

SECOND OPINION

on the proposed high speed rail in Sweden

25th May 2016

EXECUTIVE SUMMARY

ARUP



Stockholm is one of the three principle cities on the proposed HSR network

SWEDEN HIGH SPEED RAIL

INTRODUCTION

PURPOSE OF REPORT

Trafikverket have appointed Arup to undertake a second opinion on the current proposals to develop a high speed rail line linking Stockholm to Göteborg and Malmö. The scheme was originally proposed by Trafikverket and the National Negotiation on Housing and Infrastructure who have input into various aspects of the route and have now requested this second opinion.

This report therefore, this report provides a second opinion of the planned "New System" which was presented by the National Negotiation on Housing and Infrastructure on 11th February 2016. The study utilises Arup's international experience on high speed rail around the world and uses examples of best practice to benchmark against the route and the locations of the stations along it. The study undertakes a comparison of international high speed rail and how these operate and compares them to what has been proposed in Sweden.

The report undertakes analysis on the following aspect of the system:

- a. The number of stations along the route and the distance between the stations;**
- b. The criteria and principles for the station; e.g. bypass, central, peripheral or external location;**
- c. The system and frequency of traffic – currently on hold; and**
- d. A review of the geometrical restrictions and geometric design against other high speed rail standards.**

These four aspects form Task 2 of the study and challenge the thinking of the "New System".

BACKGROUND

We understand that separate proposals were originally developed for improvements to regional services between Linköping and Stockholm (the Ostlanken) and between Borås and Göteborg. The decision was subsequently made to link these proposals by means of a national High Speed Railway (HSR) connecting Stockholm and Göteborg, and also Stockholm and Malmö, reducing rail journey times and increasing passenger capacity between the cities, and also releasing capacity on existing routes for additional conventional passenger and freight traffic.

An important consideration in the development of the HSR proposals is the balancing of the requirements of long-distance, high-speed traffic with those of the major regional services, thus achieving an appropriate combination of services and avoiding a sub-optimal overall outcome.



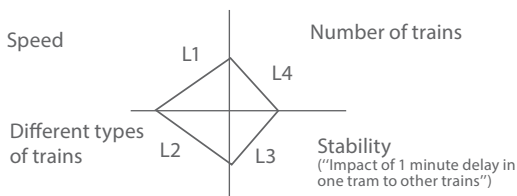
HSR geometry in urban areas will be particularly constrained

SYSTEM & FREQUENCY OF TRAFFIC

As noted above, careful service planning will be required to maximise the capacity, inter-regional connections and other benefits of the HSR proposals, particularly in terms of combining the long-distance, high-speed services with the major regional trains.

For services using the HSR (and running beyond it, within Sweden and between Sweden, Denmark and Germany), the timetable and train plan will need to achieve an appropriate balance between capacity provision (and consumption), and service frequencies, stopping patterns and interchange opportunities at intermediate stations, while maintaining acceptable levels of performance and timetable stability. The trade-offs involved are summarised in the diagram below.

Balancing capacity in case of mix traffic:



$$L1 + L2 + L3 + L4 = \text{Constant}$$

Diagram source: <http://www.uic.org/highspeed>

For services on the conventional network that connect with the HSR, the timetable should be arranged to maximise convenient and reliable connections to and from the HSR, and thus for inter-regional travel.

The eventual timetables on the HSR and conventional network will reflect the desired service specification and underlying demand, but also capacity and other operational constraints, including minimum headways, dwell times and turnaround times at termini. Data and information on all of these will be required in order for the work to proceed.

Generalised Journey Time Analysis

Generalised Journey Times (GJTs) will be assessed for station pairs, based on in-vehicle times and service intervals, using indicative service patterns and calculated journey times. The initial focus will be on journeys between the termini and other major stations.

Generalised Journey Time Comparison

The GJT's for HSR will be compared with those for the road and air travel alternatives. Indicative road journey times will be obtained from Google Maps or other appropriate sources.

For air travel, the focus will be on services between Arlanda, Skavsta, Landvetter and Malmo airports (plus any others specified by Trafikverket), and will consider airport access and minimum check-in times, as well as flight times and frequencies. The initial comparison will be on the basis of city centre – to – city centre travel, and will include airport access times from/to the relevant urban areas.

International Benchmarking

The Swedish proposals will be compared with the characteristics of other HSR systems (existing and planned/proposed) in terms of availability, resilience and journey time effects, particularly in respect of stopping times, train operating patterns and value for money of the infrastructure

GEOMETRIC RESTRICTIONS

METHODOLOGY

To help assess the Trafikverket Technical System Standard for High-speed Railway Lines Standard (TDOK 2014:0159 version 2.0, 2015-07-01), referred to in this report as the “Swedish HSR Standard”, a number of High Speed Railway (HSR) standards and guidance documents have been reviewed to aid the comparison study. These are listed in the table below.

This list is not exhaustive when compared to the number of HSR systems in operation (or in the design phase) globally, but the documents listed form a useful resource and represent current industry thinking and good practice. Other HSR systems have been in operation (or in the design phase) for some time but their standards are either confidential or unavailable to us, or are not considered reasonable currently.

Other Swedish standards such as those listed below have not been reviewed.

1. TDOK 2014:0555 (formerly BVS 1586.20) – no title given
2. TDOK 2014:0075 Banöverbyggnad – Spårgeometri Krav på spårets geometri vid nybyggnad, reinvestering/upprustning, underhåll och drift (Track superstructure – Track geometry Requirements for track geometry in connection with new construction, reinvestment/upgrading, maintenance and operation)
3. TDOK 2014:0686 (tidigare/ formerly BVS 1586.26) – no title given
4. “Standard range of turnouts from Swedish Transport Administration”

Criteria for all standards have been tabulated, with a further table of recommended criteria provided.

Several assumptions and exclusions made during this study are given in Sections “Assumptions” and “Exclusions” below. Section 5.2 gives commentary on the findings and recommendations.

