Market Potential for HSR Services: Oslo – Copenhagen via Gothenburg Oslo – Stockholm via Gothenburg Copenhagen – Stockholm via Gothenburg

ATKINS

The Scandinavian 8 Million City
#COINCO, WP2 analyse 1

Final Report

June 2012

THE SCANDINAVIAN 8 MILLION CITY

Corridor of Innovation and Cooperation #COINCO

THE EUROPEAN UNION
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1. Introduction

1.1. Background

This report is part of the preliminary tranche of work into High-Speed Rail (HSR) Market in Scandinavia commissioned by COINCO (Corridor of innovation and cooperation), and addresses the need for preliminary passenger market, demand and revenue analysis (WP2, Analyse 1).

High Speed Rail has the capacity to bind separate communities together over long distances, link a group of communities with neighbouring regions and indeed join different countries together. This was acknowledged in both the recent Norwegian and the Swedish high speed rail studies.

COINCO understand this, and are seeking to test the scale of these opportunities in helping build a Scandinavian City with an 8 million population, whose size will allow it to compete more effectively within the global markets of today. COINCO view the establishment of sustainable, efficient high quality transport connections between the major Scandinavian economic centres as a key element to achieving this goal.

There is an opportunity to put the Copenhagen – Oslo (via Gothenburg and Malmö) corridor at the centre of any future Scandinavian high speed network. The route makes up the key western leg of the European TEN-T (Trans-European) network in Scandinavia. In addition two other corridors of a potential network are those between Oslo – Stockholm and Copenhagen – Stockholm. Gothenburg has the potential to provide a key intermediate stop on all routes, and act as an interchange hub as well as a key origin and destination in itself. With the Stockholm perspective we are considering about a 12 million region that can be served by High Speed Rail.

Taking the Oslo – Copenhagen corridor as an example, today the journey time between Copenhagen and Oslo is around eight hours, and requires a change of train, because of the limitations imposed by aged and outdated infrastructure. The rail journey time is around 3 hours less than that of the coach service. The rail route is just over 500 kilometres, which translates as an average of between 60 and 70 km per hour. This means that rail struggles to compete with road particularly over moderate distances.

High speed rail could deliver (subject to the adoption of a true HSR concept) journey times of 2 hours and 40 minutes between Copenhagen and Oslo, and consequently allow direct competition with air. It would also allow the intermediate travel market to be developed further; particularly between Oslo – Gothenburg, Gothenburg – Helsingborg, Gothenburg - Malmö and Gothenburg - Copenhagen, albeit on sections where rail already accounts for the majority of traffic.

One key issue is that the existing passenger rail network is, on certain sections of route, already capacity constrained. Some incremental improvements will be developed such as the Ski tunnel, but overall the demand for rail timetable paths already exceeds supply, reflecting the limited nature of the rail infrastructure currently in place. New high speed rail lines take time to plan, design and build. In 2009 Gunnar Malm estimated that a new line between Stockholm and Malmö would take 14 years to build (suggesting it might be operational by 2023). Allowing for the passage of time and projecting this timescale forward, would indicate that a new HSR line would be unlikely to be operating before 2226/7. Further delaying the progression of new transport infrastructure and enhanced capacity will only exacerbate the impacts the constraints of existing infrastructure will have on socio-economic conditions within the region.

1.2. Overall Context of this Report

The purpose of the initial market analysis exercise is to establish the size of the potential market for HSR for a number of corridors in Scandinavia. This involves identifying the current market and its projected growth, mode share and the preferences and priorities of those markets. The current market is used as a starting point, and is combined with forecasts for growth in population and GDP and research parameters into the potential behavioural response to HSR attributes, to forecast how much of this market would be attracted to new HSR scenarios, and how much additional demand might be induced. The forecasting approach builds on that adopted for the Norwegian HSR Assessment Study and combines that forecasting approach with new data from available models in the region, most notably the TRANS-TOOLS IBU model.

The outputs from the demand forecasting are used to predict the revenue. This includes the passengers who would transfer from an existing mode (air, car, existing rail services, coach or ferry) as well as the demand generated as a result of HSR creating new journey opportunities or making travel a more attractive proposition than would have been previously.

1.3. Scope of this Report

This report presents a summary of the key results for HSR demand and revenue for each of the HSR scenario corridors examined. The report describes the detailed results of HSR options on a corridor-by-corridor basis. The analysis presented provides a summary of demand, revenue and passenger km travelled within each route on each corridor, and includes an assessment of the average occupancy of high speed services.

For HSR alternatives, the forecasts of incremental rail demand and revenue over the reference case are subdivided into (a) journeys abstracted from air, car, coach and (where appropriate) classic rail, and (b) pure generation, i.e. additional mobility induced by the improved journeys. Additionally the mode share obtained by HSR over Air is shown to assess to competitiveness for different journeys between key cities.

In addition, to the market forecasting exercise we have also sought to address one further question identified in the study brief:

- What is the market basis for relevant profitable HSR services in operation?

Specific analysis and research has been undertaken in relation to relevant profitable HSR services and is presented in this report. The report also provides conclusions with respect to all the areas of analysis and makes recommendations on next steps in the area of market analysis required to support any next phase of HSR scheme development.

1.4. Structure of this Report

The remainder of this report has the following chapters:

- Chapter 2 – Option specifications, provides details of the specification of Reference and HSR scenarios and options adopted to facilitate analysis.

- Chapter 3 – Model Development, sets out the modelling methodology building on the Norway HSR project and provides a summary of the key assumptions used in developing the market and revenue forecasts with relation to both the routes and journey time assumptions.

- Chapter 4 – Core HSR Forecasts, provides the results by corridor of the forecasting analysis of Core HSR route scenarios.

- Chapter 5 – Forecasting Analysis Sensitivity Tests, presents the results of sensitivity analysis around the Core HSR route scenarios.

- Chapter 6 – HSR Market Forecast Conclusions, presents the conclusions drawn from the forecasting analysis presented in Chapters 2 to 5.

- Chapter 7 – Review of Drivers for Profitable HSR Operations presents the findings and conclusions drawn from the research into this specific area.

- Chapter 8 – Overall Conclusions and Recommended Next Steps.

2. HSR Option Specifications

2.1. Main Forecasting Assumptions

This section discusses the forecasting assumptions with relation to the results presented later in this report. Atkins High Speed Norway model along with TRANS-TOOLS IBU model has been adopted for the future year forecasting. TRANS-TOOLS (Tools for Transport Forecasting and Scenario testing) model was developed as a European transport network model to be used by the European Commission as a reference model for projections and impact assessments. The TRANS-TOOLS model is developed by Rapidis and covers the whole long distance travel market (air, rail, car, coach) in Europe.

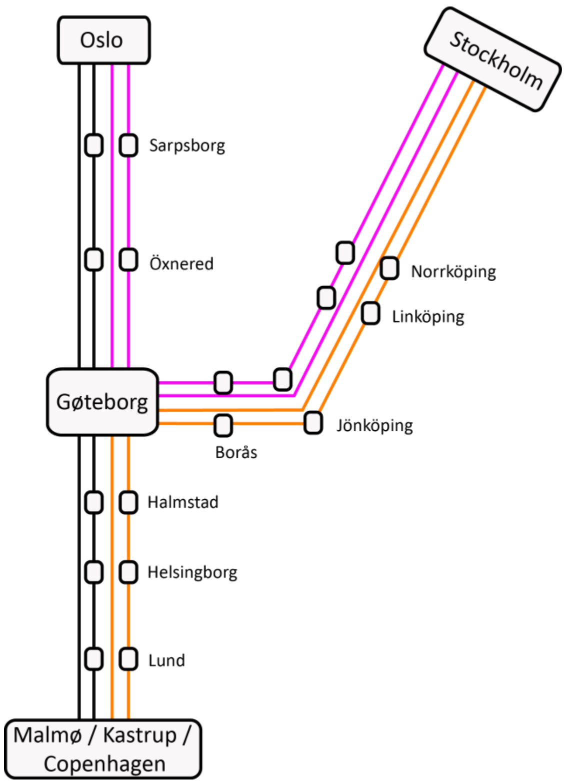
Critical to the technical analysis of the implications of HSR are the assumptions made with respect to the type of HSR service that would operate.

At this early stage in project development, there is inevitably a great deal of uncertainty as to the service that might be delivered and operated and consequently it is essential to establish a reasonable basis for "testing" the impact of HSR. The provision of HSR services is specified with the capture of demand and market share in mind. It is assumed that a core hourly HSR service, serving all the larger and significant towns and cities on the alignment is provided (approximately 18 trains a day in each direction). In the core scenarios it is assumed that rail fare is 100% of air fare, reflecting the current pricing of existing rail services compared with air services.

It is fully recognised that each of the assessed scenarios represents a simplification of what might be delivered as an HSR service, and the potential range of service and fare levels that might be offered in practice. However, in order to undertake comparative analysis of a large number of alternatives within the study timescale, and given the detail at which the available tools allow for alternatives to be considered, they provide a reasonable basis and range of service offer for assessment, consistent with this stage of study.

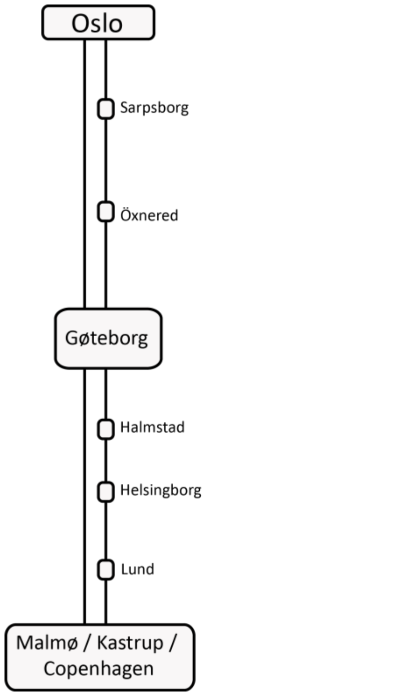
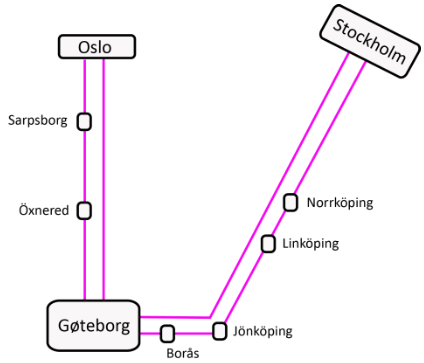
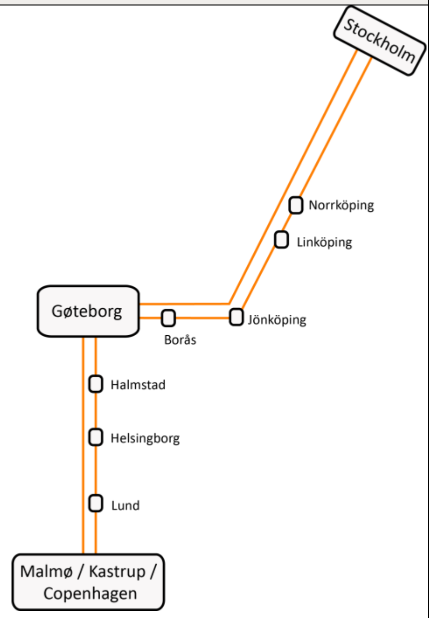
The brief was to look at a high speed rail connection between Oslo, Copenhagen and Stockholm. The network options are illustrated schematically Figure 1 below:

Figure 1. HSR Corridors



As part of this study we have looked at three HSR routes individually (provided in Table 1, below), these being Oslo – Copenhagen (OC), Oslo – Stockholm (OS) and Stockholm – Copenhagen (SC). In each case, a Core Scenario was identified reflecting a combination of target journey time and stopping pattern and service frequency. The Core Scenario is modelled for 2024, 2043 and 2060 with a gravity model applied to indicatively forecast short distance trip potential. The forecast years have been chosen to be consistent with previous HSR work undertaken as part of Norway HSR Assessment Study commissioned and managed by JBV.

Table 1. Options for High Speed Rail Routes

Oslo – Copenhagen (OC)	Oslo- Stockholm (OS)	Stockholm- Copenhagen (SC)
		

Core Scenario forecasting results are presented in Chapter 3. Testing of the sensitivity of the Core Scenario forecasts to alternative journey time, service provision, fare and growth assumptions was undertaken and the results are presented in Chapter 4. Combining Core and Sensitivity Tests, in total 24 HSR forecasts were produced.

2.2. Core Scenarios

In discussion with COINCO the core scenarios were defined. For each alignment the core scenario is a one hourly service using a stopping pattern with a combination of major and intermediate scale stops. An agreed starting point was a target journey time for a "direct" service serving a limited number of major stations:

- 2:30 (+12) Oslo - Göteborg - Malmo - Kastrup, additional 12 mins to Copenhagen
- 3:15 Oslo - Göteborg - Stockholm
- 3:15 (+12) Stockholm - Göteborg - Malmo - Kastrup, additional 12 mins to Copenhagen

Agreement was then reached on additional stops to be included in the Core Scenario specification as shown in Table 1. The resulting Core Scenario journey times are derived based on distance proportionate to the overall journey time with 5 minutes added per additional station:

- +0:25 Oslo - Copenhagen – 5 additional stops
- +0:30 Oslo - Stockholm – 6 additional stops

- +0:35 Stockholm - Copenhagen – 7 additional stops

Copenhagen Central station, Kastrup and Malmo have been split into individual stops in our modelling, but should be looked at in unison when assessing long distance demand. In addition internal demand in the Copenhagen-Malmo-Lund-Helsingborg area has been suppressed in the Mode Choice Modelling for technical reasons and also because the area is quite well served with rail at the moment.

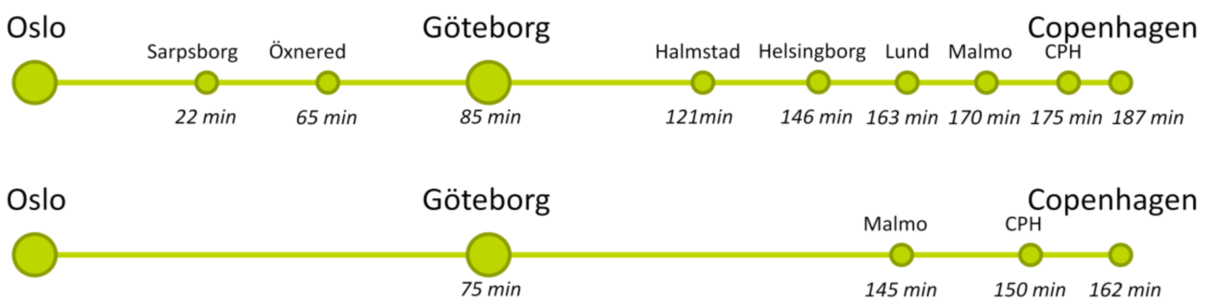
2.2.1. Stopping Patterns and Journey Times

In accordance with discussions and approval from the client the following service patterns have been setup. Each of the corridors has a fast direct service with realistic target journey times. The stopping patterns of the services below have been assessed either as Core scenarios or as sensitivity tests.

2.2.1.1. Oslo – Copenhagen (OC)

- OC1: Stopping Service via Öxnered (Core Scenario)
- OC3: Direct service Oslo-Gothenburg-Copenhagen (Sensitivity Test)
- OC4: OC1 and OC3 combined (Sensitivity Test)

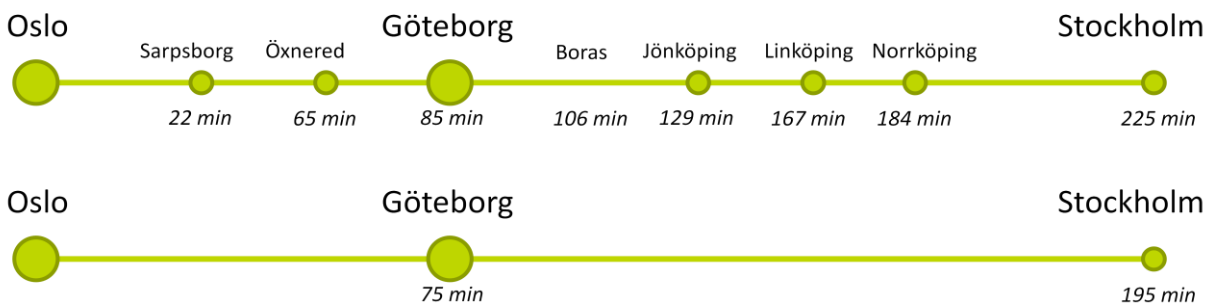
Figure 2. Oslo - Copenhagen



2.2.1.2. Oslo – Stockholm (OS)

- OS1: Stopping Service via Öxnered (Core Scenario)
- OS3: Direct service Oslo-Gothenburg-Stockholm (Sensitivity Test)
- OS4: OS1 and OS3 combined (Sensitivity Test)

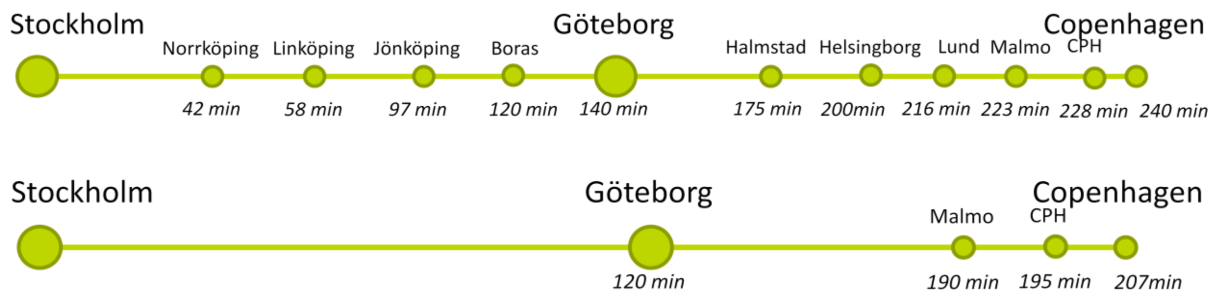
Figure 3. Oslo - Stockholm



2.2.1.3. Stockholm – Copenhagen (SC)

- SC1: Stopping Service
- SC3: : Direct service Stockholm-Gothenburg-Copenhagen (Sensitivity Test)
- SC4: SC1 and SC3 combined (Sensitivity Test)

Figure 4. Stockholm - Copenhagen



2.2.2. Fare Assumptions

The HSR fares are assumed to be approximately equivalent to the corresponding air fares.

2.2.3. Growth Assumptions

The underlying demand is based on the Norway HSR model previously developed by Atkins, in-filled with data from TRANS-TOOLS for zone pairs with trip ends in Sweden and Denmark that are not entirely covered by the existing Norway model. In essence the 'external' demand is taken from TRANS-TOOLS IBU data as follows:

- 2024 demand interpolated between 2020 and 2030 from TRANS-TOOLS
- 2043 – Norway model growth assumptions by mode
- 2060 – Norway model growth assumptions by mode

2.2.4. General Cost Assumptions

For the generalised costs the basis is also the Norway model in-filled with data from TRANS-TOOLS for Sweden and Denmark. Costs from IBU 2030 have been used for all model years.

- 2024 – 2030 data from TRANS-TOOLS
- 2043 – 2030 data from TRANS-TOOLS
- 2060 – 2030 data from TRANS-TOOLS

2.3. Sensitivity Test Specification

Details of the sensitivity test definitions are described in this chapter. Sensitivity tests are provided for looking at options for journey time, service provision, fare and growth.

