Zamora - Orense	Spain	224	Long-term planning
Orense – Vigo (vía Cerdedo)	Spain	60	Long-term planning
Palencia – Santander	Spain	201	Long-term planning
Valencia – Castellón	Spain	64	Long-term planning
Venta de Baños – Burgos - Vitoria	Spain	173	Long-term planning
Zaragoza – Castejón – Logroño	Spain	149	Long-term planning
Vitoria – Bilbao – San Sebastián	Spain	175	Under construction
La Coruna – Santiago	Spain	62	Under construction
León - Asturias	Spain	50	Under construction
(Madrid-Valencia/Alicante) - Murcia / Castellón	Spain	231	Under construction
Bobadilla – Granada	Spain	109	Under construction
Hellín – Cieza (Variante de Camarillas)	Spain	27	Under construction
Navalmoral – Cáceres – Badajoz – Fr. Port.	Spain	278	Under construction
Sevilla – Antequera	Spain	128	Under construction
Sevilla – Cádiz	Spain	152	Under construction
Variante de Pajares	Spain	50	Under construction
Goteborg - Boras	Sweden	50	Long-term planning
Jarna - Linkoping	Sweden	150	Long-term planning
Boras - Linkoping	Sweden	190	Long-term planning
Stockholm - Jarna	Sweden	50	Long-term planning
Jonkoing - Malmö/Goteburg	Sweden	300	Long-term planning
Mattstetten - Rothrist	Switzerland	52	In operation
Frutigen – Visp (Lötschberg base tunnel)	Switzerland	35	In operation
Erstfeld – Biasca (Gotthard base tunnel)	Switzerland	57	In operation
Giubiasco – Lugano (Ceneri base tunnel)	Switzerland	15	Under construction
Schiphol – Rotterdam– Belgian Border	Netherlands	120	In operation
Fawkham Junction – Tunnel	United Kingdom	74	In operation
London – Southfleet Junction	United Kingdom	39	In operation
London – Birmingham (HS2, First section)	United Kingdom	204	Long-term planning
London - Manchester/Leeds (HS2, Second section)	United Kingdom	339	Long-term planning
Sydney - Canberra	Australia	283	Long-term planning
Melbourne - Gunning (-Sydney)	Australia	611	Long-term planning
Sydney - New Castle	Australia	134	Long-term planning
Brisbane - Gold Coast	Australia	115	Long-term planning
Newcastle - Bronelton (Gold Coast)	Australia	606	Long-term planning
Rio de Janeiro – Sao Paulo - Campinas	Brazil	511	Long-term planning
Calgary - Edmonton	Canada	290	Long-term planning
Quebec - Montreal - Ottawa - Toronto - Windsor	Canada	1300	Long-term planning
Hugarian border - Botovo - Koprivnica - Zagreb - Rijeka	Croatia	380	Under study
Cairo - Alexandria	Egypt	210	Long-term planning

Cairo - Luxor	Egypt	700	Long-term planning
Hurghada - Luxor	Egypt	300	Long-term planning
Tel Aviv - Eilat	Israel	350	Under study
Mexico DF - Querétaro	Mexico	210	Long-term planning
Settat – Marrakech	Morocco	480	Long-term planning
Tanger – Kenitra	Morocco	183	Under construction
Johannesburg - Durban	South Africa	610	Long-term planning
Johannesburg - Cape Town	South Africa	1300	Long-term planning
Johannesburg - Messina	South Africa	480	Long-term planning
Boston - New York - Washington DC (North East Corridor)	USA	362	In operation
Sacramento/San Francisco - Fresno	USA	147	Long-term planning
Bakersfield - Los Angeles	USA	147	Long-term planning
Boston - New York - Washington DC (North East Corridor)	USA	735	Long-term planning
Fresno-Bakersfield	USA	483	Under construction
Samrakand - Jizzakh - Yangiyar - Tashkent	Uzbekistan	344	In operation

Note: Table based on data from: "High speed lines in the world" overview, UIC, 1 February 2017 (UIC 2017b)

Appendix C: High Speed Rail train fleet in the world

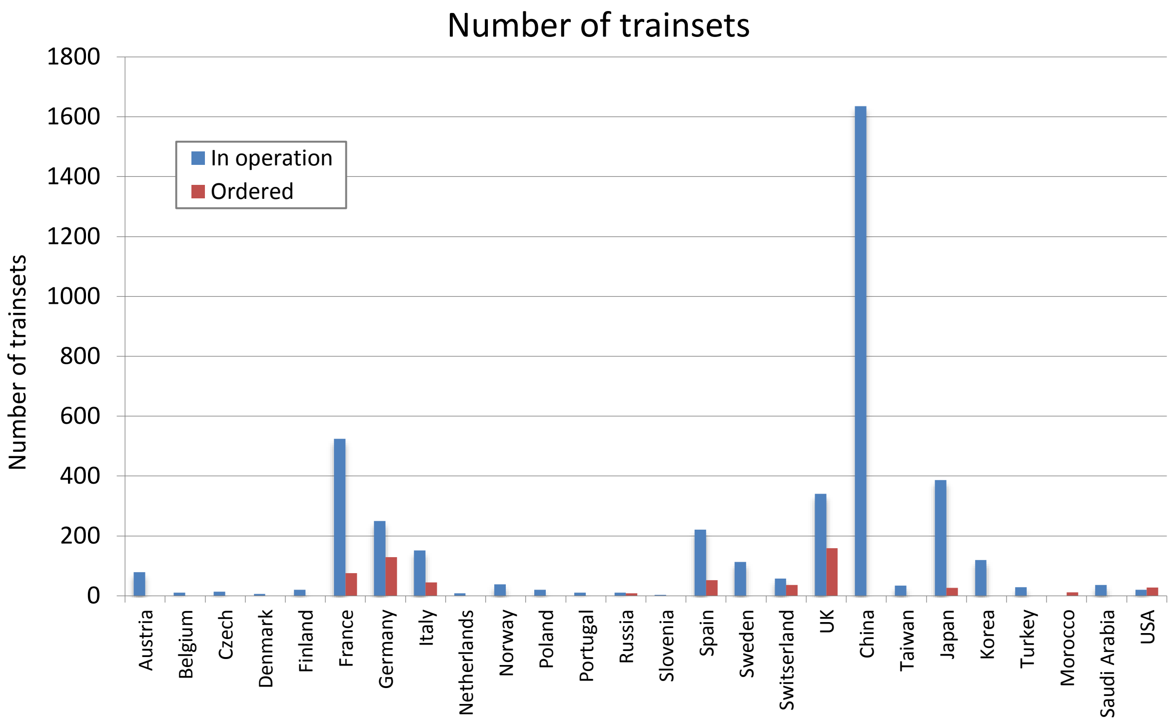

Figure A.8 - Rolling stock fleet in operation and ordered in Europe, Asia and USA

Note: Figure based on data from: “World High Speed Rolling Stock” overview, UIC, 1 February 2017 (UIC 2017a)

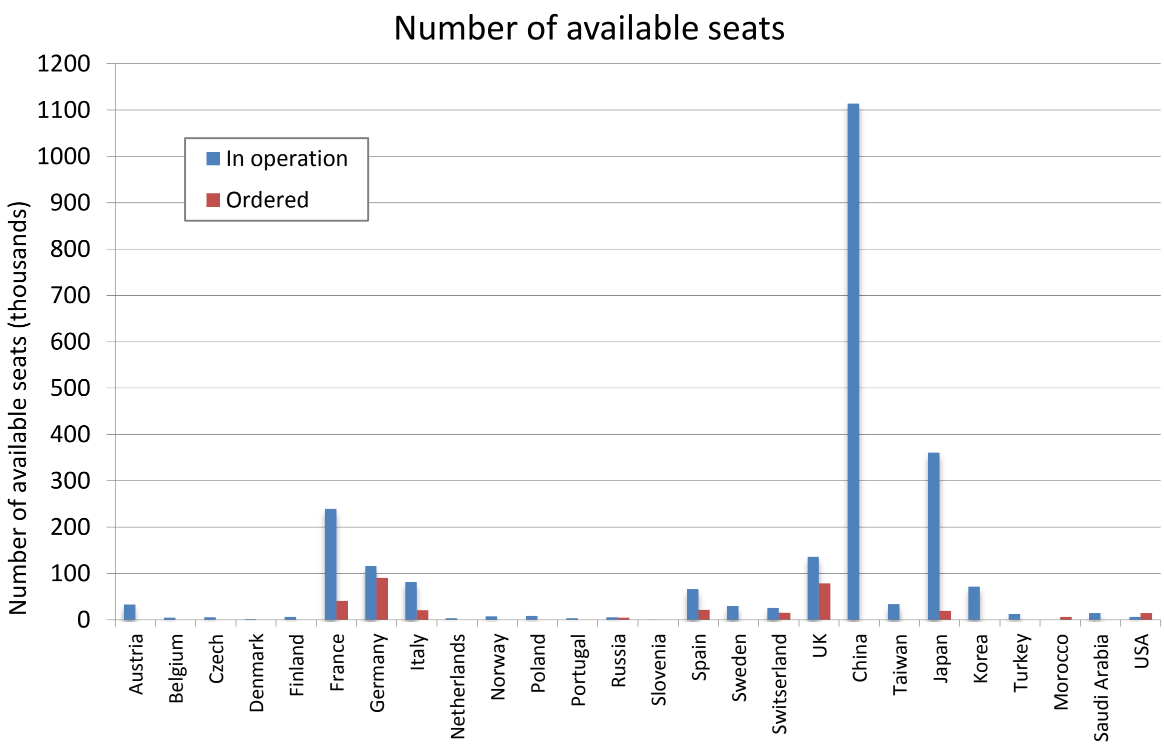

Figure A.9 - Available seat capacity in Europe, Asia and USA

Note: Figure based on data from: “World High Speed Rolling Stock” overview, UIC, 1 February 2017 (UIC 2017a)

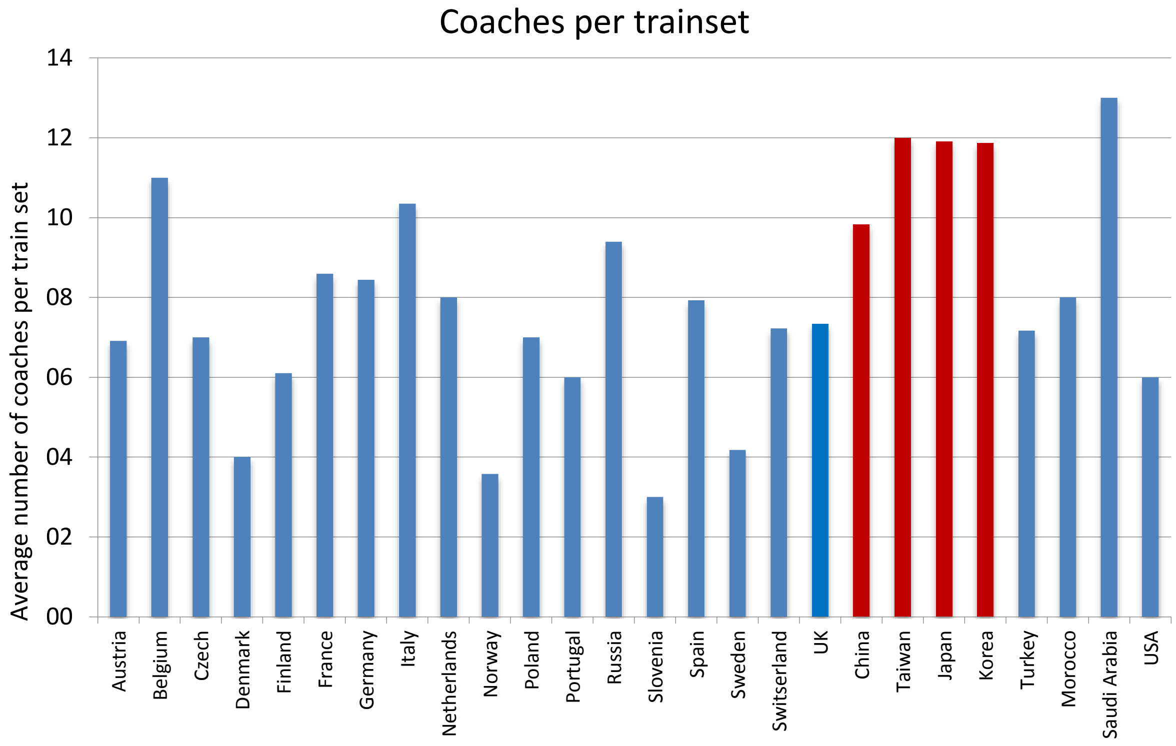

Figure A.10 - Composition of trainsets in Europe, Asia and USA

Note: Figure based on data from: “World High Speed Rolling Stock” overview, UIC, 1 February 2017 (UIC 2017a)

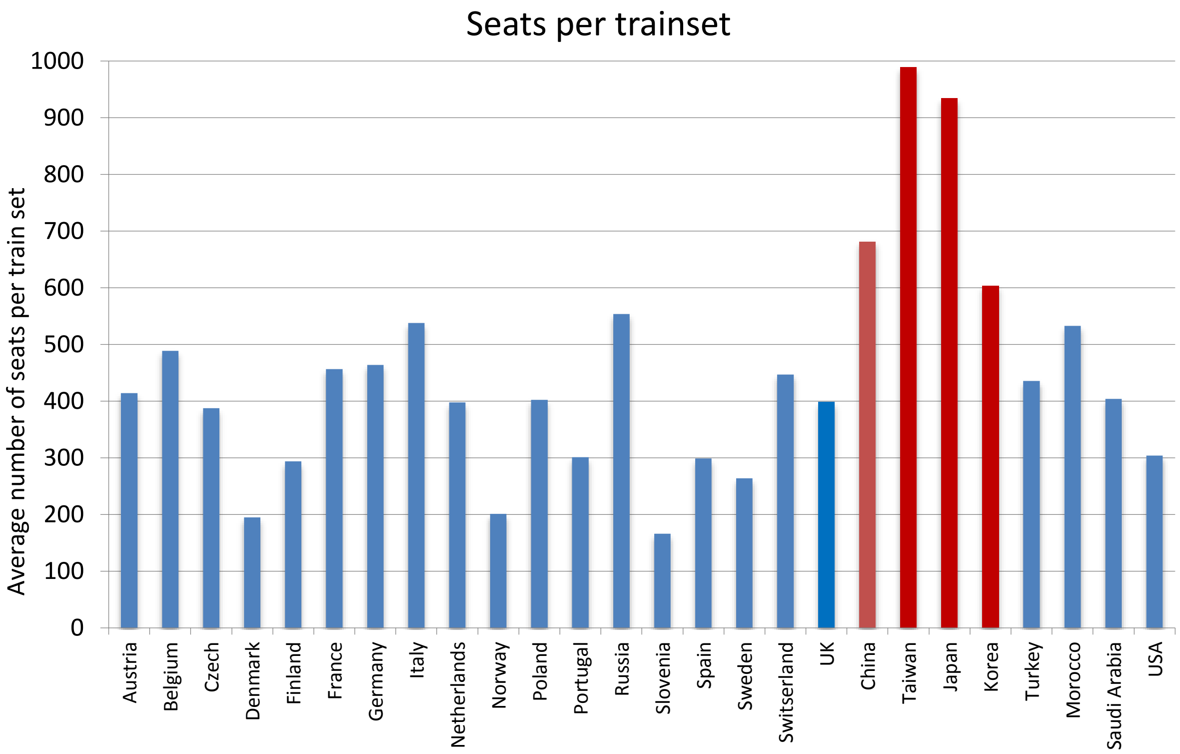

Figure A.11 - Train set capacity in Europe, Asia and USA

Note: Figure based on data from: “World High Speed Rolling Stock” overview, UIC, 1 February 2017 (UIC 2017a)

Table A.4 - High-speed rolling stock fleet in the world

Region	Country	Company	Class	Train set Formula	Number of coaches	Number of train sets	Total seats in train serie
Europe	Austria	ÖBB	Railjet	1L7T	7	69	28152
Europe	Austria	ÖBB	4011(ICE-T)	4M3T	7	3	1071
Europe	Austria	WestBahn	4010	2M4T	6	7	3507
Europe	Belgium	Eurostar	373, e300, TGV-TSMT	2L18T (+ 2MB)	18	3	2250
Europe	Belgium	SNCB	V250	4M4T	8	0	0
Europe	Belgium	Thalys	Thalys PBKA	2L8T	8	7	2639
Europe	Czech	CD	680 Pendolino	4M3T	7	7	2331
Europe	Czech	CD	Railjet	1L7T	7	7	3094
Europe	Denmark	DSB	605(ICE-TD)	4M	4	6	1170
Europe	Finland	Karelian Railways	Sm6	4M3T	7	2	704
Europe	Finland	VR		4M2T	6	18	5166
Europe	France	Eurostar	373, e300, TGV-TSMT	2L18T (+ 2MB)	18	12	9000
Europe	France	SNCF	373, TGV-TSMT	2L14T (+ 2MB)	4	7	3906
Europe	France	SNCF	TGV PSE (bic.)	2L8T (+ 2MB)	8	97	33756
Europe	France	SNCF	TGV PSE (tric.)	2L8T (+ 2MB)	8	0	0
Europe	France	SNCF	TGV Postal	2L8T (+ 2MB)	8	0	0
Europe	France	SNCF	TGV Atlantique	2L10T	10	105	50400
Europe	France	SNCF	TGV Réseau (bic.)	2L8T	8	33	12375
Europe	France	SNCF	TGV Réseau (tric.)	2L8T	8	27	10125
Europe	France	SNCF	TGV Duplex	2L8T	8	89	45568
Europe	France	SNCF	TGV Réseau Duplex	2L8T	8	19	9728
Europe	France	SNCF	TGV POS	2L8T	8	18	6426
Europe	France	SNCF	TGV Duplex Dasye	2L8T	8	52	26624
Europe	France	SNCF	TGV Duplex, RGV2N2 (tric.)	2L8T	8	30	15270
Europe	France	SNCF	TGV Duplex, RGV2N2 (bic.)	2L8T	8	16	8144
Europe	France	SNCF	TGV Océan	2L8T	8	4	2224
Europe	France	SNCF	IRIS320	2L8T	8	1	0
Europe	France	Thalys	Thalys PBA	2L8T	8	9	3393
Europe	France	Thalys	Thalys PBKA	2L8T	8	6	2262
Europe	Germany	DB AG	401(ICE1)	2L12T	12	59	41477
Europe	Germany	DB AG	402(ICE2)	1L7T	7	44	16192
Europe	Germany	DB AG	403(ICE3)	4M4T	8	50	21450
Europe	Germany	DB AG	406(ICE3M)	4M4T	8	7	2933
Europe	Germany	DB AG	406(ICE3MF)	4M4T	8	6	2478