Assumptions

Several assumptions have been made when carrying out the standards review and comparison which are given below:

1. Only the headline criteria that have significant influence over global route alignment have been assessed.
2. The criteria have been assessed assuming a dedicated high speed passenger railway, with no freight use (or differential speed) envisaged.
3. The criteria have been assessed assuming all construction is new, with no adoption or upgrade of existing infrastructure.
4. Factors effecting the fundamental constructability of the railway have not been assessed e.g. specific earthworks or tunnelling criteria.
5. No judgements on linespeed or journey time against factors such as topography and cost have been considered.
6. Where standards give different criteria values for different bands of linespeeds the most relevant have been taken as those of 250kph and above.
7. The other comparison standards and documents that were reviewed place passenger comfort and infrastructure maintainability as core principles.

| Name | Title | Document reference no. |
|----------------|---|--|
| TSI INF | Technical Specifications for Interoperability relating to the ‘Infrastructure’ subsystem of the rail system in the European union | 1299/2014 |
| EN | Railway applications – Track – Track alignment design parameters – Track gauges 1435mm and wider, Part 1 – plain line Railway applications – Track – Track alignment design parameters – Track gauges 1435mm and wider, Part 2 – Switches and crossings and comparable | BS EN 13803-1:2010 BS EN 13803-2:2006+A1:2009 |
| UK HS1 | Track Alignment Design for the Channel Tunnel Rail Link (CTRL) | 000-GDS-LCEET-00078-08 |
| USA California | Technical Memorandum – Alignment Design Standards for High-Speed Train Operation | TM 2.1.2 |
| Singapore | Arup document: ER469 Engineering Feasibility Study for the Proposed High Speed Rail, Final Report Volume 1 | DOC/ER469/QUA/PL/0003/A |

Exclusions

There are various factors that, whilst potentially relevant to overall alignment and corridor design at a later stage in the process, have been omitted from this high-level standards review and comparison.

1. No comparison has been made regarding climatic parameters such as average temperature ranges and cross-winds.
2. No comparison has been made regarding flora or fauna (livestock security fencing, distance from trees etc).
3. No comparison has been made regarding structure or earthwork design (load cases, dynamic performance etc).
4. Any commentary regards standards and parameters individually and does not treat them holistically, as would a design team in the development phase.
5. Tilting trains and any different parameter limits for them have not been considered.
6. Criteria limits around “abrupt changes in cant deficiency”, or virtual transitions, have not been considered as these are only relevant at lower speeds which will not be applicable for overall route identification.

COMMENTARY & RECOMMENDATIONS

The Swedish Standard that has been reviewed is broadly similar to the other documents reviewed, and the process has identified areas where it could be enhanced. Below are some suggestions for detail to be added or modified.

Standards “gaps”

There are several design areas that the Swedish Standard is either silent on, or should enhance the level of detail.

1. Locating switches and crossings (S&C) on the mainlines, and factors constraining the mainline around S&C (to improve S&C construction, installation and maintainability).
2. Minimum element length to avoid rapid changes of direction, or, maximum number of elements in a rolling km (to avoid frequent changes of direction and improve passenger comfort).
3. Overlapping vertical curves with either horizontal curves or horizontal transitions (to improve the constructability and maintainability of the alignment and passenger comfort).
4. Alignment constraints for electrification Neutral Sections (to ensure power distribution and supply can be facilitated).

HSR Standard amendments

The table given in Appendix A shows the recommended standards criteria, and can be compared to the table Appendix B that lists the existing Standards alongside those of the other documents.

It is recommended that these criteria be adopted for the development of the HSR corridor alignment, noting the additional comments below.

Standards flexibility

In designing a railway corridor it is necessary that a balance must be found between linespeeds/ journey time, costs, engineering and passenger comfort, as well as other considerations such as political climate and sustainability. The alignment engineering standards that the railway corridor is based upon should therefore accommodate enough flexibility to permit “value engineering” of the overall system, which the recommended values attempt to do.

HSR “system”

A railway is a system comprising infrastructure and rolling stock, which both have their own peculiarities and also interdependencies. The interdependencies (involving design criteria), are amplified for a high-speed railway, as the safe passage of vehicles relies on specific infrastructure that meets their needs. Essentially, a high-speed railway system must be designed with compatibility in mind. It is therefore important to identify as early as possible the “system” that the railway will be designed to adopt. For example, a Japanese Shinkansen train could not immediately integrate on the TGV network in France. In this way, specific design criteria should be refined with respect to the rolling stock/ system as the design development of the route progresses.

Trackform/ structure interaction:

The standards reviewed are generally silent regarding rail expansion joints for structures (e.g. viaducts). These require a constant gradient and straight alignment, with sufficient distance from S&C. Viaduct design, and the consequent need for expansion switches, can therefore have an influence over alignment design which must be considered holistically.

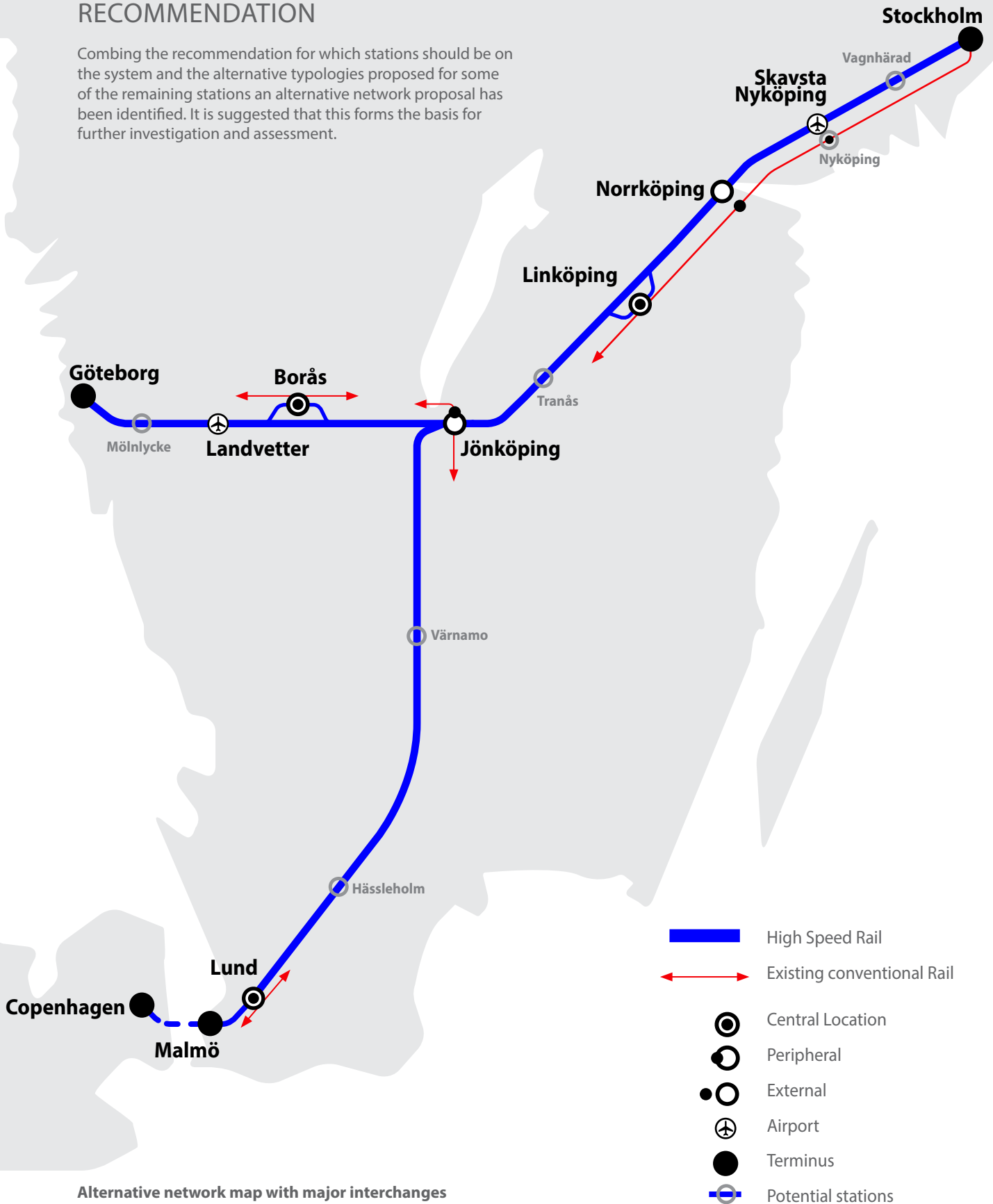
Trackform:

Various trackforms are available to construct new railways, including variations on ballasted and ballastless (slab) track. These all have differing advantages and disadvantages across a wide range of issues, such as capital cost, installation method, alignment fixity, maintenance frequency, whole life cost and so on. Whilst most design criteria/ values are supported by both general trackforms it should be noted that ballastless/ slab trackforms are more resilient to the stresses placed on the track from traffic. For example, a higher cant deficiency value (lateral force) through a curve is more easily restrained by a slab-track form and consequently may be more suitable for future linespeed enhancement.

CONCLUSIONS

OVERALL NETWORK RECOMMENDATION

Combing the recommendation for which stations should be on the system and the alternative typologies proposed for some of the remaining stations an alternative network proposal has been identified. It is suggested that this forms the basis for further investigation and assessment.



Alternative network map with major interchanges

CONCLUSION ON STATION NUMBERS & LOCATIONS

CONCLUSION ON STATION NUMBERS & LOCATIONS

In the summer of 2015, the Swedish Transport Administration was tasked by the National Negotiation on Housing and Infrastructure with developing an expansion strategy for high-speed network;

A new-generation railway, the high-speed railway from Stockholm to Göteborg/Malmö will be Sweden's biggest infrastructure project in the past 150 years. This railway will play an important role in Sweden's development, providing increased access to several of its largest cities. This will lead to larger labour market regions, which will in turn promote a surge in housing construction. With high-speed railways it will be possible to conduct more journeys and transport more freight by rail, contributing to a transport system that is more sustainable in the long term.

It is recognised that the overall viability of the proposed railway is dependent on the options selected regarding the railway's route and station locations.

Using the selection criteria established by NNHI supplemented by Arup's own criteria and further analysis a second opinion on the number of stations and location of stations has been derived. This alternative network proposal is intended to identify those stations which will best meet the project criteria discussed within this report in a way which supports the overall viability of the project. Following this provisional assessment Arup have identified for further investigation, stations which could be omitted from the HSR network.

All NNHI proposed stations have been summarised and are shown on the Assessment Table on the following page. Värnamo and Hässleholm are considered to be borderline for inclusion and it is recommended that further study is carried out, in particular relating to the relative cost of proposals and the potential for regional connectivity through interchange with existing regional rail services.

In summary Arup have recommended subject to further study the potential omission of the following stations on the network;

- **Vagnhärad**
- **Nyköping (combined with Skavsta)**
- **Tranås**
- **Mölnlycke**
- **Värnamo**
- **Hässleholm**

STATION TYPOLOGY RECOMMENDATIONS

In addition to providing a second opinion on which stations should be included in the system, Arup have made a number of recommendations on the specific location typology. This has been informed by the supplementary Arup criteria which are explained in this report. Three alternative typologies have been considered for each station including the NNHI proposal. These have been assessed against 5 station location criteria leading to a provisional recommendation.

In summary Arup have recommended the following changes to NNHI proposed station typologies;

- **Nyköping / Skavsta (airport)** – stations to be combined with PT corridor to centre avoiding duplication of station and line costs;
- **Norrköping** – station to be relocated to city edge connecting with existing rail and tramway to city centre to shorten alignment and avoid costly tunnels;
- **Linköping** – station to be relocated to new transport hub in development zone east of the river;
- **Jönköping** – station to be in same location but on mainline to allow for future stopping express service trains;
- **Borås** – station to be relocated at the existing Central Station to form a consolidated transport hub utilising existing rail corridor from north if feasible;
- **Landvetter (airport)** – station to be relocated further north and integrated with the airport city development avoiding costly tunnels.

Recommended alternative station locations are shown following the assessment table.