In total 24 calculations are provided to assess the potential for high speed demand. The tests for each of the corridors are outlined in the following set of tables:

Table 2. Oslo – Copenhagen

Route	Oslo – Copenhagen					
Test	**Core Scenario**	**Test 1: Fare level**	**Test 2: Direct service**	**Test 3: Frequency**	**Test 4: Low growth**	**Test 5: High growth**
% of air fare	**100%**	**60%**	100%	100%	100%	100%
Stops	**Sarpsborg Oxnered Goteborg Halmstad Helsingborg Lund Malmo Kastrup**	Sarpsborg Oxnered Goteborg Halmstad Helsingborg Lund Malmo Kastrup	**Goteborg Malmo Kastrup**	Sarpsborg Oxnered Goteborg Halmstad Helsingborg Lund Malmo Kastrup	Sarpsborg Oxnered Goteborg Halmstad Helsingborg Lund Malmo Kastrup	Sarpsborg Oxnered Goteborg Halmstad Helsingborg Lund Malmo Kastrup
Journey Time in minutes	**187**	187	**162**	187	187	187
Stopping pattern	**Stopping**	Stopping	**Direct**	**Stopping +Direct**	Stopping	Stopping
Frequency (train per hour)	**1**	1	1	**2**	1	1
Growth Rate	**Norway**	Norway	Norway	Norway	**0.5%**	**2%**
Forecast Year						
2024	**X**	X	X	X		
2043	**X**				X	X
2060	**X**					

Table 3. Oslo – Stockholm

Route	Oslo – Stockholm					
Test	Core Scenario	Test 1: Fare level	Test 2: Direct service	Test 3: Frequency	Test 4: Low growth	Test 5: High growth
% of air fare	100%	60%	100%	100%	100%	100%
Stops	Sarpsborg Oxnered Goteborg Boras Jonkoping Linkoping Norrkoping	Sarpsborg Oxnered Goteborg Boras Jonkoping Linkoping Norrkoping	Goteborg	Sarpsborg Oxnered Goteborg Boras Jonkoping Linkoping Norrkoping	Sarpsborg Oxnered Goteborg Boras Jonkoping Linkoping Norrkoping	Sarpsborg Oxnered Goteborg Boras Jonkoping Linkoping Norrkoping
Journey Time in minutes	225	225	195	225	225	225
Stopping pattern	Stopping	Stopping	Direct	Stopping +Direct	Stopping	Stopping
Frequency (train per hour)	1	1	1	2	1	1
Growth Rate	Norway	Norway	Norway	Norway	0.5%	2%
Forecast Year						
2024	X	X	X	X		
2043	X				X	X
2060	X					

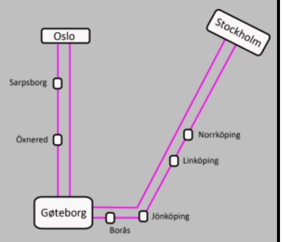
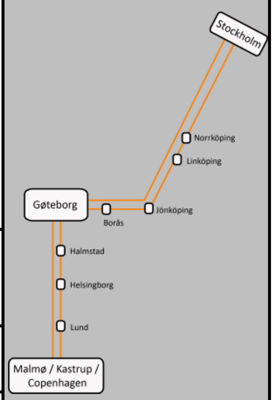


Table 4. Stockholm – Copenhagen

Route	Stockholm – Copenhagen					
Test	Core Scenario	Test 1: Fare level	Test 2: Direct service	Test 3: Frequency	Test 4: Low growth	Test 5: High growth
% of air fare	100%	60%	100%	100%	100%	100%
Stops	Norrkoping Linkoping Jonkoping Boras Goteborg Halmstad Helsingborg Lund Malmo Kastrup	Norrkoping Linkoping Jonkoping Boras Goteborg Halmstad Helsingborg Lund Malmo Kastrup	Goteborg Malmo Kastrup	Norrkoping Linkoping Jonkoping Boras Goteborg Halmstad Helsingborg Lund Malmo Kastrup	Norrkoping Linkoping Jonkoping Boras Goteborg Halmstad Helsingborg Lund Malmo Kastrup	Norrkoping Linkoping Jonkoping Boras Goteborg Halmstad Helsingborg Lund Malmo Kastrup
Journey Time in minutes	240	240	207	240	240	240
Stopping pattern	Stopping	Stopping	Direct	Stopping +Direct	Stopping	Stopping
Frequency (train per hour)	1	1	1	2	1	1
Growth Rate	Norway	Norway	Norway	Norway	0.5%	2%
Forecast Year						
2024	X	X	X	X		
2043	X				X	X
2060	X					



2.3.1. Sensitivity to alternative HSR fares level

In line with the Norway High Speed study tests and the discussions with COINCO on fare levels the following has been assumed:

- Core Scenario – 100% of air fare
- Sensitivity – 60% of air fare

It is considered that the Core Scenario realistically represents the current air-to-rail fare ratio and also allows for potential changes in the future. The 60% Air fare sensitivity has been used for tests Oslo-Copenhagen (OC2), Oslo-Stockholm (OS2) and Stockholm-Copenhagen (SC2).

Fare Sensitivities are calculated for each of the core scenarios for the year 2024 only.

2.3.2. Sensitivity to alternative exogenous growth assumptions

Sensitivity to growth assumptions is carried out by applying the following growth factors to each of the core scenarios.

- High – 2% per year creating Test Oslo-Copenhagen (OC5), Oslo-Copenhagen (OS5) and Stockholm-Copenhagen (SC5).
- Low – 0.5% per year creating Test Oslo-Copenhagen (OC6), Oslo-Copenhagen (OS6) and Stockholm-Copenhagen (SC6).

For the two different base sets of data the growth sensitivity has been applied accordingly. For TRANS-TOOLS (IBU) derived data, from the year 2030 to the demand from that model year onwards and the HSR Norway data model from the year 2030 meaning normal HSR Norway growth has been applied from 2024 to 2030 before growing by the above annual factors.

2.3.3. Sensitivity to an alternative direct limited stopping pattern

Sensitivity to operating an alternative direct service option has been examined. The sensitivity test has services call at the end stations and additionally in Gothenburg only. The target time for the service is changed accordingly. At the Copenhagen end, all services call at Malmo, Kastrup (Airport) and Copenhagen Central station.

Sensitivity test forecasts are prepared for year 2024 only for the Oslo-Copenhagen (OC3), Oslo-Stockholm (OS3) and Stockholm-Copenhagen (SC3) corridors.

2.3.4. Sensitivity to a combined core and direct HSR service offer

Sensitivity tests to cover effects of providing a combined hourly Direct and hourly Core Service has been carried out, with results prepared for 2024 only for the Oslo-Copenhagen (OC4), Oslo-Stockholm (OS4) and Stockholm-Copenhagen (SC4) corridors.

3. Model Development

3.1. General principles

The main model development done for this project has focused on merging data from the IBU TRANS-TOOLS Model with the existing Norway Model Zones and on adjusting the gravity model approach to suit the coarser zoning system and better road options available in Sweden.

All zones, existing as well as additional, are based on NUTS3 zoning or subdivisions in TRANS-TOOLS finer zones:

- The Norway HSR model already includes six zones in Sweden – two of these were divided into five zones to ensure there is only one HSR station per zone. In these zones, demand from the existing model has been split based on TRANS-TOOLS data split.
- 23 zones were created:
  - 20 in south Sweden and Denmark
  - One for all of northern Sweden
  - One for Western Europe (Germany) and one for Finland-Baltic countries

The zone disaggregation has been made to ensure there is only one High Speed Rail station per zone.

For the COINCO project we have been able to access results from TRANS-TOOLS IBU model runs from the base case scenarios for the following three forecast years 2005, 2020 and 2030. These have been used to create demand and generalised costs (weighted time) for the new zoning structure to infill new zone pairs; this is discussed in details later in this report.

3.2. Additional Airports in Mode Choice Model

In addition to the existing airports in the Norway HSR model, demand from the following airports has been included in the Mode Choice Model:

- In Sweden:
  - Malmo,
  - Göteborg,
  - Stockholm-Arlanda, (was included in the Norway HSR model)
- In Denmark:
  - Copenhagen-Kastrup,
  - Aalborg,
  - Aarhus, and
  - Billund

Two generic airport zones have been added for ‘Western Europe’ and ‘Finland – Baltic countries’ to account for international demand from the rest of Europe.

3.3. Norway HSR Model Description

3.3.1. Forecasting Assumptions

Detailed description of the HSR Norway Model is available in the following reports *Norway High Speed Rail Assessment Study: Phase III – Model Development Report*”, dated 25th January 2012. For the major interventions – which involve new infrastructure and potentially high specification rolling stock – a specially-developed mode choice modelling framework was developed to assess Norwegian HSR project options. This framework has been applied as basis for the Scandinavian HSR market review and is described in full as part of the Norway HSR model documentation. The key modelling assumptions employed in the bespoke demand model are listed as follows:

Zoning

In the main cities, excluding Kristiansand, the model zones are urban districts (bydeler). Elsewhere they are municipalities (kommuner), or in sparsely-populated areas, groups of municipalities with joint population of approximately 60,000. In total the model has 113 zones; this includes 104 area zones within Norway, eight area zones within Sweden and a ‘point’ zone for Gardermoen Airport.

Mode choice structure

The Mode Choice Model is based on the results of Stated Preference (SP)/ willingness to pay surveys using survey responses from a large panel of Norwegian ‘volunteers’. The model considers the mode choice from two automatically selected tiers. Where air is an existing option for travel the model considers the mode choice between air and HSR at an absolute level and increments around the demand from other modes based on a reduced composite cost of fast modes following the introduction of HSR. Where air travel is not an existing option the model considers the mode choice between the current rail service and HSR at an absolute level and increments around the demand from other modes based on the reduced composite cost of rail following the introduction of high speed services. As the main mode model only includes trips of over 100km where HSR journeys are under this distance forecasts are produced directly from a separate Gravity Model.

Mode choice parameters

The mode choice parameters were estimated from SP survey analysis as mentioned above. A full description of the surveys and estimated models is included is included as part of Norway HSR model documentation.

Access and Egress times

HSR and Air: For each zone, the average access/egress time applicable for (a) each major airport and (b) each potential HSR station site is estimated using GIS, allowing for the quality of the highway network (‘link speeds’ range between 20kph and 90kph), and the distribution of population within the zone.

Access/egress time penalty weightings: Access/egress time weighting, relative to in-vehicle time, is provided by the SP surveys. Where access times exceed 120 minutes, the maximum access time considered in the SP surveys, an additional access time weighting of 1.5 is applied.

Air, coach and classic rail levels of service

They are assumed to be the same as the existing situation.

Air, Rail and HSR service frequency penalties

The impact of improvements in air, rail or HSR service frequency is included in the estimated model and considers a set penalty divided by the number of services in a day, effectively considering service frequency as a headway.

Air, Rail and HSR fares

Average domestic air fares for leisure and business travel between the principal Norwegian airports are based on Avinor’s survey of air passengers (2009). Rail fares are taken from NTM5. As a default, it is assumed that HSR fares are set to 60% of existing air fares, broadly comparable to current existing rail fare levels. To account for HSR being a high level service, able to compete with air over the length of the corridors, sensitivities have been conducted around the fare to set HSR fares to equal existing air fares.

Air in-vehicle times

They are based on a combination of internet research, plus use of NTM5 data for flows to/from minor airports.

Wait Times

Wait times for air and HSR have been taken as those stated by existing users in the stated preference surveys; classic rail wait times have been used to approximate the waiting times for a HSR service. The time waiting at airports before take-off has been calculated at approximately 40 minutes in excess of that spent at an HSR station before departure.

Generation

A logsum formulation is used to calculate the change in overall accessibility between zones as a result of introducing HSR. The increased levels of trip making as a result are calculated using an exponential formulation to forecast the increase in trips as a result of the improved levels of accessibility.

Other modes' monetary costs and journey times
The structure of the Mode Choice Model does not require these 'Generalised Cost' data for other modes as abstraction from car and coach is based on incremental changes from existing journey volumes.

'Nesting' parameters
'Nesting' parameters which reduce the sensitivity of modal shift between HSR and 'slow modes' (car, classic rail and bus), relative to that between HSR and air are included in the SP model estimation.

Forecasting years
The model is developed to produce forecasts for 2024, 2043 and 2060. In the absence of detailed information on forecasting parameters by mode, growth for future year matrices has been taken from NTM5. The use of NTM5 ensures maximum compatibility with the growth assumptions applied in the appraisal of other Norwegian schemes.

We emphasise the assumption that in the core analysis the existing air and rail services are assumed to be retained after introduction of HSR services.

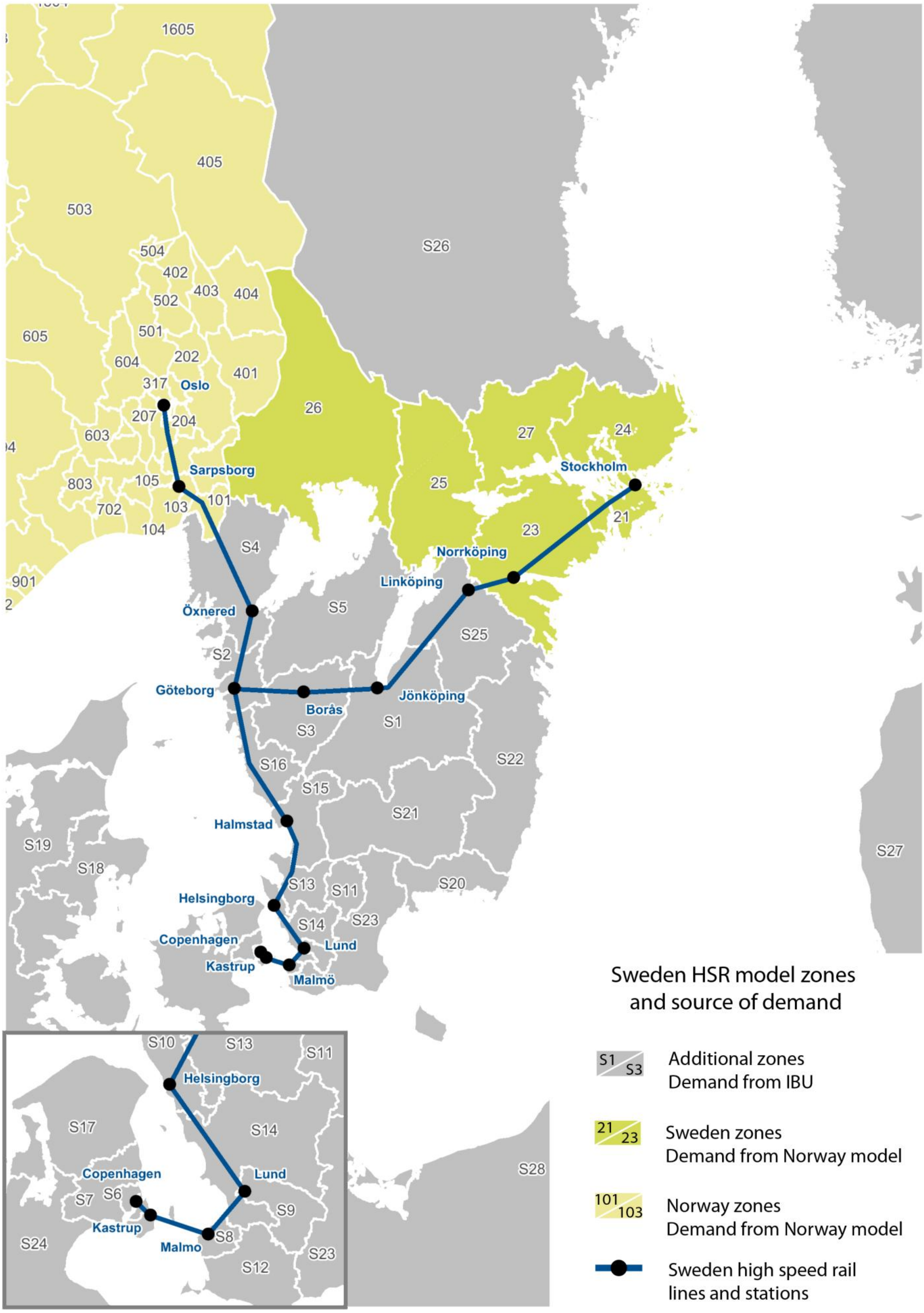
The exact assumptions and limitations of Norway HSR model can be found in the full model development documentation. Key points to take into account are:

- Estimates of individual station usage are limited by zone system and representation of road and rail network access.
- Forecasts do not include origin-destination forecasts where trips are less than 20km or are part of the core inter-city market. There is a potential overlap with the market for intercity rail services, which we have identified in the main report.
- Short distance trips are forecast with relation to journey time aspects only and are not related to fares. Additional survey data would improve estimates of shorter distance travel.

3.4. Expansion

Figure 5 below shows the origins of zones created for the COINCO study. Zone relations (OD pairs) are taken from the Norway data where both zones in the pair are coloured in. Relations between a grey zone and any coloured zone are in-filled by TRANS-TOOLS IBU data. It should be noted that the **Oslo – Stockholm** relation is different from the **Oslo – Copenhagen**, **Stockholm – Copenhagen** and Goteborg-any in that the data is derived from the Norway model and not the IBU data.

Figure 5. Origins of zones cost and demand data



3.5. IBU TRANS-TOOLS Description

This section provides an introduction to the TRANS-TOOLS IBU model data structure. All references are to data from IBU and do not apply to the Mode Choice Model used in this study unless expressly stated.

3.5.1. Underlying Assumptions for the IBU model

The infrastructure and growth assumptions are described in detail in the technical note 52001001_C_Forudsætninger.doc (in Danish). These assumptions are slightly different to the assumptions used for the Norway High Speed leading to the introduction of small inconsistencies in the merged data.

The main difference is that the Norway model operated with costs grown from a base infrastructure as in 2007 where IBU introduces planned network improvements up to 2030.

Modes and User Classes

TRANS-TOOLS IBU works with trip matrices for the following modes:

- Air
- Rail
- Bus
- Road
- Freight (on NUTS 2 level)

The **user clasess** are as follows. Note that not all user classes are modelled for all travel modes.

- Business
- Private
- Vacation
- Commute
- Trucks

3.5.2. Costs and trip units

Trip Matrix structure and units

The trip matrices are generation and attraction (GA) trips per year (the demand model in TRANS-TOOLS works with yearly trips with the assignment and with the rest of the model based on Average Annual Daily Traffic (AADT))

The year to AADT transformation is as follows: **Year = 365 * AADT.**

The GA means that the numbers cover return trips. For example if we find this in the AirTrip Matrix

FromZoneID	ToZoneID	CategoryID	Val
17	19	2	5

It means 5 Private trips generated in zone 17 and attracted to zone 19. Meaning they set out from zone 17 to 19 and they go back from 19 to 17 as well. In other words 1 GA trip is two OD trips in this concept.

Cost Matrix units and structure

Cost matrices are also at GA level. That means cost is for a return trip and the same is applied for the distance.

- Distance is in kilometres
- Time is in minutes

3.5.3. Air Trips calculation and cost weighting explained

Air trips are from zone to zone. Each zone is connected to one or more relevant (nearby) airports – for example a local airport and a bigger airport further away.

The Air Route Choice Model distributes the trips between available sensible routes e.g. direct flights and flights with interchanges. These are divided into three categories with stochastic variations on time costs meaning that not all trips between a zone pair will use the same route.

Connector loads from the assigment model shows the demand from a given zone to a given airport. These connecting trips are then split by mode (rail or road) and are then assigned to the respective networks.

Costs on Air trips are then calculated as a compound of the costs of each trip chain leg weighted by mode split on connector trips and demand split on the Air route choice.

3.5.4. Zone Structures

The Zone structure in TRANS-TOOLS IBU is based on the NUTS 3 level zoning in Europe. This structure has been further refined around Copenhagen and in Southern Sweden to make the model suitable for potentially answering questions on alignment options for High Speed Rail from Copenhagen to Stockholm. NUTS3 in Europe results in 1441 Zones whereas the TRANS-TOOLS IBU model has 1535 zones. This refined zoning system has enabled us to create a zoning system, which is appropriate for the COINCO task.

