CHALMERS

Station design on high speed railway in Scandinavia

A study of how track and platform technical design aspects are affected by high speed railway concepts planned for the Oslo – Göteborg line

Master of Science Thesis in the Master's Programme Infrastructure and Environmental Engineering

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Cover:
Shin-Kobe high speed railway station with platform fences (Wikipedia, 2013b).

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ABSTRACT

The last couple of years, two investigations of the possibilities for high speed railway have been conducted in Norway. One of the corridors that are investigated is Oslo - Göteborg where two alternative concepts are analysed. An important subject in the planning of a new railway line is the design of the railway stations since they affect for example the capacity, flexibility and the safety of the rail transport system. The main objective of this master thesis is to investigate how stations can be designed to align with the proposed high speed railway concepts on the line Oslo - Göteborg. The focus in the report is to describe track and platform technical aspects of station design and investigate how they are affected by the high speed railway concepts in comparison with conventional railway concepts. The project consists of a literature study and interviews with specialists within the subject. The knowledge gained is then used to suggest possible station layouts for Ed, Sarpsborg and Rygge on the Oslo - Göteborg line. Some aspects of station design that are investigated in the literature study are the arrangement of tracks and platforms, platform safety issues, necessary dimensions of platforms and stations and how challenges related to the Nordic climate with snow and ice can be handled. It is concluded that for some of the aspects there are only small differences between high speed railway stations and conventional railway stations but for others, for example the platform safety, new solutions are necessary. The suggested station layouts vary due to different conditions. Ed will require a station with high platform safety since the speed limit for passing trains are high while Sarpsborg is a more complex station where two tracks meet. Rygge station is planned to be kept as it is but this report suggests how it can be upgraded for a high speed concept. It is important to remember that the plans for a new Oslo - Göteborg line still is in an early idea stage. The suggested layouts are therefore based on several assumptions which would have to be investigated in depth to give a more certain recommendation. There are also aspects of station design that are not covered in the report such as the costs for construction and maintenance for different station alternatives. However, the suggested stations are examples of possible options and show which fundamental challenges that will be encountered in the design process.

Key words: High speed railway, Norway, Sweden, Oslo - Göteborg, station design, track and platform technique.

Utformning av stationer på höghastighetsjärnväg i Skandinavien

En studie av hur spår- och plattformstekniska utformningsaspekter påverkas av höghastighetskoncept framtagna för linjen Oslo - Göteborg

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SAMMANFATTNING

De senaste åren har två utredningar angående möjligheterna till höghastighetsjärnväg genomförts i Norge. En av de korridorer som utreds är Oslo - Göteborg där två alternativa koncept analyseras. En viktig fråga i planeringen av en ny järnvägslinje är utformningen av järnvägsstationer eftersom de påverkar exempelvis kapaciteten, flexibiliteten och säkerheten i järnvägstransportsystemet. Huvudsyftet med detta examensarbete är att undersöka hur stationer kan utformas för att ligga i linje med de föreslagna koncepten för höghastighetsjärnvägen på sträckan Oslo - Göteborg. Fokus i rapporten är att beskriva spår- och plattformstekniska aspekter av stationsutformning och undersöka hur de påverkas av de höghastighetskoncept jämfört med konventionella järnvägskoncept. Projektet består av en litteraturstudie och några intervjuer med specialister inom ämnet. Den erhållna kunskapen används sedan för att föreslå lämpliga stationsutformningar för Ed, Sarpsborg och Rygge på linjen Oslo - Göteborg. Några aspekter inom stationsutformning som undersöks i litteraturstudien är spår- och plattformsararrangemang, plattformssäkerhet, dimensioner på plattformar och stationer och hur problem orsakade av det nordiska klimatet med snö och is kan undvikas. Resultatet visar att för några av aspekterna är skillnaderna små mellan höghastighetsstationer och konventionella järnvägsstationer men för andra aspekter, exempelvis plattformssäkerhet, är nya lösningar nödvändiga. De föreslagna stationsutformningarna varierar beroende på de olika orternas förutsättningar. Ed kommer att kräva en station med hög plattformssäkerhet eftersom hastigheten för passerande tåg är hög medan Sarpsborg är en mer komplex station där två spår möts. Rygge station är planerad att behållas i sin nuvarande utformning, men den här rapporten föreslår hur den kan uppgraderas för ett höghastighetskoncept. Det är viktigt att komma ihåg att planerna för en ny bana mellan Oslo och Göteborg fortfarande är i ett tidigt idéstadium. De föreslagna utformningarna bygger därför på ett antal antaganden som skulle behöva undersökas mer ingående för att kunna ge en mer specifik rekommendation. Det finns också aspekter av stationsutformning som inte omfattas av rapporten såsom kostnaderna för konstruktion och underhåll för olika stationsalternativ. De föreslagna stationerna är ändå exempel på möjliga alternativ och visar vilka grundläggande utmaningar som kan uppkomma i utformningsarbete.