Europe	Germany	DB AG	407(ICE3)	4M4T	8	17	7548
Europe	Germany	DB AG	411(ICE-T)	4M3T	7	27	9639
Europe	Germany	DB AG	411(ICE-T2)	4M3T	7	29	10904
Europe	Germany	DB AG	415(ICE-T)	3M2T	5	10	2500
Europe	Germany	DB AG	605(ICE-TD)	4M	4	0	0
Europe	Germany	DB AG	412 ICE4 (7-car)	3M4T	7	0	0
Europe	Germany	DB AG	412ICE4 (12-car)	5M5T	12	1	830
Europe	Germany	DB AG	ICE-S	2L1T	1	1	0
Europe	Italy	NTV	AGV575	EMU-11 (5MB7TB)	12	25	11250
Europe	Italy	NTV		4M3T	12	0	0
Europe	Italy	RFI	"Epsilon"	2L8T	8	2	0
Europe	Italy	Trenitalia	ETR450	8M1T	9	6	2340
Europe	Italy	Trenitalia	ETR460	6M3T	9	9	4320
Europe	Italy	Trenitalia	ETR470	6M3T	9	5	2375
Europe	Italy	Trenitalia	ETR480	6M3T	9	15	7200
Europe	Italy	Trenitalia	ETR500	2L12T	12	59	39589
Europe	Italy	Trenitalia	ETR600	4M3T	7	12	5184
Europe	Italy	Trenitalia	ETR610	4M3T	7	7	3010
Europe	Italy	Trenitalia	ETR1000	4M4T	7	13	5941
Europe	Netherlands	NS	406(ICE3M)	4M4T	8	4	1676
Europe	Netherlands	NS Hispeed	V250	4M4T	8	0	0
Europe	Netherlands	Thalys	Thalys PBKA	2L8T	8	4	1508
Europe	Norway	Flytoget	BM71	3M	3	16	2688
Europe	Norway	NSB	BM73	4M	4	22	4950
Europe	Poland	PKP Intercity	"Pendolino"	4M3T	7	20	8040
Europe	Portugal	CP	CPA4000	4M2T	6	10	3010
Europe	Russia	Karelian Railways	Sm6	4M3T	7	2	704
Europe	Russia	RZD	ER200	8M2T	10	0	0
Europe	Russia	RZD	"Sapsan" B1	4M6T	10	3	1812
Europe	Russia	RZD	"Sapsan" B2	4M6T	10	5	3020
Europe	Slovenia	SZ	ETR310	2M1T	3	3	498
Europe	Spain	ADIF	A330	2L3T	3	1	0
Europe	Spain	Renfe Operadora	S100 (bic.)	2L8T	8	14	4620
Europe	Spain	Renfe Operadora	S100 (tric.)	2L8T	8	10	3300
Europe	Spain	Renfe Operadora	S101	2L8T	8	0	0
Europe	Spain	Renfe Operadora	S102	2L12T	12	16	5024
Europe	Spain	Renfe Operadora	S103	4M4T	8	26	10478

Europe	Spain	Renfe Operadora	S104	4M	4	20	4720
Europe	Spain	Renfe Operadora	S105	4M (6M,8M)	4	1	250
Europe	Spain	Renfe Operadora	S106/S122	2L12T	12	0	0
Europe	Spain	Renfe Operadora	S112	2L12T	12	30	10950
Europe	Spain	Renfe Operadora	S114	4M	4	13	3081
Europe	Spain	Renfe Operadora	S120	4M	4	22	5214
Europe	Spain	Renfe Operadora	S121	4M	4	15	4200
Europe	Spain	Renfe Operadora	S130	2L11T	11	30	8940
Europe	Spain	Renfe Operadora	S730	2L11T, (Diesel 2T)	11	14	3640
Europe	Spain	Renfe Operadora	S490	2M1T	3	10	1600
Europe	Sweden	Arlanda Express	X3	2M2T	4	7	1330
Europe	Sweden	SJ	X2(X2000)	1L5T	5	7	1827
Europe	Sweden	SJ	X2(X2000)	1L6T	6	36	11124
Europe	Sweden	SJ	X40	2M	2	16	2880
Europe	Sweden	SJ	X40	3M	3	27	7776
Europe	Sweden	SJ	X55 (SJ 3000)	EMU-4	4	20	4900
Europe	Switzerland	SBB	TGV PSE (tric.)	2L8T (+ 2MB)	8	0	0
Europe	Switzerland	SBB	TGV POS	2L8T	8	1	357
Europe	Switzerland	SBB	ETR470	6M3T	9	4	1900
Europe	Switzerland	SBB	ETR610	4M3T	7	7	2954
Europe	Switzerland	SBB	RABDe500(ICN)	4M3T	7	44	19844
Europe	Switzerland	SBB	Girumo (EC250)	4M7T	11	1	405
Europe	UK	CC, EC, EM, FGW, GC, V	IC125	2L7T, 2L8T	8	80	37760
Europe	UK	Cross Country	220	4M	4	34	6392
Europe	UK	Cross Country, Virgin	221	4M	4	4	752
Europe	UK	Cross Country, Virgin	221	5M	5	40	10000
Europe	UK	East Coast	IC225	1L9T	9	30	14160
Europe	UK	East Midlands	222	4M	4	4	1368
Europe	UK	East Midlands	222	5M	5	17	5814
Europe	UK	East Midlands	222	7M	7	6	2052
Europe	UK	EC, GC, HT, NR	180	5M	5	14	3752
Europe	UK	Eurostar	373, e300, TGV-TSMT	2L18T (+ 2MB)	18	11	8250
Europe	UK	Eurostar	374 e320	8M8T	16	10	8940
Europe	UK	GreatWestern	802	3M2T	5		0
Europe	UK	GreatWestern	802	9-cars	9		0
Europe	UK	IEP (GreatWestern, EastCoast mainline)	800	3M2T	5	6	1890
Europe	UK	IEP (GreatWestern, EastCoast mainline)	800	9-cars	9		0

Europe	UK	IEP(East Coast mainline)	801	3M2T	5		0
Europe	UK	IEP(East Coast mainline)	801	9-cars	9		0
Europe	UK	Southeastern	395	4M2T	6	29	10092
Europe	UK	Virgin	390	6M3T	9	56	24584
Asia	China	CR	CRH1A	5M3T	8	128	81920
Asia	China	CR	CRH1B	10M6T	16	25	32525
Asia	China	CR	CRH1E	10M6T	16	15	9300
Asia	China	CR	CRH2A	4M4T	8	313	190930
Asia	China	CR	CRH2B	8M8T	16	10	12290
Asia	China	CR	CRH2C	6M2T	8	60	36600
Asia	China	CR	CRH2E	8M8T	16	20	12400
Asia	China	CR	CRH2G	4M4T	8	1	613
Asia	China	CR	CRH3C	4M4T	8	80	44480
Asia	China	CR	CRH5A	5M3T	8	141	85164
Asia	China	CR	CRH5G	5M3T	8	26	15704
Asia	China	CR	CRH6A	4M4T	8	1	1488
Asia	China	CR	CRH380A	6M2T	8	186	89280
Asia	China	CR	CRH380AL	14M2T	16	100	102700
Asia	China	CR	CRH380B	4M4T	8	173	103800
Asia	China	CR	CRH380BL	8M8T	16	115	117990
Asia	China	CR	CRH380BG	4M4T	8	131	78600
Asia	China	CR	CRH380CL	8M8T	16	25	25100
Asia	China	CR	CRH380D	4M4T	8	16	7920
Asia	China	CR	CRH380DL	8M8T	16	60	60780
Asia	China	CR	CIT001	5M3T	8	1	0
Asia	China	CR	CIT400A	7M1T	8	1	0
Asia	China	CR	CIT400B	6M2T	8	1	0
Asia	China	MTR	CRH380AH	6M2T	8	9	4320
Asia	Japan	JRC	300	10M6T	16	0	0
Asia	Japan	JRC	700	12M4T	16	32	42336
Asia	Japan	JRC	N700-2000, N700-3000, N700-5000	14M2T	16	100	132300
Asia	Japan	JRC	923	6M1T	7	1	0
Asia	Japan	JRE	200	10M	10	0	0
Asia	Japan	JRE	400	6M1T	7	0	0
Asia	Japan	JRE	E1	6M6T	12	0	0
Asia	Japan	JRE	E2	6M2T	8	1	630
Asia	Japan	JRE	E2-1000	8M2T	10	25	20350

Asia	Japan	JRE	E3	4M2T	6	2	676
Asia	Japan	JRE	E3-700	4M2T	6	1	143
Asia	Japan	JRE	E3-700	4M2T	6	1	143
Asia	Japan	JRE	E3-1000	5M2T	7	3	1206
Asia	Japan	JRE	E3-2000	5M2T	7	12	4728
Asia	Japan	JRE	E4	4M4T	8	24	19608
Asia	Japan	JRE	E5	8M2T	10	33	24123
Asia	Japan	JRE	E6	5M2T	7	24	8112
Asia	Japan	JRE	E7	10M2T	12	18	16812
Asia	Japan	JRE	E926	5M1T	6	1	0
Asia	Japan	JRH	H5	8M2T	10	4	2924
Asia	Japan	JRK	N700-8000	8M	8	11	6006
Asia	Japan	JRK	800	4M2T	6	6	2352
Asia	Japan	JRK	800-1000, 800-2000	4M2T	6	3	1152
Asia	Japan	JRW	0	6M	6	0	0
Asia	Japan	JRW	100	6M	6	0	0
Asia	Japan	JRW	300-3000	10M6T	16	0	0
Asia	Japan	JRW	500	16M	16	0	0
Asia	Japan	JRW	500-7000	8M	8	8	4864
Asia	Japan	JRW	700-3000	12M4T	16	15	19845
Asia	Japan	JRW	700-7000	6M2T	8	16	9136
Asia	Japan	JRW	N700-3000, N700-4000, N700-5000	14M2T	16	17	22491
Asia	Japan	JRW	N700-7000	8M	8	19	10374
Asia	Japan	JRW	W7	10M2T	12	11	10274
Asia	Japan	JRW	923-3000	6M1T	7	1	0
Asia	Korea	KORAIL	KTX	2L18T (+ 2MB)	18	46	43010
Asia	Korea	KORAIL	KTX-Sancheon	2L8T	8	24	8712
Asia	Korea	KORAIL	KTX-Honam	2L8T	8	22	9020
Asia	Korea	KORAIL	KTX-Wongang	2L8T	8	15	6150
Asia	Korea	SR	SRT-Suseo	2L8T	8	12	4920
Asia	Taiwan	THSRC	700T	9M3T	12	34	33626
Asia	Turkey	TCDD	HT65000	4M2T	6	12	5028
Asia	Turkey	TCDD	HT80000	4M4T	8	17	7599
North America	USA	Amtrak	Acela	2L6T	6	20	6080
North America	USA	Amtrak	Acela II	2L10T	10	0	0
Rest	Morocco	ONCF	RGV-M	2L8T	8	0	0
Rest	Saudi Arabia	Haramain HSR	Talgo 350	2L13T	13	36	14544

Note: Table based on data from: "World High Speed Rolling Stock" overview, UIC, 1 February 2017 (UIC 2017a)

Table A.2 – Interoperable trains in Europe

Country	Company	Class	Train set Formula	Number of train sets	Year in Service	Number of train sets	Year in Service	Interoperability
Austria	ÖBB	Railjet	1L7T	69	2008-			Czech, Germany, Hungary, Italy
Belgium	Eurostar	373, e300, TGV-TSMT	2L18T (+ 2MB)	3	1993-			France, UK
Belgium	Thalys	Thalys PBKA	2L8T	7	1996-			France, Germany, Netherlands, UK
Czech Republic	CD	680 Pendolino	4M3T	7	2003-			Slovakia, Austria
Czech Republic	CD	Railjet	1L7T	7	2014-			Austria, Germany
France	Eurostar	373, e300, TGV-TSMT	2L18T (+ 2MB)	12	1993-			Belgium, UK
France	SNCF	373, TGV-TSMT	2L14T (+ 2MB)	7	1993-			Belgium, UK
France	SNCF	TGV Réseau (tric.)	2L8T	27	1993-			Belgium, Italy
France	SNCF	TGV Réseau Duplex	2L8T	3	2006-			Germany
France	SNCF	TGV POS	2L8T	18	2006-			Switzerland
France	SNCF	TGV Duplex, RGV2N2 (tric.)	2L8T	30	2011-			Germany, Switzerland
France	SNCF	TGV Duplex, RGV2N2 (bic.)	2L8T	10	2013-		2017-	Spain
France	Thalys	Thalys PBA	2L8T	9	1996-			Belgium, Netherlands
France	Thalys	Thalys PBKA	2L8T	6	1996-			Belgium, Germany, Netherlands
Germany	DB AG	406(ICE3M)	4M4T	7	2000-			Belgium, Netherlands, Switzerland
Germany	DB AG	406(ICE3MF)	4M4T	6	2000-			Belgium, France, Netherlands, Switzerland
Germany	DB AG	407(ICE3)	4M4T	17	2014-			France
Germany	DB AG	412 ICE4 (7-car)	3M4T	0		45	2017-	France
Italy	Trenitalia	ETR470	6M3T	5	1996-			Switzerland
Italy	Trenitalia	ETR610	4M3T	7	2009-			Switzerland
Italy	Trenitalia	ETR1000	4M4T	13	2015-	37	2017-	France, Switzerland, Germany, Spain, Belgium, Netherlands
Netherlands	NS	406(ICE3M)	4M4T	4	2000-			Belgium, Germany, Switzerland
Netherlands	Thalys	Thalys PBKA	2L8T	4	1996-			Belgium, France, Germany
Spain	Renfe	S100 (tric.)	2L8T	10	1992-			France
Spain	Renfe	S105	4M (6M,8M)	1	2016-			
Spain	Renfe	S106/S122	2L12T	0		30	2020-	France
Spain	Renfe	S112	2L12T	10	2010-			France
Switzerland	SBB	TGV POS	2L8T	1	2006-			France
Switzerland	SBB	ETR470	6M3T	4	1996-			Italy
Switzerland	SBB	ETR610	4M3T	7	2009-	8	2017-	Italy
Switzerland	SBB	Giruno (EC250)	4M7T	1	2016-	28	2019-	Italy
UK	Eurostar	373, e300, TGV-TSMT	2L18T (+ 2MB)	11	1993-			Belgium, France
UK	Eurostar	374 e320	8M8T	10	2015-	7	2017-	Belgium, France, Netherlands
				333		**155**		

Note: Table based on data from: "World High Speed Rolling Stock" overview, UIC, 1 February 2017 (UIC 2017a)

Appendix D: High-speed train performance

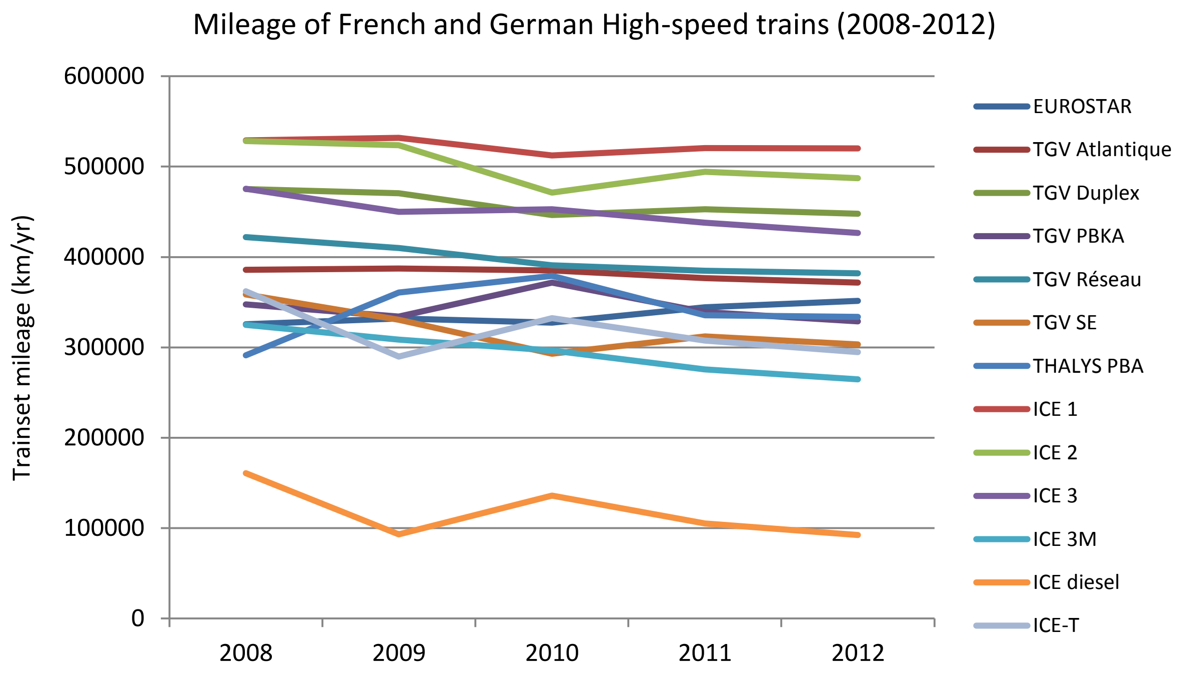

Figure A.12 - Mileage of French and German high-speed trains (2008-2012)

Table A.5 - Number of trainsets (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	409	406	422	435	450	463	475
Germany	DB AG	257	254	254	254	254	255	255
Italy	FS SpA	97	97	109	108	110	110	110
Spain	Renfe	106	136	162	162	162	203	193
Japan	JR Central	121	128	133	133	133	131	133
Japan	JR East	132	131	134	134	137	137	130
Japan	JR West	90	89	90	94	96	99	83
Japan	JR Kyushu	6	6	6	6	9	19	19
Korea	KORAIL	46	46	46	52	61	65	68
China	CRH	27	113	191	279	466	551	632
Taiwan	THSRC	0	30	30	30	30	30	30
		1,291	1,436	1,577	1,687	1,908	2,063	2,128
Japan	JR All	349	354	363	367	375	386	365

Table A.6 - Number of available seats (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	180,511	181,215	189,407	196,063	203,743	209,913	216,381
Germany	DB AG	114,106	113,008	113,008	113,008	113,008	113,374	113,374
Italy	FS SpA	56,569	56,569	61,801	61,321	62,233	62,233	62,233
Spain	Renfe	29,098	37,494	47,972	48,020	48,020	61,706	58,986
Japan	JR Central	160,083	169,344	175,959	175,959	175,959	173,313	175,959
Japan	JR East	88,950	88,188	89,105	89,637	92,298	92,298	84,126
Japan	JR West	81,075	80,675	89,552	95,773	96,845	95,831	83,023
Japan	JR Kyushu	2,334	2,334	2,334	2,334	3,501	8,961	8,961
Korea	KORAIL	43,010	43,010	43,010	45,188	48,455	49,907	50,815
China	CRH	16,934	70,762	128,014	186,279	306,869	383,359	455,429
Taiwan	THSRC	0	29,670	29,670	29,670	29,670	29,670	29,670
		772,670	**872,269**	**969,832**	**1,043,252**	**1,180,601**	**1,280,565**	**1,338,957**
Japan	JR All	332,442	340,541	356,950	363,703	368,603	370,403	352,069

Table A.7 - Number of trainset-kilometers (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	397,154	397,608	405,226	399,432	382,674	386,737	383,882
Germany	DB AG	427,759	429,832	432,230	402,066	402,753	395,544	387,071
Italy	FS SpA	480,206	482,742	416,468	435,194	433,864	442,918	437,255
Spain	Renfe	437,887	357,787	341,123	360,685	355,531	288,429	298,601
Japan	JR Central	440,050	424,969	427,692	436,338	428,722	432,176	428,917
Japan	JR East	294,674	297,794	290,627	279,940	264,569	272,577	308,200
Japan	JR West	421,444	434,258	433,844	421,968	393,292	401,030	473,024
Japan	JR Kyushu	513,333	521,000	519,667	519,500	363,556	478,211	492,737
Korea	KORAIL	448,222	465,541	474,358	423,709	382,682	426,211	438,473
China	CRH	0	353,982	277,487	311,828	390,558	453,721	474,684
Taiwan	THSRC	0	264,200	508,567	499,567	515,533	531,900	533,500
		402,120	**397,364**	**386,504**	**381,539**	**385,182**	**399,225**	**412,743**
Japan	JR All	381,527	381,870	380,140	376,913	358,117	369,808	399,274