TRANS-TOOLS IBU Model Zone Data Structure

IBU model operates with 1535 zones that references back to the NUTS3 level and from there to National levels as well. For technical historical reasons the IBU model has got two parallel unique zoneID systems in use in different result sets. A zoneID with more than four digits is a reference to the field CODE3 in the ZoneTable and a Zone ID reference with four or less digits refer to the ZONEID field.

The zoning system has been provided to Atkins as an ArcGIS geodatabase in access format and is represented on Figure 6 below.

Figure 6. NUTS3 level zones with the IBU refinements in Southern Sweden and Eastern Denmark

3.6. Demand and Cost Aggregation

3.6.1. Matrix aggregating from TRANS-TOOLS IBU

To enable consistency between the different datasets a common approach for merging the data was required. The matrices were aggregated to combine demand for the zones and to create a new aggregated cost for the new zone pairs in the Scandinavian HSR model.

The total demand (for all modes) for each TRANS-TOOLS IBU zone pair was considered and used to weigh the component costs (e.g. air, rail, car and bus) into the total aggregation of several zone pairs. The weighting applied to the costs by mode for each zone pair was decided by the proportion of the total demand for all modes for that zone pair of the total demand from all the zone pairs to be combined:

$$AggregatesZoneCost_{Mode} = \sum_{ZonePairs} \left(Cost_{Mode} \times \frac{\sum_{modes} demand}{\sum_{ZonePairs} (\sum_{modes} demand)} \right)$$

The demand, which is just a simple sum, is created for the years 2020 and 2030. This demand is merged on a 60%-40% basis to create the demand for 2024 to be consistent with the Norway model. For the rest of the future years the demand from 2030 is grown using the Norway growth factors by Mode.

The costs were calculated purely for 2030 and have been used as a basis for all the forecast years.

3.6.2. Growth Assumptions

Future growth in the Norway High Speed Rail (NHSR) demand model

For the Norway HSR demand model, in the absence of detailed information on forecasting parameters by mode, it was decided to use the future year matrices from NTM5. The NTM5 matrices were provided for the following years: 2010, 2014, 2018, 2024, 2043, and 2060.

The NTM5 future year matrices are based on national data for economic growth, and regional data for population. NTM5 Do minimum matrices also allow for a number of improvements to the road and rail network.

International demand between Norway and Sweden

International journey are not included in NTM5 and have been added to Norway HSR demand model from other sources. The volume of passengers between Norway and each area zone within Sweden has been taken from the Sampers model incorporating demand within the six area zone in Sweden.

For domestic trips, sourced from the NTM5 base matrices, the cross-border trips have been adjusted to match direct count data on major flows where available. Adjustments have included:

- total air flows between Stockholm and Oslo using Avinor count data
- total car, bus, air and rail flows between Gothenburg and Oslo using totals quoted in ‘Kollectivtrafrik Goteborg Oslo Regionen’, Sweco 2007

Distribution of these trips within Norway is assumed to be proportional to the overall distribution taken from the NTM5 matrices.

For use in the Norway HSR study, Sampers matrices have been received for 2007. Trips have been adjusted using national Swedish growth to 2010 with average from the NTM5 matrices applied beyond this point.

Future Growth in the Scandinavian High Speed Rail (SHSR) demand model

For the SHSR model, the modelled years are the same as for the Norway model: 2024, 2043 and 2060.

Demand for Sweden comes from the TRANS-TOOLS matrices, received for the year 2020 and 2030 at both County zoning level and at a sub-county, further refined level around Copenhagen and south Sweden. These 2020 and 2030 matrices are used to interpolate demand for the first modelled year – 2024.

For long term forecasting, beyond 2030, the initial approach considered was to re-base NTM5 forecast using Sweden GDP forecast. However, this approach was discarded as internet research concluded that GDP forecast are not readily available beyond 2017.

An alternative method considered was a linear projection beyond 2030 by mode, based on growth from 2020 and 2030 using TRANS-TOOLS data. This approach was also discarded as a linear projection would not reflect economic uncertainties at such long term forecasts.

The preferred approach was therefore to use the NTM5 growth for each mode to provide a single growth factor for each mode. Although it does not take Swedish growth and improvements into account, since data are not available beyond 2030, this method was preferred as it is consistent with the method used to forecast Swedish demand in the existing Norway model.

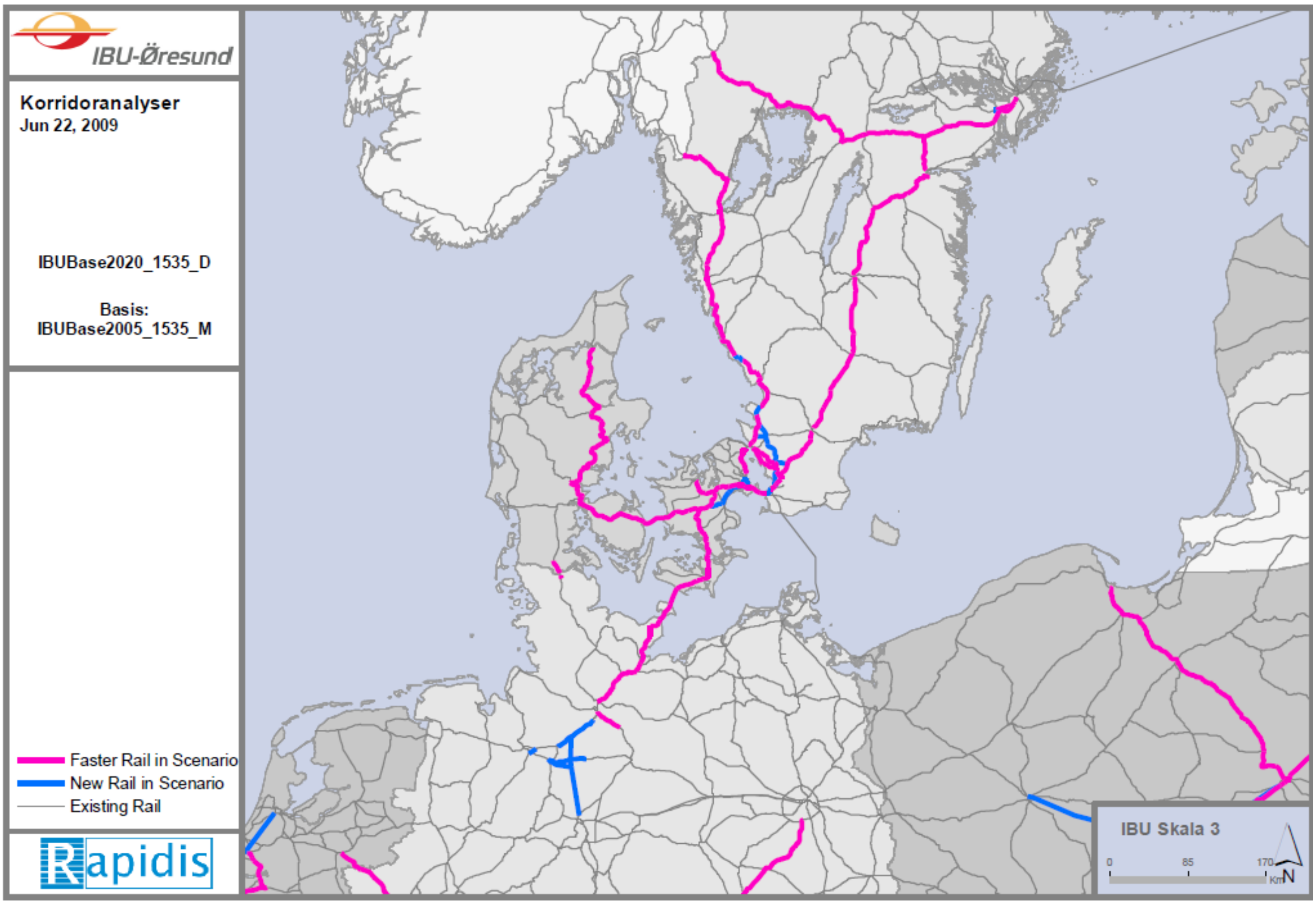
For overall demand the basis is the Norway model in-filled with data from TRANS-TOOLS for zone pairs with trip ends in Sweden and Denmark that are not entirely covered by the existing Norway HSR model. In essence 'external' demand is taken from TRANS-TOOLS IBU data as follows

- 2024 demand interpolated between 2020 and 2030 from TRANS-TOOLS
- 2043 – Norway model growth assumptions by mode
- 2060 – Norway model growth assumptions by mode

3.6.3. Generalised Cost Assumptions

For the generalised costs the basis is also the Norway HSR model in-filled with data from TRANS-TOOLS for Sweden and Denmark. The TRANS-TOOLS IBU 2030 costs from has been used for all model years. This is considered a robust approach as not many improvements are proposed beyond 2030 and deemed appropriate to keep to the tight budget and time scale. The base infrastructure in IBU model years 2020 (see changes from 2005 below) and 2030 is virtually unchanged, so this seems a sensible approximation.

Figure 7. IBU Rail Infrastructure 2020 improvements on base year 2005 (from note 52001-001 IBU Banestrategier)



Generalised cost skims in terms of time and distance (no new services post 2030 assumed) are used as follows:

- 2024 – TRANS-TOOLS 2030 data
- 2043 – TRANS-TOOLS 2030 data
- 2060 – TRANS-TOOLS 2030 data

3.7. Gravity Model Infill

Long distance trip models such as the Norway HSR model as well as TRANS-TOOLS IBU model in nature do not model the shorter distance trips. This may lead to an exclusion of trip potential for the High-speed Rail services. To enable some quantification of the commuting market that is potentially unlocked by providing faster services between cities a gravity model has been applied to each of the three core scenarios for the year 2024. The gravity model has been used to estimate the potential number of journeys with and without high-speed rail options between all the stops on the lines. Using this method to give us the difference between the two situations gives us the unlocked potential for high-speed patronage.

3.7.1. Gravity Model Development

The Mode Choice Model only accounts for trips with a total distance of more than 100km. Giving consideration to the core alternatives required for testing, this would understate the market for travel between intermediate stations, although generally these are low revenue trips, with shorter time savings over existing modes. In order to infill these missing areas of demand, a separate “gravity” forecasting model was developed using the basis of the Norway High Speed study.

The Gravity Model is the most commonly used method of deriving trips where no existing trip matrix exists or where new journey opportunities are unlocked by significant reductions in travel time and cost. In this instance the Gravity Model forecasts demand directly based on the population served by each station and the generalised journey time between the stations. It is named from the gravity analogy in that the number of trips between two zones is directionally proportional to their mass (e.g. population/employment) and indirectly proportional to the cost of travel between them. It should be noted that the model does not account for the levels of accessibility, or competition provided, from other modes between stations.

The decay factor is central to the Gravity Model and represents the decrease in trip making associated with increased travel cost. The decay factor has been calibrated through regression of rail trips against rail generalised journey time, the full model development is included in the Norway HSR Study documentation. Results have been cross-validated against existing NSB flows and with results from the main Mode Choice Model.

Initial runs of the gravity model showed unrealistically high unlocked demand because the gravity model was using existing rail journey times only. On a number of the short distance journeys the direct competition would be car or bus journeys which would be a lot faster than the original rail offering. As a consequence of these results we introduced the competitive cost between stations as the minimum of the Rail and the road journey times. The distance was the distance by rail if rail was faster or by road (quickest journey distance) if road was faster. This combined modes cost gave a more realistic assessment of the unlocked potential for new journeys.

4. Core HSR Forecasting Results

This chapter presents results from the model forecasting for each corridor. The next section defines the output provided for each corridor in the remaining of this chapter.

4.1. Explanation of Model Outputs

The purpose of this section is to present an example of the key model outputs, as presented for each scenario examined in the following sections and in Chapter 5. The objective is to assist in the interpretation of results presented in this report. Standard outputs presented for each alternative are as follows:

4.1.1. Summary of Demand and Revenue

For the modelled years of 2024, 2043 and 2060 the table gives annual figures of:

- Demand in terms of passenger numbers on HSR.
- Demand in terms of passenger-km of HSR. In many respects this is a better figure of demand than passenger numbers which does not differentiate between short intermediate trips and end-end trips.
- HSR train-km. The number of HSR train-km assumed to be operated within the scenario.
- Total revenue in 2009 values.

For each corridor's core service, results are given for the Mode Choice model, the Gravity model and the combination of both.

4.1.2. Source of Forecast HSR Demand

Each corridor has a table which describes the assumptions used for modelling demand and revenue, in particular where demand is excluded. Within each table:

- '0' signifies that the trip is not an option, this should only occur where the origin and the destination are the same.
- 'M' signifies that demand has come from the main Mode Choice Model; this is the default source of HSR demand.
- 'G' indicated that demand has come from the Gravity Model. This can be for one of two reasons:
    - Firstly no trips under 100km are included in the Mode Choice Mode; the Gravity Model has been used to infill trips on all origin-destination movements of under 100km.
    - Secondly, where the origin-destination trip is less than 200km and the Gravity Model forecasts demand of more than double the mode choice mode the Gravity Model has been used. This Gravity Model has been used in these scenarios as; on some movements of up to 200km the Mode Choice Model under-forecasts demand. This is a rare occurrence within the modelling results and generally happens for one of two reasons either; O-D pairs are not well served by either existing air or rail services and so the Mode Choice Model structure is not well placed to forecast demand, or the amalgamation from smaller zones excludes trips of under 100km where zone centroids are further than 100km apart.
- 'E' indicates that demand between station O-D pairs is not included in the high-speed demand. This is due to one of the following reasons:
    - High speed stations are less than 20km apart. Over these distances the Gravity Model is not considered reliable.
    - The demand is within the Oslo, Copenhagen or Stockholm inter-city area and is not considered to be part of the HSR market.

4.1.3. HSR Demand by Origin / Destination and Boarding / Alighting Station

For each alternative, we also present a breakdown of daily station to station usage and total HSR station boardings and alightings.

Figures are given for an average day – different mixes of business and leisure demand will affect the balance of station usage on weekdays and weekends.

We emphasise that forecasts of individual station usage are dependent on zoning definitions in the model, where inadequate information was available on individual station accessibility. Where such issues affect forecasts, they are noted in the text.

As described above, certain of the station to station flows are excluded from forecasting, so all station usage figures need to be interpreted in conjunction with the modelling sources matrices.

4.1.4. Passenger number per station to station link

The number of passengers on each link between HSR stations is graphically represented for each modelled year on each corridor. The passenger figure for each inter-station link represents the sum of passengers on the link, travelling between any stations along the corridor crossing that link. Figures are given for an average day and represent two-way traffic.

4.1.5. Generated Demand

In line with Norway HSR study a totally new generated demand due to the introduction of the High-Speed Rail has been considered. As presented in the Norway High Speed study (*Norway High Speed rail Assessment Study: Phase III, Model Development Report*, dated 25 January 2012), the levels of induced journeys are typically shown to be between 10-30%. Madrid-Seville is shown to be an exception where generation is cited as 50% of all HSR trips; however, it is suggested that some if this may be due to external growth on the line. The levels of generated traffic from the Sweden HSR generally sit within the range 30%-40% of total high speed rail demand. This is similar to the results from the Norway Study where generated trips ranged from 30% to 35% of total rail demand.

4.2. Oslo-Copenhagen

4.2.1. Core results

Table 5 below summarises the forecast demand and revenue for HSR travel for the years 2024, 2043 and 2060 for the core service between Oslo and Copenhagen.

Table 5. Summary of Demand and Revenue – Oslo-Copenhagen

	Mode Choice Model	Gravity Model	Total
2024			
Annual HSR passengers (million)	2.665	6.788	**9.453**
Annual HSR passenger-km (million)	921	606	**1,526**
Annual HSR train-km (million)	7.582	7.582	**7.582**
Annual Revenue (million NOK)	1,598	1,052	**2,650**
2043			
Annual HSR passengers (million)	3.469	7.734	**11.203**
Annual HSR passenger-km (million)	1,236	687	**1,923**
Annual HSR train-km (million)	7.582	7.582	**7.582**
Annual Revenue (million NOK)	2,122	1,179	**3,301**
2060			
Annual HSR passengers (million)	4.053	8.364	**12.416**
Annual HSR passenger-km (million)	1,465	814	**2,279**
Annual HSR train-km (million)	7.582	7.582	**7.582**
Annual Revenue (million NOK)	2,504	1,265	**3,769**

It can be seen that annual HSR journeys in 2024 are estimated at over 9.4 million passengers, increasing to 11.2 million in 2043, representing respectively 1.5 billion and 1.9 billion passenger-km. Total annual revenue is estimated to be nearly 2.7 BnNOK in 2024 and 3.3 BnNOK in 2043. It should be noted that short distance trips (under 200km) from the Gravity Model account for a large part of the total passenger figure this can be seen in the split of passenger-km, with a higher figure for the Mode Choice Model (921m, against 606m from the gravity model). The passenger-km figure is likely to be a mode representative figure as it takes into account the short length of the high number of journeys from the gravity model.

Table 6 below determines which model has been used to forecast HSR demand for each station pairing, where "M" denotes that the Mode Choice Model has been used and "G" indicates that demand has been forecast using the Gravity Model. "E" is shown where demand has been excluded based on the criteria described in earlier in this section. Trips between Copenhagen/Kastrup Airport and Malmo and between Malmo and Lund have been excluded from our analysis as they are expected to be served by local rail services.

Table 6. Source of HSR Demand – Oslo-Copenhagen

Station	Oslo	Sarpsborg	Öxnered	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup
Oslo	0	G	M	M	M	M	M	M	M
Sarpsborg	G	0	G	M	M	M	M	M	M
Öxnered	M	G	0	G	M	M	M	M	M
Göteborg	M	M	G	0	G	M	M	M	M
Halmstad	M	M	M	G	0	G	G	G	G
Helsingborg	M	M	M	M	G	0	G	G	G
Lund	M	M	M	M	G	G	0	E	G
Malmö	M	M	M	M	G	G	E	0	E
Copenhagen / Kastrup	M	M	M	M	G	G	G	E	0

From the model source matrix above it can be seen that the short distance trips are derived from the Gravity model and the long distance ones are from the Mode choice model. Each of the models is created with specific application and is more robust for each area of interest. From the table above it could be seen that no double counting is allowed as part of the modelling methodology.

Table 7**Error! Reference source not found.** to Table 9 below provide a breakdown of daily journeys grouped by station, while Figure 8 presents the forecast average daily boardings/alightings for each of the HSR stations. All figures are the combination of the mode choice and gravity models results.