Nyckelord: Höghastighetsjärnväg, Norge, Sverige, Oslo - Göteborg, stationsutformning, spår- och plattformsteknik.

Contents

Preface

This master thesis has been performed during the spring 2013, at the Department of Civil and Environmental Engineering at Chalmers University of Technology in Göteborg, Sweden. Gunnar Lannér has been the supervisor and examiner for the thesis and his advice has been appreciated during the project. The thesis has been carried out in cooperation with Norconsult AB in Göteborg and we would like to thank Maria Young and Jörgen Knutsson for support and providing of office space. We also want to thank all the colleagues on the fourth floor for their friendly reception.

Mads Veiseth and Lars-Petter Nesvåg at Norconsult AS in Norway have been helpful in the development of an interesting subject for the thesis and we appreciate their feedback and advice. Two persons that also have been important for the project are Christer Löfving and Pär Färnlöf at the Swedish Transport administration. They have contributed with their knowledge during interviews and we are very grateful for the time they spent. Finally we would like to thank our opponent Jimmy Johansson for his valuable feedback on our report.

Göteborg, May 2013

Tove Andersson
David Lindvert

List of abbreviations

CCAIC - Concept Choice Assessment for InterCity in Norway

HSR - High Speed Railway

IC - InterCity Railway

NHSRA - Norwegian High Speed Railway Assessment

NTP - National Transport Plan

PSD - Platform Screen Doors

TR - Technical Regulations

TSI - Technical Specifications for Interoperability

Glossary

Island platform - Mittplattform

Norwegian Ministry of Transport and Communications - Samferdselsdepartementet

Norwegian National Rail Administration - Jernbaneverket

Passing loop - Förbigångsspår

Plattform loop - Plattformsspår

Rolling stock - Rullande materiel

Swedish Transport Administration - Trafikverket

Track loop - Krysstation

1 Introduction

There is an on-going population growth in the world, particularly in urban regions. This situation also applies to Norway and Sweden. For instance, the Norwegian population is expected to increase by 45% until 2060 (Atkins, 2011a). A larger population will naturally lead to a higher transport demand. In addition to that, the demand growth is expected to be even higher than the population growth since the travelling per capita is increasing. This development will induce the need for increased capacity in the transport system. Another reason to increase the capacity of the transport system is to enable a geographic expansion of the labour market. That can give companies competitive advantages and make a region more attractive for both inhabitants and businesses.

Increased travelling will cause a higher energy use for the transport sector which will increase the pressure on the environment. It is a common opinion that the possibilities for oil extraction in the world are declining and that it is necessary to reduce our dependency on fossil fuel. This situation is often referred to as peak oil. It is necessary to develop energy efficient transport solutions that can meet future demands. Electrified railway is often considered to be one of the most energy efficient transport modes, but to be able to compete with road and air transport the railway needs higher capacity, better punctuality and shorter travel times. These are all properties that are associated with high speed railway. In addition to the environmental advantages there are several other benefits with rail transport such as high comfort, ability to use travel time in a productive way and arriving in central parts of town without having to look for a parking space or to change means of transport.

The last couple of years, major work have been performed in Norway regarding how to develop the national railway transport system. Between 2010 and 2012, two extensive investigations have been completed, the “Norwegian High Speed Railway Assessment” (NHSRA) and the “Concept Choice Assessment for InterCity in Norway” (CCAIC). The NHSRA was initiated in February 2010 when the Norwegian National Rail Administration was given the task by the Norwegian Ministry of Transport and Communications to investigate the subject of high speed railway in the southern parts of Norway (Samferdselsdepartementet, 2010). The purpose of the investigation is to provide a decision basis for the Norwegian government in the development of future strategies for long distance passenger rail transport. The NHSRA investigates six different corridors which are illustrated in figure 1. One of the corridors connects the capital city Oslo with Göteborg (Jernbaneverket, 2012a). The NHSRA compares different strategies and alternative routes in the corridors in regard to passenger market, societal economy, technical complexity, environmental issues, safety and security.