Table A.8 - Millions of train-kilometers (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	162.4	161.4	171.0	173.8	172.2	179.1	182.3
Germany	DB AG	109.9	109.2	109.8	102.1	102.3	100.9	98.7
Italy	FS SpA	46.6	46.8	45.4	47.0	47.7	48.7	48.1
Spain	Renfe	46.4	48.7	55.3	58.4	57.6	58.6	57.6
Japan	JR Central	53.2	54.4	56.9	58.0	57.0	56.6	57.0
Japan	JR East	38.9	39.0	38.9	37.5	36.2	37.3	40.1
Japan	JR West	37.9	38.6	39.0	39.7	37.8	39.7	39.3
Japan	JR Kyushu	3.1	3.1	3.1	3.1	3.3	9.1	9.4
Korea	KORAIL	20.6	21.4	21.8	22.0	23.3	27.7	29.6
China	CRH	0.0	40.0	53.0	87.0	182.0	250.0	300.0
Taiwan	THSRC	0.0	7.9	15.3	15.0	15.5	16.0	16.0
		519.1	570.6	609.5	643.7	734.9	823.6	878.1
Japan	JR All	133.2	135.2	138.0	138.3	134.3	142.7	145.7

Table A.9 - Billions of seat-kilometers (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	71.7	72.1	76.8	78.3	78.0	81.2	83.1
Germany	DB AG	48.8	48.6	48.8	45.4	45.5	44.8	43.9
Italy	FS SpA	27.2	27.3	25.7	26.7	27.0	27.6	27.2
Spain	Renfe	12.7	13.4	16.4	17.3	17.1	17.8	17.6
Japan	JR Central	70.4	72.0	75.3	76.8	75.4	74.9	75.5
Japan	JR East	26.2	26.3	25.9	25.1	24.4	25.2	25.9
Japan	JR West	34.2	35.0	38.9	40.4	38.1	38.4	39.3
Japan	JR Kyushu	1.2	1.2	1.2	1.2	1.3	4.3	4.4
Korea	KORAIL	19.3	20.0	20.4	19.1	18.5	21.3	22.3
China	CRH	0.0	25.0	35.5	58.1	119.9	173.9	216.2
Taiwan	THSRC	0.0	7.8	15.1	14.8	15.3	15.8	15.8
		311.7	**348.7**	**379.9**	**403.3**	**460.5**	**525.2**	**571.2**
Japan	JR All	132.0	134.5	141.2	143.5	139.2	142.8	145.1

Table A.10 - Occupancy rate (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	0.625	0.666	0.680	0.662	0.677	0.666	0.651
Germany	DB AG	0.443	0.451	0.478	0.496	0.528	0.515	0.553
Italy	FS SpA	0.328	0.339	0.362	0.424	0.425	0.511	0.527
Spain	Renfe	0.651	0.619	0.620	0.596	0.596	0.606	0.589
Japan	JR Central	0.632	0.647	0.612	0.556	0.580	0.591	0.622
Japan	JR East	0.739	0.759	0.745	0.723	0.723	0.732	0.776
Japan	JR West	0.444	0.455	0.409	0.367	0.408	0.439	0.437
Japan	JR Kyushu	0.344	0.353	0.351	0.318	0.387	0.423	0.402
Korea	KORAIL	0.507	0.492	0.490	0.516	0.584	0.629	0.632
China	CRH		0.519	0.718	0.797	0.544	0.564	0.669
Taiwan	THSRC		0.449	0.435	0.463	0.490	0.516	0.546
		0.555	**0.564**	**0.577**	**0.584**	**0.564**	**0.577**	**0.625**
Japan	JR All	0.602	0.616	0.578	0.530	0.556	0.570	0.593

Table A.11 - Millions of passenger-kilometers (2006-2012)

Country	Operator	2006	2007	2008	2009	2010	2011	2012
France	SNCF	44,817	47,963	52,225	51,865	52,784	54,038	54,035
Germany	DB AG	21,635	21,919	23,333	22,561	23,903	23,306	24,753
Italy	FS SpA	8,912	9,248	9,313	11,327	11,476	14,093	14,341
Spain	Renfe	8,468	8,466	10,491	10,788	10,423	10,462	10,416
Japan	JR Central	44,487	46,540	46,044	42,685	43,741	44,303	46,930
Japan	JR East	19,375	19,925	19,302	18,152	17,651	18,425	20,119
Japan	JR West	15,164	15,932	15,887	14,818	15,547	16,878	17,171
Japan	JR Kyushu	413	430	426	385	493	1,814	1,774
Korea	KORAIL	9,782	9,854	9,994	9,876	10,823	13,375	14,083
China	CRH	0	13,000	25,500	46,300	65,200	98,100	144,600
Taiwan	THSRC	0	3,520	6,566	6,864	7,491	8,148	8,642
		173,053	196,796	219,081	235,621	259,531	302,942	356,863
Japan	JR All	79,439	82,826	81,659	76,040	77,431	81,420	85,994

Appendix E: Performance benchmark of six Asian HSR operators

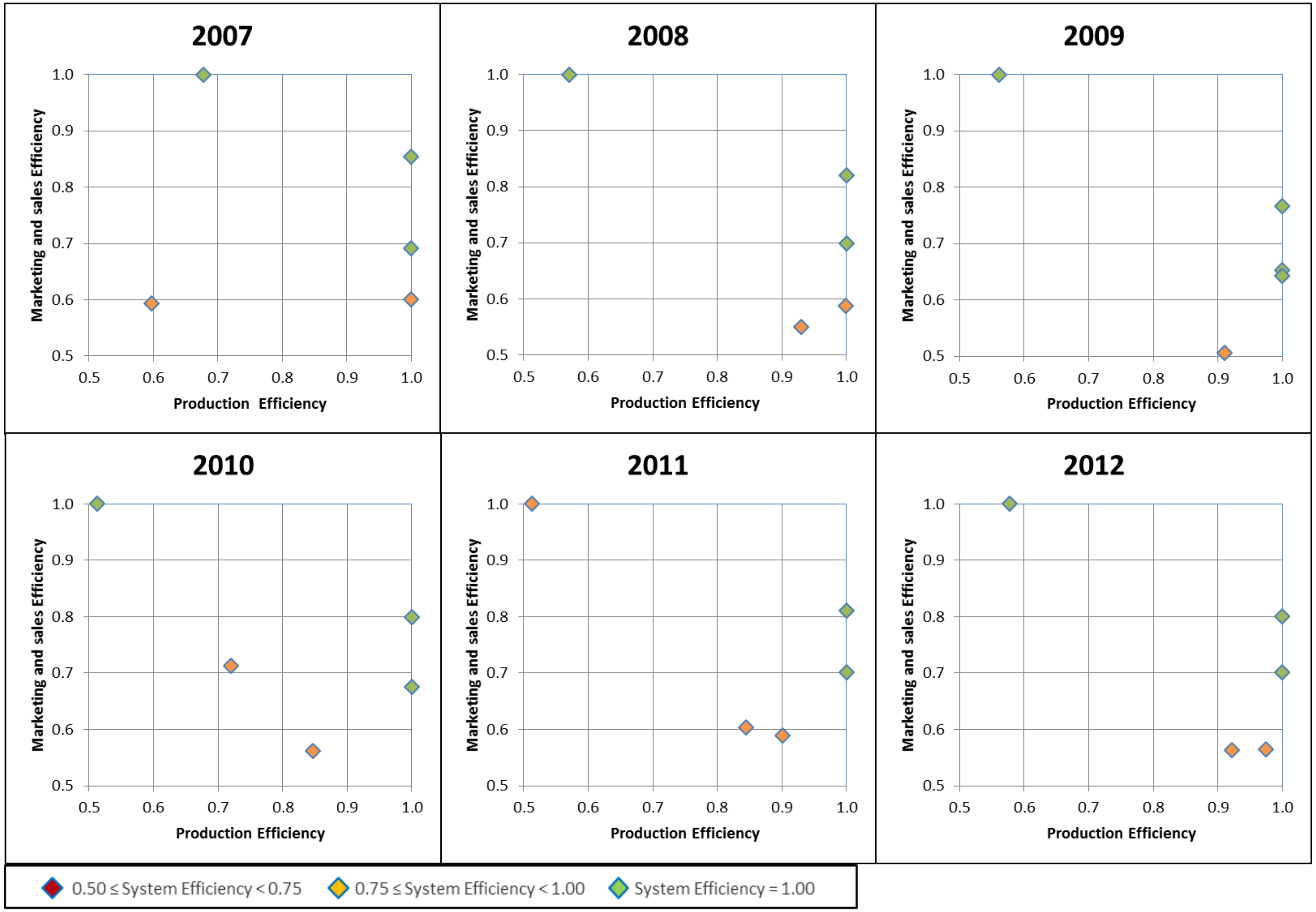

Figure A.13 - Performance per year of selected Asian HSR operators (2007-2012)

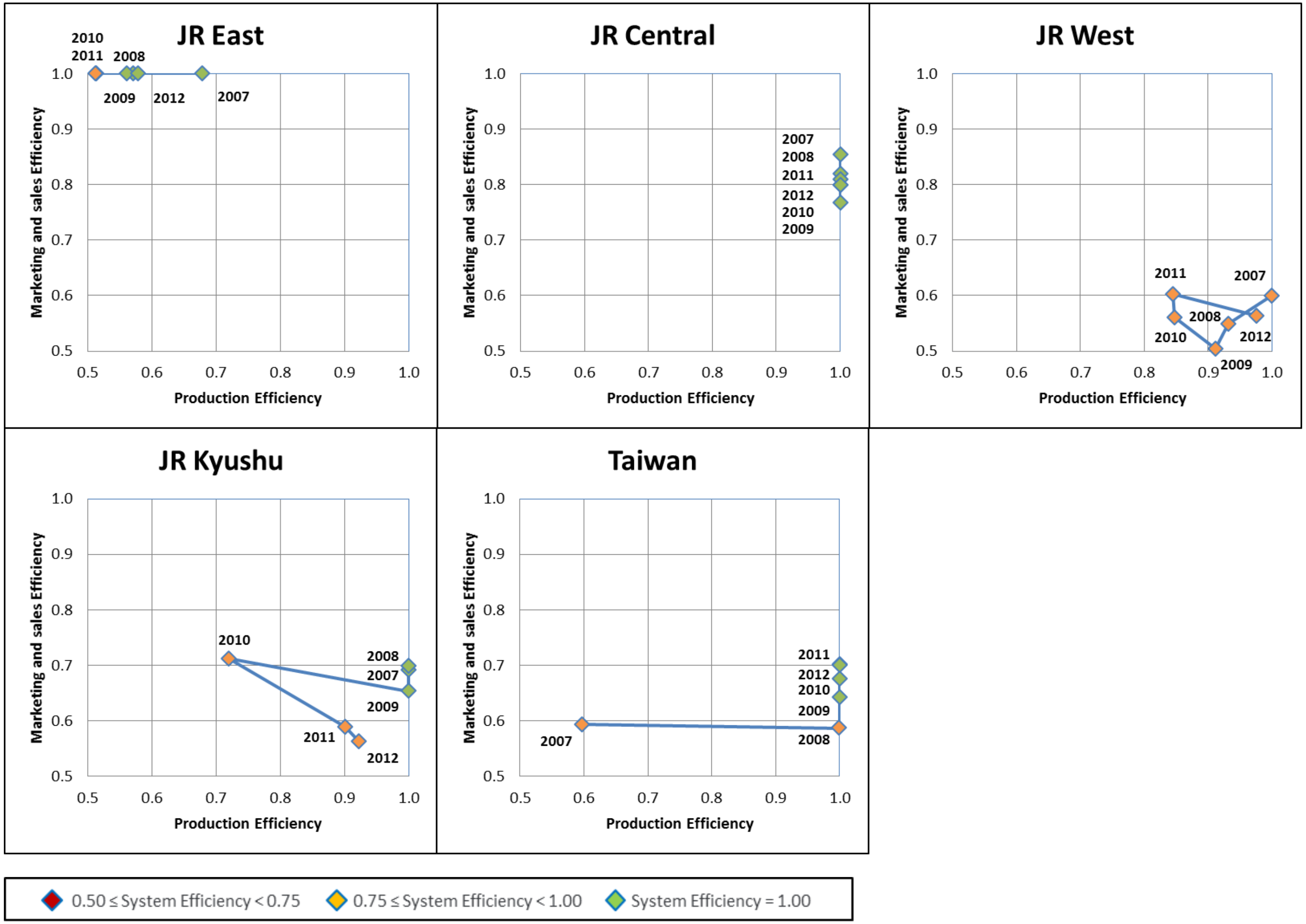

Figure A.14 - Performance of selected HSR Asian operator (2007-2012)

Appendix F: Calibration and simulation algorithm

For the calibration process, we follow the procedure as described by Ivaldi and Vibes (2008) based on the available data for market shares, prices, marginal costs and quality attributes. As a result, the demand parameters h and σ and the coefficients for the quality parameters are recovered.

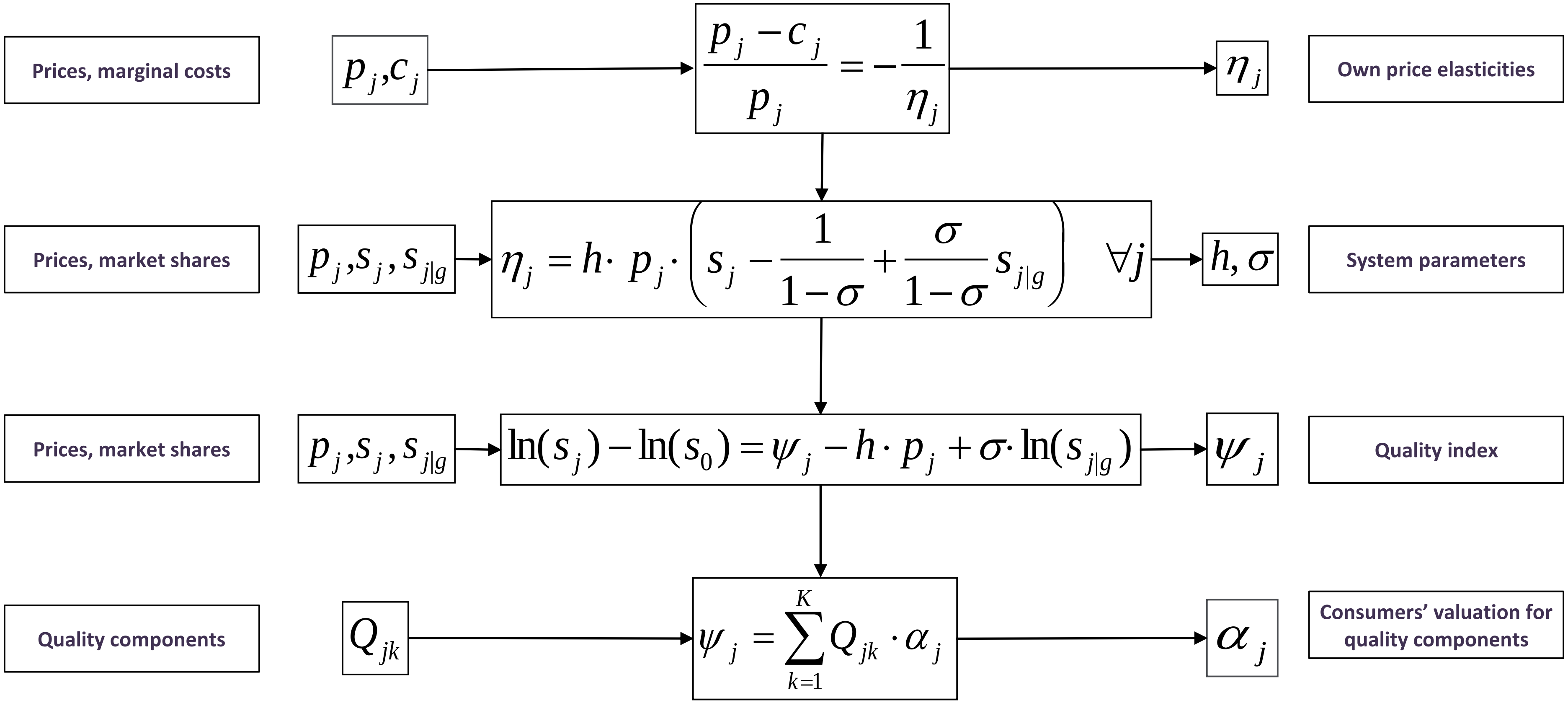

Figure A.15 - Calibration procedure

Market simulations can be run by an iterative process starting from the calibrated demand and supply parameters. First step is to define the scenarios to be studied and to translate the calibrated values into the simulation start values. The iterative process runs until the difference between successive calculated market shares is less than 0.1%.

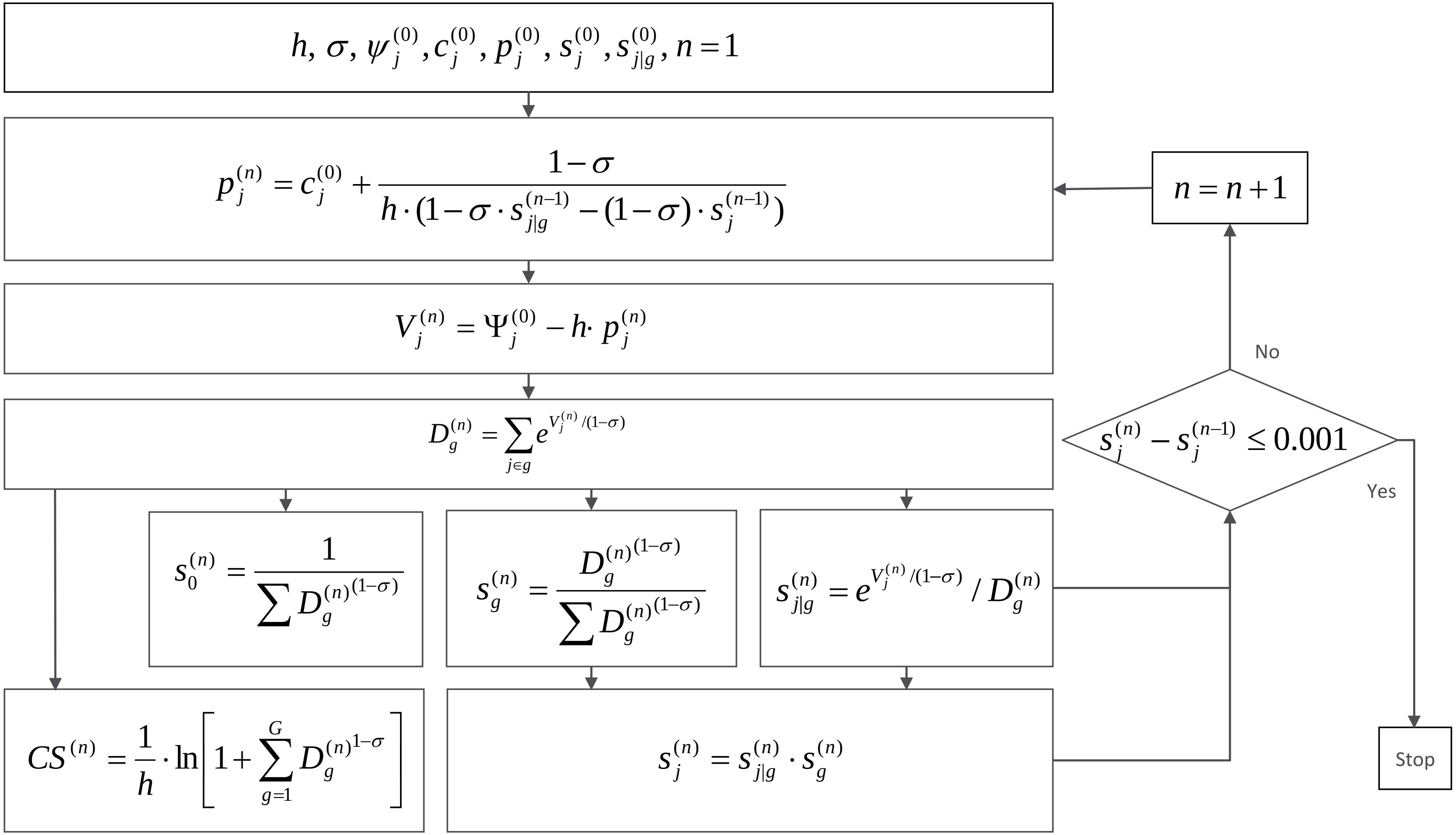

Figure A.16 - Simulation procedure

Appendix G: Validation results

As marginal costs for the business market are not available, the demand parameters for this segment are recovered by running a Monte Carlo simulation as described by Ivaldi (2008). The mean values for the elasticity distribution for the three modalities were set according to the average values as given by Oum et al (1990): -0.65 for Rail, -0.80 for Air and -0.60 for Car and the standard deviation was set to 2.8 to fit the results obtained by Ivaldi (2008).[54] The same mean values are used for the Rome-Milan route, but with a standard deviation of 4.0 (Mancuso 2014).