Table 7. 2024 HSR Daily Demand by Origin / Destination Oslo-Copenhagen

Station	Distance in Km	Oslo	Sarpsborg	Öxnered	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup	Total
Oslo	0	**0**	**1,933**	**474**	**107**	**286**	**52**	**74**	**73**	**536**	3,535
Sarpsborg	72	**1,979**	**0**	**65**	**0**	**2**	**1**	**1**	**0**	**7**	2,055
Öxnered	277	**471**	**65**	**0**	**756**	**155**	**113**	**236**	**177**	**374**	2,347
Göteborg	404	**107**	**0**	**741**	**0**	**639**	**117**	**130**	**210**	**480**	2,424
Halmstad	484	**286**	**2**	**156**	**648**	**0**	**351**	**170**	**438**	**1,043**	3,094
Helsingborg	529	**52**	**1**	**114**	**117**	**350**	**0**	**176**	**557**	**1,503**	2,870
Lund	549	**74**	**1**	**236**	**130**	**170**	**177**	**0**	**0**	**1,740**	2,526
Malmö	570	**73**	**0**	**178**	**209**	**434**	**554**	**0**	**0**	**0**	1,447
Copenhagen / Kastrup	577	**536**	**8**	**376**	**482**	**1,020**	**1,475**	**1,705**	**0**	**0**	5,601
Total		3,578	2,010	2,338	2,448	3,057	2,838	2,492	1,455	5,683	25,900

Table 8. 2043 HSR Daily Demand by Origin / Destination Oslo-Copenhagen

Station	Distance in Km	Oslo	Sarpsborg	Öxnered	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup	Total
Oslo	0	**0**	**2,429**	**492**	**137**	**369**	**67**	**99**	**94**	**820**	4,507
Sarpsborg	72	**2,488**	**0**	**76**	**1**	**3**	**1**	**1**	**1**	**11**	2,581
Öxnered	277	**489**	**76**	**0**	**885**	**169**	**143**	**298**	**231**	**512**	2,802
Göteborg	404	**137**	**1**	**867**	**0**	**748**	**151**	**171**	**278**	**651**	3,005
Halmstad	484	**369**	**3**	**169**	**759**	**0**	**383**	**185**	**477**	**1,140**	3,486
Helsingborg	529	**67**	**1**	**144**	**151**	**382**	**0**	**192**	**607**	**1,644**	3,189
Lund	549	**99**	**1**	**298**	**171**	**185**	**192**	**0**	**0**	**1,903**	2,850
Malmö	570	**94**	**1**	**232**	**277**	**473**	**604**	**0**	**0**	**0**	1,681
Copenhagen / Kastrup	577	**820**	**13**	**513**	**653**	**1,116**	**1,613**	**1,865**	**0**	**0**	6,592
Total		4,563	2,524	2,791	3,034	3,445	3,154	2,812	1,689	6,681	30,693

Table 9. 2060 HSR Daily Demand by Origin / Destination Oslo-Copenhagen

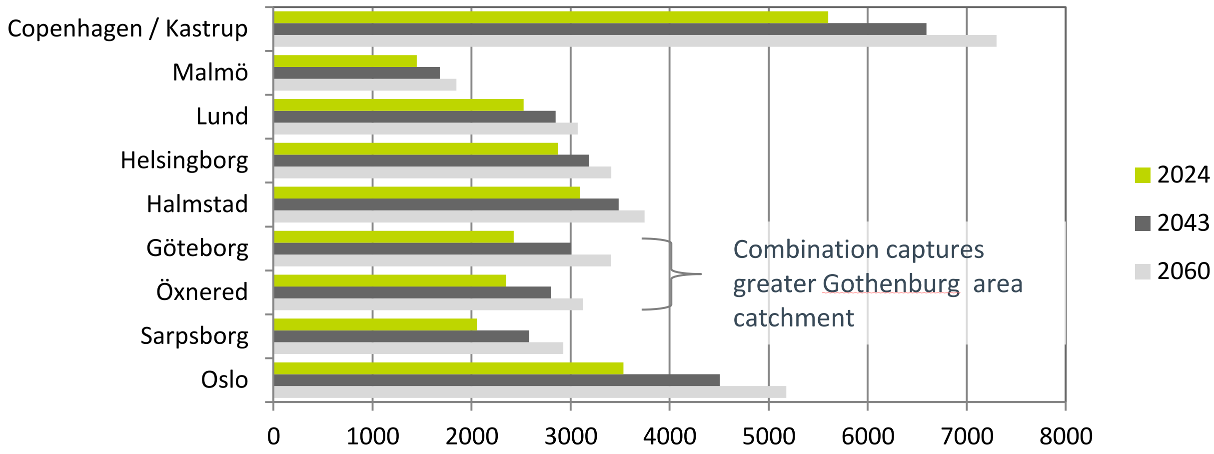
Station	Distance in Km	Oslo	Sarpsborg	Öxnered	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup	Total
Oslo	0	**0**	**2,757**	**510**	**154**	**427**	**77**	**114**	**107**	**1,033**	5,180
Sarpsborg	72	**2,824**	**0**	**83**	**1**	**3**	**1**	**2**	**1**	**14**	2,928
Öxnered	277	**507**	**83**	**0**	**970**	**175**	**164**	**341**	**273**	**613**	3,125
Göteborg	404	**154**	**1**	**949**	**0**	**819**	**178**	**202**	**329**	**775**	3,408
Halmstad	484	**427**	**3**	**175**	**831**	**0**	**405**	**196**	**505**	**1,206**	3,748
Helsingborg	529	**77**	**1**	**166**	**178**	**404**	**0**	**203**	**642**	**1,739**	3,410
Lund	549	**114**	**2**	**342**	**202**	**196**	**203**	**0**	**0**	**2,012**	3,071
Malmö	570	**107**	**1**	**274**	**328**	**500**	**638**	**0**	**0**	**0**	1,848
Copenhagen / Kastrup	577	**1,033**	**16**	**615**	**777**	**1,180**	**1,706**	**1,972**	**0**	**0**	7,300
Total		5,243	2,864	3,114	3,441	3,704	3,372	3,030	1,857	7,392	34017

The 2-way end to end journeys for 2024, between Copenhagen and Oslo, are 1072 journeys per day, representing 4% of the total daily demand (25,900 trips).

Journeys between Copenhagen and the Gothenburg (including Oxnered, considered within Gothenburg catchment area) is 1, 712 daily trips, nearly 7% of the total demand. Due to the coarse zoning system in the area around Oxnered, we consider that the demand from there should be viewed as a part of the Gothenburg catchment.

This table also shows the relative importance of short distance journey, from the gravity model, as the highest O/D pairs are Oslo-Sarpspborg, Copenhagen-Lund and Copenhagen- Helsingborg.

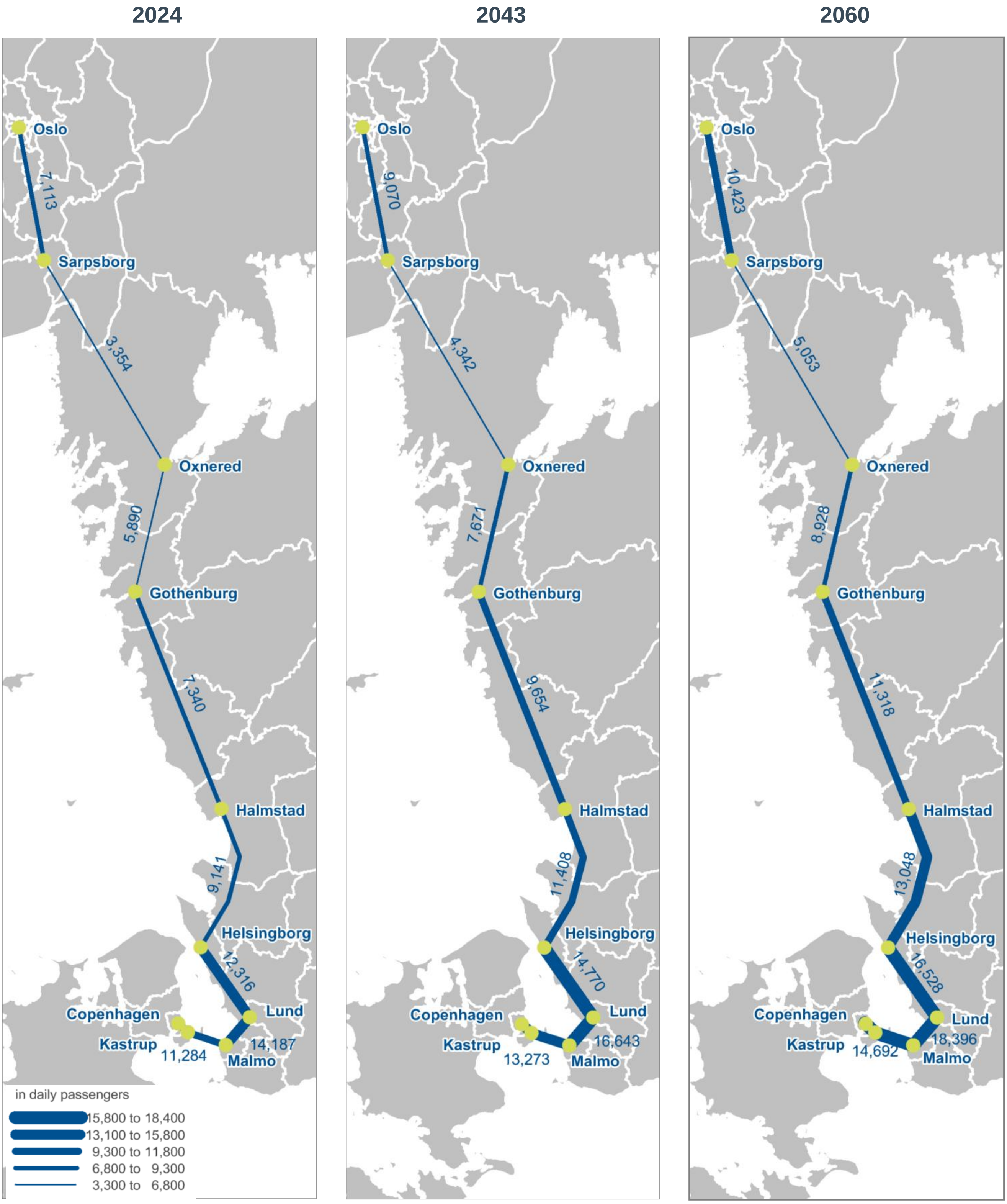
Figure 8. HSR Daily Boardings/Alightings by Station – Oslo-Copenhagen



In 2024 he highest overall demand originates from stations at Copenhagen (6,592 daily boardings/alightings) and Oslo (3535) at either end of the corridor. The lower than expected demand at Gothenburg is due to the small size of the Gothenburg station and the proximity of Oxnered station in a separate, far larger zone as explained above. In reality, passengers are more likely to use Gothenburg than Oxnered as this station can be considered part of Greater Gothenburg catchment area. Demand to and from Gothenburg, when consider alongside demand at Oxnered, constitutes the second highest demand along the corridor at 4,771 daily boardings / alightings. The same pattern is reproduced in 2043 and 2060.

Figure 9 provides a GIS representation of the number of passengers per day on each link of the core service, for each of the three modelled years, 2024, 2043 and 2060. Figures provided are two way trips.

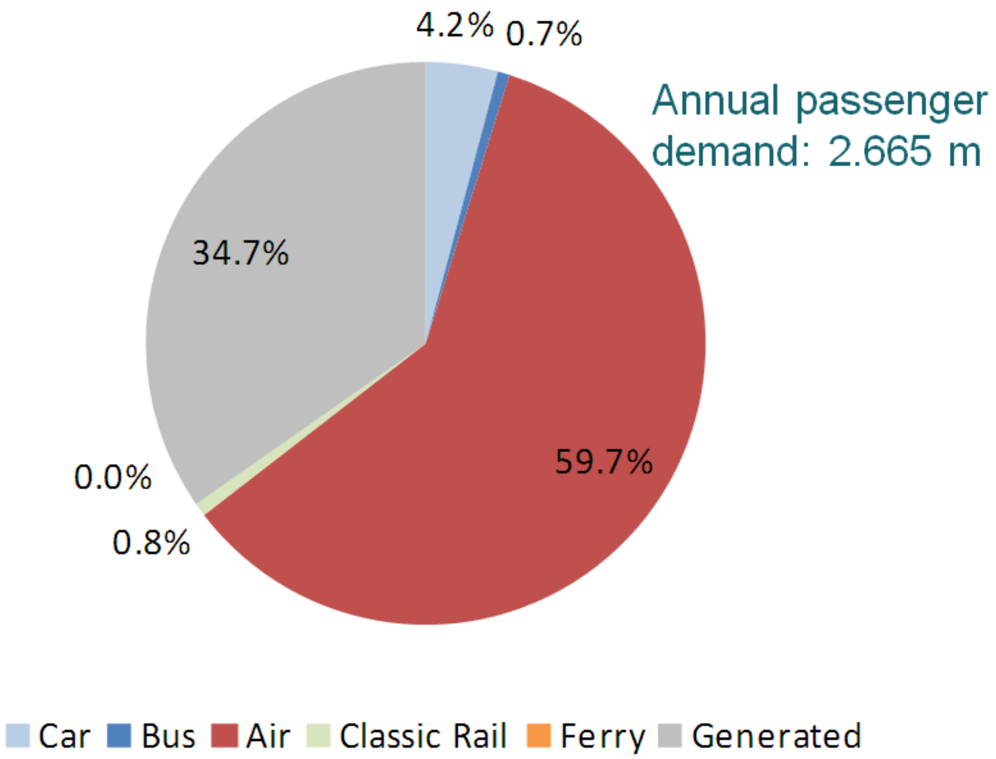
Figure 9. Daily HSR Two Way Travel per link Oslo-Copenhagen



The higher number of trips at both ends of the corridors compared to the central sections around Gothenburg illustrates the relatively high weight of short distance journeys (Oslo-Sarpsborg, or Helsingborg Copenhagen for example) on this corridor. The link with the highest number of trips is Lund-Malmo, with 14,187 daily passengers in 2024 while the lowest used link is Sarpsborg – Oxnered with 3,354 daily passengers.

Figure 10 presents the source of demand for HSR services.

Figure 10. Origin Mode of HSR demand, 2024 core service, Oslo-Copenhagen



HSR demand, as was expected, is mainly subtracted from Air passenger, with 59.7% of the total HSR demand. The second largest component of HSR demand is generated trips, representing 34.7% of the total demand with lower percentages from the rest of the considered modes.

4.3. Oslo-Stockholm

4.3.1. Core results

Table 10 below summarises the forecast demand and revenue for HSR travel for the years 2024, 2043 and 2060 for the core service between Oslo and Stockholm.

Table 10. Summary of Demand and Revenue – Oslo-Stockholm

	Mode Choice Model	Gravity Model	Total
2024			
Annual HSR passengers (million)	6.515	6.616	**13.131**
Annual HSR passenger km (million)	2,408	668	**3,076**
Annual HSR train-km (million)	9.264	9.264	**9.264**
Annual Revenue (million NOK)	4,126	1,145	**5,271**
2043			
Annual HSR passengers (million)	8.751	7.675	**16.426**
Annual HSR passenger km (million)	3,212	768	**3,980**
Annual HSR train-km (million)	9.264	9.264	**9.264**
Annual Revenue (million NOK)	5,522	1,321	**6,843**
2060			
Annual HSR passengers (million)	10.527	8.322	**18.849**
Annual HSR passenger km (million)	3,846	920	**4,766**
Annual HSR train-km (million)	9.264	9.264	**9.264**
Annual Revenue (million NOK)	6,605	1,421	**8,026**

It can be seen that annual HSR journeys in 2024 are estimated at 13 million passengers, increasing to 16.4 million in 2043, representing respectively 3.1 billion and 4 billion passenger-km. Total annual revenue is estimated to be 5.3 BnNOK in 2024 and 6.8 BnNOK in 2043.

As for the Oslo-Copenhagen corridor, short distance trips (under 200km) from the Gravity Model account for a large part of the total passenger figure this can be seen in the split of passenger-km, with a higher figure for the Mode Choice Model (2,408m, against 668m from the gravity model). The passenger-km figure is likely to be a more representative figure as it takes into account the short length of the journeys from the gravity model.

Table 11 below determines which model has been used to forecast HSR demand for each station pairing, where “M” denotes that the Mode Choice Model has been used and “G” indicates that demand has been forecast using the Gravity Model. “E” is shown where demand has been excluded based on the criteria described in earlier in this section.

Table 11. Source of HSR Demand – Oslo-Copenhagen

Station	Oslo	Sarpsborg	Öxnered	Göteborg	Borås	Jönköping	Linköping	Norrköping	Stockholm
Oslo	0	G	M	M	M	M	M	M	M
Sarpsborg	G	0	G	M	M	M	M	M	M
Öxnered	M	G	0	G	M	G	M	M	M
Göteborg	M	M	G	0	G	G	M	M	M
Borås	M	M	M	G	0	G	G	M	M
Jönköping	M	M	G	G	G	0	G	M	M
Linköping	M	M	M	M	G	G	0	G	M
Norrköping	M	M	M	M	M	M	G	0	G
Stockholm	M	M	M	M	M	M	M	G	0

For Olso-Copenhagen corridor again it can be seen that there is no double counting of the trips and the Gravity Model accounts for the short distance neighbouring stops journeys.

Table 12 to Table 14 below provide a breakdown of daily journeys grouped by station, while Figure 11 presents the forecast average daily boardings/alightings for each of the HSR stations. All figures are the combination of the mode choice and gravity models.

Table 12. 2024 HSR Daily Demand by Origin / Destination Oslo-Stockholm

Station	Distance	Oslo	Sarpsborg	Öxnered	Göteborg	Borås	Jönköping	Linköping	Norrköping	Stockholm	Total
Oslo	0	**0**	**1,933**	**33**	**266**	**12**	**91**	**289**	**95**	**841**	3,560
Sarpsborg	72	**1,979**	**0**	**65**	**3**	**1**	**2**	**2**	**11**	**98**	2,161
Öxnered	212	**33**	**65**	**0**	**756**	**64**	**127**	**0**	**0**	**714**	1,759
Göteborg	277	**266**	**3**	**741**	**0**	**971**	**2,007**	**2**	**2**	**1,286**	5,278
Borås	341	**12**	**2**	**64**	**983**	**0**	**723**	**162**	**1**	**1,076**	3,024
Jönköping	405	**91**	**3**	**125**	**2,015**	**717**	**0**	**570**	**223**	**2,594**	6,338
Linköping	524	**289**	**2**	**0**	**2**	**162**	**573**	**0**	**182**	**616**	1,826
Norrköping	565	**95**	**11**	**0**	**2**	**1**	**223**	**182**	**0**	**2,166**	2,681
Stockholm	705	**841**	**98**	**716**	**1,286**	**1,076**	**2,594**	**616**	**2,120**	**0**	9,348
Total		3,606	2,116	1,744	5,313	3,004	6,342	1,823	2,635	9,391	35,975

Table 13. 2043 HSR Daily Demand by Origin / Destination Oslo – Stockholm

Station	Distance	Oslo	Sarpsborg	Öxnered	Göteborg	Borås	Jönköping	Linköping	Norrköping	Stockholm	Total
Oslo	0	0	2,429	46	314	16	121	334	112	1,047	4,418
Sarpsborg	72	2,488	0	76	4	2	4	3	13	123	2,712
Öxnered	212	46	76	0	885	70	139	1	0	1,033	2,250
Göteborg	277	314	4	867	0	1,136	2,349	3	2	1,847	6,522
Borås	341	16	2	70	1,151	0	788	177	2	1,432	3,639
Jönköping	405	121	4	136	2,359	781	0	621	286	3,437	7,746
Linköping	524	334	3	1	3	176	625	0	198	910	2,250
Norrköping	565	112	13	0	2	2	286	198	0	2,536	3,150
Stockholm	705	1,047	124	1,036	1,847	1,432	3,437	909	2,481	0	12,314
Total		4,477	2,656	2,232	6,565	3,616	7,749	2,246	3,095	12,366	45,001

Table 14. 2060 HSR Daily Demand by Origin / Destination Oslo-Stockholm

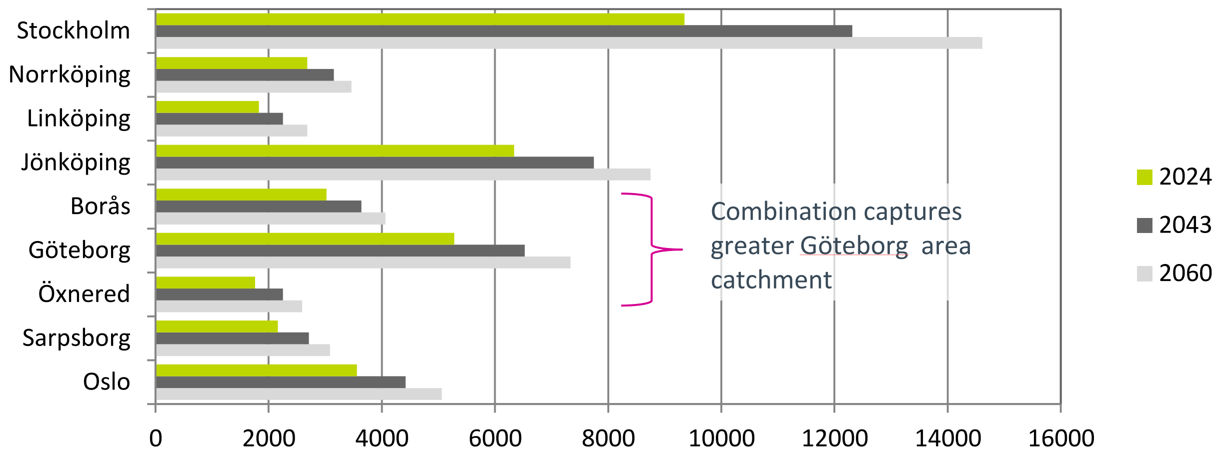
Station	Distance	Oslo	Sarpsborg	Öxnered	Göteborg	Borås	Jönköping	Linköping	Norrköping	Stockholm	Total
Oslo	0	0	2,757	52	326	19	142	379	128	1,257	5,059
Sarpsborg	72	2,824	0	83	4	2	4	4	16	149	3,086
Öxnered	212	52	83	0	970	73	147	1	0	1,265	2,591
Göteborg	277	326	5	949	0	1,244	2,572	4	3	2,229	7,332
Borås	341	19	3	73	1,261	0	833	187	2	1,687	4,064
Jönköping	405	142	5	144	2,584	826	0	657	328	4,062	8,747
Linköping	524	379	4	1	4	186	661	0	209	1,241	2,685
Norrköping	565	128	16	1	3	2	328	209	0	2,778	3,465
Stockholm	705	1,257	150	1,268	2,229	1,687	4,062	1,241	2,717	0	14,611
Total		5,125	3,022	2,572	7,380	4,039	8,749	2,680	3,404	14,668	51,640

In 2024, the number of end to end journeys between Stockholm and Oslo is 1,682 journeys per day, representing close to 5% of the total daily demand (35,975 trips).