Figure 1 *The six corridors, and their route alternatives, that are investigated in the NHSRA. The corridors extend from Oslo to Trondheim, Bergen, Stavanger, Stockholm and Göteborg and one connects Bergen and Stavanger (Jernbaneverket, 2012a).*

About a year after the start of the NHSRA project, the Concept Choice Assessment for InterCity was initiated after a new mandate from the Norwegian Ministry of transport and Communications in January 2011 (Jernbaneverket, 2012b). This project investigates different alternatives for development of the existing InterCity rail network in three corridors starting from Oslo and extending to Lillehammer, Skien and Halden, see figure 2. The Oslo - Halden corridor is the same as the Norwegian part of the Oslo - Göteborg corridor. The investigation consists of several parts such as a demand analysis, objectives and requirements, possible concepts, concept analysis and finally a concept choice assessment.

Figure 2 The three corridors investigated in the CCAIC connects Oslo with Lillehammer, Skien and Halden (Jernbaneverket, 2013a).

Both the NHSRA and the CCAIC have corridors heading towards Göteborg and there has been a close cooperation between the two investigations regarding the development of plans for this line. From a Swedish and Göteborg point of view this is probably the most interesting corridor to study and therefore it has the main focus in this report.

Many different technical aspects are discussed and analysed in the investigations. Those are for example route choice, traffic patterns, station locations and design, foundation base, tunnel construction and noise issues. The issue of station design is investigated both in the NHSRA and the CCAIC where different possible station layouts are presented and location of stations in the different cities and villages are proposed. Station design is an important part of the railway planning since stations affect for example the capacity, flexibility and the safety of the rail transport system. Stations are also important since they can affect if rail traffic will be perceived as an attractive mode of transport by the travellers. In addition to that, high speed rail is a rather new concept in Scandinavia and Norway and therefore it is important to investigate how the local conditions can be considered in the design of the stations.

In early parts of the NHSRA, a palette of recommended station layouts suitable for different situations is presented. In the CCAIC the discussion is mostly focused on the location of the stations and which ones that would require reconstruction. In the next step in the planning process it is interesting to study the subject of station design on high speed railway lines more in depth and to take these presented concepts further and investigate how they can be applied to the specific stations on the line between Oslo and Göteborg.

1.1 Aim

The main objective of this master thesis is to investigate how high speed railway stations can be designed to align with the proposed High Speed Railway concept and the planned Norwegian InterCity concept on the line Oslo - Göteborg. The report aims to identify which technical station design parameters that are affected by high speed railway concepts and how they are influenced. Possible layouts are proposed for stations in Rygge, Sarpsborg and Ed based on their unique conditions.

To meet the main objective this thesis aims at answering and analysing the following questions:

- Which aspects are of interest in the design of railway stations?
- Which technical design aspects are affected by high speed railway concepts compared to conventional railway concepts and in which way?
- What are the specific conditions in Norway and Sweden regarding station design?
- What are the main features of the suggested Norwegian High speed railway concept and InterCity concept?
- What are the unique prerequisites for the investigated stations?

1.2 Scope definition

The study is based on traffic concepts and route choices presented in the High Speed Railway Assessment and Concept Choice Assessment for InterCity from the Norwegian National Rail Administration. The investigation is limited to the Oslo - Göteborg corridor of the NHSRA which includes the Oslo - Halden corridor of the CCAIC. The stations for which new layouts are proposed are existing stations in the Oslo - Göteborg corridor. The stations that have been chosen, Rygge, Sarpsborg and Ed are among the stations where through going trains are expected to run with the highest speeds. The study focuses on technical design aspects regarding tracks and station platforms and how these aspects are affected by high speed railway traffic.

1.3 Method

The first part of the investigation is a literature study with the purpose to answer the questions regarding the different aspects that are important for railway station design as well as finding out the main features of the traffic concepts presented in the Norwegian investigations. An important part of the literature that is used in the report are the numerous reports from the NHSRA and the CCAIC. Other literature that has been used is for example reports from other countries where high speed railways exists and one report from a Scandinavian development project which also has studied possibilities for high speed railway traffic in the Oslo - Göteborg corridor. The different national and international regulations that apply for railway infrastructure in Sweden, Norway and the European Union have also been studied and compared.

In addition to the literature, information about railway station design has also been obtained from interviews with two experts at The Swedish Transport Administration. The purpose of the interviews was to get the Swedish authority's view on the different subjects that are discussed in this report since a part of the studied railway line is located in Sweden. The interviews were performed as meetings where the different aspects of station design were discussed. During the project, there has also been a discussion with railway planning specialists at Norconsult AS Norway. Norconsult has participated in the NHSRA and the CCAIC and has helped in developing this project.