Table A.12 - Equilibrium outcomes

			Business			Leisure		
Share outside alternative (%)			15	30	60	15	30	60
Market shares (%)								
	Rail	DB	14.4	11.8	6.8	47.9	39.5	22.6
	Air	DBA	15.6	12.9	7.4	6.0	5.0	2.8
		HLX	14.5	12.0	6.8	5.6	4.6	2.6
		GW	8.7	7.1	4.1	3.3	2.7	1.6
		LH	15.1	12.5	7.1	5.9	4.8	2.8
	Car	Car	16.7	13.7	7.8	16.2	13.4	7.6
	Outside alternative		15.0	30.0	60.0	15.0	30.0	60.0
Marginal utility of income:			0.024	0.022	0.020	0.040	0.034	0.027
Within group correlation coefficient:			0.15	0.16	0.18	0.20	0.33	0.48
Own price elasticities								
	Rail	DB	-1.82	-1.78	-1.72	-1.25	-1.25	-1.26
	Air	DBA	-3.86	-3.80	-3.73	-2.29	-2.28	-2.27
		HLX	-3.92	-3.85	-3.76	-2.11	-2.10	-2.10
		GW	-4.23	-4.11	-3.94	-2.18	-2.19	-2.21
		LH	-5.52	-5.42	-5.31	-2.40	-2.39	-2.38
	Car	Car	-2.17	-2.13	-2.07	-2.67	-2.39	-2.00
Consumer surplus:			80.1	53.7	25.0	47.5	34.9	18.9

Note 1: DB: Deutsche Bahn, DBA: Deutsche BA, HLX: Hapag-Lloyd Express, GW: German Wings, LH: Lufthansa
Note 2: Compare with Ivaldi and Vibes, 2008, Table 2a

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[54] In the appendix of their paper describing the calibration algorithm for the business market, Ivaldi and Vibes state a mean value of -3.2 and a standard deviation of 4.0 for each alternative. With these values their results cannot be reproduced.

Table A.13 - Cross Price Elasticities of Demand

Share outside alternative (%)		Business 15					
		DB	DBA	HLX	GW	LH	Car
Cross price elasticities							
Rail	DB	-1.82	0.63	0.58	0.35	0.86	0.43
Air	DBA	0.31	-3.86	0.77	0.46	1.13	0.43
	HLX	0.31	0.82	-3.92	0.46	1.13	0.43
	GW	0.31	0.82	0.77	-4.23	1.13	0.43
	LH	0.31	0.82	0.77	0.46	-5.52	0.43
Car	Car	0.31	0.63	0.58	0.35	0.86	-2.17

Share outside alternative (%)		Leisure 30					
		DB	DBA	HLX	GW	LH	Car
Cross price elasticities							
Rail	DB	-1.25	0.09	0.07	0.04	0.09	0.37
Air	DBA	0.82	-2.28	0.28	0.17	0.34	0.37
	HLX	0.82	0.33	-2.10	0.17	0.34	0.37
	GW	0.82	0.33	0.28	-2.19	0.34	0.37
	LH	0.82	0.33	0.28	0.17	-2.39	0.37
Car	Car	0.82	0.09	0.07	0.04	0.09	-2.39

Note 1: DB: Deutsche Bahn, DBA: Deutsche BA, HLX: Hapag-Lloyd Express, GW: German Wings, LH: Lufthansa
Note 2 : Compare with Ivaldi and Vibes, 2008, Table 2b

Table A.14 - Calibration of the Quality Index and its components

		Business			Leisure		
Share outside alternative (%)		15	30	60	15	30	60
Quality mode ranking							
Rail	DB	2.09	1.09	-0.34	3.56	2.34	0.65
Air	DBA	4.22	3.13	1.58	1.39	0.37	-1.06
	HLX	4.16	3.07	1.52	1.15	0.17	-1.22
	GW	3.72	2.64	1.09	0.71	-0.21	-1.51
	LH	5.88	4.70	3.00	1.45	0.43	-1.02
Car	Car	2.71	1.68	0.21	3.27	1.95	0.11
Quality characteristics							
DB Dummy		-25.11	-24.57	-23.68	-17.24	-14.20	-10.25
LCA Dummy		-8.52	-5.94	-2.24	-12.11	-8.14	-2.66
LH Dummy		-6.25	-3.77	-0.22	-11.64	-7.75	-2.36
Speed		1.33	0.80	0.03	1.65	0.97	0.02
1/Frequency		-6.16	-6.08	-5.94	-6.95	-5.92	-4.55
Capacity		0.03	0.03	0.03	0.02	0.02	0.02

Note: Compare with Ivaldi and Vibes, 2008, Table 3

Table A.15 - Simulation of the entry of a Low-cost Train (Business and Leisure market)

Share outside alternative (%):			Business 15		Business 30		Business 60	
Prices (€):			Value	Change	Value	Change	Value	Change
	Rail	DB	84.1	-6.6	84.0	-6.6	83.9	-6.8
		New train	76.2		76.2		76.0	
	Air	DBA	168.0	-0.6	168.3	-0.4	168.8	-0.1
		HLX	168.1	-0.6	168.4	-0.4	168.8	-0.1
		GW	168.5	-0.3	168.6	-0.2	168.9	-0.1
		LH	239.0	-0.4	239.3	-0.3	239.8	-0.1
	Car	Car	108.6	-1.3	109.1	-0.9	109.7	-0.3
Market shares (%):			Value	Change	Value	Change	Value	Change
	Rail	DB	12.2	-15.1	10.3	-12.9	6.2	-8.9
		New train	15.2		12.7		7.5	
	Air	DBA	13.3	-14.8	11.3	-12.2	6.8	-7.1
		HLX	12.4	-15.0	10.5	-12.3	6.4	-7.1
		GW	7.3	-16.0	6.2	-13.0	3.8	-7.3
		LH	12.9	-14.9	10.9	-12.3	6.6	-7.1
	Car	Car	14.3	-14.1	12.1	-11.7	7.3	-6.9
	Outside alternative		12.5	-16.9	25.9	-13.6	55.5	-7.5
Consumer surplus:			88.0	6.6	60.2	10.1	28.8	18.4

Share outside alternative (%):			Leisure 15		Leisure 30		Leisure 60	
Prices (€):			Value	Change	Value	Change	Value	Change
	Rail	DB	63.4	5.6	48.3	-19.4	41.0	-31.7
		New train	63.6		47.1		39.3	
	Air	DBA	50.6	-1.2	50.8	-0.7	51.1	-0.2
		HLX	46.1	-1.2	46.4	-0.7	46.6	-0.2
		GW	45.8	-0.7	45.9	-0.4	46.1	-0.1
		LH	52.8	-1.1	53.1	-0.6	53.3	-0.2
	Car	Car	77.5	-3.2	78.1	-2.4	79.2	-0.9
Market shares (%):			Value	Change	Value	Change	Value	Change
	Rail	DB	36.7	-23.5	31.5	-20.1	19.9	-11.8
		New train	37.7		33.3	0.0	21.7	
	Air	DBA	2.9	-51.6	2.9	-42.2	2.1	-24.6
		HLX	2.7	-51.7	2.7	-42.3	2.0	-24.6
		GW	1.6	-52.3	1.6	-42.7	1.2	-24.8
		LH	2.8	-51.7	2.8	-42.2	2.1	-24.6
	Car	Car	8.5	-47.7	8.1	-39.1	5.9	-23.2
	Outside alternative		7.1	-52.8	17.1	-42.9	45.1	-24.8
Consumer surplus:			66.4	39.6	51.2	46.6	29.4	55.8

Note 1: Compare with Ivaldi and Vibes, 2008, Table 5

Note 2: Change in %

Appendix H: UK International Passenger Survey (IPS)

The UK Office for National Statistics conducts the International Passenger Survey (IPS). The IPS is a continuous survey of international passengers conducted at all major ports and routes into the UK. The yearly dataset contains approximately 250,000 records of people interviewed. It has been running since 1961[55]. The IPS is used to collect data on traffic volumes, market shares, prices and fares for leisure and business travellers to and from the UK. It provides information on trip characteristics (departure airport/station, arrival airport/station, carrier, fare, ticket type and trip purpose), traveller characteristics (age, gender, country of residence) and passenger categories (UK and overseas residents leaving from and arriving in the UK by air, rail and sea). Data is analysed using IBM SPSS Statistics version 22 over the years 2008 till 2015 in two subsequent processes: i) The selection process to reduce the dataset by filtering out all irrelevant data (result in table A.16) and ii) The analysis process (table A.17) to obtain the data needed for the econometric model.

H.1 Selection process

In the first step, variables and codes are checked to prevent errors in the selection. In step 2, a distinction is made between air and tunnel/sea transport modes. In step 3, the London airports (Heathrow, Gatwick, Luton, City and Stansted), the high-speed train stations (St. Pancras, Ebsfleet and Ashford) and the Eurotunnel Folkestone Terminal in Cheriton are selected. For the destination ports, the airports Paris CDG and Paris Orly, the seaport of Calais and the Eurotunnel shuttle terminal in Cocquelles were selected in step 4. In step 5, we select the cases with an origin/destination Paris by excluding the transfer flights. In step 6, travel purposes are deducted from the variable “purpose”. For leisure travellers, codes 11 to 18 were used covering Holiday/pleasure, Visit family (priority), Visit friends, Getting married, Play amateur sport, Watch sport, Personal shopping, Cruise 0-2 nights ashore - UK owned ship, Cruise 0-2 nights ashore - Foreign ship. For business travellers, codes 20 to 26 were selected covering Business/Work, Trade fair/exhibition, Conference/large business meeting, Definite job to go to, International commuter, Looking for work, Au Pair. The operators selected in step 7 are the airlines British Airways, Air France and EasyJet, the high-speed rail operator Eurostar, Eurotunnel Shuttle, DFDS Seaways and P&O Ferries.

1. Overseas residents departing UK via air
2. UK residents departing UK via air
3. Overseas residents arriving in UK via air
4. UK residents arriving in UK via air
5. Overseas residents departing UK via sea or tunnel
6. UK residents departing UK via sea or tunnel
7. Overseas residents arriving in UK via sea or tunnel
8. UK residents arriving in UK via sea or tunnel

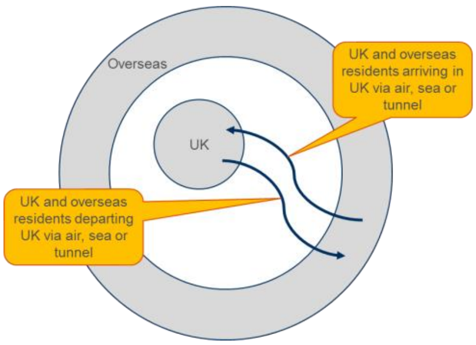

Figure A.17 - Passenger flows (International Passenger Survey, UK ONS)

55 International Passenger Survey Overseas Travel and Tourism Data Sets - User Guide, Office for National Statistics, 2012

Table A.16 shows the number of cases selected from the IPS databases using the selection process as described. About 1.2% of all cases is used for the analysis process. From the total London-Paris market, about 26% is related to business purposes.

Table A.16 - Selected cases from IPS 2008 - 2015

year	file	# records	# selected cases		
			Total	Business	Leisure
2008	UKDA 5993	244455	4494	1124	3370
2009	UKDA 6255	310980	3739	922	2817
2010	UKDA 6534	319618	3352	906	2446
2011	UKDA 6846	294176	3338	878	2460
2012	UKDA 7087	295247	3576	936	2640
2013	UKDA 7380	306736	3306	926	2380
2014	UKDA 7534	281113	3502	964	2538
2015	UKDA 7754	299091	3710	1245	2465

H.2 Analysis process

Table A.17 - Analysis process International Passenger Survey

	Step	Variable
1	Calculate average fare and standard deviation (and # people in car)	fare
2	Determine share of Business and Leisure travellers	purpose
3	Calculate average fare and standard deviation per purpose (and # people in car)	fare
4	Determine ports of origin	ukport
5	Determine market share of operators	carrier1
6	Calculate average fare and standard deviation per operator	fare
7	Calculate market share Business/Leisure for each operator	carrier1
8	Check on flows that are covered!	flow

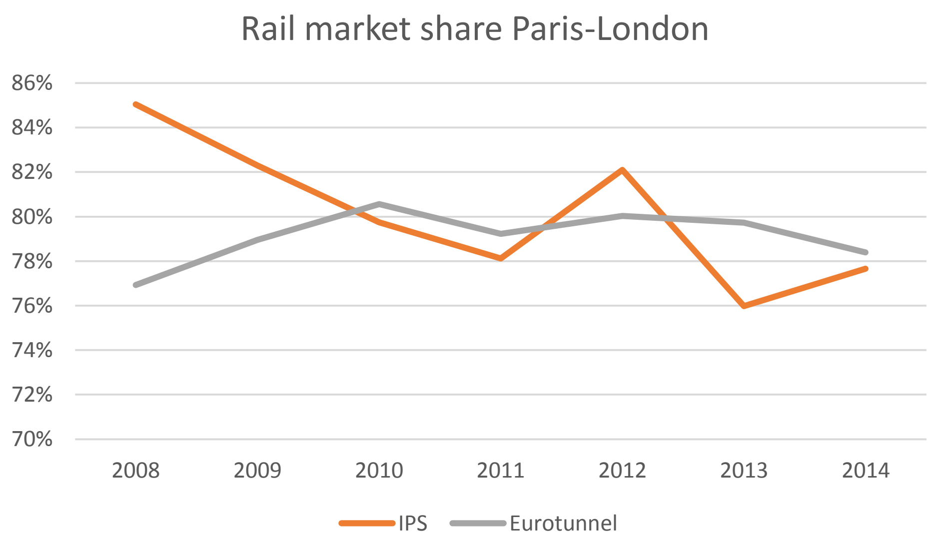

Figure A.18 - Rail market share Paris London

Note: Figure by author based on data from IPS 2008-2014 and Eurotunnel Reference documents 2008-2014

Comparing the market share results with data registered by Eurotunnel shows that there are some deviations, but differences remain to be less than 10% (see figure A.18). For our study market shares, prices, fares and load factors are computed based on the selected IPS cases.

H.3 Market shares

For both the leisure and business market, Eurostar had in 2012 a dominant market share of approximately 70%. On the contrary, to leisure travellers who favour the Eurotunnel shuttle and the ferries, business travellers prefer the full service airlines. EasyJet's market share is about the same in the leisure and business market.

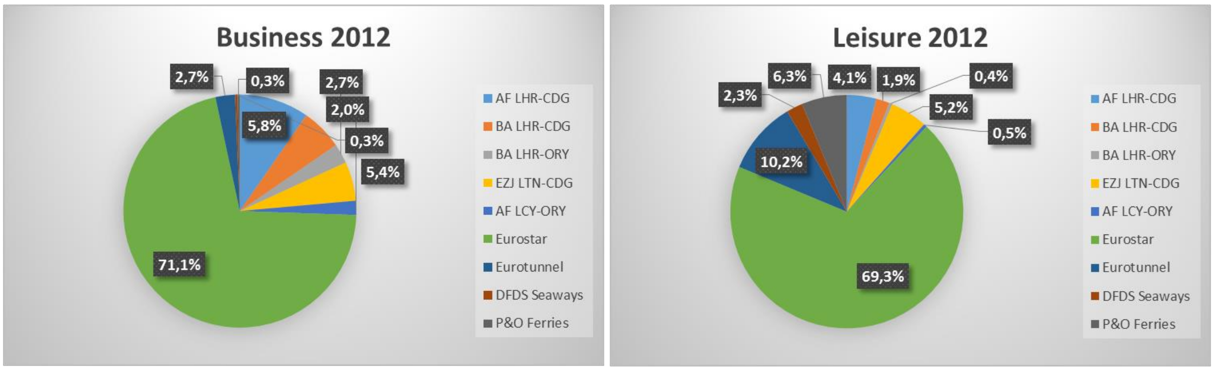

Figure A.19 - London-Paris market shares for Business and Leisure

Note: Figure by author based on data from IPS 2012

The IPS database gives information about the number of car passengers crossing the Channel by ferry or shuttle train (flows 5, 6, 7 and 8 in figure A.17). The diagram in figure A.20 is used to estimate the market share of private cars between London and Paris.

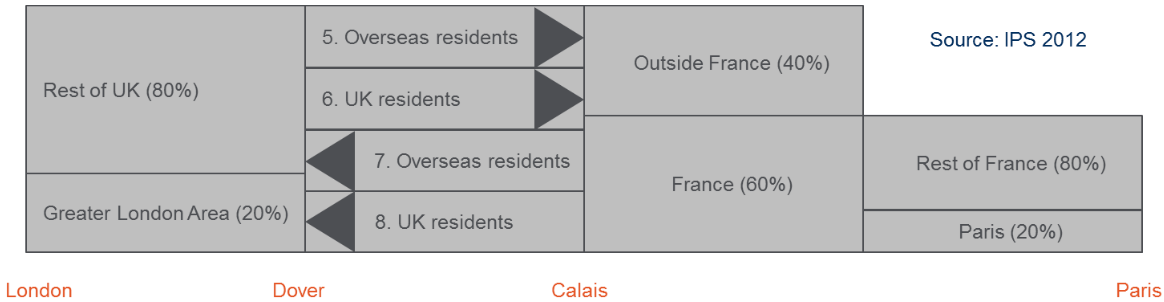

Figure A.20 - Estimated market share for Car alternative London-Paris

Note: Figure by author based on IPS 2012 data

From all private cars using the Dover-Calais connection to cross the Channel, 44% takes the ferry (DFDS Seaways and P&O Ferries) and 56% use Eurotunnel (IPS 2012). In 2012, Eurotunnel transported 2,424,342 cars[56] with 3.2 passengers on average resulting in 7,757,894 car passengers. The origin or destination of car passengers are split into the Greater London Area (inner and outer London) and the rest of the UK. The IPS shows a ratio

[56] Eurotunnel Registration Document 2012

of 20/80%[57]. On the French side, 60% of the car passengers crossing the Channel have their origin/destination in France (IPS 2012). The assumption is made that about 20% of this flow have the Paris region as origin/destination. Taking the numbers as indicated by figure H.21, about 2.4% of passengers are travelling via Sea or Tunnel on the London-Paris link. As the total car passengers via ferry or tunnel in 2012 between London and Paris is 326,940, this results in a 3.6% market share of total market.

H.4 Fares and prices

Figure H.22 shows a close match of fares from British Airways (BA) and Air France (AF) between LHR and CDG, except for 2015 where Air France ticket prices rise sharply. The variation in prices for business travellers is larger than for leisure travellers. The fares for EasyJet and Eurostar are lower and less volatile compared to Air France and British Airways. EasyJet shows a competitive price setting for the Luton – CDG connection. Leisure fares for Eurostar are comparable to EasyJet airfares, but are higher for business travellers.

[57] This assumption is arbitrary as the catchment area for the Dover-Calais transfer is not only restricted to the Greater London area.