The number of journeys between Stockholm and the Gothenburg area (including Oxnered and Boras, considered within Gothenburg catchment area) is 6,154 daily trips, over 17% of the total demand. Due to the coarse zoning system we have considered the wider Gothenburg area again.

High station to station trips are also recorded on the section of the corridor east of Gothenburg: Boras-Stockholm (2,152 daily trips) and Jonkoping-Stockholm (5,188 trips). This is explained by the importance of industrial and other economic activities in this region, generating demand, and the poor accessibility of airports and classic rail services, making HSR very attractive. 2043 and 2060 show similar patterns.

Figure 11. **HSR Daily Boardings/Alightings by Station – Oslo-Stockholm**

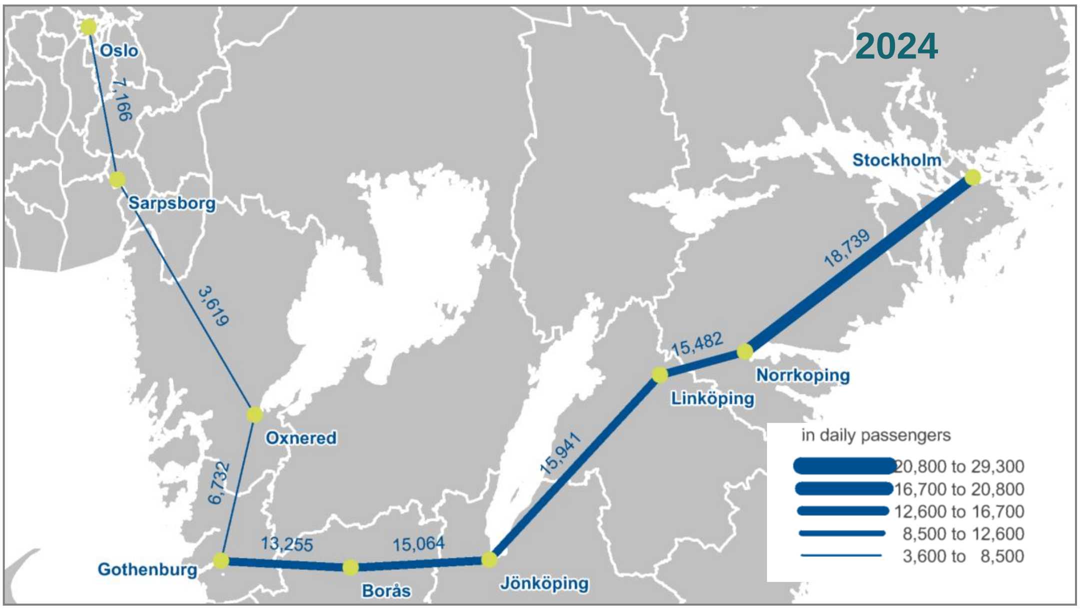


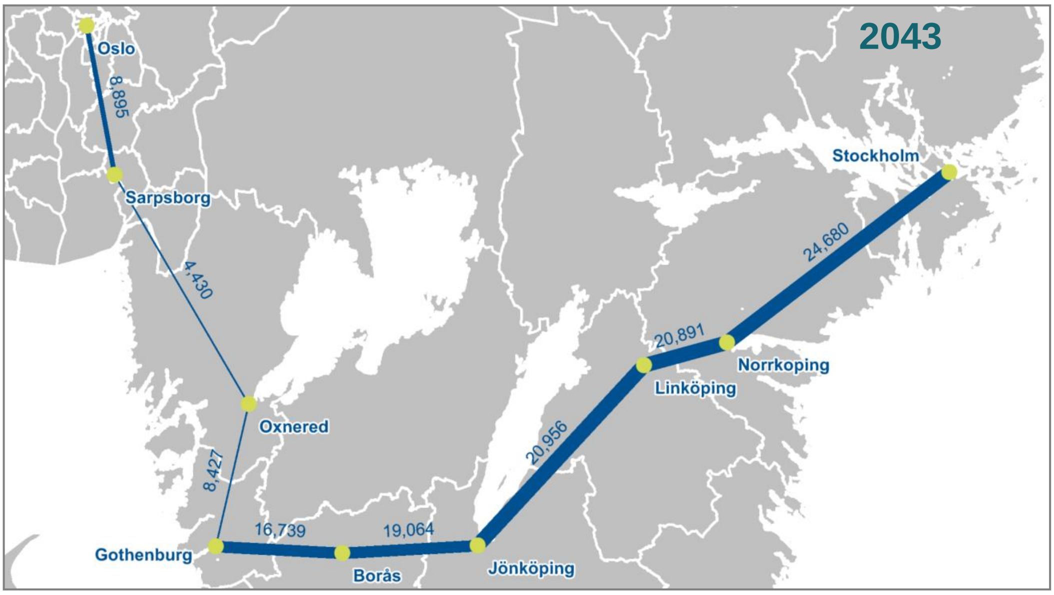
In 2024 he highest overall demand originates from Stockholm (9,348 daily boardings/alightings) and Jonkoping (6,338). The lower than expected demand at Gothenburg is due to the small size of the Gothenburg station and the proximity of Oxnered and Boras stations in separate, far larger zones. In reality, passengers are more likely to use Gothenburg than Oxnered or Boras as these stations can be considered part of Greater Gothenburg catchment area. Demand to and from Gothenburg, when consider alongside demand at Oxnered and Boras, constitutes the highest demand along the corridor at 10,061 daily boardings/alightings. The same pattern is reproduced in 2043 and 2060.

Figure 12 provides a GIS representation of the number of passengers per day on each link of the core service, for each of the three modelled years, 2024, 2043 and 2060. Figures provided are two way trips.

The three maps show the relative importance of the Gothenburg-Stockholm section of the corridor, with far higher use than the Gothenburg-Oslo section. The link with the highest number of trips is Norrkoping-Stockholm, with 18,739 daily passengers in 2024 while the lowest used link is Sarpsborg-Oxnered with 3,619 daily passengers.

Figure 12. **Daily HSR Two Way Travel per link, 2024, 2043, 2060, Oslo – Stockholm**




2043
Oslo
8,895
Sarpsborg
4,430
Oxnered
8,427
Gothenburg
16,739
Borås
19,064
Jönköping
20,956
Linköping
20,891
Norrkoping
24,680
Stockholm

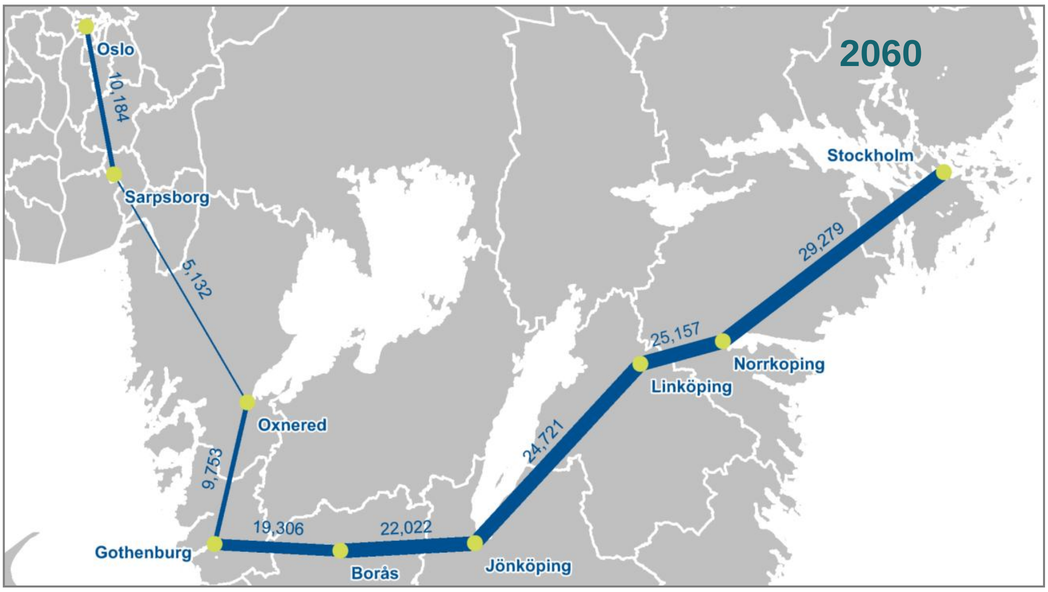
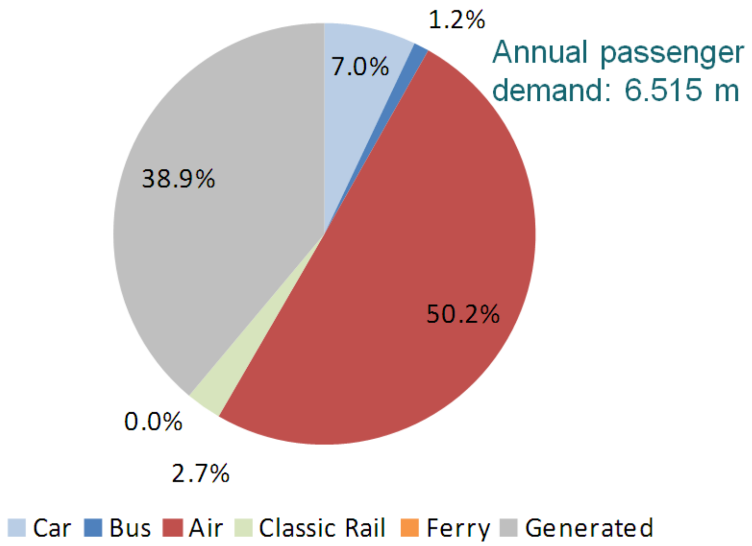

2060
Oslo
10,184
Sarpsborg
5,132
Oxnered
9,753
Gothenburg
19,306
Borås
22,022
Jönköping
24,721
Linköping
25,157
Norrkoping
29,279
Stockholm

Figure 13 below presents the source of HSR demand for the Oslo-Stockholm core scenario.

Figure 13. Origin Mode of HSR demand, 2024 core service, Oslo-Stockholm



HSR demand, as was expected, is mainly subtracted from Air passenger, with 50.2% of the total HSR demand. The second largest component of HSR demand is generated trips, representing 38.9% of the total demand and again with lower percentages from the rest of the considered modes.

4.4. Stockholm-Copenhagen

4.4.1. Core results

Table 15 below summarises the forecast demand and revenue for HSR travel for the years 2024, 2043 and 2060 for the core service between Stockholm and Copenhagen.

Table 15. Summary of Demand and Revenue Stockholm - Copenhagen

	Mode Choice Model	Gravity Model	Total
2024			
Annual HSR passengers (million)	8.381	9.986	**18.367**
Annual HSR passenger km (million)	3,611	1,064	**4,676**
Annual HSR train-km (million)	9.553	9.553	**9.553**
Annual Revenue (million NOK)	4,613	1,360	**5,973**
2043			
Annual HSR passengers (million)	11.330	11.147	**22.477**
Annual HSR passenger km (million)	4,933	1,190	**6,123**
Annual HSR train-km (million)	9.553	9.553	**9.553**
Annual Revenue (million NOK)	6,279	1,515	**7,794**
2060			
Annual HSR passengers (million)	13.577	11.863	**25.440**
Annual HSR passenger km (million)	5,910	1,426	**7,336**
Annual HSR train-km (million)	9.553	9.553	**9.553**
Annual Revenue (million NOK)	7,515	1,609	**9,123**

The annual HSR journeys in 2024 are estimated at 18.4 million passengers, increasing to 22.5million in 2043. These represent respectively 4.7 billion and 6.1 billion passenger-km. The total annual revenue is estimated to be 6 BnNOK in 2024 and 7.8 BnNOK in 2043.

As for the two other corridors, although the gravity model accounts for more than 50% of the annual passengers, they are short distance trips (under 200km) and represent only 20% of passenger-km (1,064m, against 3,611m from the Mode choice model).

Table 16**Error! Reference source not found.** below determines which model has been used to forecast HSR demand for each station pairing, where “M” denotes that the Mode Choice Model has been used and “G” indicates that demand has been forecast using the Gravity Model. “E” is shown where demand has been excluded based on the criteria described in section 4. Trips between Copenhagen – Kastrup Airport and Malmo, and between Malmo and Lund have been excluded from our analysis as they are expected to be served by local rail services.

Table 16. Source of HSR Demand – Oslo-Copenhagen

Station	Stockholm	Norrköping	Linköping	Jönköping	Borås	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup
Stockholm	0	G	M	M	M	M	M	M	M	M	M
Norrköping	G	0	G	G	M	M	M	M	M	M	M
Linköping	M	G	0	G	G	M	M	M	M	M	M
Jönköping	M	G	G	0	G	G	M	M	M	M	M
Borås	M	M	G	G	0	G	G	M	M	M	M
Göteborg	M	M	M	G	G	0	G	M	M	M	M
Halmstad	M	M	M	M	G	G	0	G	G	G	G
Helsingborg	M	M	M	M	M	M	G	0	G	G	G
Lund	M	M	M	M	M	M	G	G	0	E	G
Malmö	M	M	M	M	M	M	G	G	E	0	E
Copenhagen / Kastrup	M	M	M	M	M	M	G	G	G	E	0

Table 17 to Table 19 below provide a breakdown of daily journeys grouped by station, while Figure 14 presents the forecast average daily boardings/alightings for each of the HSR stations. All figures are the combination of the mode choice and gravity models.

Table 17. 2024 HSR Daily Demand by Origin / Destination Stockholm-Copenhagen

Station	Distance in Km	Stockholm	Norrköping	Linköping	Jönköping	Borås	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup	Total
Stockholm	0	0	2,051	844	2,287	311	1,380	1,391	523	626	894	555	10,863
Norrköping	139	2,095	0	182	329	0	0	1	1	205	0	8	2,820
Linköping	180	845	182	0	573	160	1	2	1	224	0	11	1,998
Jönköping	299	2,284	326	570	0	708	2,066	0	39	41	69	185	6,287
Borås	364	311	0	161	714	0	1,046	156	27	30	47	111	2,603
Göteborg	428	1,380	0	1	2,058	1,033	0	681	154	177	295	668	6,446
Halmstad	554	1,391	1	2	0	156	690	0	359	173	452	1,070	4,294
Helsingborg	634	523	1	1	39	27	154	358	0	176	574	1,535	3,389
Lund	680	626	205	224	42	30	177	173	176	0	0	1,793	3,445
Malmö	699	894	0	0	69	47	294	448	571	0	0	0	2,323
Copenhagen / Kastrup	727	555	8	11	185	112	670	1,048	1,507	1,757	0	0	5,852
Total		10,904	2,773	1,995	6,296	2,584	6,478	4,257	3,356	3,409	2,332	5,936	50,319

Table 18. 2043 HSR Daily Demand by Origin / Destination Stockholm-Copenhagen

Station	Distance in Km	Stockholm	Norrköping	Linköping	Jönköping	Borås	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup	Total
Stockholm	0	0	2,400	1,124	2,976	423	1,952	1,860	719	868	1,247	843	14,412
Norrköping	139	2,452	0	198	358	0	0	1	1	275	0	11	3,298
Linköping	180	1,125	198	0	625	175	1	2	1	295	0	15	2,438
Jönköping	299	2,973	356	621	0	772	2,418	1	49	52	87	241	7,570
Borås	364	423	0	175	778	0	1,224	170	33	38	60	145	3,047
Göteborg	428	1,951	0	1	2,408	1,208	0	796	190	223	373	876	8,027
Halmstad	554	1,860	1	2	1	170	808	0	392	189	492	1,171	5,085
Helsingborg	634	719	1	1	50	33	191	391	0	192	626	1,679	3,883
Lund	680	868	275	295	53	38	223	188	192	0	0	1,961	4,093
Malmö	699	1,247	0	0	87	60	372	488	622	0	0	0	2,876
Copenhagen / Kastrup	727	843	11	15	242	146	879	1,146	1,648	1,922	0	0	6,851
Total		14,461	3,242	2,434	7,578	3,025	8,068	5,043	3,847	4,054	2,886	6,943	61,580

Table 19. 2060 HSR Daily Demand by Origin / Destination Stockholm-Copenhagen

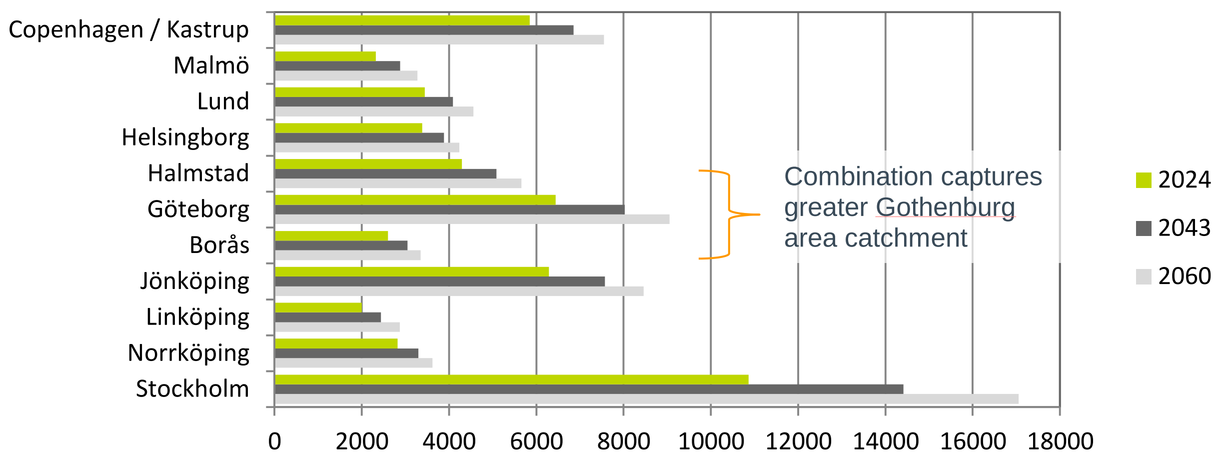
Station	Distance in Km	Stockholm	Norrköping	Linköping	Jönköping	Borås	Göteborg	Halmstad	Helsingborg	Lund	Malmö	Copenhagen / Kastrup	Total
Stockholm	0	0	2,628	1,448	3,466	500	2,308	2,219	869	1,049	1,510	1,055	14,412
Norrköping	139	2,687	0	209	379	0	1	1	1	329	0	13	3,298
Linköping	180	1,448	209	0	661	185	1	2	1	347	0	18	2,438
Jönköping	299	3,462	376	657	0	816	2,649	1	57	61	101	284	7,570
Borås	364	500	0	185	823	0	1,341	179	39	44	69	170	3,047
Göteborg	428	2,307	1	1	2,637	1,323	0	872	217	254	425	1,015	8,027
Halmstad	554	2,219	1	2	1	179	885	0	414	199	521	1,238	5,085
Helsingborg	634	869	1	1	57	39	217	413	0	203	662	1,776	3,883
Lund	680	1,049	329	347	61	44	254	199	203	0	0	2,074	4,093
Malmö	699	1,509	0	0	101	69	425	516	658	0	0	0	2,876
Copenhagen / Kastrup	727	1,055	13	18	285	172	1,018	1,212	1,743	2,032	0	0	6,851
Total		14,461	3,242	2,434	7,578	3,025	8,068	5,043	3,847	4,054	2,886	6,943	61,580

In 2024, the number of end to end journeys between Stockholm and Copenhagen is 2,110 journeys per day, representing 2.2% of the total daily demand (50,319 trips).