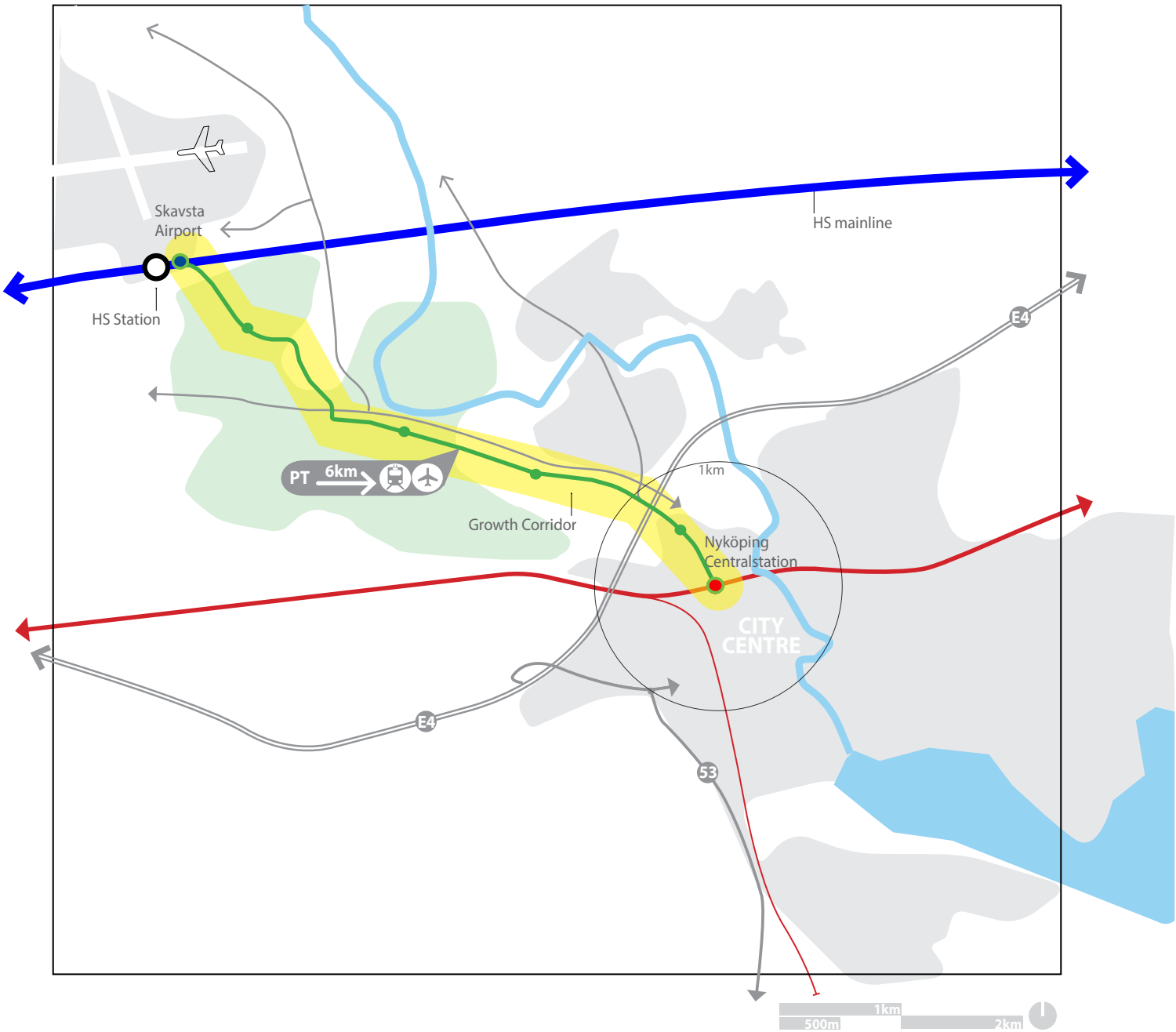
SUMMARY TABLE

| | 1  Bring 3 metropolitan areas closer to each other [Impact on end to end journey time] | 2  Size and national / regional significance of a city | 3  Forecast passenger numbers |
|---------------------|--|---|--|
| Vagnhärad | minor impact |  3,324 |  1,018 |
| Nyköping | no impact |  29,891 |  6,140 |
| ✈ Skavsta | minor impact |  487 |  487 |
| Norrköping | significant impact |  87,247 |  11,428 |
| Linköping | No impact |  104,232 |  15,305 |
| Tranås | Minor impact |  14,197 |  2,385 |
| Jönköping | No impact |  89,396 |  14,045 |
| Borås | No impact |  66,273 |  20,949 |
| ✈ Landvetter | Minor impact |  784 |  784 |
| Mölnlycke | Significant impact |  15,608 |  5,050 |
| Värnamo | Minor impact |  18,696 |  3,447 |
| Hässleholm | No impact |  18,500 |  21,161 |
| Lund | Significant impact |  82,800 |  43,664 |



NYKÖPING

Schematic map showing Station typology recommendation

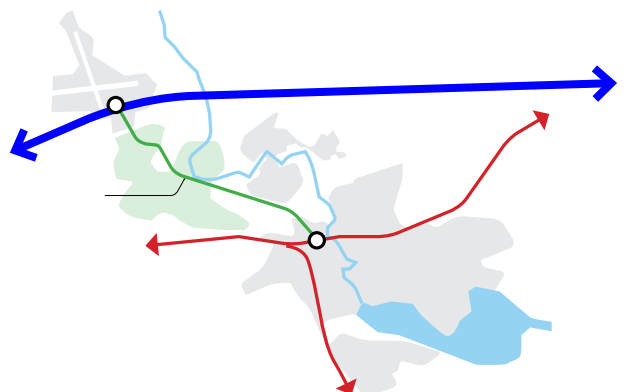


KEY

- Existing Rail
- Proposed High Speed Rail
- Proposed High Speed Station
- Existing Station
-
- Tram line
- Tram stop
- == Highway
- Road