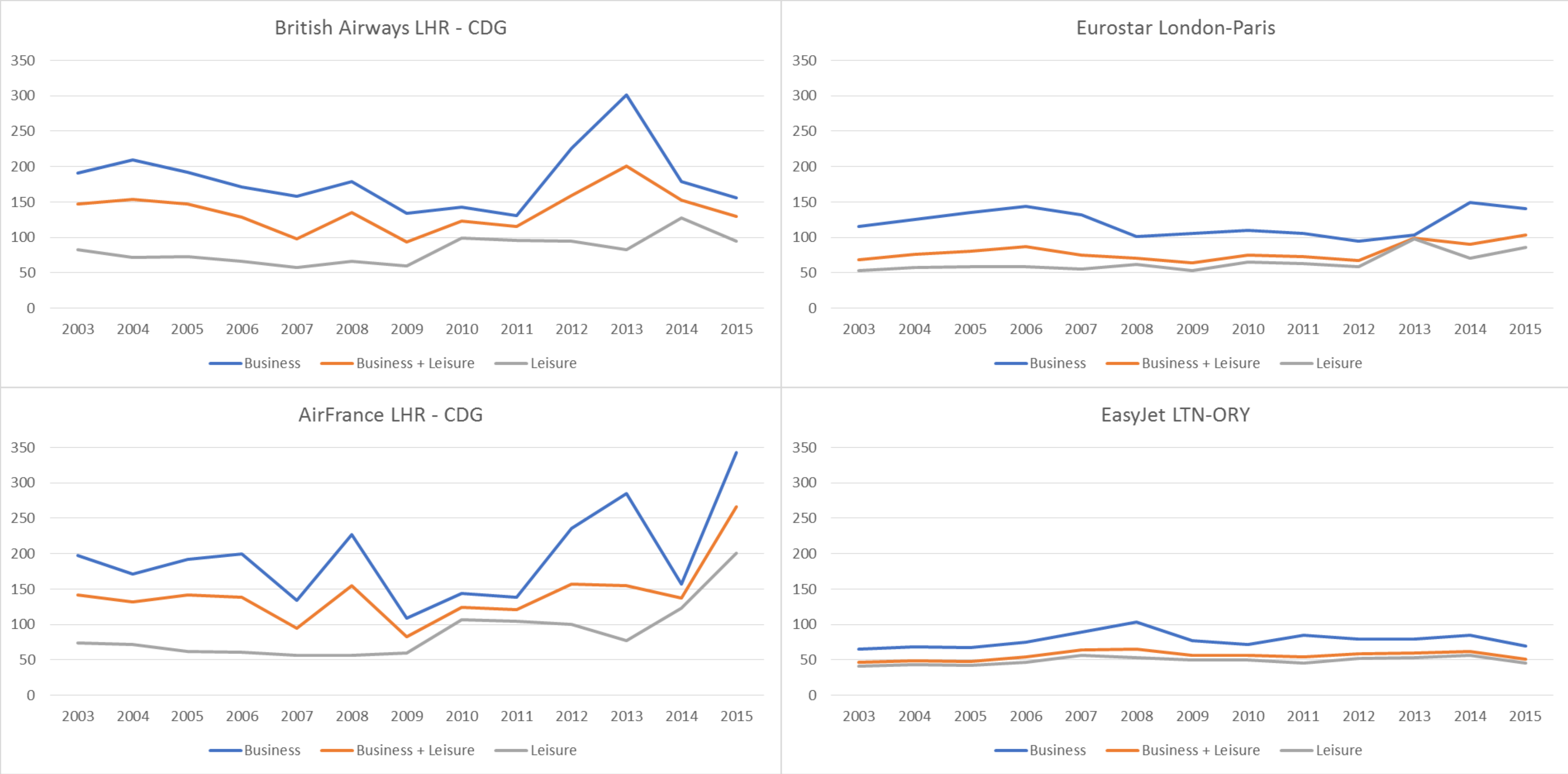

Figure A.21 - Air and high-speed rail fares for London-Paris (2003-2015)

Note 1: Figure by author based on IPS 2008-2015 data, UK ONS
Note 2: Data 2003-2008 from Behrens and Pels (2012)
Note 3: All fares in Sterling

Table A.18 - Market shares and fares for the London- Paris link (2012)

		Purpose	# Cases	Market Share	Fare (Sterling)			Fare (Euro)		
London-Paris link	Carrier				Mean	Std Dev	Error M.	Mean	Std Dev	Error M.
LHR - CDG	AIR FRANCE	Business	89	9.7%	235.62	149.844	31.131	290.55	184.780	38.389
		Leisure	122	4.5%	99.80	34.871	6.188	123.06	43.001	7.630
LHR - CDG	BRITISH AIRWAYS	Business	54	5.9%	226.19	121.456	32.394	278.92	149.772	39.947
		Leisure	56	2.0%	94.48	39.485	10.342	116.51	48.691	12.753
LHR - ORLY	BRITISH AIRWAYS	Business	25	2.7%	209.68	69.853	27.382	258.57	86.139	33.766
		Leisure	13	0.5%	99.38	24.364	13.244	122.56	30.044	16.332
LUTON - CDG	EASYJET	Business	50	5.5%	79.88	34.976	9.695	98.50	43.130	11.955
		Leisure	154	5.6%	51.62	17.997	2.842	63.65	22.193	3.505
CITY - ORLY	CITYJET	Business	18	2.0%	163.72	57.174	26.413	201.89	70.504	32.571
		Leisure	14	0.5%	83.14	28.382	14.867	102.53	34.999	18.333
ST PANCRAS - CDG	EUROSTAR	Business	654	71.5%	94.64	26.842	2.057	116.70	33.100	2.537
		Leisure	2070	75.7%	58.81	16.492	0.710	72.52	20.338	0.876
FOLKESTONE-CALAIS	EUROTUNNEL	Business	25	2.7%	45.80	37.599	14.738	56.48	46.365	18.175
		Leisure	304	11.1%	22.73	17.129	1.925	28.03	21.122	2.374
DOVER - CALAIS	DFDS + P&O	Business	6	0.7%	22.67	11.776	9.422	27.95	14.521	11.619
		Leisure	256	9.4%	16.64	13.114	1.606	20.52	16.172	1.981

Note 1: Data from IPS 2012, UK ONS
Note 2: Exchange rate Sterling/Euro = 1.2331 (2012) http://www.x-rates.com/average/?from=GBP&to=EUR&amount=1&year=2012

Appendix I: Total Travel Time

Table A.19 - Total Travel Time for the London-Paris route (2012)

Total Travel Time (minutes)	Rail	Air FSC LHR --> CDG	Air FSC LHR --> CDG	Air FSC LHR --> ORY	Air LCC LCY --> CDG	Air LCC LCY --> ORY	Air LCC LTN --> CDG	Air FSC LGW --> CDG	Air LCC LHR --> CDG	Road LDN --> PAR	Road LDN --> PAR
London - Paris	Eurostar	British Airways	Air France	British Airways	CityJet	CityJet	EasyJet	British Airways	BMI	Euro-tunnel	DFDS/ P&O
Access time to airport/train station/terminal	5	28	28	28	45	45	45	28	45	80	80
Port processing time (leisure)	30	60	60	60	20	20	40	60	40	20	20
Port processing time (business)	30	45	45	45	20	20	40	45	40	20	20
Take-off/taxi time	0	25	25	25	15	15	12	18	25	0	0
Scheduled in-vehicle time (train, plane, ferry, shuttle)	135	45	45	45	60	60	60	45	60	35	90
Expected delay	11	10	15	10		6	10	10	10	9	14
Landing/taxi time	0	10	10	10	10	10	10	10	10	0	0
Egress time from airport/train station/terminal	6	21	21	35	35	35	21	21	21	155	155
Punctuality (on arrival)	92.1%	77.0%	67.4%	77.6%		90.7%	83.4%	77.0%	83.4%	75.0%	85.0%
Scheduled Travel Time (gate to gate)	135	80	80	80	85	85	82	73	95	35	90
Total travel Time (business)	165	125	125	125	105	105	122	118	135	299	359
Total travel Time (leisure)	165	140	140	140	105	105	122	133	135	299	359

Note 1: Data from IPS 2012, UK ONS
Note 2: Access time to airport/train station/terminal (Dobruszkes 2011)
Note 3: Port processing time (Behrens and Pels 2012)
Note 4: Take-off/taxi time (Civil Aviation Authority UK)
Note 5: Scheduled in-vehicle time from timetables and flight schedules www.flightstats.com
Note 6: Expected delay = (1-punctuality) * In-vehicle time
Note 7: Punctuality (on arrival) (Civil Aviation Authority UK Punctuality statistics, Eurostar Press releases and Reference Documents). For road assumptions made by author.
Note 8: CityJet claims 10 min port processing time at London City Airport check-in time, we have assumed 20 mins.

Appendix J: SCP variables London-Paris (2003-2015)

Table A.20 - SCP variables London-Paris high-speed passenger market (2003-2015)

Case	Year	Mode	Link	Operator	NUM	HHI	SIZE	TRV	GR	CAP	TTT*	FREQ	FARE***	MKS	PUNC**	OC	TRVO	GRO
1	2003	Air FSC	LHR-CDG	BA	6	0.433	12.178	7.256	-0.028	1.112	144	71	147	0.100	0.710	0.653	0.726	-0.084
2	2003	AIR FSC	LGW-CDG	BA	6	0.433	12.178	7.256	-0.028	0.547	134	38	126	0.041	0.785	0.547	0.299	0.064
3	2003	AIR LCC	LHR-CDG	BMI	6	0.433	12.178	7.256	-0.028	0.590	159	38	116	0.053	0.593	0.653	0.385	-0.084
4	2003	Rail	QQS-XPG	EUR	6	0.433	12.178	7.256	-0.028	8.112	194	104	69	0.634	0.783	0.567	4.597	-0.044
5	2003	Air FSC	LHR-CDG	AF	6	0.433	12.178	7.256	-0.028	1.326	150	85	141	0.119	0.610	0.653	0.865	-0.084
6	2003	Air LCC	LTN-CDG	EJ	6	0.433	12.178	7.256	-0.028	0.492	136	32	47	0.053	0.770	0.780	0.384	0.779
7	2004	Air FSC	LHR-CDG	BA	6	0.480	11.391	7.944	0.095	1.095	145	71	154	0.095	0.683	0.688	0.753	0.038
8	2004	AIR FSC	LGW-CDG	BA	6	0.480	11.391	7.944	0.095	0.369	140	26	140	0.028	0.637	0.596	0.220	-0.264
9	2004	AIR LCC	LHR-CDG	BMI	6	0.480	11.391	7.944	0.095	0.512	162	33	114	0.044	0.544	0.688	0.352	-0.084
10	2004	Rail	QQS-XPG	EUR	6	0.480	11.391	7.944	0.095	7.644	180	98	76	0.673	0.892	0.699	5.346	0.163
11	2004	Air FSC	LHR-CDG	AF	6	0.480	11.391	7.944	0.095	1.302	148	85	132	0.113	0.632	0.688	0.896	0.035
12	2004	Air LCC	LTN-CDG	EJ	6	0.480	11.391	7.944	0.095	0.468	136	29	49	0.047	0.759	0.804	0.377	-0.018
13	2005	Air FSC	LHR-CDG	BA	5	0.522	10.870	7.713	-0.029	1.113	146	69	147	0.100	0.659	0.694	0.772	0.064
14	2005	AIR LCC	LHR-CDG	BMI	5	0.522	10.870	7.713	-0.029	0.514	153	32	129	0.046	0.703	0.694	0.357	-0.074
15	2005	Rail	QQS-XPG	EUR	5	0.522	10.870	7.713	-0.029	7.644	183	98	80	0.704	0.863	0.710	5.429	0.181
16	2005	Air FSC	LHR-CDG	AF	5	0.522	10.870	7.713	-0.029	1.276	145	79	142	0.115	0.691	0.694	0.885	0.023
17	2005	Air LCC	LTN-CDG	EJ	5	0.522	10.870	7.713	-0.029	0.324	137	21	48	0.035	0.749	0.833	0.270	-0.296
18	2006	Air FSC	LHR-CDG	BA	5	0.533	11.381	7.936	0.029	1.146	146	69	129	0.097	0.661	0.668	0.766	0.017
19	2006	AIR LCC	LHR-CDG	BMI	5	0.533	11.381	7.936	0.029	0.521	151	31	115	0.044	0.727	0.668	0.348	-0.012
20	2006	Rail	QQS-XPG	EUR	5	0.533	11.381	7.936	0.029	8.034	176	103	87	0.713	0.915	0.704	5.659	0.059
21	2006	Air FSC	LHR-CDG	AF	5	0.533	11.381	7.936	0.029	1.294	148	78	138	0.109	0.646	0.668	0.864	-0.035
22	2006	Air LCC	LTN-CDG	EJ	5	0.533	11.381	7.936	0.029	0.386	150	25	54	0.038	0.533	0.775	0.299	-0.207
23	2007	Air FSC	LHR-CDG	BA	4	0.577	9.930	8.025	0.011	1.193	147	70	98	0.102	0.711	0.686	0.818	0.060
24	2007	Rail	QQS-XPG	EUR	4	0.577	9.930	8.025	0.011	8.190	176	105	75	0.743	0.915	0.728	5.962	0.098
25	2007	Air FSC	LHR-CDG	AF	4	0.577	9.930	8.025	0.011	1.335	148	78	94	0.114	0.667	0.686	0.916	0.034

26	2007	Air LCC	LTN-CDG	EJ	4	0.577	9.930	8.025	0.011	0.405	144	26	64	0.041	0.634	0.812	0.329	0.218
27	2008	Rail	QQS-XPG	EUR	6	0.609	11.658	8.454	0.053	8.814	175	113	70.13	0.769	0.924	0.738	6.503	0.149
28	2008	Air FSC	LHR-CDG	BA	6	0.609	11.658	8.454	0.053	1.131	143	65	135.12	0.095	0.724	0.711	0.805	-0.017
29	2008	Air FSC	LHR-CDG	AF	6	0.609	11.658	8.454	0.053	0.966	152	56	155.21	0.081	0.539	0.711	0.687	-0.250
30	2008	Air LCC	LCY-ORY	CJ	6	0.609	11.658	8.454	0.053	0.252	111	26	141.40	0.012	0.897	0.398	0.100	
31	2008	Air LCC	LTN-CDG	EJ	6	0.609	11.658	8.454	0.053	0.401	142	26	65.51	0.038	0.668	0.793	0.318	-0.033
32	2008	Air LCC	LCY-CDG	AF	6	0.609	11.658	8.454	0.053	0.094	121	10	171.50	0.005	0.727	0.432	0.041	
33	2009	Rail	QQS-XPG	EUR	6	0.637	11.474	8.272	-0.021	8.892	172	114	64.60	0.789	0.950	0.734	6.526	0.004
34	2009	Air FSC	LHR-CDG	BA	6	0.637	11.474	8.272	-0.021	0.983	140	58	93.77	0.083	0.846	0.701	0.688	-0.144
35	2009	Air FSC	LHR-CDG	AF	6	0.637	11.474	8.272	-0.021	0.933	147	55	82.37	0.079	0.687	0.701	0.653	-0.049
36	2009	Air LCC	LCY-ORY	CJ	6	0.637	11.474	8.272	-0.021	0.228	110	23	121.58	0.011	0.921	0.387	0.088	-0.121
37	2009	Air LCC	LTN-CDG	EJ	6	0.637	11.474	8.272	-0.021	0.397	138	25	56.81	0.036	0.740	0.751	0.298	-0.061
38	2009	Air LCC	LCY-CDG	AF	6	0.637	11.474	8.272	-0.021	0.041	120	4	92.00	0.002	0.748	0.432	0.018	-0.561
39	2010	Rail	QQS-XPG	EUR	5	0.662	10.951	8.355	0.010	8.580	183	110	75.18	0.805	0.866	0.784	6.728	0.031
40	2010	Air FSC	LHR-CDG	BA	5	0.662	10.951	8.355	0.010	0.916	143	51	122.80	0.074	0.759	0.678	0.621	-0.098
41	2010	Air FSC	LHR-CDG	AF	5	0.662	10.951	8.355	0.010	1.005	149	56	124.56	0.082	0.645	0.678	0.681	0.043
42	2010	Air LCC	LCY-ORY	CJ	5	0.662	10.951	8.355	0.010	0.169	116	27	105.89	0.011	0.842	0.563	0.095	0.079
43	2010	Air LCC	LTN-CDG	EJ	5	0.662	10.951	8.355	0.010	0.281	148	17	56.29	0.027	0.568	0.815	0.229	-0.233
44	2011	Rail	QQS-XPG	EUR	6	0.640	11.188	8.592	0.039	8.580	175	110	72.76	0.792	0.928	0.793	6.806	0.012
45	2011	Air FSC	LHR-CDG	BA	6	0.640	11.188	8.592	0.028	0.924	141	53	115.50	0.073	0.799	0.680	0.629	0.012
46	2011	Air FSC	LHR-CDG	AF	6	0.640	11.188	8.592	0.028	0.950	149	55	121.26	0.075	0.655	0.680	0.646	-0.052
47	2011	Air FSC	LHR-ORY	BA	6	0.640	11.188	8.592	0.028	0.277	147	18	101.44	0.019	0.851	0.587	0.162	
48	2011	Air LCC	LCY-ORY	CJ	6	0.640	11.188	8.592	0.028	0.159	125	30	110.03	0.011	0.904	0.602	0.096	0.004
49	2011	Air LCC	LTN-CDG	EJ	6	0.640	11.188	8.592	0.028	0.299	136	18	54.57	0.030	0.763	0.849	0.254	0.108
50	2012	Rail	QQS-XPG	EUR	6	0.651	11.111	8.720	0.015	8.580	176	110	67.41	0.800	0.921	0.813	6.979	0.025
51	2012	Air FSC	LHR-CDG	BA	6	0.651	11.111	8.720	0.015	0.824	143	48	159.14	0.065	0.770	0.688	0.567	-0.098
52	2012	Air FSC	LHR-CDG	AF	6	0.651	11.111	8.720	0.015	0.874	149	51	157.09	0.069	0.674	0.688	0.601	-0.069
53	2012	Air FSC	LHR-ORY	BA	6	0.651	11.111	8.720	0.015	0.379	150	27	171.95	0.026	0.776	0.606	0.230	0.417
54	2012	Air LCC	LCY-ORY	CJ	6	0.651	11.111	8.720	0.015	0.154	111	30	128.47	0.010	0.907	0.576	0.089	-0.070
55	2012	Air LCC	LTN-CDG	EJ	6	0.651	11.111	8.720	0.015	0.299	132	18	58.55	0.029	0.834	0.849	0.253	0.000