In the last part of the report, the information gained during the literature study and the interviews is used to suggest possible future layouts for the railway stations in Ed, Sarpsborg and Rygge. The choice of these three stations is based on the speed limit through the station and their differences in size, location and whether they are considered to need major reconstruction or just a smaller upgrade. The station designs are then suggested based on the unique prerequisites of each location.

2 High speed concepts and InterCity concepts

This chapter explains the concepts of high speed railway and InterCity railway. It also describes the history of high speed rail in the world and the present situation in Norway and Sweden.

2.1 What is high speed railway?

When looking at the concept of High Speed Railways (HSR) it is impossible to find one single definition. What could be considered as HSR varies significantly between different countries and different traffic concepts. What is common though for all so called HSR services is that they operate with considerably higher speeds than conventional trains.

There is a definition given by the European Union in directive 96/48/EC - Interoperability of the trans-European high speed rail system. In order to strive towards good operability within the trans-European high speed rail network and to create technical specification three different categories of HSR-lines are defined.

- **Category I:** specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h.

- **Category II:** specially upgraded high-speed lines equipped for speeds of the order of 200 km/h.

- **Category III:** specially upgraded high-speed lines which have special features as a result of topographical, relief or town-planning constraints, on which the speed must be adapted to each case (2008/217/EC).

In a more general context it is possibly only category I with speeds above 250 km/h that could be considered pure high speed railway. However, the main goal with HSR services is of course to achieve short and competitive travel times between important destinations. To reach this, the maximum speed is however not the only thing that is important. What is more important is to strive for a high average speed. A high average speed is dependent on several different factors and all of them have to be adapted to optimize the HSR service.

One of the most important factors is to have an infrastructure that allows high speed. To permit high speeds the tracks have to be designed with much larger horizontal and vertical curve radii than conventional tracks. This makes it more difficult to fit the tracks in the topography and therefore high speed tracks often requires more construction works such as tunnels and bridges. Also infrastructure related to power supply and signalling has to be adapted for higher speeds. Of course also the rolling stock, i.e. trains and locomotives, have to be more powerful and aerodynamic to manage higher speeds (Fröidh et al, 2011).

There are also traffic related aspects that have a great influence on the average speed. One such aspect is the stopping pattern. HSR services mostly run with larger cities as endpoint markets with few stops in between. Due to time loss related to braking, passenger exchange and acceleration at intermediate stops it is hard to keep a high average speed with many stops. What is also important is if high speed traffic is run separated from conventional traffic on dedicated high speed tracks or if it is integrated with other traffic on mixed tracks. The big advantage with dedicated lines and traffic with uniform speed is that there will be much better capacity and slower trains will not have to stop on passing loops to be overtaken by faster trains. Fast trains will also avoid the risk of being slowed down behind a slower train between two passing loops (Fröidh et al, 2011). A negative aspect with dedicated tracks is that a parallel conventional track for non-high speed trains is necessary and that might be associated with higher costs and increased areal use.

Today there is a rising interest for high speed railways in the world and there are several countries with HSR in both Europe and Asia. High speed lines are mostly to be found in densely populated regions connection important cities. The world's first real high speed service was the Japanese Tōkaidō Shinkansen. The line between Tokyo and Osaka opened in 1964 with a maximum speed of 210 km/h. Seventeen years later in 1981 the first European HSR service, the TGV opened in France. It was the world's first train service with a top speed above 250 km/h. Today France has an extensive HSR network that in 2012 consisted of about 2036 km of high speed tracks for speeds up to 320 km/h. That is currently the fastest train service on rails in the world. In Europe HSR networks can also be found in Germany, Spain and Italy. Single high speed lines can also be found in some other European countries.

In Japan there has also been a strong development in the HSR sector since the first service started in the sixties. In 2012 the Japanese HSR network was about 2664 km. However the most ambitious HSR development last years has taken place in China. Since 2008 about 6000 km of high speed lines has been built and several new HSR-projects are in construction or planning stage. According to the International Union of Railways (UIC) there were totally 17 547 km of high speed railways in the world in 2012 and it is expected to be doubled until 2025. Among countries that are constructing or planning new high speed lines are USA, India, Russia, Saudi Arabia, Morocco and Portugal (UIC, 2012).