The number of journeys between Stockholm and the Gothenburg (including Boras, considered within Gothenburg catchment area) is 3,382 daily trips, 6.7% of the total demand. While the number of journeys between Copenhagen and the Gothenburg (again including Boras) is lower at 1,561 daily trips, 3.1% of the total demand.

As for Oslo-Stockholm, high station to station trips are also recorded on the section of the corridor between Gothenburg and Stockholm: Jonkoping -Gothenburg (4,124 daily trips) and Jonkoping-Stockholm (4,571 trips) are the two highest. This is explained by the importance of industrial and other economic activities in this region, generating demand, and the poor accessibility of airports and classic rail services, making HSR very attractive. 2043 and 2060 show similar patterns.

Figure 14. HSR Daily Boardings/Alightings by Station – Stockholm-Copenhagen



In 2024 he highest overall demand originates from Stockholm (10,863 daily boardings/alightings) and Jonkoping (6,338). As described for the other corridors, Boras should be considered together with Gothenburg, as the station can be considered part of Greater Gothenburg catchment area. Demand to and from Gothenburg, when consider alongside demand at Boras, constitutes the second highest demand along the corridor at 9,049 daily boardings/alightings. Jonkoping also has high demand, with 6,287 daily trips.

The same pattern is reproduced in 2043 and 2060.

Figure 15 overleaf provides a GIS representation of the number of passengers per day on each link of the core service, for each of the three modelled years, 2024, 2043 and 2060. Figures provided are two way trips.

The three maps show the relative importance of the Gothenburg-Stockholm section of the corridor, with far higher use than the Gothenburg-Oslo section. In 2024 the link with the highest number of trips is Norrkoping-Stockholm, with 21,767 daily passengers while the lowest used link is Malmo-Copenhagen with 11,789 daily passengers.

Figure 15. Daily HSR Two Way Travel per link Stockholm – Copenhagen

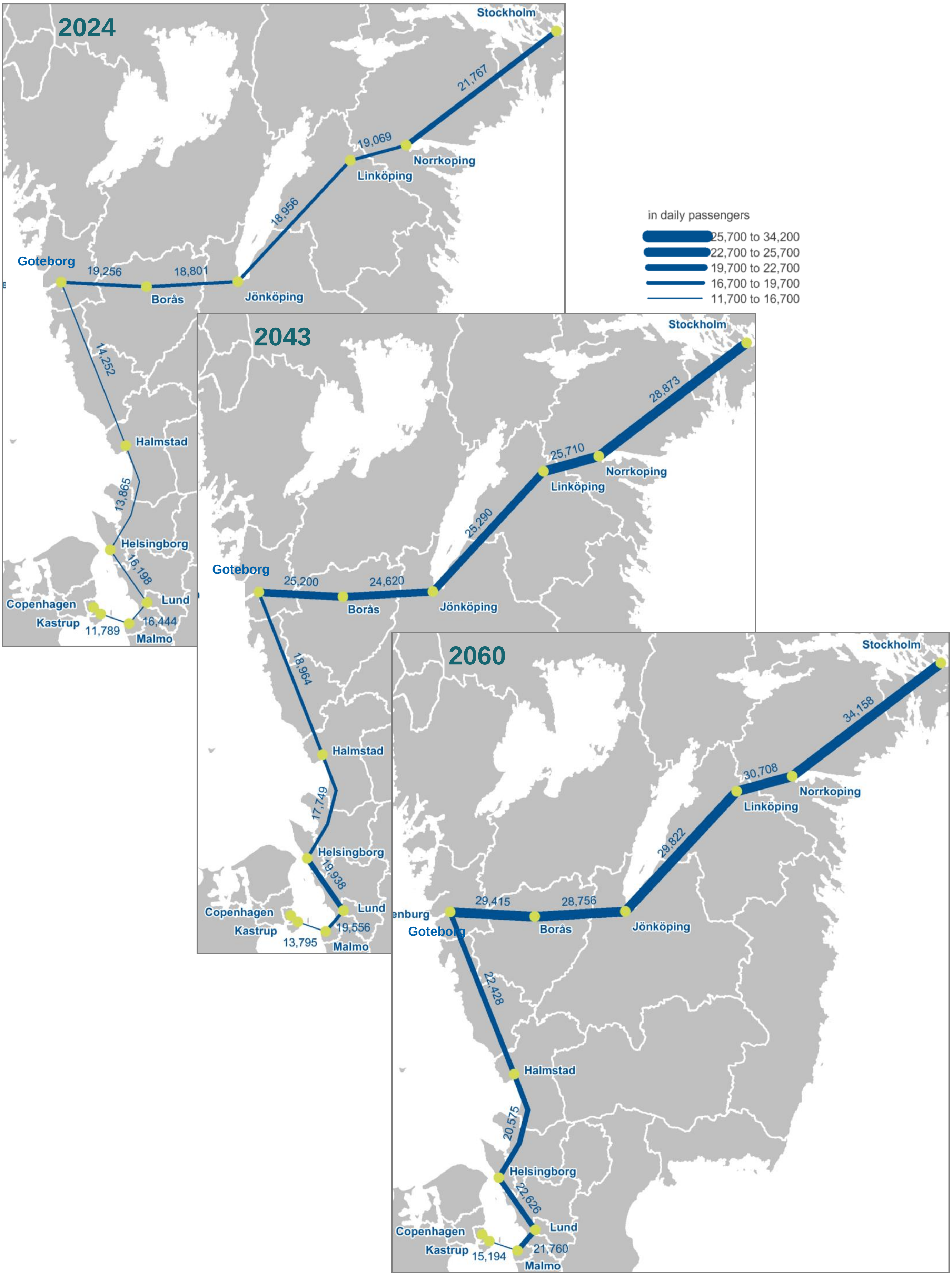
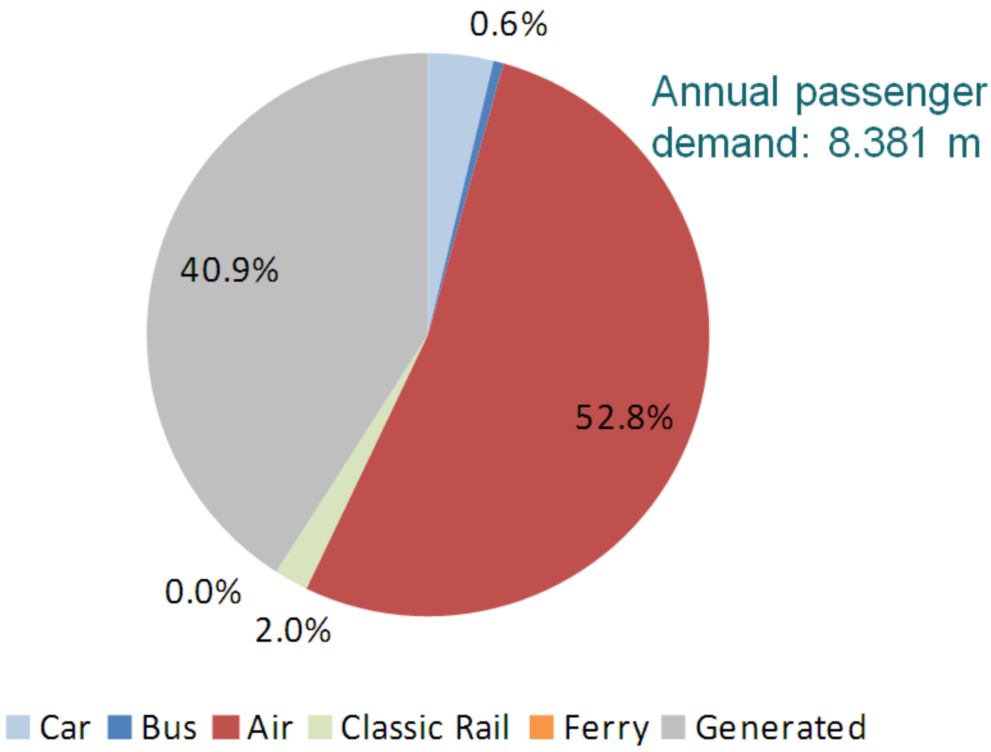


Figure 16 presents the source of HSR demand in the core scenario for the Stockholm-Copenhagen corridor.

Figure 16. Origin Mode of HSR demand, 2024 core service, Stockholm-Copenhagen



HSR demand, as was expected, is mainly subtracted from Air passenger, with 52.8% of the total HSR demand. The second largest component of HSR demand is generated trips, representing 40.9% of the total demand, as for the other two corridors with lower percentages from the rest of the considered modes.

5. Sensitivity Tests

As described in Section 0, each core service was tested for sensitivity on the following elements:

- Fare, with rail fare at 60% of air fare
- Growth, with higher growth rate at 2% and lower growth rate at 0.5%
- Stopping pattern, with a direct service stopping only at Gothenburg
- Service frequency, with two trains an hour (one stopping and one direct)

Comparisons between the sensitivity tests across the three corridors are provided in this chapter. The key indicators presented are:

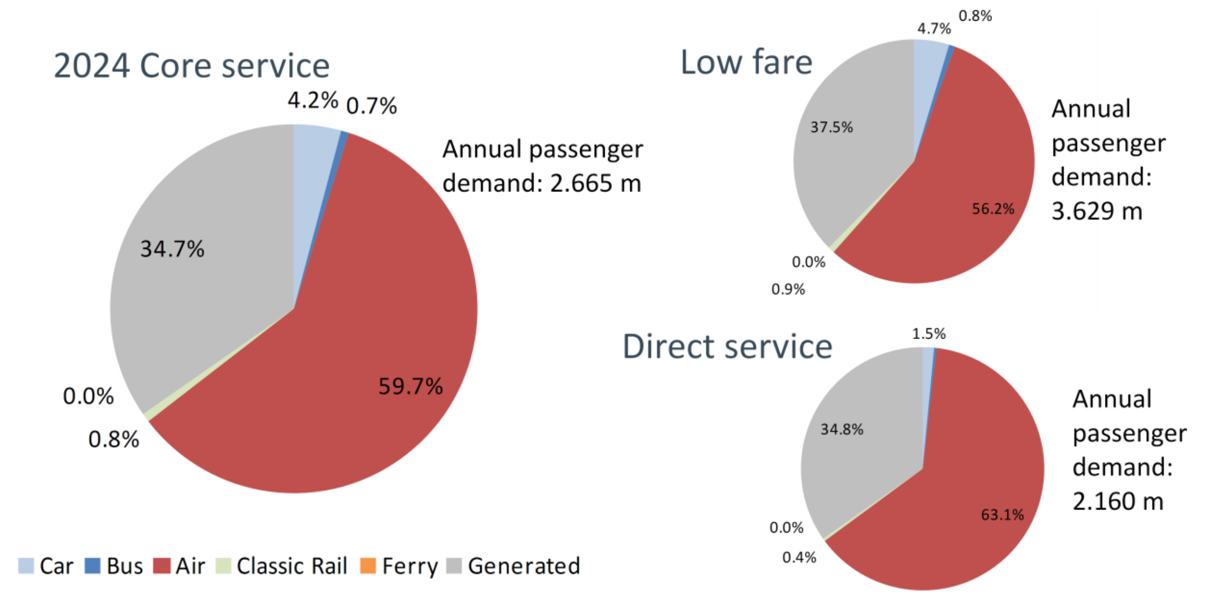
- Origin mode of HSR demand
- Core Scenarios passenger growth,
- HSR / Air Split for major city to city journeys, and
- Annual passengers, revenue and growth.

5.1. Origin Mode of HSR Demand

5.1.1. Oslo-Copenhagen

The pie charts on Figure 17 to Figure 19 below represent the origin mode of HSR passengers for the core service, the lower fare and direct service options. The total annual demand provided next to each chart.

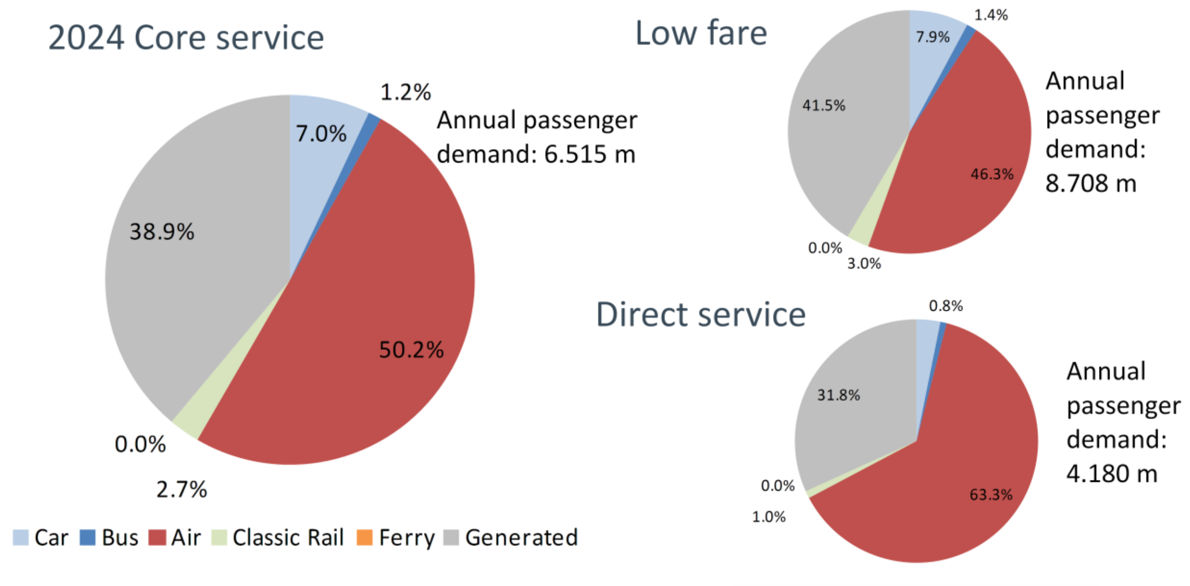
Figure 17. Oslo – Copenhagen - Sensitivity Tests - Origin Mode of HSR demand



When testing for low rail fare, the percentage of demand coming from Air decrease from 59.7% to 56.2%, in number of passengers, low fare still attracts more air passengers than the core service as the total HSR demand increases (from 2.665 million to 3.629 million).

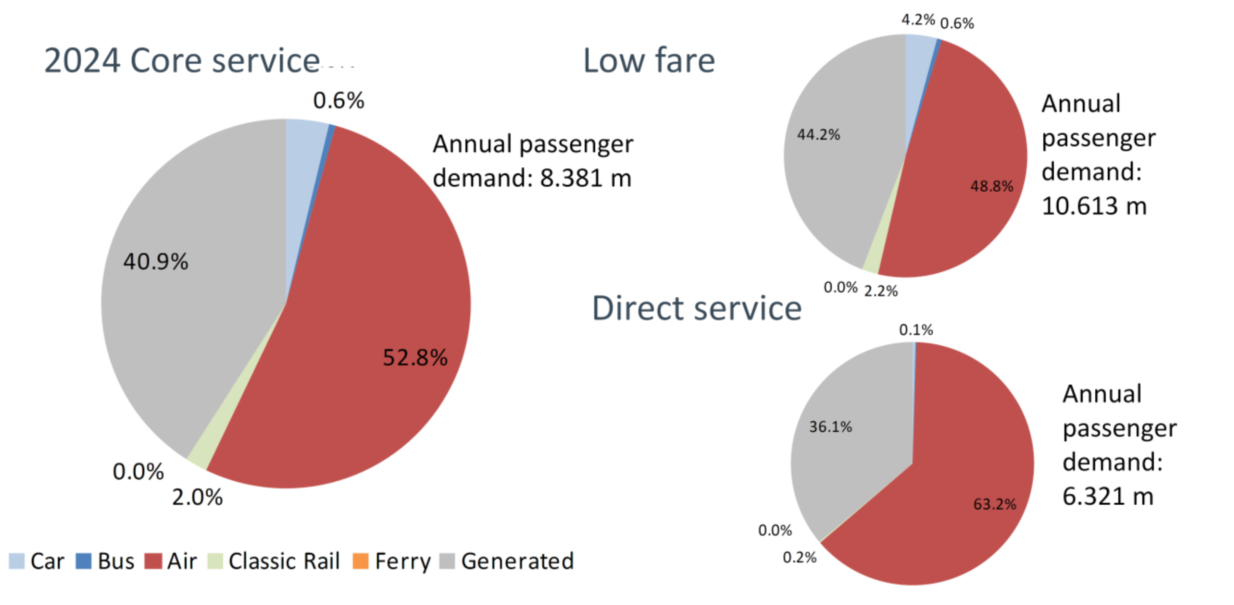
The direct service option is more competitive against Air than the core service, due to the limited number of stops and a shorter journey time. Demand coming from Air is higher, at 63.1% of HSR demand, although the total demand is slightly smaller (2.160 million).

Figure 18. Oslo – Stockholm - Sensitivity Tests - Origin Mode of HSR demand



The changes in performance of the low fare and Direct service options is similar to the Oslo-Copenhagen corridor, with a lower percentage of demand from Air (46.3%) for the lower fare option, but from a larger total demand (8.708 million annual passengers; and a direct service significantly more competitive against Air (63.3% of total demand from Air).

Figure 19. Stockholm - Copenhagen - Sensitivity Tests - Origin Mode of HSR demand

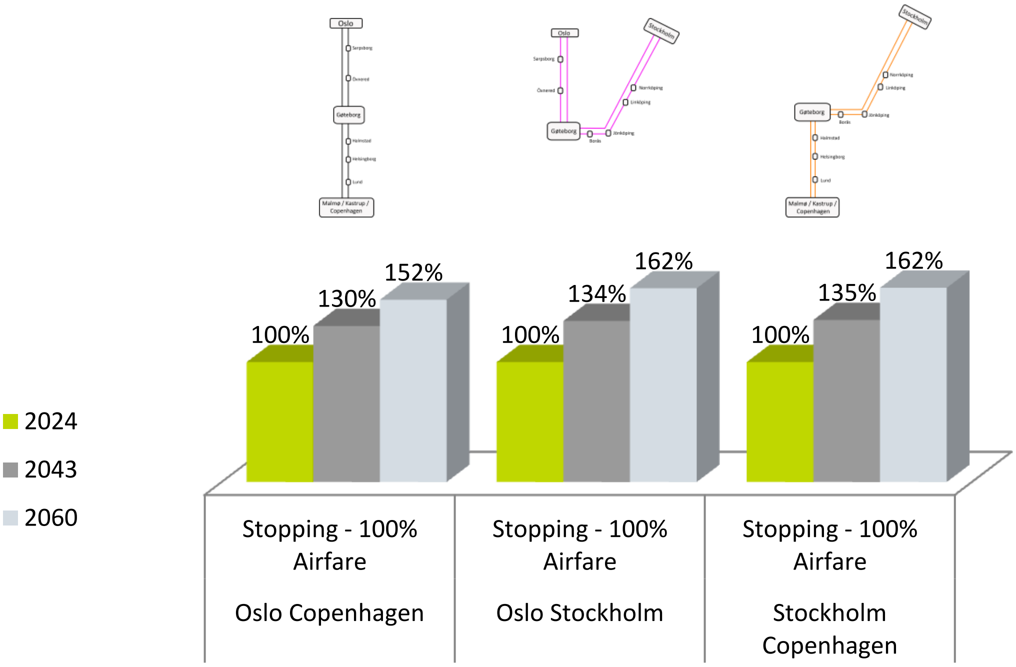


Again the pattern for the Stockholm-Copenhagen service is similar to the other two corridors. For the low fare test, the percentage of the total HSR demand coming for existing air traffic drops from 52.8% in the core service to 48.8% but this is compensated by an increase in the total demand from 8.381 million to 10.613 passengers. In the Direct Service option, the Air passengers share rises to 63.2%.