56	2013	Rail	QQS-XPG	EUR	6	0.646	11.217	8.985	0.030	8.736	178	112	98.94	0.797	0.904	0.820	7.163	0.026
57	2013	Air FSC	LHR-CDG	BA	6	0.646	11.217	8.985	0.030	0.781	146	45	201.15	0.064	0.690	0.742	0.579	0.022
58	2013	Air FSC	LHR-CDG	AF	6	0.646	11.217	8.985	0.030	0.851	149	49	154.63	0.070	0.659	0.742	0.631	0.049
59	2013	Air FSC	LHR-ORY	BA	6	0.646	11.217	8.985	0.030	0.394	153	27	154.70	0.030	0.708	0.679	0.267	0.163
60	2013	Air LCC	LCY-ORY	CJ	6	0.646	11.217	8.985	0.030	0.154	116	30	200.80	0.011	0.812	0.619	0.095	0.070
61	2013	Air LCC	LTN-CDG	EJ	6	0.646	11.217	8.985	0.030	0.302	132	18	59.65	0.028	0.837	0.825	0.249	-0.018
62	2014	Rail	QQS-XPG	EUR	7	0.625	11.731	9.401	0.046	9.009	175	115	90.10	0.784	0.924	0.818	7.370	0.029
63	2014	Air FSC	LHR-CDG	BA	7	0.625	11.731	9.401	0.046	0.765	145	44	152.71	0.062	0.742	0.757	0.579	-0.001
64	2014	Air FSC	LHR-CDG	AF	7	0.625	11.731	9.401	0.046	0.885	146	51	137.10	0.071	0.739	0.757	0.670	0.061
65	2014	Air FSC	LHR-ORY	BA	7	0.625	11.731	9.401	0.046	0.409	151	27	133.19	0.032	0.746	0.729	0.298	0.116
66	2014	Air LCC	LCY-ORY	CJ	7	0.625	11.731	9.401	0.046	0.182	121	30	132.67	0.010	0.736	0.501	0.091	-0.044
67	2014	Air LCC	LTN-CDG	EJ	7	0.625	11.731	9.401	0.046	0.311	137	18	61.95	0.026	0.744	0.798	0.248	-0.001
68	2014	Air LCC	LGW-CDG	EJ	7	0.625	11.731	9.401	0.046	0.170	142	10	80.94	0.015	0.806	0.852	0.145	
69	2015	Rail	QQS-XPG	EUR	7	0.606	11.892	9.504	0.011	9.048	181	116	103.72	0.771	0.879	0.810	7.332	-0.005
70	2015	Air FSC	LHR-CDG	BA	7	0.606	11.892	9.504	0.011	0.768	144	45	130.19	0.062	0.705	0.767	0.589	0.017
71	2015	Air FSC	LHR-CDG	AF	7	0.606	11.892	9.504	0.011	0.868	145	51	266.45	0.070	0.733	0.767	0.665	-0.007
72	2015	Air FSC	LHR-ORY	BA	7	0.606	11.892	9.504	0.011	0.421	153	27	121.61	0.034	0.720	0.765	0.322	0.078
73	2015	Air LCC	LCY-ORY	CJ	7	0.606	11.892	9.504	0.011	0.213	124	26	124.22	0.013	0.685	0.579	0.123	0.351
74	2015	Air LCC	LTN-CDG	EJ	7	0.606	11.892	9.504	0.011	0.337	142	18	51.34	0.028	0.662	0.793	0.267	0.076
75	2015	Air LCC	LGW-CDG	EJ	7	0.606	11.892	9.504	0.011	0.238	144	14	72.06	0.022	0.750	0.868	0.206	0.422

Note 1: *TTT is port processing time, in-vehicle time and expected delay (leisure), TTT Data from spreadsheet Total Travel Time (version 1.2)
Note 2: ** The links LCY-CDG and LCY-ORY operated by CityJet. VLM and BA CityExpress are excluded.
Note 3: * Fares 2003-2007 for EasyJet estimated on basis of Leisure fares and average ratios 2008-2015**
Note 4: Market shares estimated on passenger volumes (not on # cases from IPS data)

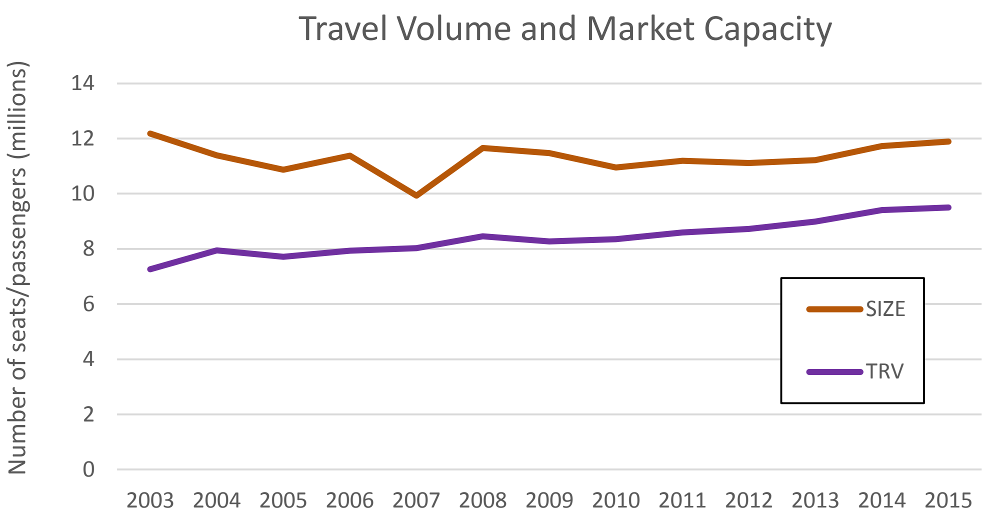

Figure A.22 - Travel Volume versus Market capacity London-Paris market

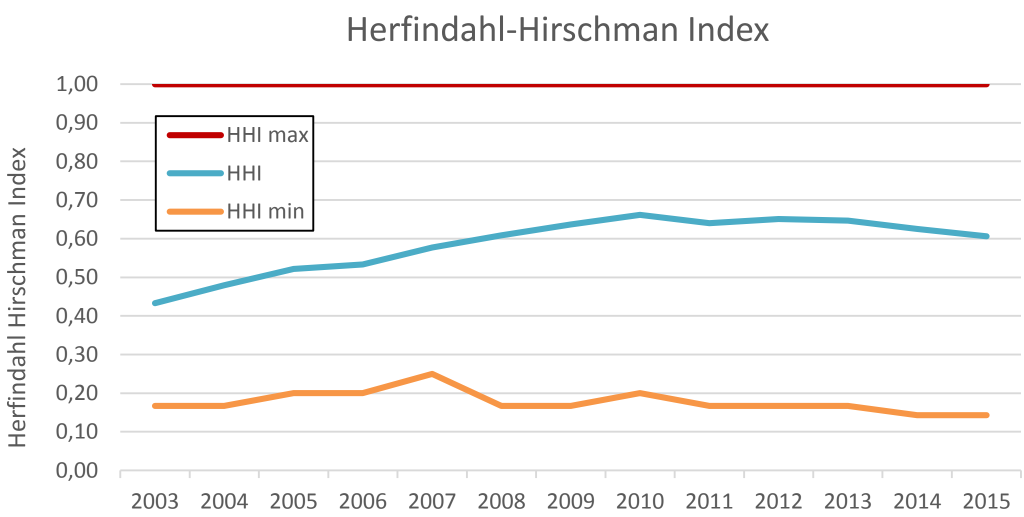

Figure A.23 - Number of operators and Herfindahl-Hirschman Index

Appendix K: Marginal costs train, aircraft and car

Operators can compete on price and service quality, but for a sustainable profitable business, the associated delivery costs need to be lower than the revenues. Railway operators have different cost structures than airlines or road transport. In the economic model, we use marginal costs for rail, air and road transport are used as an input parameter. In this appendix, marginal costs for the transport modes under investigation are explained in more detail.

K.1 Marginal costs

"Marginal costs are the additional cost a firm incurs in order to produce one additional unit of output." (Lipczynski et al, 2013). In passenger transport, a unit of output can be an extra flight, train, seat or passenger. In our model, the marginal costs are the costs associated with carrying extra passengers. In their decisions, transport operators need to consider their fixed and variable costs. In estimating the marginal costs, the fixed costs are set aside.

"A key distinction is drawn between the short run (when some inputs are variable and others are fixed) and the long run (when all inputs are variable)" (Lipczynski et al, 2013). Variable costs depend on the time available to plan the transportation in question (Blauwens et al, 2010). Marginal cost of an extra passenger during peak-hours may be quite high when extra vehicles need to be scheduled. In rail and air transport schedules, frequencies and type of aircraft of rolling stock need to be planned and are fixed for day-to-day decisions. On a yearly basis changes in schedules, frequencies or staffing levels are not uncommon, but changes in fleet require a more long-term planning. Fröidh suggests splitting costs into direct, indirect and intermediate costs as an in-between category depending on the timescale that these costs can be influenced. "Direct operating costs, which are strongly dependent on operations, are energy costs and infrastructure user fees. Staff costs must in general be characterized as intermediate. Most staff receive a salary and cannot be employed and dismissed from one day to another, but possibly in a couple of months as long as it is a question of non-specialist competence. Capital costs for rolling stock and other long-term agreements are slowly manageable and might take years to change." (Fröidh 2006). Short-Run Marginal Costs (SRMC) only cover costs related to ticket sales, catering, compensation payments for delays and other passenger related charges. In the case of Medium-Run Marginal Costs, capital costs and overheads are fixed and all other costs are variable.

Marginal costs cannot be observed directly (Prady and Ulrich 2010). Marginal costs can be derived when the cost functions related to a specific transport mode on the link under investigation is known where first of all total costs need to be split into fixed and variable costs. This requires adequate data on the type of service, operating model and vehicle characteristics. In addition, information on load factors (number of passengers per vehicle) need to be available to calculate the marginal costs per passenger. Although unit costs for producing a train, car, aircraft, seat or passenger kilometre is not the same as marginal costs, transport variable costs can be used as an approximation of the marginal costs when this information is missing (Ivaldi and Vibes 2008). For road and rail transport, marginal costs include costs of infrastructure use such as road, rail and tunnel fees and fuel costs (Prady and Ulrich 2010).

Operating costs change in time caused by variations in fuel and energy prices, cost of labour, interest and capital cost, infra and station charges, taxes etc. In addition, operating costs are country specific.

K.2 Rail operating costs

"The costs necessary for the operation of rail services are called "operating costs", including repayment of rolling stock, maintenance, sales and distribution costs, energy, infrastructure charges and capital and financial costs. "Operating costs" do not include infrastructure investment costs, external costs and taxes on company profits." (Alverez 2010). Passenger rail operating costs are country-specific (infra charges, salaries) and depend on the operational model (speed, stops), the geography of the route (grades, curves), the type of infrastructure (power supply), the rolling stock used for the service and the drivers' behaviour. In addition, costs may evolve over time. In general, the unit to express operating costs is "Eurocent per Available Seat-Kilometer (ASK)".

Operating costs can be top-down estimated from the operators' financial accounts or by building a bottom-up cost model. The advantage of a top-down operating cost estimation is that the aggregate data contain all the costs that need to be taken into account. The difficulty is to disaggregate the data to the level needed to calculate marginal cost for a specific route. In these cases, it is preferred to build a cost model reflecting the actual train, service and operational characteristics. To validate the results, a combination of both approaches can be advantageous.

Operating costs for high-speed trains are investigated by the Fundación de los Ferrocarriles Españoles (FFE) under contract by the International Union of Railways (UIC) (Garcia 2010). In this study, the "Costs necessary for moving the train" is introduced consisting of "Train movement costs" and "Marginal costs for infrastructure use". It contains all direct costs excluding any commercial costs related to passenger services and ticket sales and charges for infrastructure use above marginal costs. For calculating the marginal cost, the commercial costs need to be taken into account as they depend on the number of passengers.

Fröidh (2010) has developed a cost model for the Green Train project in Sweden. Costs include capital (depreciation and interest), salaries, terminal costs, energy, maintenance, track access charges, administration and sales. In figure A.24 the operating costs for X2000 high-speed trains, GTW trains, Full Service Carriers (FSC) and a Low Cost Carriers (LCC) are compared for the Swedish domestic market. The dot (LCC+ B737–800) represents Ryanair's average operating costs at average stage length (790 km). Smaller aircraft like the Saab 340A with 34 seats, typically used for domestic services, have approximately 20% higher operating costs per ASK than larger aircraft. The cost for an X2000 high-speed train (maximum speed 200 km/h, 309 seats), running in Sweden over a 500 km distance, is 0.045 Euro per ASK as calculated by the Green Train model (Fröidh 2010).

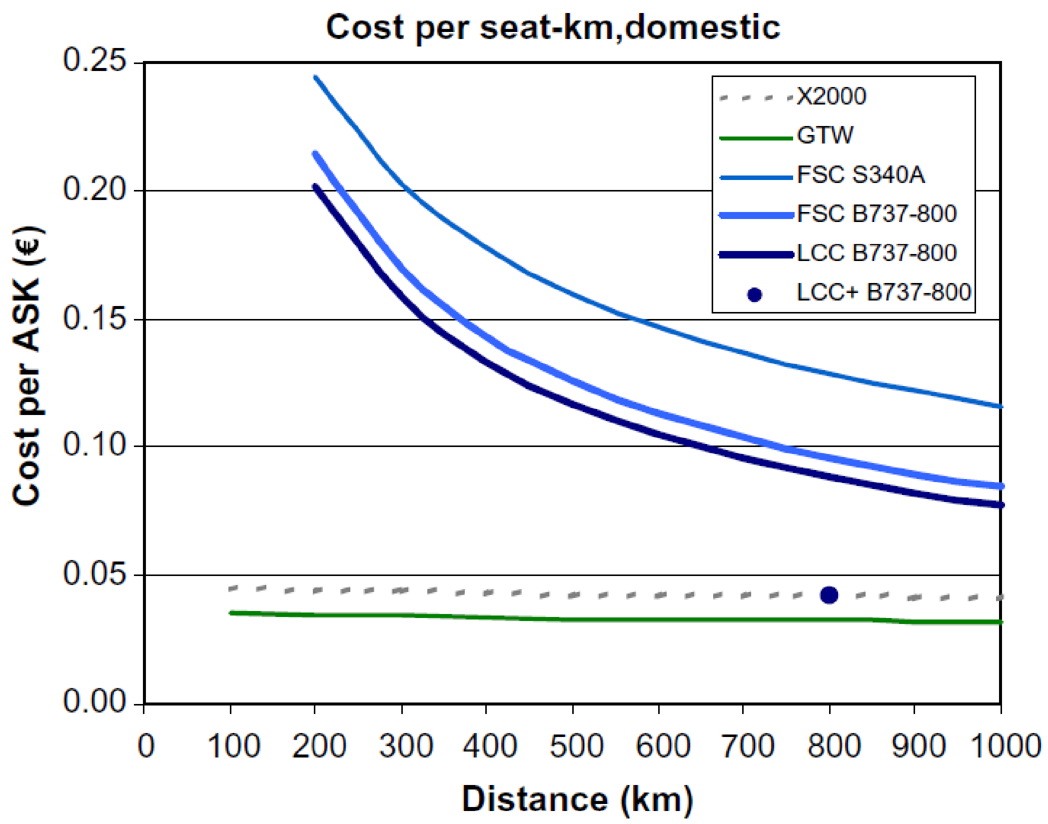

Figure A.24 - Calculated total costs on Swedish domestic routes in 2005 for rail and air

Source: Froïdh 2010

A similar cost breakdown is given by a study carried out for the European Commission where costs and their cost drivers are divided into several categories as shown in table A.21. Variations can occur during country-specific regulations.

Table A.21 - Rail operating costs

Category	Cost item	Cost driver
Infrastructure	Track access	fixed
	Capacity charge	train.km
	Station costs	train.hour
Rolling stock	Leasing charges or Capital costs	# trains
	Maintenance costs	train.km
Staff	Drivers	train.hour
	Other on-train staff	train.hour
Energy	Energy	train.km
Passenger service	Ticket sales	#passengers
	Compensation	punctuality
Administration	Administration	fixed
	Overheads	fixed

Note: Adopted from European Commission, 2006

For illustration, the rail operating costs for a new entrant on the route Frankfurt – Cologne as calculated by Steer Davies Gleave are shown in figure A.25 (European Commission 2006). The largest single cost for most railway operators is the infrastructure cost. The infrastructure charges paid by the operator do not reflect the full cost of infrastructure provision. Rolling stock costs (capital and maintenance costs) are the second largest cost category.

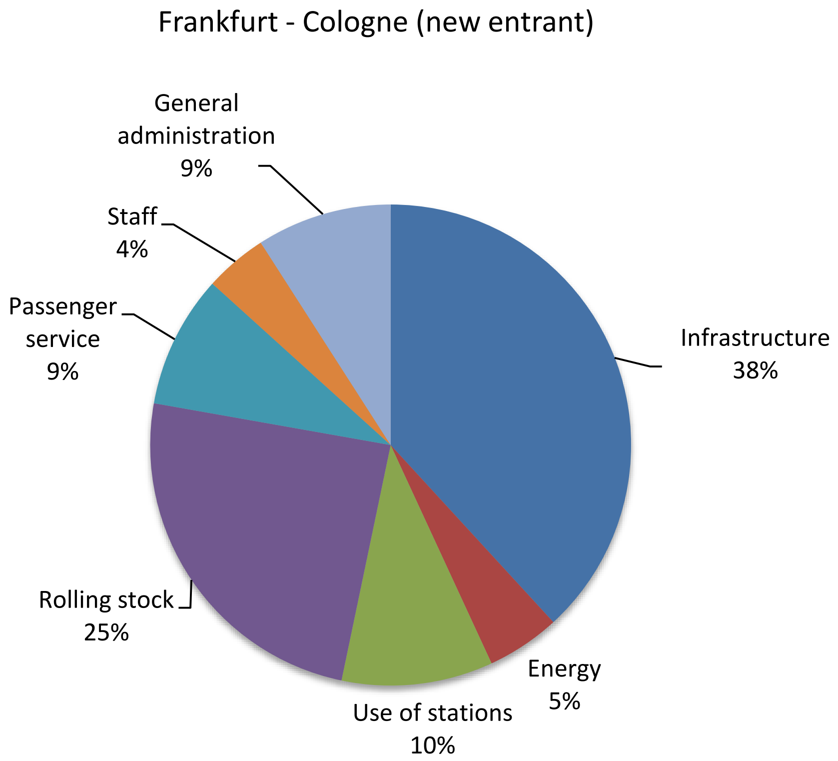

Figure A.25 - Rail operating costs for a new entrant on Frankfurt-Cologne

Note: Adopted from European Commission, 2006

For the new entrant on the Frankfurt – Cologne route, provision of an hourly service for 15 hours per day is assumed, resulting in 1.971 million trainkm's, 818 million available seatkm's per year (ICE3 trainsets with 429 seats each). As the total costs are estimated at 67.25 million Euros per year, the cost per available seat-kilometre is 0.080 Euro (European Commission 2006).

To estimate marginal costs for our study we have developed a HSR Operating Cost Model figure A.26) based on the Green Train model as developed by Fröidh (2006, 2010). The formulas used are derived from the study conducted by the International Union of Railways (UIC) (Garcia 2010). Based on given train and operational data the fixed and variable operational costs can be calculated for a specific origin-destination pair. The variable operating costs are covering the costs for moving the train and ticket sales. Overhead costs, train ownership costs and infrastructure charges above marginal costs are excluded from the equation.