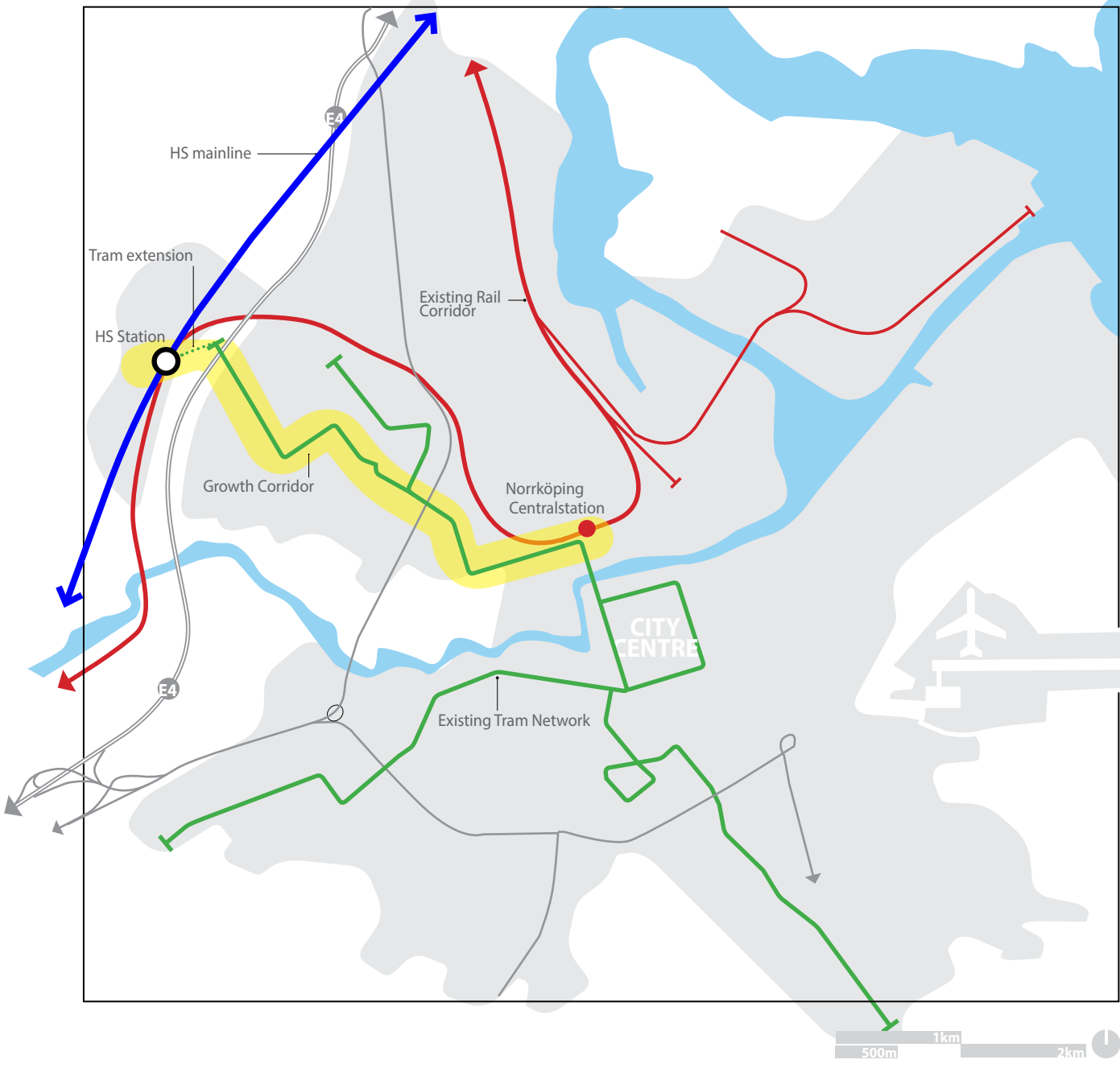


KEY REGIONAL MAP



NORRKÖPING

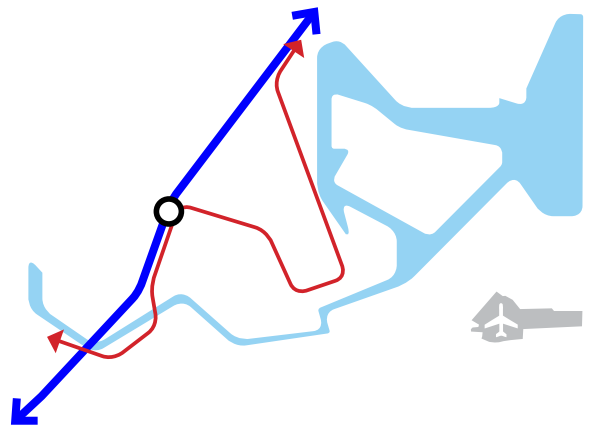
Schematic map showing Station typology recommendation



KEY

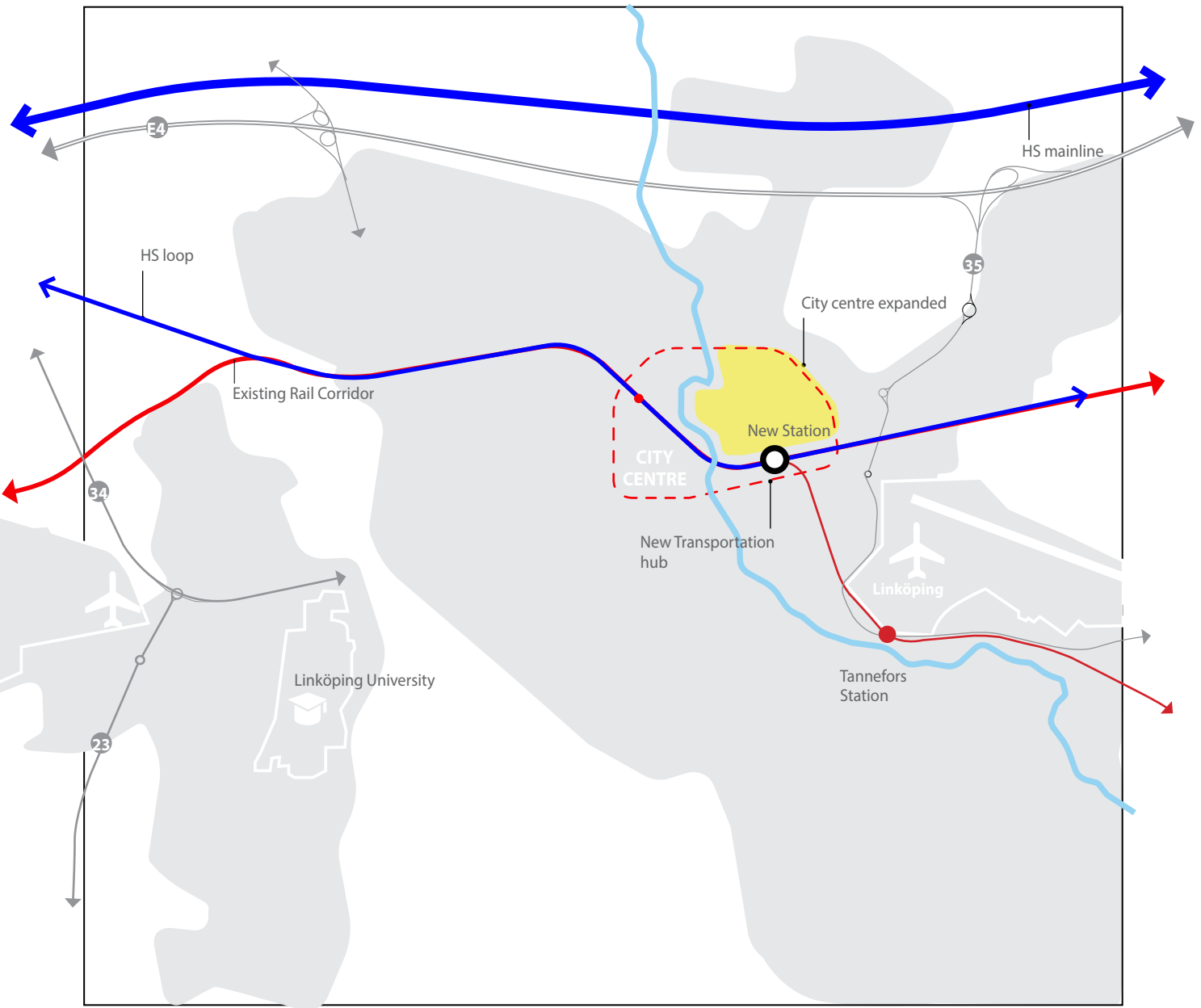
- Existing Rail
- Proposed High Speed Rail
- Proposed High Speed Station
- Existing Station
- Interchange Station
- Tram line
- Tram stop
- == Highway
- Road