5.2. Exogenous growth sensitivities

Figure 20 below represents the growth in number of passengers for each corridor over the three forecast years 2024, 2043 and 2060. Figures are in percentage of the 2024 passenger number.

Figure 20. Core scenario passenger growth 2024-2043-2060 per corridor



To identify the sensitivity exogenous growth, lower and higher growth scenarios have been considered. Figure 21 below represents the variation in passenger numbers for the growth rate assumption, 2043 core service, at 0.5% and at 2%. Figures are as a percentage of the 2024 core service. As expected, the results show a small increase in passenger numbers with a 2% growth assumption, and a slight drop for the 0.5% growth test.

Figure 21. Annual 2043 HRS Passengers for three growth rate options, as % of 2024 core service

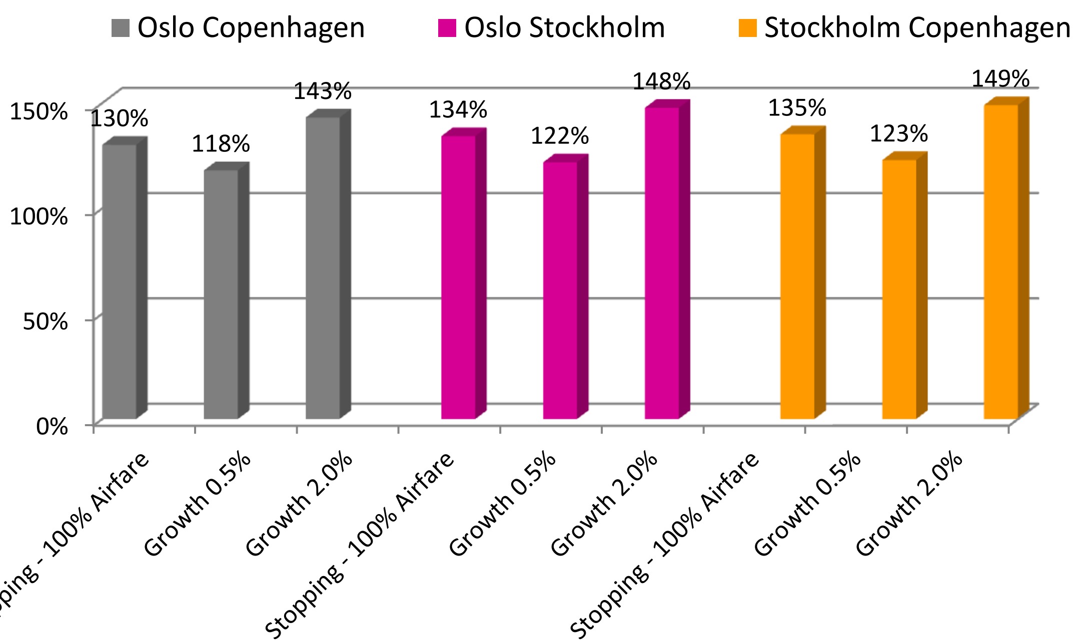


Figure 21 provides an indication of the expected revenue and passengers' demand if alternative growth assumptions are considered. With 0.5% growth 12% less demand is forecasted and with the 2% growth scenario 13% growth in passenger number is expected for the Oslo-Copenhagen corridor. Similar deviations in passenger numbers are observed in the other two corridors.

5.3. HSR / Air Split for major city to city journey

Figure 22 to Figure 24 show the mode split between air and HSR for the core service, the direct service and rail fare at 60% of air fare, for journey between major cities.

The share of HSR over air is highest between Gothenburg and Stockholm, with between 76% and 85% of market share.

Oslo – Copenhagen has the lowest mode share, with 52% of market share for the core service, up to 71% with a lower rail fare.

For all city pairs, the share of HSR is highest in the low rail fare test, with HSR market share all over 71%.

Figure 22. HSR/Air split – Core Service

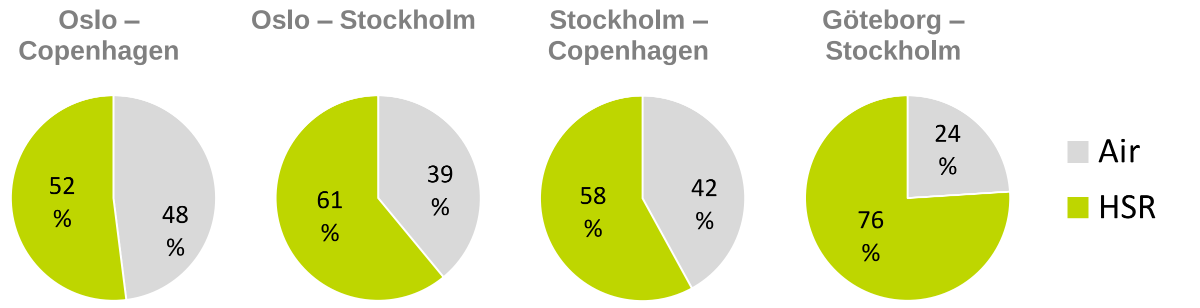


Figure 23. HSR/Air split – Direct Service

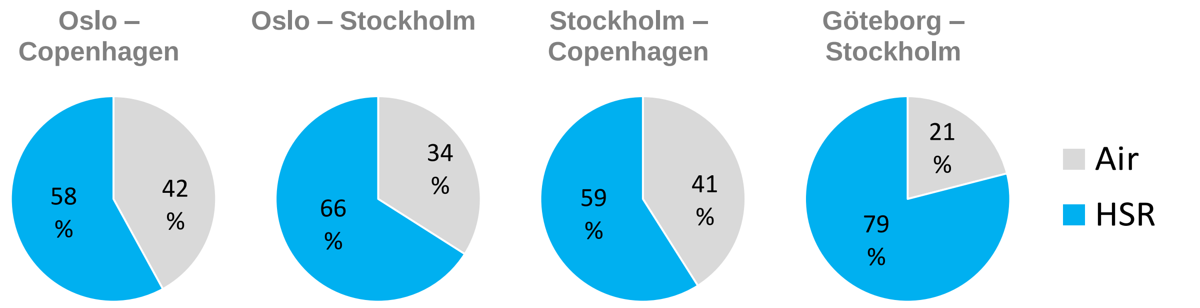
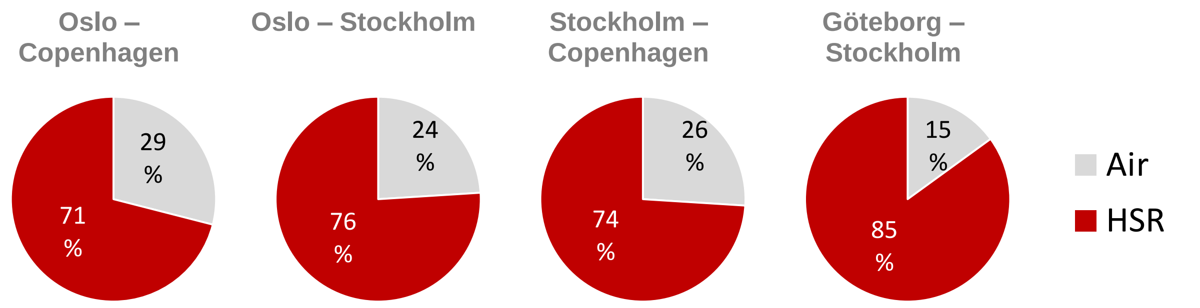


Figure 24. HSR/Air split – Rail fare 60 % of Air Fare



5.4. Fare, stopping pattern and frequency sensitivity tests

Figure 25 below summarises the annual passenger numbers for the core service and each sensitivity test with figures as a percentage of the core service. The figure presents the impact on demand of HSR fare levels at 60% of air fare rather than at 100%. It also presents the impact of an alternative direct stopping pattern and of a combined direct and core (stopping) service doubling the hourly frequency.

Reducing the fare increase the demand by between 27% and 36%. The introduction of a direct service in place of a stopping service results in an important reduction in number of passengers, up to 34% less in the case of the Oslo – Stockholm corridor. The benefit of a multiple service is minimal in terms of passenger numbers, with an increase of 2% to 4% across corridors while lower fare results in a significant increase of passengers, between 27% and 36%.

Figure 25. Annual HRS Passengers as a % of core service

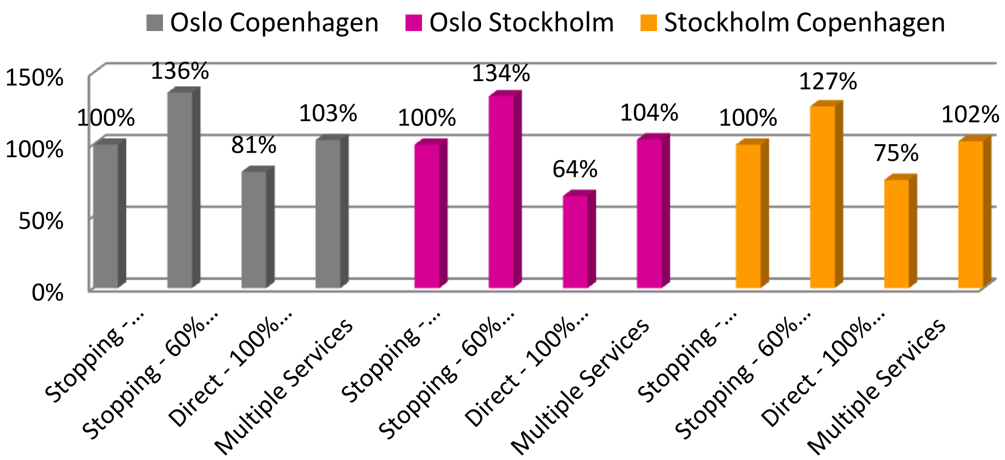
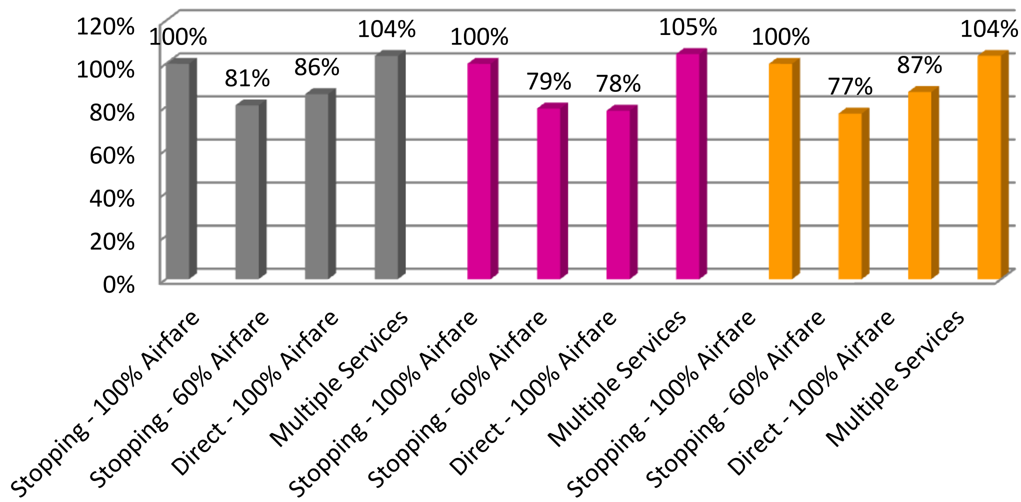


Figure 26 below presents the variation in annual revenue for as in Figure 25 above.

Importantly, this chart shows that the important increase in the number of passengers generated by lower fares does not translate into higher revenues. In other words, lower fares do not generate in enough additional trips to compensate for the lower return per ticket, resulting in revenues 19% to 23% lower than for the core service. In similar way, for the direct service test, the decrease in the number of passengers is not reflected as strongly when looking at revenues. For example, with a direct service on the Oslo – Stockholm line, the passenger number drops by 36% (see chart above) but revenues only decrease by 22%.

Figure 26. Annual Revenue % of core service



6. HSR Market Forecasting Conclusions

6.1. Introduction

In this section, we set out the key conclusions from the initial Scandinavian High Speed Rail assessment, related to the demand and revenue impacts of the three considered corridors selected by COINCO for testing.

6.2. Demand and Revenue Forecasts

This initial stage of High Speed study has developed demand and revenue forecasts for the selected three main corridors considered in this work.

Our cross-checking of demand model outputs against observed international HSR usage suggest that the forecasting model provides a robust basis for decision-making at this stage of scheme assessment. This comparison also reflects the nature of the Scandinavian long-distance travel market, with significantly higher propensity to travel longer distances than most European countries, as well as a geography that suits the services – if not the engineering – of HSR.

However, it is also important to note that there are some limits to forecasting, especially related to estimation of individual HSR station usage, and the potential for new rail markets – particularly commuting into major cities – to be developed by introduction of HSR services.

Analysis of market potential is preliminary and indicative only. Forecasts should be considered at the upper end of the range of likely demand.

Forecasting suggests levels of annual passenger demand in 2024 with the Core HSR scenarios could be as high as:

- Oslo-Copenhagen: c.9.5 million
- Oslo-Stockholm: c. 13.1 million
- Stockholm-Copenhagen: c.18.4 million

Forecasts increase by 30%-35% by 2043 and 50%-60% by 2060 compared to 2024.

6.3. Caveats with respect to gravity model forecasts

Gravity model demand is likely to be an overestimate as:

- The gravity model has not been calibrated / validated;
- There are limitations in available base demand data affecting mode shares; and
- The current zoning system and demand model structure limits the scope to “cordon” in-scope demand by journey length and mode.

The provided and assessed results of the gravity model should be viewed as a reasonable starting point for further investigation of the shorter distance High Speed Rail market.

6.4. Impact of stopping patterns

The core routes are inclusive of a number of intermediate stations that do significantly enhance demand in some cases (add 20%-35%) over the direct service specification. This does indicate that there is sizable market potential in relation to intermediate sized locations which indeed could be further enhanced in an overall HSR network (combined operation of two or more corridors) context.

6.5. HSR vs Air competition

HSR shares compared to Air for major city-city journeys are between 60%-80%. This is in line with previously undertaken studies. It is also considered representative for other High Speed markets across the world. However, it is also recognised that this does not represent a market equilibrium position reflecting potential competitive responses between modes.

6.6. Sensitivity tests

Generally the sensitivity tests indicate:

- Additional stops serving sufficiently large population catchments do add value overall despite the increased end-to-end times they introduce. Revenue does not increase to the same extent as demand reflecting some reduction in higher revenue yield end-to-end passengers, offset by a larger number of moderate revenue yield intermediate passengers.
- Increased frequency of service through combining core and direct services delivers only quite small growth in demand and revenue. This reflects the fact that service frequency is less of a driver for demand for long distance travel which tends to be pre-planned rather than turn-up-and-go in nature. However, it is also recognised that the current model is an all day model and is not as sophisticated in forecasting responses to frequency as would be ideal. Nevertheless, indications are that any frequency increases should be tailored to peaks in demand profile.
- Reducing the HSR fare to 60% of the air fare increases demand by up to 36% but this increase in demand is insufficient to offset the reduced revenue yield per passenger with annual revenue being reduced by around 20%.
- Response to alternative growth assumptions is as would be anticipated, increasing or decreasing proportionately to changes made.

6.7. Key forecasting aspects to note

The focus of the analysis work undertaken during this study was to forecast initial levels of passenger demand and revenue for specified key corridors using consistent forecasting assumptions consistent with the Norway HSR Assessment Study. We emphasise that actual demand and revenue forecasts will vary according to a number of factors:

- All the demand and revenue forecasts are clearly dependent on the fare and journey time assumptions for developed for each option. As options are gradually developed, assumptions on both fares and journey times will change to match the objectives of HSR on that corridor. In particular, optimisation of fare levels for intermediate flows may have a significant impact on demand and revenue levels.
- Each of the scenarios has been tested individually, and in isolation. When combined, it is reasonable to expect an increased “network effect”, where HSR services provide greater connectivity to other parts of the national rail network, including those served by both high speed and conventional or Inter-City services.
- The results presented in this summary report assume no changes to other modes, particularly air and the existing rail services. The response of airlines is difficult to predict, but reductions in air service frequency would, in turn, increase the attractiveness of HSR services, with associated increases in demand and revenues for each alternative. A similar situation may occur with competing bus, coach and existing rail services – although there is much greater potential for the “slower” modes to compete on price.
- Station accessibility is a critical factor in determining the attractiveness of HSR services, both in terms of station location and catchment area, and connectivity by road, rail and bus. Our analysis has demonstrated different ways that a HSR network could be accessed by different modes, which will in turn have an effect on HSR patronage; and
- The train specification used allows for peaks in the demand for services, but further work would be required going forward to optimise the distribution of peak and non-peak services and any other differentials (for example in the calling pattern) between those services.

Finally, we emphasise that all options have been modelled on a consistent basis, reflecting the level of development of each of them at this stage as provided by COINCO. Going forward, bespoke approaches should be developed for each corridor to match its individual market potential which will further increase the accuracy of demand and revenue forecasts.

7. Review of drivers for profitable HSR operations

This chapter sets out the key indicators for a profitable High Speed Rail operation and reflects research undertaken as part of the study by Rapidis as part of the Atkins team. It draws upon the team's extensive experience of high speed rail, model data and financial indicators available in the public domain.

The structure of this chapter is as follows:

- a short description of a number of major European lines including recent financial performance;
- a qualitative description of how the lines' performance compare with one another;
- a look at how they compare with air and highway, potential competing modes, and
- A discussion of what the key drivers are for profitable operation of high speed rail.

The European lines that we have looked at are:

- Barcelona to Madrid,
- Paris to London,
- Frankfurt to Cologne,
- Paris to Marseille, and
- Milan to Bologna

In addition, other lines operating worldwide have been examined to provide a broader perspective on HSR operations. It should be noted that it can be difficult to obtain information directly about the specific lines, so most of the finances refer to the operator, who will often have responsibility for other lines as well.

7.1. Benchmark Analysis: Profitability of High Speed Rail

7.1.1. Barcelona to Madrid

This 621km of tracks opened in February 2008 and is part of the Spanish network of high speed trains, Alta Velocidad Española (AVE). Work is currently underway to connect the tracks to the French high speed railway and is currently forecast to be in place by 2013. The service is operated by RENFE, a state owned company, which operates Spain's passenger and freight services.

The line faces intense competition from air as Barcelona to Madrid is one of Europe's busiest routes. The journey times are roughly comparable at 3 hours, as are the fares, though the cheapest air fares at €60 are cheaper than the cheapest rail fares, €117.60. Departure frequency on air is 25-50 per day (down from 70-80 before HSR) compared to 17 on rail. Journey time on road is about 6 hours.