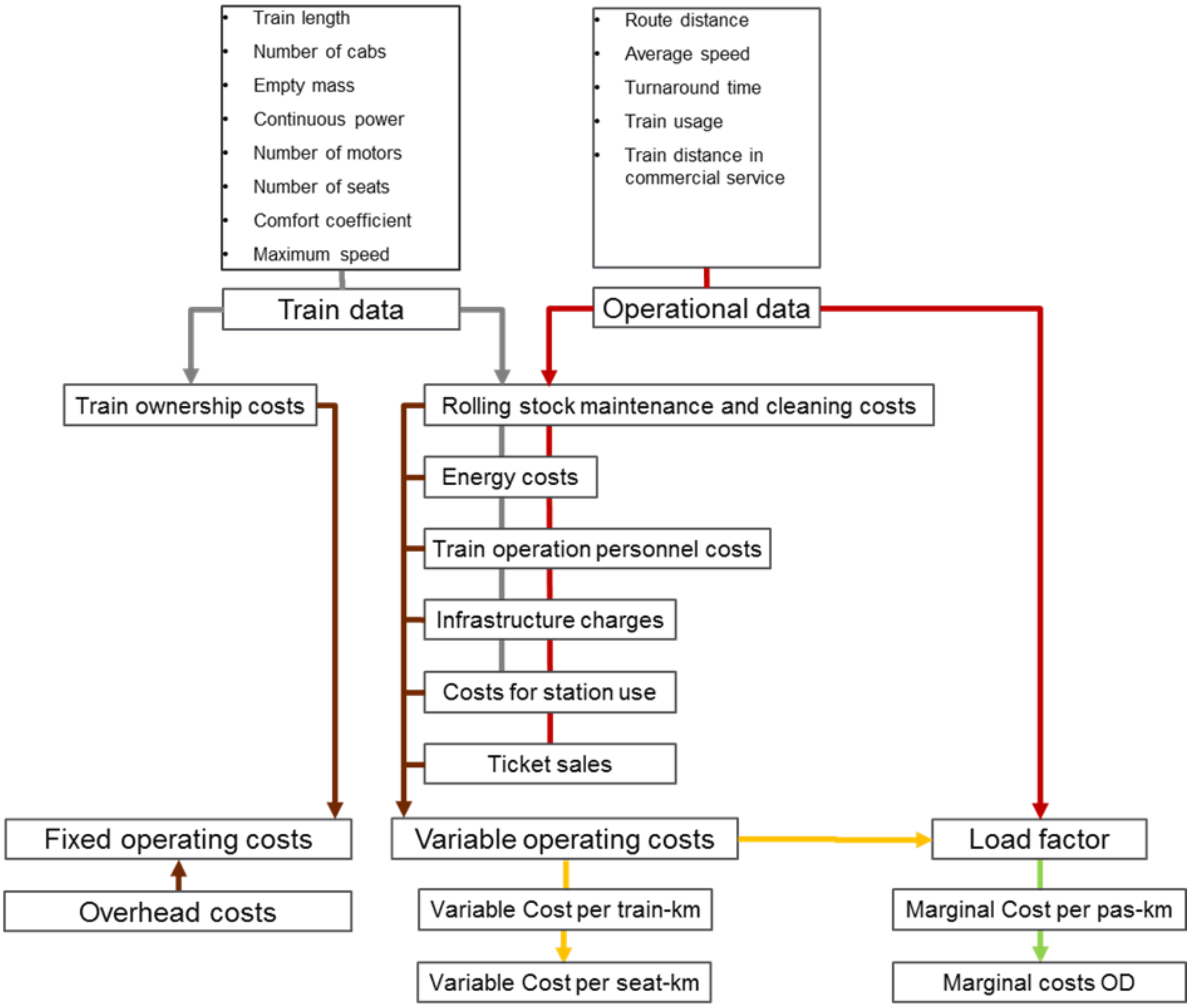

Figure A.26 - High Speed Rail Operating Cost model

For validation the operating cost is calculated for running ICE 3 trainsets on the Frankfurt-Cologne link as presented earlier, using the HSR Operating Cost Model.

Train and Operational Data		
Variable	**Unit**	**Value**
Length	m	200
Number of cabs	-	2
Empty mass	ton	409
Continuous power	kW	8,000
Number of motors	-	16
Number of seats	-	429
Comfort coefficient	-	1.5
Maximum speed	km/h	330
Route distance	km	180
Average speed	km/h	186
Load factor	pas/seat	0.40
Turnaround time	minutes	70
Train usage	hours/day	15
Train distance	km/year	461,720

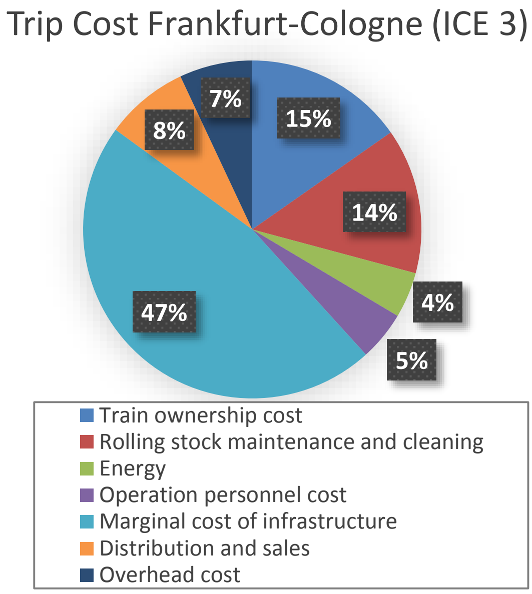

Figure A.27 - Operating costs ICE 3 on Frankfurt – Cologne link

Note: Calculations by Author using the High Speed Rail Operating Cost model

The calculated total operating cost is 0.070 Euro per Available Seat-Kilometre, which is about 15% lower than a cost of 0.080 Euro per ASK as presented by Steer Davies Gleave (European Commission 2006). In both cases, the bottom-up approach is applied, but the difference is that our calculation is based on one trainset and SDG has assumed an ICE 3 fleet with one extra trainset for maintenance cover on top of the four trainsets to operate the service. Taking this into account, the results are consistent.

Givoni has calculated the operating costs for high-speed train operators using a top-down financial approach. The operating costs derived from the 2002 profit and loss statement and operational data for a Eurostar train are 0.057 €/ASK[58]. The indirect costs associated with retail costs, customer service, marketing and advertising, catering, overheads and depreciation on investments not related to the track or rolling stock are not included in this figure. Including the indirect operating costs would have led to 0.093 €/ASK (Givoni 2005). Steer Davies Gleave applied the same approach using the 2004 Eurostar accounts resulting in an operating cost figure of 0.13 €/ASK (EC 2006)[59]. The differences are caused by the higher direct costs and difference in performance in 2004.

By using the HSR Operating Cost Model for the London-Paris link, the Capital Expenditures (CAPEX), the fixed and variable Operational Expenditures (OPEX) and the Total Expenditures (TOTEX) are calculated from the train and operational data and used for estimating the short-, medium- and long-run marginal cost. The Short-Run Marginal Cost (SRMC) expresses the cost for an extra passenger on a train with spare seats and is determined by the access charge of the Channel Tunnel (€16.60 per passenger plus 10% overhead) and the cost of ticket sales (€2.50 per passenger). The Medium Run Marginal Cost (MRMC) reflects the case

[58] Based on 2002 accounts: €310 mln direct costs, 6.3 mln passengers, 766 seats per train, 47% load factor.

[59] Based on 2004 accounts: €559 mln direct costs, 5.3 mln passengers, 750 seats per train, 66% load factor.

where extra trains from the existing fleet need to be scheduled to meet the demand. The basis for the calculation are the fixed and the variable Operational Expenditures. Besides OPEX, also Capital Expenditures for extending or modernising the rolling stock fleet needs to be taken into account to compute the Long Term Marginal Cost (LTMC). The results are presented in table A.22 and figure A.28 for the 2012 Eurostar operation.

Table A.22 - Cost calculated for Eurostar trains

Train and Operational Data			Cost Results		
Variable	Unit	Value	Variable	Unit	Value
Length	m	394	Train ownership cost	€/seat-km	0.0114
Number of cabs	-	2	Maintenance and cleaning	€/seat-km	0.0089
Empty mass	ton	752	Energy	€/seat-km	0.0037
Continuous power	kW	12,200	Operation personnel cost	€/seat-km	0.0019
Number of motors	-	12	Marginal infrastructure cost	€/seat-km	0.0651
Number of seats	-	750	Distribution and sales	€/seat-km	0.0041
Comfort coefficient	-	1.5	Overhead cost	€/seat-km	0.0080
Maximum speed	km/h	300	Total operating cost	€/seat-km	0.0916
Route distance	km	492	Fixed operating cost	€/seat-km	0.0574
Average speed	km/h	211	Variable operating cost	€/seat-km	0.0342
Load factor	pas/seat	0.81	Short Run Marginal Cost	€/pas	20.76
Turnaround time	minutes	300	Medium Run Marginal Cost	€/pas	49.01
Train usage	hours/day	15	Long Run Marginal Cost	€/pas	54.59
Train distance	km/year	355,155	OPEX Cost (at load factor)	€/pas	55.63

Note: Calculations by Author

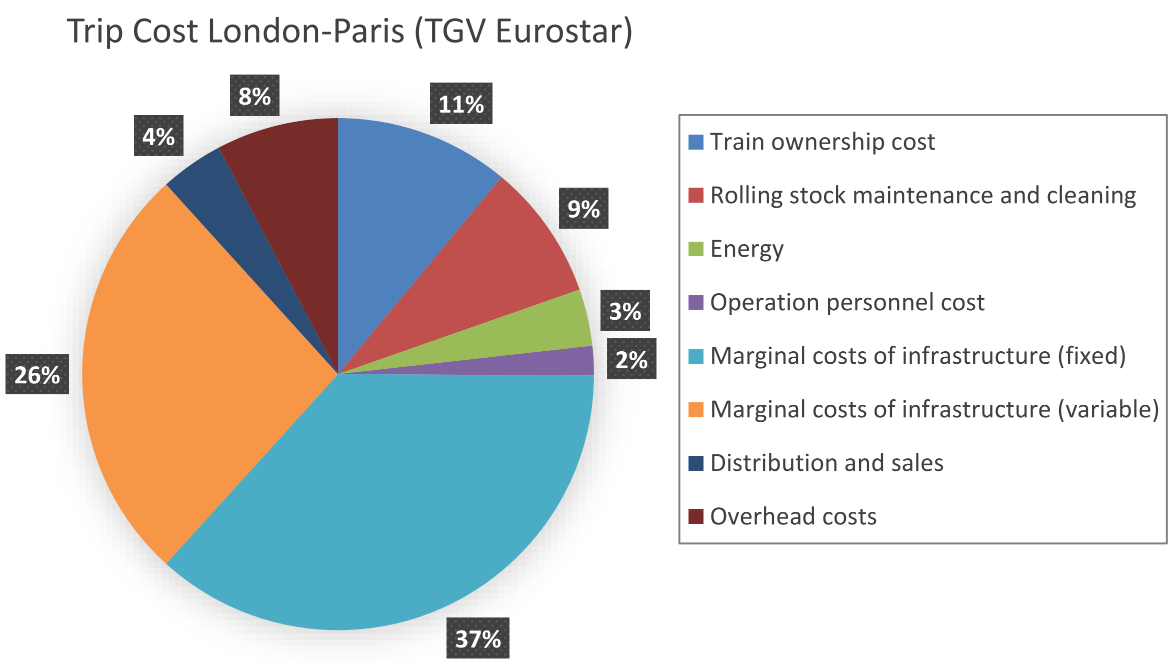

Figure A.28 - Trip cost for London-Paris (2012)

Marginal costs per passenger are computed from the cost function resulting from the HSR Operating Cost model by varying the load factor as shown in figure A.29. For an 81% load factor, this results in a Short-Run Marginal Cost (SRMC) of 0.034 €/ASK (€21 per passenger) Medium-Run Marginal Cost (MRMC) of 0.081 €/ASK (€49 per passenger) for a trip London-Paris. For London-Brussels with a load factor of 65%, the resulting SRMC is 0.036 €/ASK (€21 per passenger) and the MRMC is 0.077 €/ASK (€44 per passenger). The relatively high marginal costs on these routes are caused by the Channel tunnel access charges (UIC 2012). For Frankfurt – Cologne (180 km), the calculated SRMC is 0.006 €/ASK (€3 per passenger), MRMC is 0.027 €/ASK (€12 per passenger) for a single ICE 3 trainset with a 40% load factor. For running double ICE 2 sets with 736 seats and 40% load factor on the 600 km Cologne – Berlin link, the SRMC is 0.004 €/ASK (€3 per passenger) and the MRMC is 0.017 €/ASK (€25 per passenger). Ivaldi and Vibes used in their simulation for the Cologne – Berlin link a marginal cost value provided by DB of €13 per seat and not per passenger as information on load factors was missing (Ivaldi 2008). With an assumed load factor of 40%, this results in a €33 per passenger, which is close to the calculated medium-run marginal costs of €25 per passenger. Applying the approach of Prady and Ulrich (2010) to use costs of infrastructure use and fuel consumption as variable costs for estimating the marginal costs for rail transport results in €32 per passenger and €13 per seat for the Cologne-Berlin link. This is in line with the figures presented by Ivaldi and Vibes (2008). Although the distance is shorter, for the London-Paris link, the total of energy costs and infrastructure charges are €42 per passenger caused by the extra Channel tunnel fees.

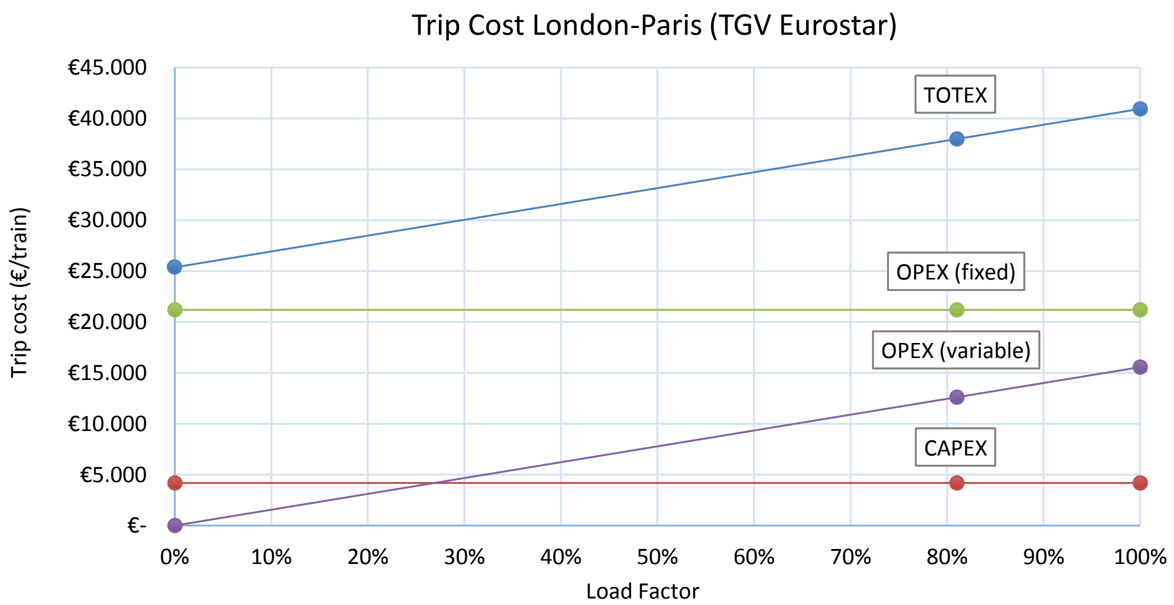

Figure A.29 - Eurostar operating and marginal cost for London-Paris (2012)

The results from the operating cost model are validated by calculation of the operational expenditures by taking a top-down view from Eurostar's 2012 financial accounts[60]. With a total direct cost of £713 m in 2012 and 9.9 m passengers the operational expenditures are £72 per passenger (€86 per passenger at an exchange rate of 1.20). This result shows that the bottom-up figures are underestimated by approximately 50% (table A.23). This may be

[60] Director's report and consolidated financial statements, 31 December 2012, Eurostar International Limited.

caused by the fact that some cost factors are underestimated[61] or not taken into consideration in the cost model like reserve trains for maintenance cover, lease costs, cost for distribution and sales, passenger services and extra overheads. The railways involved formerly owned the fleet of 27 Eurostar trains (SNCF: 12 trains, SNCB: 4 trains, Eurostar UK (EUKL): 11 trains). EUKL, SNCF and SNCB own their assets and were each responsible for running Eurostar services in their own territory[62]. On 1 September 2010, the three national Eurostar operators merged into EIL as a conventional three-way joint venture with its own staff, accounting procedures and a single management structure owned by three shareholders; SNCF (55%), LCR (40%) and SNCB (5%). LCR's holding was transferred to the HM Treasury in June 2014. In May 2015, the UK government completed the sale of its 40% share to a consortium made up of two companies: Caisse de Depot et Placement du Quebec (CDPQ) and Hermes Infrastructure[63]. The financial accounts of EIL are not detailed enough for further analysis, but hidden costs still incurred by the former national operators can disturb the operating cost figures[64].

Table A.23 - Eurostar operational costs 2012

	Route Distance	Load Factor	Operational Expenditures (at load factor)		
	km	%	€/pas	€ct/passkm	€ct/seatkm
Top-down Ldn-Par and Ldn-Bru	448	76	86	19.2	14.6
Bottom-up Ldn-Par	492	81	56	11.3	9.2
Bottom-up Ldn-Bru	373	65	57	15.3	9.9

Note: Calculations by author

K.3 Airline operating costs

Analysis of airline operating costs is simpler than analysis of railway operating costs for two main reasons:

- Airline costs are largely generic, whereas rail costs differ significantly between operators
- Airline operating and financial data is often publicly available, whereas rail data generally is not. (European Commission 2006).

A study carried out by Swan and Adler for the US market (2006) presented a breakdown of aircraft operational cost (figure A.30) and cost function in a planar and a classic Cobb-Douglas form, with respect to seat capacity and distance for short-haul and long-haul flights in the US.

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[61] The infra charges used for UK HS1, France and Belgium are based on a "UIC standard high-speed train" with ten cars, 430 tons, 200 meters and 500 seats and not on the actual Eurostar trains.

[62] Competition policy newsletter 2010 > number 3, European Commission

[63] The sale of Eurostar, HM Treasury, National Audit Office, 6 November 2015

[64] Rolling stock assets that are leased instead of owned do not appear as assets on the balance sheet, but raise the operational expenditures. It is unclear if the rolling stock assets owned by each national railway company are transferred to EIL.

For short-haul single-aisle operations between 1000 and 5000 km, the trip costs are presented by:

$$C = (D + 722) * (S+ 104) * 0.019 \quad (\$)$$

with D the Great Circle Distance and S the number of seats. Unit cost according to the Cobb-Douglass function for short-haul are:

$$c = 2.44 * S^{-0.40} * D^{-0.25} \quad (\$/seatkm)$$

The Planar and Cobb-Douglas cost functions are presented in figure A.31.