KEY REGIONAL MAP



LINKÖPING

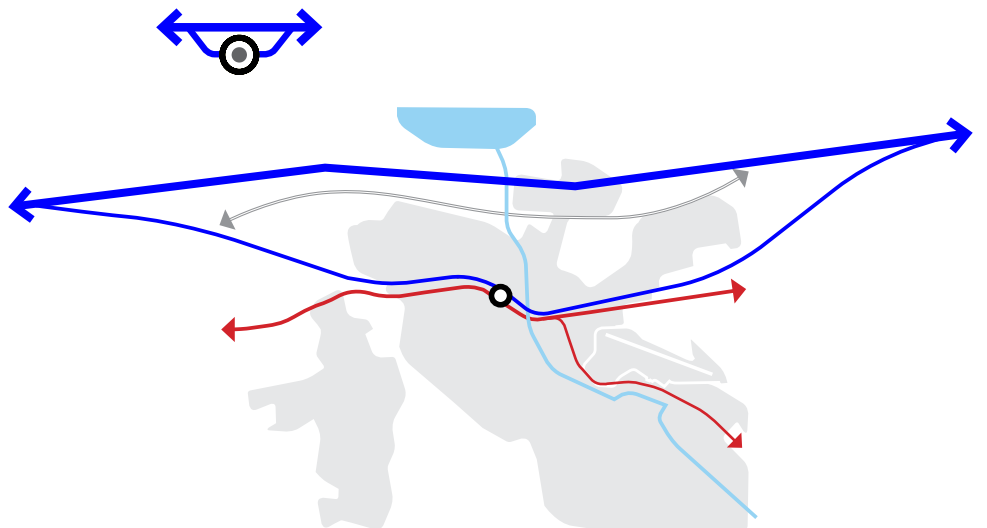
Schematic map showing Station typology recommendation



KEY

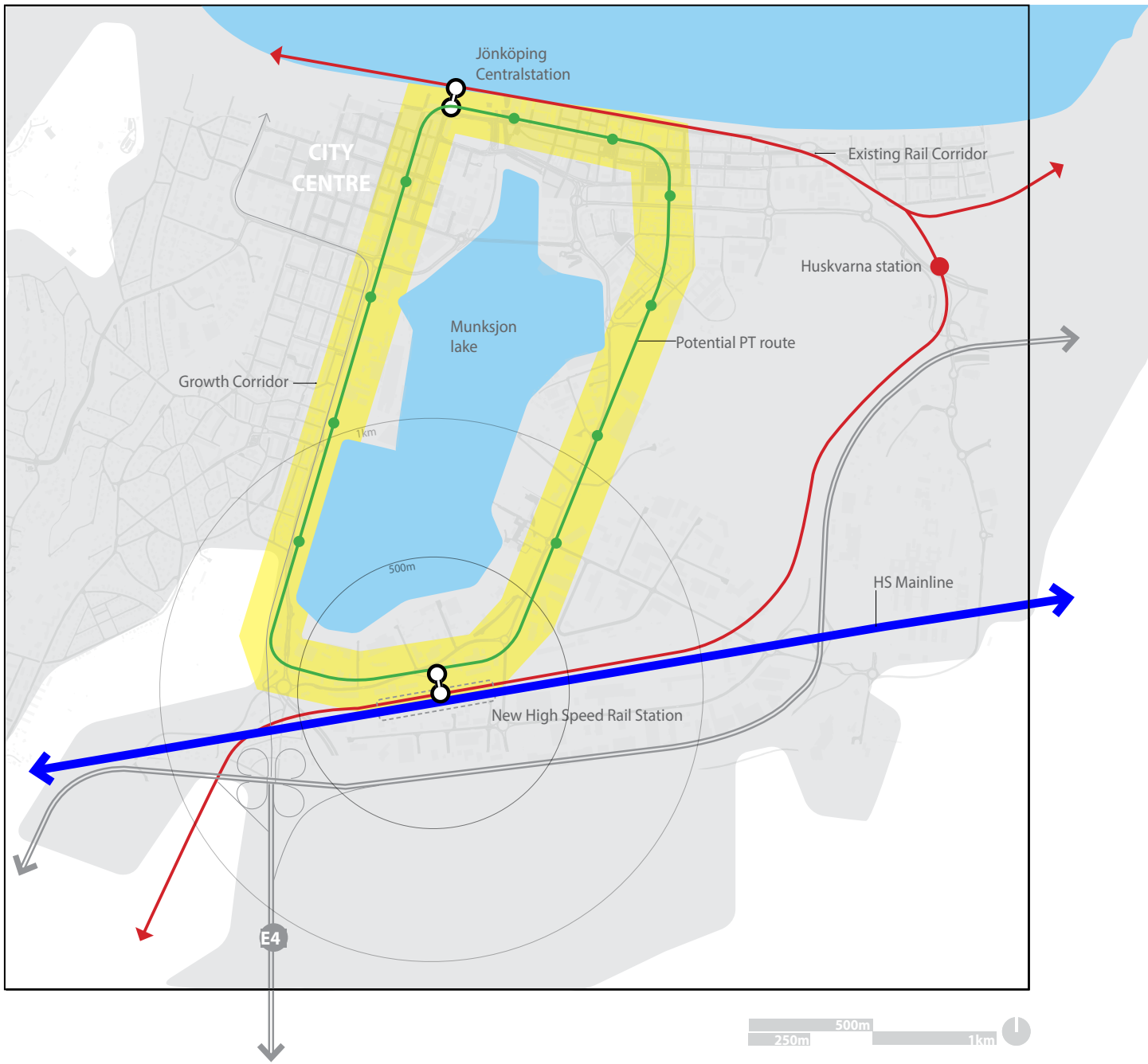
- Existing Rail
- Proposed High Speed Rail
- Proposed High Speed Station
- Existing Station
-
- Tram line
- Tram stop
- Highway
- Road