2.1.1 The situation for HSR in Norway and Sweden today

In Norway, apart from many other countries, also railway lines constructed for speeds of only 200-250 km/h are considered to be high speed railways. At the moment there is however only one line with operation in such speeds and that is the Gardermoen line between Oslo and the airport Gardermoen. The Airport Express Train (Flytoget) runs there since 1999 with a maximum speed of 210 km/h (Flytoget, 2013). There are also some parts of the Vestfold line that has been or are about to be upgraded with double track equipped for 200 or 250 km/h. In direction south east from Oslo, in the Oslo - Göteborg corridor, the construction of the new double track Follo line is planned to start in 2013-2014 and it will be equipped for 250 km/h. The Follo line as well as the upgraded parts of the Vestfold line will be used in potential future HSR and IC networks (Jernbaneverket, 2013b). More information about future HSR and IC plans in Norway can be found in chapter 3.

In Sweden there is today no traffic that is referred to as high speed traffic. However within the traffic concept “Fast trains” the Swedish State Railways (SJ AB) has been running trains in speeds up to 200 km/h on conventional tracks since 1990. This has been possible due to use of tilting train cars which allows higher curve speeds than conventional trains. The two recently opened lines the Bothnia line and the Norway/Vänern line are constructed for 250 km/h but there are not yet any rolling stock allowed to run faster than 200 km/h.

There is an on-going discussion in Sweden regarding construction of new dedicated HSR-lines and on behalf of the Swedish government an extensive inquiry on possibilities for high speed railways in Sweden was presented in 2009. In this inquiry new dedicated high speed links between Stockholm-Göteborg and Stockholm-Malmö were assessed. In this assessment HSR was defined as train services that operate in speed higher than 250 km/h (Malm, 2009). As a first step in creating a Swedish HSR network the government decided in 2012 to realize the so called Eastern link. The Eastern link will enable high speed traffic between Stockholm-Linköping through a new high speed double track from Järna to Linköping (Trafikverket, 2013). However, yet there have been no assessments on high speed railways between Sweden and Norway from the Swedish authorities.

2.2 What is an InterCity concept?

InterCity or IC is a popular name for railway services between larger cities within many European countries. The term InterCity is often connected to a specific traffic concept or traffic product and has normally nothing to do with the speed of the trains. There could be services operating at both high and low speed that is referred to as InterCity. Typical features of an IC service are that it runs with uniform modern high comfort rolling stock and are operated on lines of good quality. The trains stop only in bigger cities and can thereby offer shorter travel times than ordinary regional trains. They often run according to a regular timetable and are well coordinated with other railway links (Fröidh et al. 2011). However the standard of IC services varies significantly between different countries.

In Norway the term InterCity is mostly used within the so called InterCity area around Oslo. The IC area consists of the area served by the lines Oslo - Halden, Oslo - Skien and Oslo - Lillehammer. The area is quite densely populated and the train traffic within the IC area do account for around 80 % of the total Norwegian State Railway (NSB) traffic according to Veiseth[1].

[1] Mats Veiseth (PhD Norconsult AS, Railway section) meeting with authors 2012-12-18.

3 Future plans for Norwegian rail traffic

As mentioned in the introduction, two investigations regarding the future rail network in Norway have been carried out the last years, the Norwegian High Speed Railway Assessment and the Concept Choice Assessment for InterCity. In this chapter, these two investigations will be reviewed, but first the railway line between Oslo and Göteborg as it is today will be described. In addition to the two investigations initiated by the Norwegian government, the project “The Scandinavian 8 million city” has also performed some work within the same subject. “8 million city” refers to the number of inhabitants in the corridor Oslo - Göteborg - Copenhagen and the project is financed by the regions and municipalities in the corridor together with the EU (The Scandinavian 8 Million City, 2013). In one of the reports from that project, the possibilities for high speed railway between Oslo and Copenhagen via Göteborg are investigated (Ramböll, 2012). The concept presented by this project is not used as a basis for the work in this report but it has been used as a reference to widen the perspectives of station design.

3.1 The existing railway line Oslo – Göteborg

The Oslo - Göteborg railway line is in total around 350 kilometres (Norconsult, 2011). Figure 3 illustrates the line and its major stations. The part from Oslo to Ski is already planned for to be rebuilt to a higher standard and from Göteborg to Öxnered the construction of a new double track was finished in 2012. Therefore it is only the section from Ski to Öxnered that is included in the Norwegian investigations as well as in this report.

Figure 3: The existing railway line Oslo - Göteborg and its major stations (Modified from Google Maps, 2013).