The profitability figures reported by RENFE are given in Table 20 below:

Table 20. RENFE profitability figures

Year	Passengers (m)	Revenue	Net income	EBIT	EBITDA
2010	17	2,161.09	46.2	-4.8	270.65
2009	17	2,142.04	13.1	-36.4	257.89
Note all monetary figures in Euros (m) *Source: http://www.renfe.com/docs/2010_Economico ing.pdf*					

Passenger totals for rail include all regional and high speed services and not just this line.

Although the total income is slightly negative, that is including depreciation. Even with 264 million Euros paid to Administrador de Infraestructuras Ferroviarias, the Spanish rail network owner and operator, for trackage rights, the AVE system garners sufficient ticket revenue to pay for the operation of the system. In 2010, Renfe merged all of its passenger services into one department; the numbers here include all ticket revenue for commuters and other trains as well plus subsidies for these services (382.98 million Euros in 2009, 366.68 million in 2010).

7.1.2. Paris to London

This line is operated by Eurostar (formerly SNCF,LCR & SNCB) and links Paris, London and Brussels via the Channel Tunnel. It was opened in 1994, with high speed link to London having commercial services running from 2007 to the terminus at St Pancras. Paris and London are the two major urban centres, and have between them a population of 20 million, which represents the largest potential market for existing High Speed Rail in Europe.

The main competitor to High Speed Rail is from air. Including wait times, rail (2 hours) is faster than air (three hours) by about an hour, whilst fares are roughly comparable, €83 for an economy ticket on rail compared to €86 via air. Frequency is higher via air, with 36-38 services per day, compared to 17 on rail. Journey time via car is about 5 and a half hours.

Recent profitability reported by Eurostar is given in Table 21 below.

Table 21. Eurostar profitability figures

Year	Passengers (m)	Revenue	Net income
2011	9.7	1,003.75	26
2010	9.5	950.00	profits increasing
2009	9.2	843.75	profits increasing

Note all monetary figures in Euros (m)

Source:

http://www.eurostar.com/UK/uk/leisure/about_eurostar/press_release/20120308_eurostar_reports_growth.jsp &

http://www.eurostar.com/UK/uk/leisure/about_eurostar/press_release/press_archive_2011/Eurostar_reports_strong_growth_in_2010.jsp

In recent years, Eurostar has focussed on the business market. Annual passenger numbers are much higher than on the competing air services (1.4 million). Passenger numbers do include services to Brussels as well, but overall show that High Speed Rail has been successful in gaining a large share of the market and in recent years has increasing operating surplus.

7.1.3. Paris to Marseille

France's High Speed Rail network is the TGV and is operated by SNCF Voyages. The line opened between Paris and Lyon in 1981. The section of the network between Lyon and Marseille opened in 2001. Paris has a population of 10.8m, and Lyon a population of 1.5m.

The route from Paris to Marseille is 750km and takes 3 hours, with 16 trains per day. Air is its principal competitor and has a roughly similar travel time, but has a lower share of the market, with 1.6m passengers with 16-25 services per day. By comparison, 25m use the TGV train between Paris and Lyon. Fares on rail range between €25 and €184, whilst by air they range between €68 and €326.

Profitability figures reported by SNCF Voyages are given in Table 22 below.

Table 22. SCNF Voyages profitability figures

Year	Passengers (m)	Revenue	Operating Profit
2011	25	7,279.00	581.00
2010	25	7,217.00	535.00
2009	25	7,375.00	707.00
Note all monetary figures in Euros (m) Source: *http://medias.sncf.com/resources/en_EN/medias/MD0006_20120217/file_pdf.pdf* *http://www.sncf.com/Finance/pdf/en/financial_reports/SNCF_Group-2010_Financial_Report.pdf*			

High Speed Rail in France is highly profitable, compared with that in the rest of Europe. SNCF is very much commercially focussed.

7.1.4. Frankfurt to Cologne

This line is operated by DB Fernverkehr, a subsidiary of Deutsche Bahn, and it operates all long distance passenger trains in Germany. It effectively operates as a monopoly in the high speed rail market. The distance on the tracks is short relative to the others at 171km. The two cities are of similar size at 2.3m and 2.0m respectively.

There is no direct air service between Frankfurt and Cologne, which means that road is HSR’s only competitor. The non-stop service at 62 minutes is just under an hour quicker than road. Fares are €67 for a regular ticket and €39 for savings ticket.

Recent profitability figures reported by DB Fernverkehr (for their whole network) are given in Table 23 below.

Table 23. DB Fernverkehr profitability figures

Year	Revenue	EBIT	EBITDA
2011, H1 x 2	3,650.00	92	454
2010, H1 x2	3,656.00	160	522
2009	3,565.00	141	504
2008	3,652.00	306	678
Note all monetary figures in Euros (m), only H1 figures found for 2010 and 2011. *Source:* *http://www1.deutschebahn.com/ecm2-db-en/zb/gmr/units/passenger/long-distance.html*			

Despite the recent decline, High Speed Rail in Germany remains relatively profitable. HSR gained some one-off benefits in the first half of 2010 due to disruption in aviation weather and a pilots’ strike. There was also some one-off negative disruption in 2011 due to construction and a train drivers’ strike. There were also higher costs, with an increase in operating costs (leased trains) and capital expenditure due to implementing re-design measures for the HDR ICE-2 fleet (Inter City Express).

7.1.5. Milan to Bologna

The High Speed Rail connects Milan and Bologna, via Rome, Florence and Naples. It is operated by Trenitalia, with a competing service (NTV) recently introduced. The distance between the two is 215km, with a journey time of 65 minutes. There is no direct flight, which means that the principal competition comes from road, where journey times are 135 minutes. The service opened at the end of 2008 and Trenitalia note that in the first half of 2011, they moved back into profitability though no figures are available.

7.1.6. Japan - Shinkansen

Japan has operated the Shinkansen High Speed Rail service since 1964, and it is a highly profitable operation. The Shinkansen, also known as the 'bullet train' is a highly developed network that covers both of the main islands of Japan linking most major cities. The network has over 2,000km of track with maximum speeds of 240-300 km/h. Table 24 below provides financial results reported by three of the rail companies.

Table 24. Shinkansen operators profitability figures

Company	Revenue	Expense	Income
Central, 2010/11	11,447	8,721	2,726
West, 2010/11	8,085	7,473	612
East,2009/10	18,123	15,805	2,318
Note all monetary figures in Euros (m) converted at a rate of 99.8Yen to the Euro			

The Shinkansen accounts for roughly half of the revenue. The value of Shinkansen specific expenses (operating costs) cannot be determined.

7.1.7. Taiwan

High Speed Rail in Taiwan was opened in 2007, and by 2009 was making an operating profit of €150m and €260m in 2010, although high depreciation and interest costs meant it still made an overall loss and had to be taken over by the Government. It consists of a single line from Taipei to Zuoying, of 179km with a frequency of 60 trains per day.

7.1.8. USA

The USA's only High Speed Rail line is the ACELA express operated by AMTRAK. It runs between Boston and Washington DC via New York and Philadelphia. It operates 20 trains per day, and covers a distance of 734km over 7 hours, making it relatively slow compared to other High Speed Rail around the world. In the financial year to 2010 it made $100m in operating profit.

7.2. Comparing HSR in Europe

High Speed Rail Europe's characteristics relative to one another are compared in Table 25 below.

Table 25. European High Speed Rail lines characteristics comparison

	Barcelona - Madrid	Paris - London	Frankfurt - Cologne	Paris - Marseille	Milano - Bologna
Profitability	-4.7m (EBITDA)	26m	92m (EBITDA)	581m	Break even
distance	621km	479km	177km	750km	215km
Frequency / day	17	17	40	16	17
Passengers	17m (all services)	9.7m	n/a	25m (Paris to Lyon)	n/a
Fare	117-211	83-312	39,67	27-184	44-62
Opened	2008	1994	2002	2001	2008
Urban areas served	4.2m, 5.4m	10.8m, 8.6m	2.3m, 2.0m	10.8m, 1.5m	5.2m, 0.5m

Whilst Barcelona to Madrid and Milan to Bologna are labelled as low on profitability, they are both relatively new, and whilst the Paris to London line has been open since 1994 it's operator has recently been re-structured and the line in its current form has only been open since 2007. The one operator that has made a loss (Spain) has the highest fares, although this loss is decreasing and break even will occur if this trend continues.

Distance does not appear to be a significant factor, and it is difficult to tell whether the size of the urban areas served is a factor, though it is logical to suppose that they would be as this is the potential market that HSR draws on. For example, Japan, Taiwan, and North Eastern USA have high population density.

The two most profitable operators run Paris to Marseille and Frankfurt to Cologne. Paris to Marseille has a wide range of fares, whilst Frankfurt to Cologne is relatively cheap. Paris to London and Barcelona to Madrid have higher fares for the business market.

7.3. Comparing HSR against modal competition

Another important indicator is the degree of competition that HSR faces. HSR potentially has advantages over air travel: higher service quality, better access to urban centres, a reduced need for interchange and better perceived reliability.

Table 26 below compares key journey characteristics for three of the European HSR operators who face competition from air services. Air travel time includes waiting and access time to airports, but there are no generalised cost penalties to interchange applied.

Table 26. Relative indicators vs. Air competition

	Travel time	Frequency	Fares	Average Speed on Rail (km/h)
Barcelona-Madrid	Rail: 158m Air: 180m	Rail: 17/day Air: 25-50 /day	Rail: 117-211 Air: 60-279	236
Paris-London	Rail: 142m Air: 200m	Rail: 17/day Air: 36-38/day	Rail: 83-312 Air: 86-634	202
Paris-Marseille	Rail: 185m Air: 170m	Rail: 16/day Air: 16-25/day	Rail: 27-184 Air: 68-326	241

It is interesting to note that for the two low-profit HSR operators, rail is actually quicker, whilst for the high-profit line, air is slightly faster. This shows that journey time compared to air, allowing for a margin of error, on its own may not be a significant factor in profitability. Although Paris to London has the biggest benefit in journey time, it still has the lowest average journey speed at 202 km/h.

What does seem to be significant is the difference in service frequency and fares. The Paris to Marseille route has similar air and rail frequency but fares cover a higher range, though there is some overlap, so we might expect most HSR fares to be cheaper than their equivalent air fares.

Whilst we don't have a direct comparison of passenger numbers, there were 25m passengers using the Paris to Lyon section in 2009, which compares to 1.6m air passengers. This suggests that HSR has a dominant market position.

On the Paris to London route, passenger numbers have grown 5% in two years. There are 9.7m rail passengers on all Eurostar (including services to Brussels), compared to 1.4m by air, which will be part of the reason behind the recent increase in profitability. With its faster journey time, Paris to London can afford to have comparable fares with air.

The Barcelona to Madrid route has impacted on air services, with a reduction in services from a peak of 70-80 flights per day to the current 25-50. This is still fierce competition, and with a slightly faster journey time but much higher fares, HSR may not seem a much more attractive offering than some of its counterparts may do. The fares may be constrained by inelastic demand elasticity and higher costs such as tracks access and interest charges, however this more intense competition may be part of the explanation why this service is loss making.

Table 27. Relative indicators vs road competition

	Travel time	Average Speed (km/h)
Frankfurt-Cologne	Rail: 62m Road: 116m	Rail: 171 Road: 92
Milano-Bologna	Rail: 65m Road: 135m	Rail: 198 Road: 96

The Frankfurt-Cologne operator, DB Fernverkehr is making healthy profits, whilst the Milan to Bologna operator, Trenitalia has only just broken even. Neither of the routes have direct competition from air so the only competition comes from road. The above table shows that the Milan to Bologna has a more attractive offering in journey time savings and overall speed.

DB Fernverkehr operates a de facto monopoly, and the line has been in operation for over ten years, whilst Trenitalia will now start to face competition from the newly introduced NTV services (part owned by SNCF), which may curtail growth in operating profit.

7.4. Summary and conclusions

7.4.1. Market size

A 'critical mass' of urban areas to serve is required for HSR commercial viability. The Frankfurt to Cologne line operation has the smallest serving combined population associated with its major city locations at 4.3m, and this is on the context of a relatively short route. Populations served per 100km of route length range between 1.5m and over 4m for the European HSR routes examined. Taking the metropolitan area populations for Oslo, Gothenburg, Malmo and Copenhagen, the population served per 100km of route is around 1m.

7.4.2. Length of time opened

The evidence is that given a sufficiently large market (size of urban centres) High Speed Rail will usually be attractive enough to cover its operating costs. If revenues and costs are appropriately managed, then post-construction it can take around three years for revenue to cover operating costs (Taiwan, Spain, Italy, and Eurostar since the opening of HS1). Ridership can take time to adjust to equilibrium levels as passengers get used to the idea of using HSR instead of other modes, such as air (for example, Eurostar).

7.4.3. Network size

The most profitable HSR is in Japan, but France is also highly profitable, and Germany has also exhibited profit despite a recent decline. Probably the most distinguishing feature of these is that they sit within comparatively large HSR rail networks and have been in operation for some time. This enables them to take advantage of very large economies of scale, as they do not need to invest in new technologies and potentially face high interest charges.

7.4.4. Degree of competition

The more competition that HSR faces, the bigger the squeeze on profit margins. The TGV trains in France face relatively low competition from air, and in Germany, the Frankfurt to Cologne line has none. For other lines, however, there is strong competition from air (Barcelona-Madrid, Paris-London).

7.4.5. Comparative journey times and behavioural response

Distance is shown to be not as important a factor as "perceived" time competitiveness. Shorter routes are more likely to compete with road, longer ones to compete with air services, and achieving genuinely competitive door-to-door times, accounting of perception of time for different journey elements, is critical. It should be noted that the importance or weight on particular journey attributes may vary with overall journey distance.

7.4.6. Importance of careful service specification and pricing

Careful and bespoke service specification and pricing and revenue / yield management is essential to achieving competitive and profitable operations. Significant effort and focus has been put by operators on researching markets and potential behavioural and competitive responses in order to structure service levels and fares, as well as associated marketing, in order to optimise yields and margins. This process is inevitably a dynamic and ongoing process. Evidence shows that services with the highest spread of fares are most profitable which suggests that demand may be elastic to price, particularly where alternatives are available

7.4.7. Recognising that each HSR operation is unique

Great care needs to be taken not to draw false parallels or conclusions from operations elsewhere:

- behaviour and elasticity of response of the market will vary;
- socio-economic and demographic characteristics will influence this;
- costs for operation and relative pricing will vary;
- as will maturity of markets and quality of pre-HSR offer by mode; and
- characteristics of the mode choice available and associated travel cost and cost components may also vary significantly

Consequently, it is essential that any new “HSR product” is tailored and designed to optimise performance in relation to its unique circumstances.

8. Overall Conclusions and Next steps

8.1. Overall Conclusions

The following conclusions may be drawn from the analyses undertaken in this study.

8.1.1. HSR market forecasts

The overall conclusions of the market forecasting analysis undertaken are summarised as follows:

- Analysis of market potential at this stage is preliminary and indicative only, and forecasts should be considered at upper end of range of likely demand
- Gravity model demand likely to be an overestimate at this stage reflecting the fact that the model has not been calibrated / validated and limitations in available model structure and base demand data affecting mode shares
- Forecasts suggest levels of annual passenger demand in 2024 for core HSR routes could be as high as:
  - Oslo – Copenhagen: c.9.5 million
  - Oslo – Stockholm: c. 13.1 million
  - Stockholm – Copenhagen: c.18.4 million
- Forecasts increase by 30%-35% by 2043 and 50%-60% by 2060 compared to 2024
- Core routes inclusive of a number of intermediate stations that significantly enhance demand in some cases (add 20%-35%)
- The analysis does indicate that there is sizable market potential that could be further enhanced in a network context
- HSR share vs Air for major city-city journeys is between 60%-80%
- Sensitivity tests indicate:
  - Additional intermediate stops at sizeable locations are likely to be worthwhile from a demand and revenue perspective despite the increased end-to-end journey times that result
  - Additional demand in the region of 30% from reducing fare levels to 60% of air fare is insufficient to offset the lost revenue per passenger, with annual revenue falling by 20%. The case for HSR will be sensitive to HSR pricing.
  - Increased frequency delivers quite small growth in demand and revenue – should only consider frequency increases tailored to peaks in demand profile.

8.1.2. Review of the drivers for profitable HSR operations

The overall conclusions of the review of the drivers for profitable HSR operation are summarised as follows:

- A ‘critical mass’ of urban areas to serve is required for HSR commercial viability. Populations served per 100km of route length range between 1.5m and over 4m for the European HSR routes examined. Taking the metropolitan area populations for Oslo, Gothenburg, Malmo and Copenhagen, the population served per 100km of route is around 1m.
- The evidence is that given a sufficiently large market (size of urban centres) High Speed Rail will usually be attractive enough to cover its operating costs. Ridership can take time to adjust to equilibrium levels as passengers get used to the idea of using HSR instead of other modes, such as air (for example, Eurostar).
- The most profitable HSR is in Japan, but France is also highly profitable, and a distinguishing feature of these is that they sit within comparatively large HSR rail networks and have been in operation for some time. This enables them to take advantage of very large economies of scale, as they do not need to invest in new technologies and potentially face high interest charges.

- The more competition that HSR faces, the bigger the squeeze on profit margins. The TGV trains in France face relatively low competition from air, and in Germany, the Frankfurt to Cologne line has none. For other lines, however, there is strong competition from air (Barcelona-Madrid, Paris-London).

- Distance is shown to be not as important a factor as "perceived" time competitiveness. Achieving genuinely competitive door-to-door times, accounting of perception of time for different journey elements, is critical.

- Careful and bespoke service specification and pricing and revenue / yield management is essential to achieving competitive and profitable operations. Evidence shows that services with the highest spread of fares are most profitable which suggests that demand may be elastic to price, particularly where alternatives are available

- However, great care needs to be taken not to draw false parallels or conclusions from operations elsewhere:
  - behaviour and elasticity of response of the market will vary;
  - socio-economic and demographic characteristics will influence this;
  - costs for operation and relative pricing will vary;
  - as will maturity of markets and quality of pre-HSR offer by mode; and
  - characteristics of the mode choice available and associated travel cost and cost components may also vary significantly

- Consequently, it is essential that any new "HSR product" is tailored and designed to optimise performance in relation to its unique circumstances

8.2. Next Steps

The following recommendations are made with respect to next steps following completion of this study.

8.2.1. Development and refinement of HSR market forecasts

The core area of analysis undertaken as part of this study has been the derivation of preliminary HSR market forecasts. Next steps with respect to establishing more robust forecasts looking forward are:

- There is need to secure more consistent and detailed base data than is currently available. A common level of base data travel across modes will be required.

- A comprehensive and detailed calibration and validation exercise will be required to refine model response and provide a higher degree of confidence in forecasting results.

- The sophistication and functionality of any adopted forecasting framework should ideally be enhanced in a number of respects, and be supported where necessary by new surveys / research, addressing the need to capture:
  - Forecasting variation by time period (AM and PM peaks and inter-peak).
  - Forecasting variation by travel market / demand segments.
  - Variability in behavioural responses by geography and socio-demographic characteristics.
  - Representation of interaction with other rail services and network effects.
  - Destination choice and redistribution effects generated by the introduction of HSR.
  - Impacts of competitive responses and derivation of associated equilibrium market positions.

8.2.2. Understanding HSR viability

Additionally, there are a number of further areas of analysis that should be addressed looking forward:

- The relationship between HSR revenue and operating costs needs to be understood as this will be central to determining commercial viability and ultimate deliverability of HSR.

- Examination of the balance between capital investment and operating revenue.

- Detailed modelling of capital, operating and life-cycle costs and risk.

- Examination of the relationship / implications for the utilisation and operation of the wider rail network.

- Identification and examination of the potential phasing and commercial structures for HSR delivery.

- Detailed economic and financial appraisal in keeping with international best practice and capturing the full breadth of potential impacts of HSR.

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