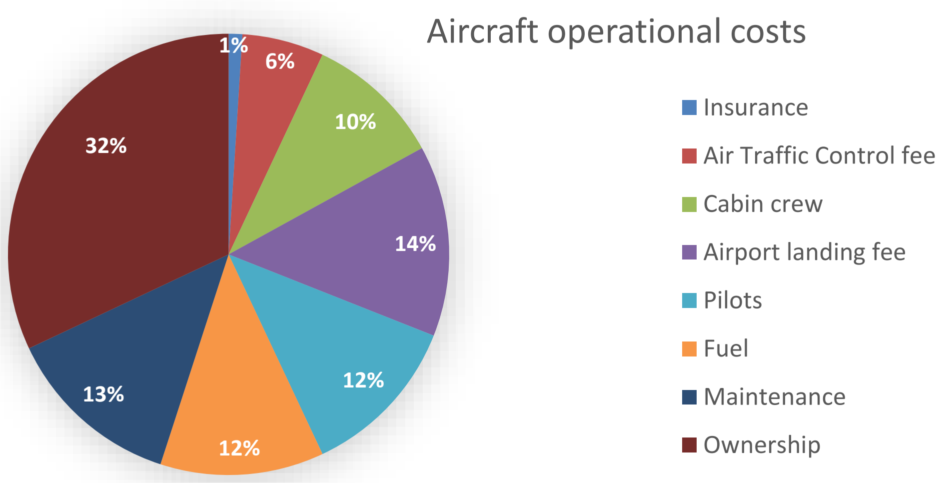

Figure A.30 - Aircraft cost breakdown

Note: Figure by author based on Swan and Adler 2006

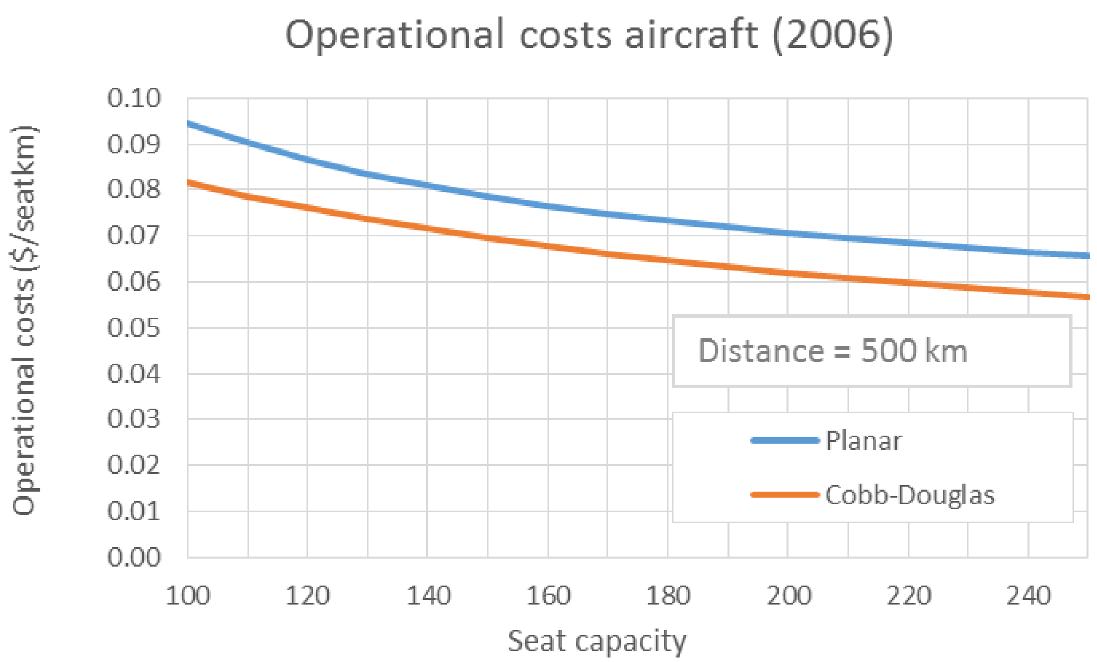

Figure A.31 - US Airline short-haul operating costs

Note: Figure by author based on Swan and Adler 2006

The results are presented in the graph below for a 500 km trip. The estimated operating costs for an aircraft with 150 seats on a 500 km flight is 7.0 to 7.9 $ct/seatkm. Remember that these cost functions are valid for US legacy airlines and cover all fixed and variable costs including aircraft cost of ownership as illustrated in figure A.31.

The airline operating cost model has developed by Steer Davies Gleave for the European market (European Commission 2006) gives the operating cost[65] for Full Service Carriers (FSC) and Low Cost Carriers (LCC):

$$c_{FSC} = 0.048 + (46/D) \text{ (€/seatkm)}$$

$$c_{LCC} = 0.029 + (30/D) \text{ (€/seatkm)}$$

LCC operating unit cost (8.9 €ct/seatkm) are about 35% lower than for FSC (14.0 €ct/seatkm) on a 500 km flight. The cost functions are presented in the graph below (figure A.32).

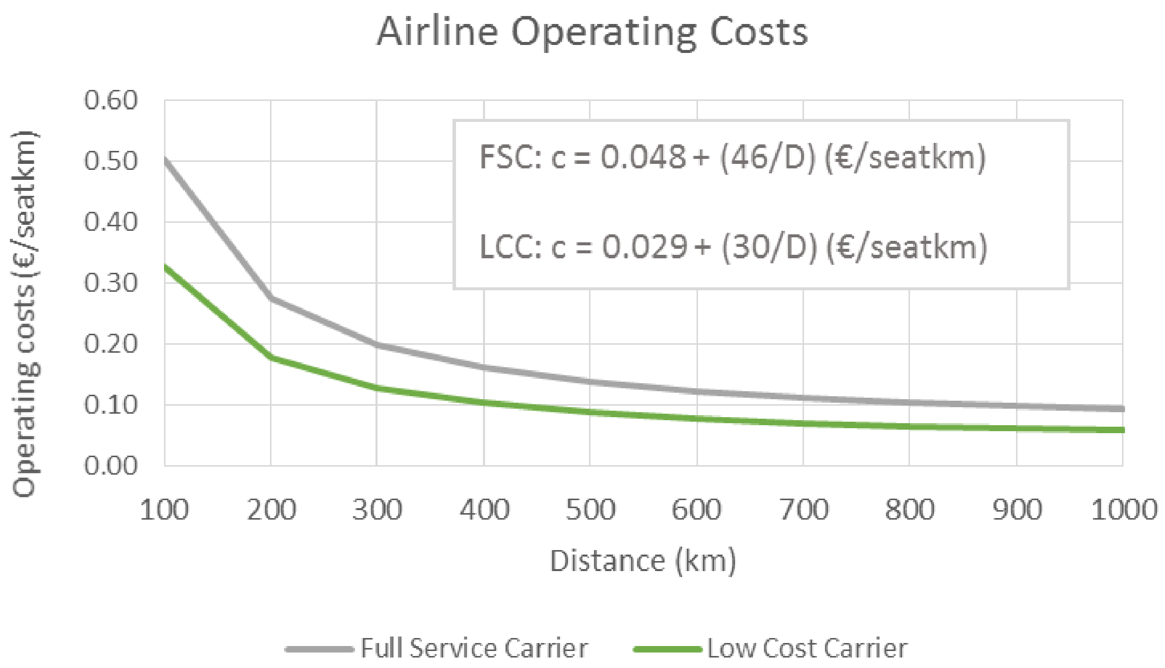

Figure A.32 - EU Airline operating cost

Source: European Commission, 2006

From these cost estimates, it can be concluded that for an aircraft with 160 seats and a distance of 500 km, the EU FSC costs are about 60% higher than for US Legacy airlines (exchange rate $/€ =1.2)[66]. The estimated operating costs for the Swedish domestic services provided by SAS (Full Service Carrier with B737-800 aircraft) as presented in figure K.1 is about 15% higher than predicted by the FSC cost curve presented in figure K.9. One of the

[65] Included are operational aircraft cost, pilots and cabin crew, airport handling charges, sales and reservations, advertising and promotion, commission, en-route and airport charges, passenger service charges. Costs for aircraft ownership are excluded.

[66] Besides differences in the US and European market structure, price levels are also not the same. Swan and Adler collected their data from 1996 to 2001 and Steer Davies Gleave used sources from 2003 to 2005.

reasons is the relatively high cost of pilots and cabin crew in Scandinavia (Froïdh 2008). For an average flight distance of 790 km Fröidh calculated 0.039 €/ASK for Ryanair (LCC, B737-800, 189 seats) compared to 0.067 €/ASK as estimated by Steer Davies and Gleave for a Low Cost Carrier.

The airline operating costs estimated by Givoni (2005) using a bottom-up approach for 2001 for a flight from London Heathrow to Paris CDG (346 km) are 0.069 €/ASK for an A320 Airbus (150 seats) and 0.075 €/ASK for a Boeing B737-300 (128 seats). As LCC airlines achieve lower operating costs than FSC's, Givoni assumes 25% lower aircraft operating costs for an A320 Airbus operated by a LCC, which reduces the aircraft operating costs to 0.057 € per seat-km for the London-Paris route. The operating costs curves in figure A.32 indicate 0.181 €/ASK for a Full Service Carrier and 0.116 €/ASK for a Low Cost Carrier for the London-Paris route. The estimates presented by Givoni (2005) are much lower than those presented by Steer Davies Gleave (2006), which may indicate that not all cost factors are taken into account.

The operating costs from the Steer Davies Gleave study as presented in figure A.32 are used as an estimation of the Medium-Run Marginal Costs. For the London-Paris route the operating cost varies between 48 €/pas for EasyJet on the Luton-Charles de Gaulle route and 105 €/pas for British Airways on the Heathrow-Orly connection (Table A.24).

Table A.24 - Airline operating costs for Paris-London 2012

London – Paris (2012)			**GCD**	**LF**	**OC**			**MC**
	Connection	Carrier	km	%	€ct/ skm	€ct/ pkm	€/ pas	€/ pas
FSC	LHR - CDG	British Airways	346	68.8	18.1	26.3	91	43
	LHR - CDG	AirFrance	346	68.8	18.1	26.3	91	43
	LHR - ORY	British Airways	366	60.6	17.4	28.7	105	50
LCC	LCY - ORY	CityJet	378	57.6	13.7	23.8	84	40
	LTN - CDG	EasyJet	352	84.9	10.8	12.8	48	23

Note 1: Based on the available data no distinction can be made between the load factors for British Airways and Air France on the Heathrow-Charles de Gaulle connection.
Note 2: For CityJet flying with Fokker 50 aircraft (50 seats) since 2011, the operating costs per ASK are assumed to be 20% higher than for LCC carriers (Froïdh 2008)
Note 3: Price index 1.0 assumed over the period 2006 to 2012
Note 4: Great Circle Distances (GCD): www.dices.net/airport/distances
Note 5: Load Factors (LF): Eurostat 2012
Note 6: Table by author based on data from the European Commission (EC 2006)

Taking the approach of Prady and Ulrich (2010) for road and rail transport to use fuel costs and fees as variable costs for estimating the marginal costs and applying it to air transport, the fuel costs and Air Traffic Control (ATC) and airport landing fees need to be taken into account. For US airlines, fuel is approximately 12%, landing fees 8 to 14% and ATC charges 2 to 6% of the total aircraft operating costs. Ownership represents approximately 32% of the airplane costs (Swan and Adler 2006). Using the upper limits of these indicative numbers and excluding the ownership costs, about 48% of the operating costs are related to fuel and fees and 52% to cabin crew, pilots and maintenance (see figure A.30). Combining this with the results from figure A.32 and table A.24, the variable costs for flights between London and Paris are €23 per passenger for LCC and €50 per passenger for FSC.

K.4 Car operating costs

In our model, car owners are considered private profit-maximising transport operator. To calculate the operating costs for leisure travellers, we assume a new compact (B) class car with four seats per car available per trip. Catalogue value of € 27,000 running on petrol for 15,000 km/yr. over a five-year period. This results in a total car cost of 0.114 €/ASK consisting of 0.072 €/ASK fixed costs and 0.042 €/ASK variable cost. For the business market, the operating cost calculation follows the same procedure but now taking a new middle (D) class diesel car with five seats and a catalogue value of € 45,000 running 35,000 km/yr over a five-year time period. This results in total car cost of 0.082 €/ASK consisting of 0.047 €/ASK fixed costs and 0.034 €/ASK variable cost. The cost breakdown is illustrated in figure A.33. The marginal costs are estimated by dividing the variable costs by the trip distance and the number of seats.

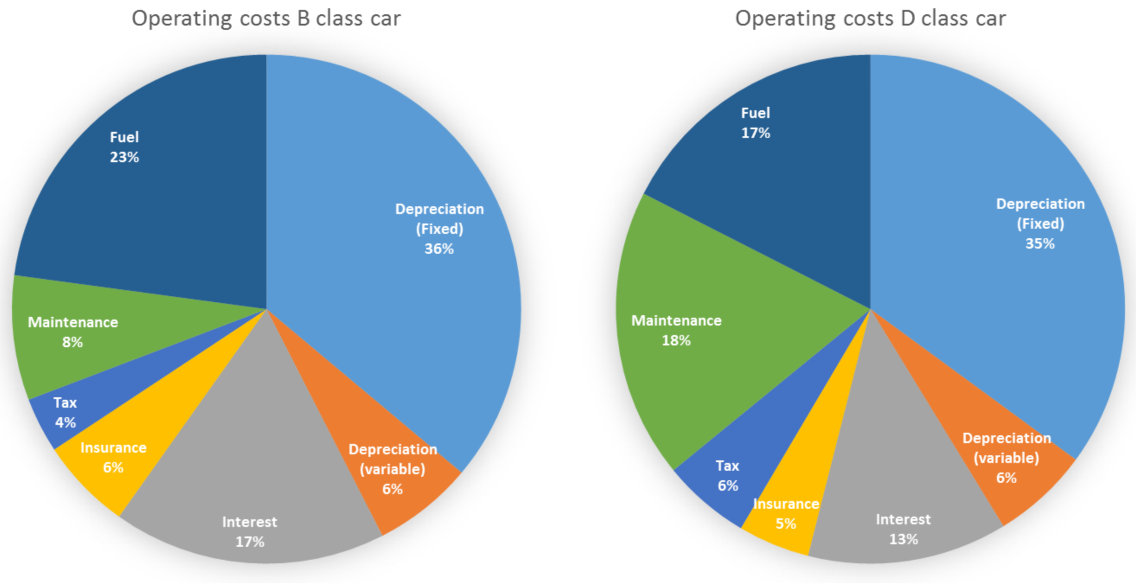

Figure A.33 - Car cost breakdown for leisure and business cars

Note: Calculations by author

When crossing the Channel, cars can choose between the Euroshuttle train and a ferry. These ticket costs need to be added as a variable component to the operating costs and to the marginal costs. Single fares for the Eurotunnel and two main ferries DFDS Seaways and P&O Ferries are derived from the UK International Passenger Survey (IPS)[67]. Fares for DFDS and P&O are almost equal and lower than the Eurotunnel fares. The data also show that business travellers pay more than leisure travellers, both for the Eurotunnel as for the ferries.

The short-run marginal costs and prices for travelling by car & ferry or car & tunnel can be computed from the IPS data and the car operating costs. Figure A.34 shows that the short-run marginal costs for leisure passengers travelling from London to Paris are about €8 and for business travellers €37-40. There is little difference between the tunnel and ferry option. Marginal costs are relatively low (especially for the leisure market) as the fares for tunnel

[67] The UK International Passenger Survey is published by the UK Office for National Statistics and is accessible from www.ons.gov.uk

and ferry fall sharply with the rising number of passengers per car. The price for the trip per passenger is computed from the total car costs and the average load factor as reported in the IPS 2012 survey (star markers in figure A.35). The average load factor for business trips is 2.1-2.3 and 3.0-3.3 for leisure trips, resulting in a trip cost of €73-74 for leisure and €108-113 for business travellers (see Table A.25).

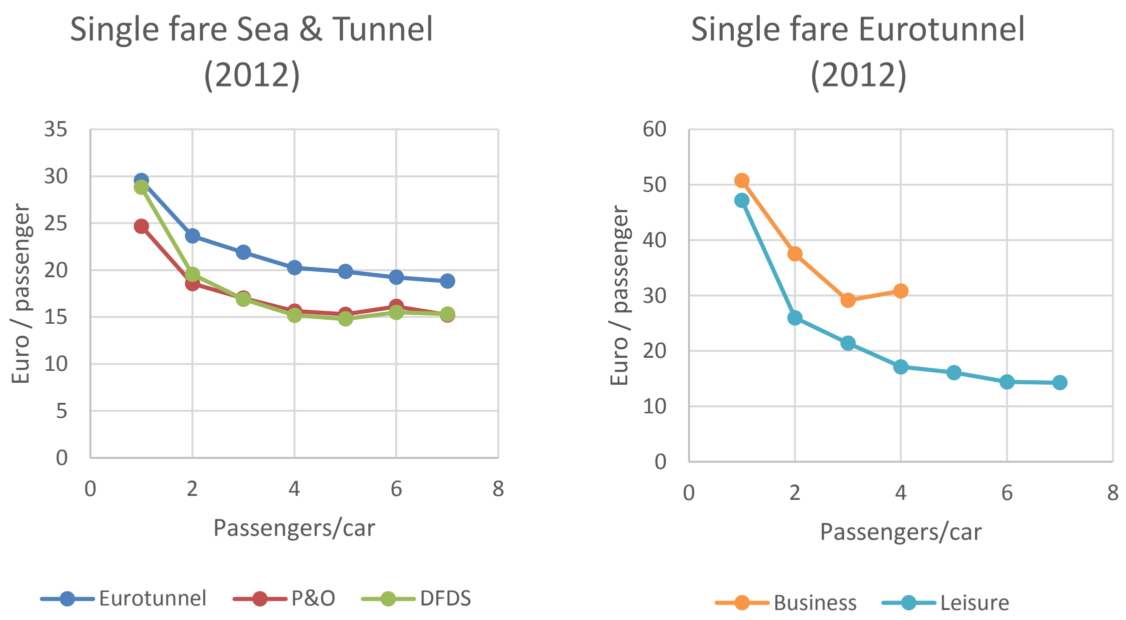

Figure A.34 - Fares for crossing the Channel by car

Source: Figure by author based on IPS 2012 data

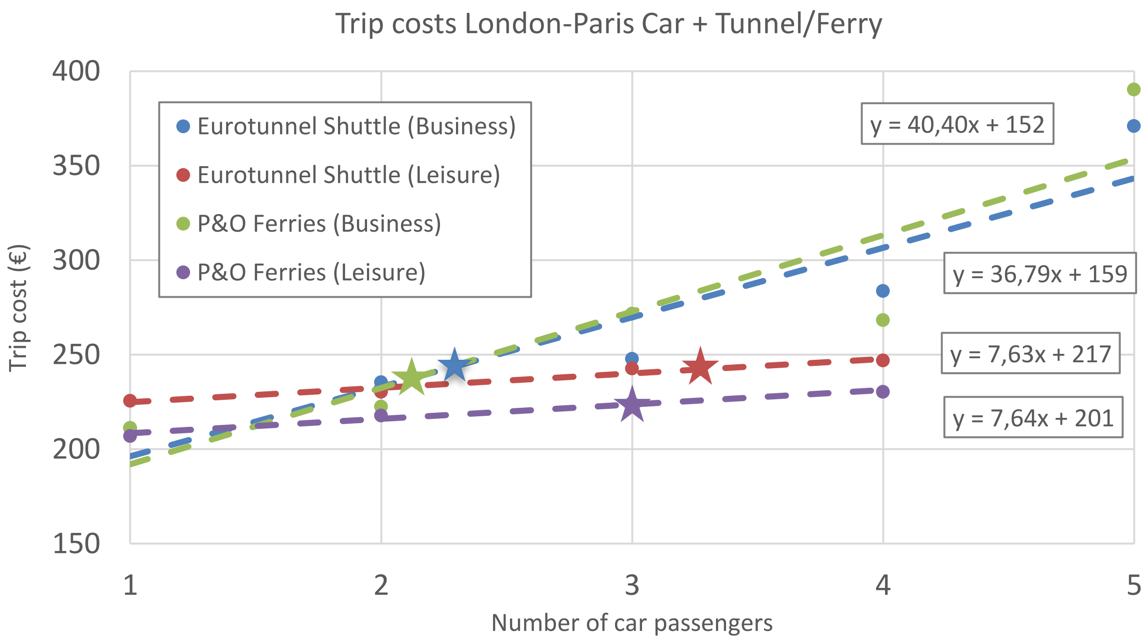

Figure A.35 - Car trip cost function for London-Paris

Table A.25 also shows the numbers for fuel costs and fares for crossing the Channel at the average load factor. Taking the approach of Prady and Ulrich (2010) for estimating the marginal car costs using fuel costs and fees as variable costs results in a marginal cost of €24-28 for leisure and €51-53 for business travellers. Compared to the SRMC estimation, the fuel costs are no longer fixed in this case.

Table A.25 - Car travelling cost London to Paris

		Eurotunnel Shuttle		P&O Ferries	
		Business	Leisure	Business	Leisure
Load factor	(pax/car)	2.3	3.3	2.1	3.0
Trip cost	(€/car)	242	242	236	224
Trip cost	(€/seat)	48	61	47	56
Trip cost	(€/pax)	108	73	113	74
Fuel cost	(€/pax)	18	8	20	9
Fare (Tunnel/Ferry)	(€/pax)	35	20	31	15
Short-Run Marginal Cost	(€/pax)	40	8	37	8

Note: Calculations by author from IPS 2012 data