The line between Ski and Öxnered is at present around 250 km (Norconsult, 2011). It has a low geometric standard with tight curves that limit the maximum allowed speed. Most of the line consists of a single track. Two parts of the line on the Norwegian side has a double track, Ski - Moss and Rygge - Råde. On the Swedish side the whole line from Öxnered to the border has a single track. The speed limits on the line vary between 35 and 200 km/h and the travel time Oslo - Göteborg is around 3 hours and 50 minutes (NSB, 2013).

3.2 The Norwegian High Speed Railway Assessment – NHSRA

The overall aim of the Norwegian High Speed Railway Assessment is to provide a recommendation of which strategies that should be used in the development of future long distance passenger transport in Norway (Samferdselsdepartementet, 2010). The investigation should analyse if high speed railway is a feasible and appropriate option that could be socioeconomically efficient and sustainable in a future growing transport system. A development of high speed railways should be compared to other options such as the reference alternative which is to continue with the present transport politics as in the National Transport Plan for 2010-2019.

The high speed railway assessment was divided into three phases defined in the mandate from the Norwegian government (Samferdselsdepartementet, 2010). In phase one, the present state of knowledge in the field of high speed railway in Norway is reviewed. The purpose of phase two was to develop a common basis of principles for how different concepts should be assessed and identified which concepts that may be relevant for Norwegian conditions. The studies in phase two resulted in about 30 reports on different subjects (Jernbaneverket, 2011). In phase three, the high speed railway assessment focuses more on specific investigations for the six corridors with route choices, station locations and technical construction. Based on the results from phase one and two, the investigations in phase three should result in a recommendation of which development strategies that should be implemented in each corridor (Samferdselsdepartementet, 2010). As mentioned earlier in this report, six different corridors have been analysed in NHSRA. One of those is the Oslo - Göteborg corridor which is in focus in this report.

To start with, many different route choices and design options were considered (Railconsult AS, 2012). For the Oslo - Göteborg corridor, two alternatives were chosen for a full analysis and those are called alternative 2* and alternative D1. The alternatives are shown in figure 4. Alternative 2* has a design speed of maximum 250 km/h for the whole line. Between Ski and Halden, a future InterCity line which is planned for in the CCAIC, will be used. That line follows the existing route quite closely. The parts where double track has been built already will be kept as they are and the rest of the track will be upgraded to double track and the line will be straightened at some locations (Norconsult, 2011). From Halden to Öxnered a completely new double track will be constructed. Since alternative 2* consists of both track specially built for high speed and upgraded existing track it is a combination of the categories 1 and 2 which were described in chapter 2.1. The travel time Oslo - Göteborg would be 2 hours and 18 minutes for alternative 2* (Jernbaneverket, 2012a).

In the other alternative, D1, the design speed will be 330 km/h on the Norwegian side and 250 km/h on the Swedish side (Norconsult, 2011). Between Ski and Sarpsborg a direct high speed double track line with a new route and no intermediate stops will be constructed. The existing track between Ski and Sarpsborg will be kept and used by local and regional trains. From some kilometres south of Halden and all the way to Öxnered, alternative 2* and D1 are identical. Alternative D1 is based on a new track on the whole line and is therefore of category 1. The higher design speed and fewer stops for alternative D1 gives a travel time of 1 hour and 40 minutes (Jernbaneverket, 2012a). In both alternatives it is planned for freight trains and passenger trains to use the same track. That means it will be a scenario with mixed traffic with both slow and fast trains.