KEY REGIONAL MAP



JÖNKÖPING

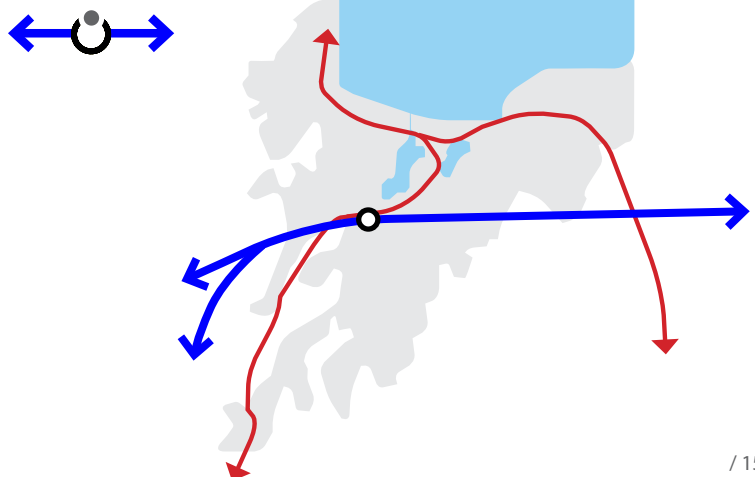
Schematic map showing Station typology recommendation



KEY

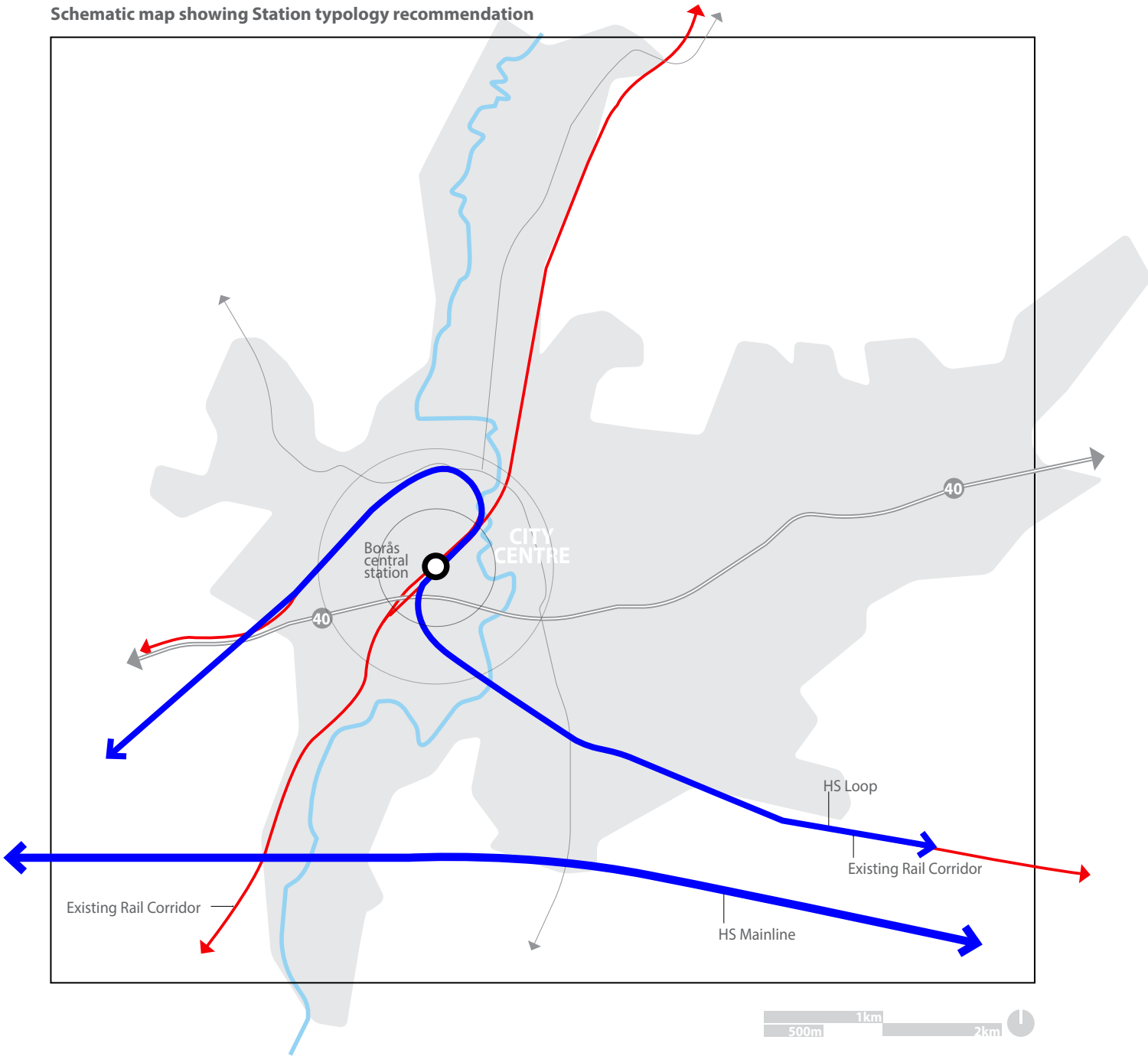
- Existing Rail
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- Tram line
- Tram stop
- == Highway
- Road