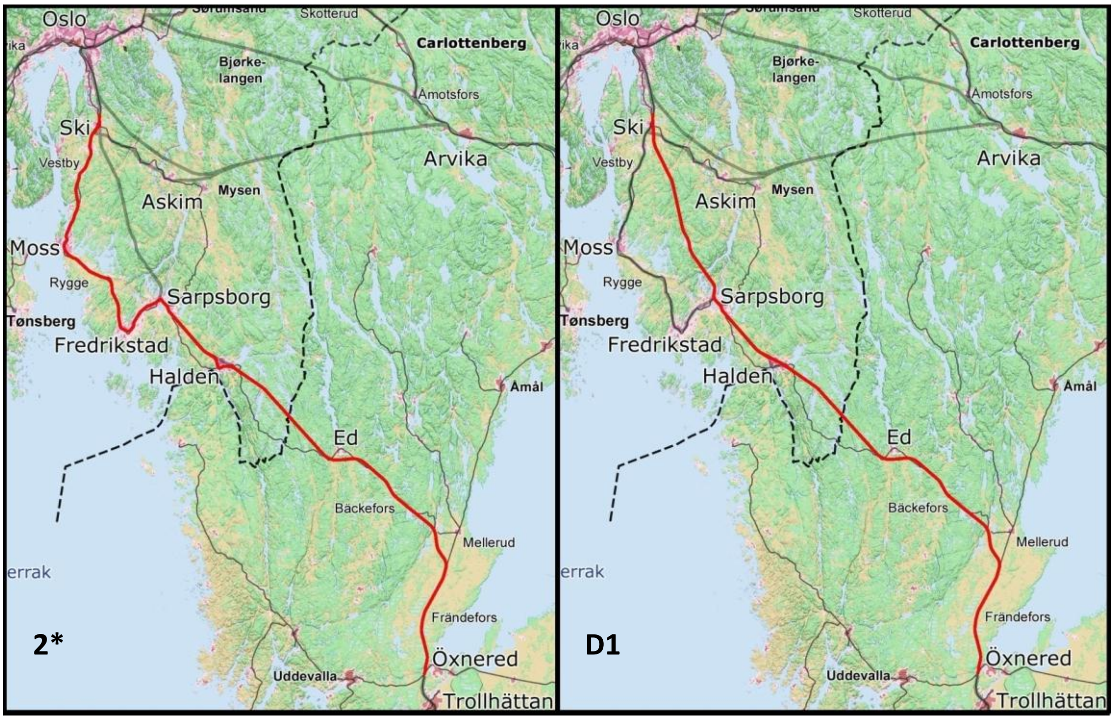

Figure 4 *Alternative 2* (left) and D1 (right) of the NHSRA are shown in red. Thin grey lines illustrate existing tracks, thick grey lines illustrate other investigated routes (Norconsult, 2011).*

3.3 Conceptual Choice Assessment for InterCity – CCAIC

The Conceptual Choice Assessment for InterCity was carried out simultaneously with the high speed railway assessment. The purpose of the project is to investigate how the rail network in the so called InterCity area around Oslo should be developed in the nearest future. The project consists of three parallel investigations regarding the lines Oslo - Lillehammer, Oslo - Skien and Oslo - Halden. Oslo - Halden is a part of the line Oslo - Göteborg and is therefore of interest in this report (Jernbaneverket, 2012b). During the investigation a number of reports was prepared, among those is one concerning station and transport node development where information about the different towns along the line are presented and location of the stations are discussed (Norconsult, 2012).

The investigation have studied several alternative concepts for the line Oslo - Halden with some differences in route choice, single or double track configuration, design speed and train service (Jernbaneverket, 2012c). Since the High Speed Railway Assessment and the Conceptual Choice Assessment to a major part deals with the same railway corridor there has been a close cooperation between the two investigations. The concept alternative that was eventually recommended by the CCAIC is called ØB 4B and can be seen in figure 5. This concept is actually identical to the Oslo - Halden part of alternative 2* in NHSRA which has been described above (Jernbaneverket, 2012b). All the way to Sarpsborg, the proposed concept follows the existing line except that some curves will be straightened out and that there will be an upgrade to double track for a large section. From Sarpsborg to Halden the line follows a new route adapted for high speed. The ØB 4B concept has a design speed of 250 km/h for most of the line.