KEY REGIONAL MAP



BORÅS

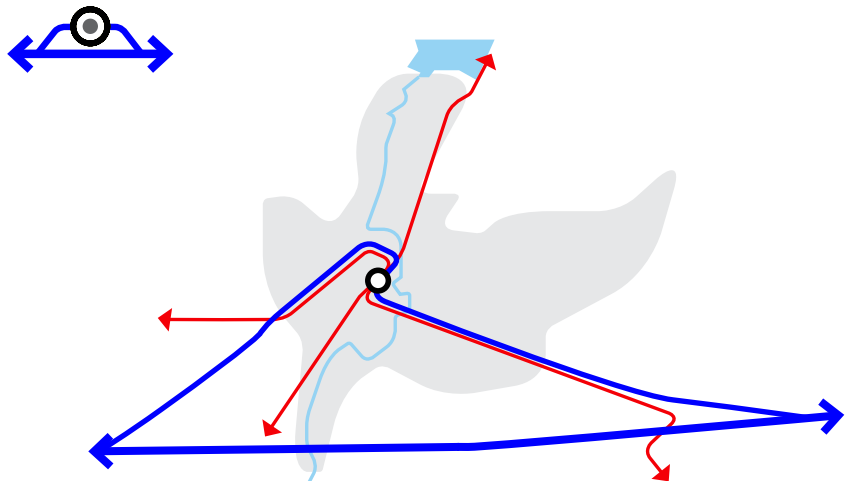
Schematic map showing Station typology recommendation



KEY

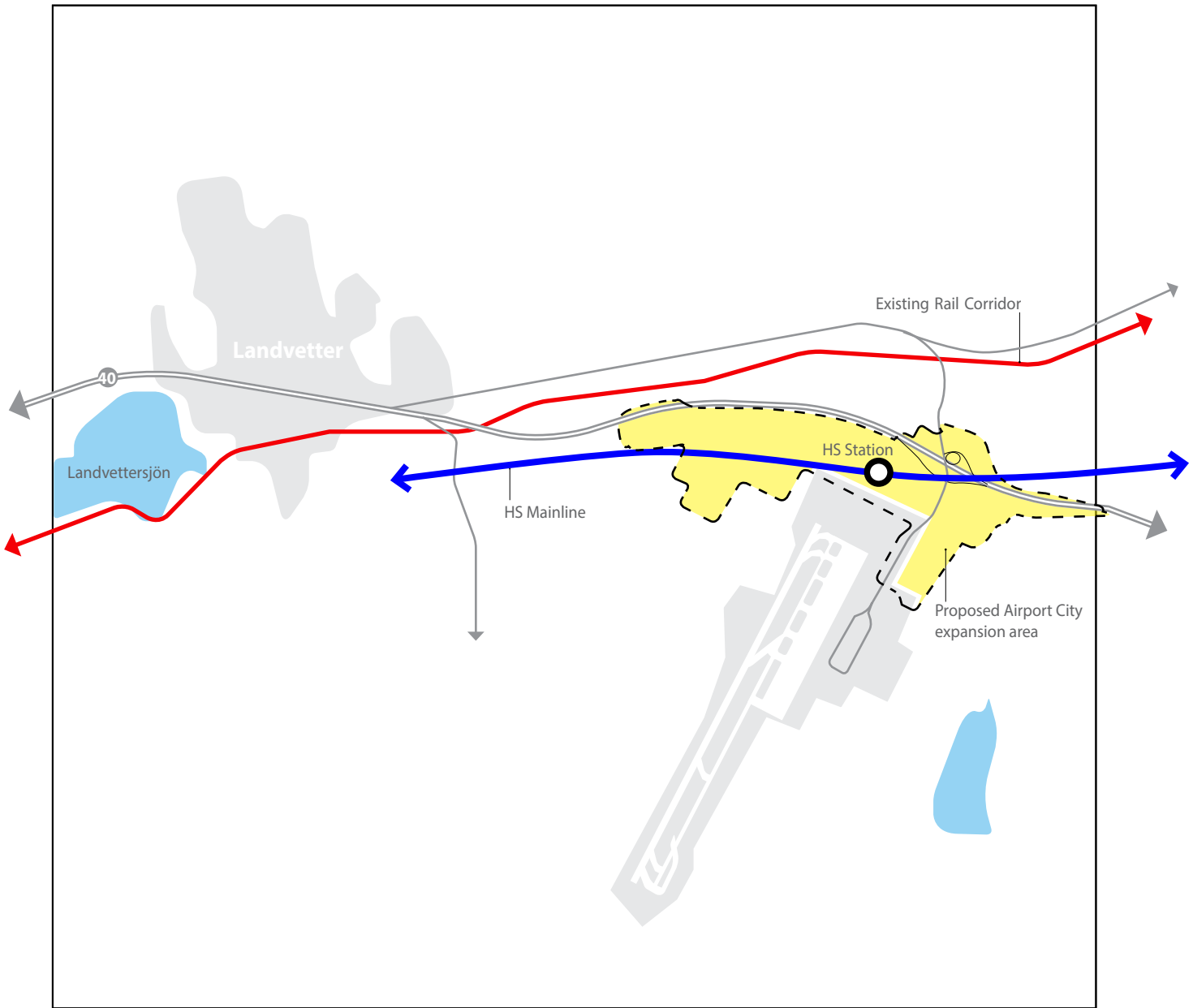
- Existing Rail
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-
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- Road

KEY REGIONAL MAP



LANDVETTER

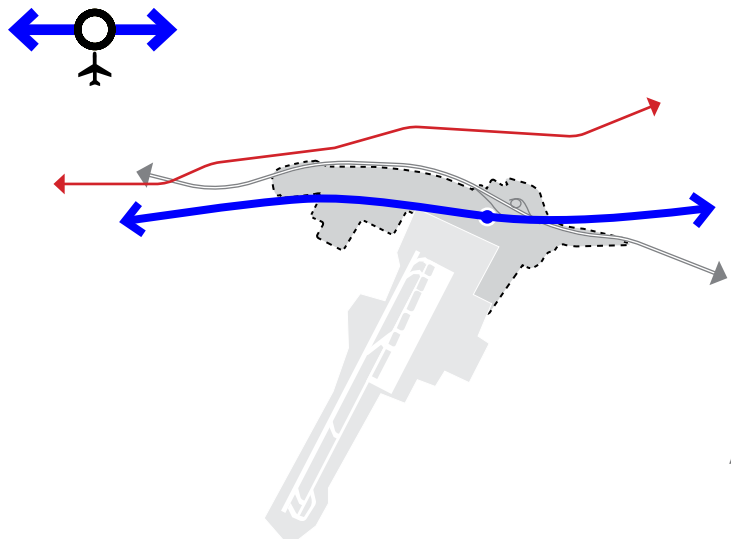
Schematic map showing Station typology recommendation



KEY

- Existing Rail
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- Road

KEY REGIONAL MAP





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