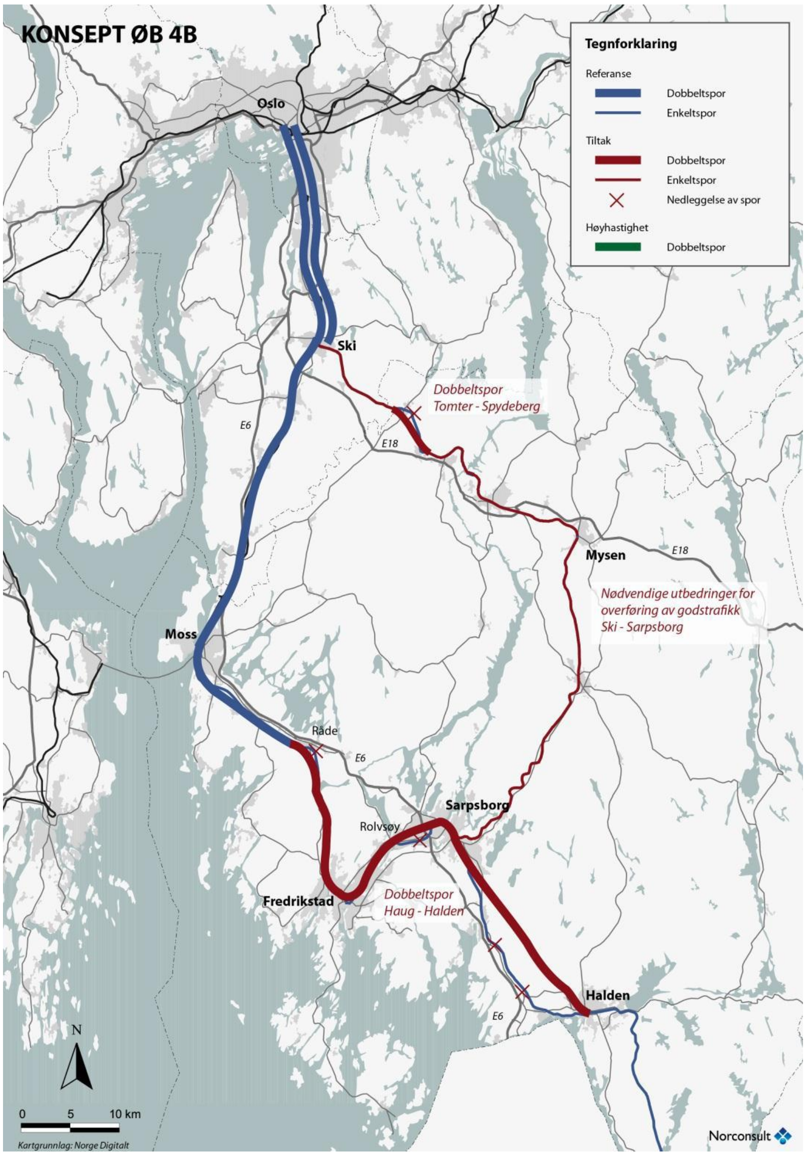

Figure 5 *The recommended concept, ØB 4B, from the CCAIC. This alternative is identical to the Oslo - Halden part of alternative 2* in figure 4 (Jernbaneverket, 2012c).*

3.4 Current status of the future plans for the Norwegian railway

Since the results of the NHSRA and the CCAIC were presented in 2012 there has been a discussion in Norway on how the development of the future railway system should continue. In April 2013 the Norwegian Ministry of Transport and Communications presented the new National Transport Plan (NTP) 2014 - 2024 which is the government's view on how the transport system should be developed in the nearest future. In this document stated that no pure high speed railway lines should be built within the plan period. This is because the market basis for such lines is considered to be too small. However, the government has decided to make extensive investments in the development of the InterCity network around Oslo. In the NTP it is said that the development of the IC-network should follow the results from the CCAIC and the line should be designed for 250 km/h if possible so that they can be parts of eventual future high speed lines.

For the Østfold line it has been declared that there should be a complete double track from Oslo to Fredrikstad before the end of 2026 and before the end of 2028 the double track should be completed all the way to Sarpsborg. For the section between Sarpsborg and Halden it is said that the single track should kept but developed to increase the capacity until 2026 (Samferdselsdepartementet, 2013).

4 Station design

This chapter presents the outcome of the literature study and the interviews regarding station design. The first parts of the chapter include a review of different aspects that are relevant for station design and which regulations that apply in the design process. Following that, some of the identified aspects are described more in depth and it is explained how these parts of railway stations can be designed to be suitable for high speed railway traffic.

4.1 Aspects that are relevant for station design

In the design of railway stations there are a large number of aspects that should be considered. The aspects are connected to different levels of detail and are therefore interesting in different stages of the planning process. This chapter reviews the aspects of station design that has been found in the studied literature and the interviews and explains in which way they can be affected by a high speed concept compared to conventional railway traffic. There are more aspects than what can be covered in the further analysis in this report but all aspects are mentioned below to provide a more complete picture of the subject. Table 1 contains a summary of the aspects and divides them into categories to increase clarity. There are probably several ways to do this categorization and aspects in different categories are also connected to each other. The main focus in this report is on the first four aspects in the category “track and platform technical aspects”. For these aspects some examples of necessary input data are also given in the table since it is needed for the analysis later in the report

Table 1 Aspects that are relevant for station design.

Design parameter	Description	Examples of necessary input data
Market and economic aspects		
Station location	Number of stations on the railway line, in which cities, location in the cities.	
Capacity of the station	Required capacity of station facilities.	
Costs and revenues	Investment costs, maintenance costs, revenues from travelling.	
Track and platform technical aspects		
Track and platform arrangement	Number of parallel tracks and platforms. Placement of platforms in relation to tracks. Track curvature and gradient. Additional tracks such as stabling/reversing tracks and track loops.	Traffic operation aspects such as timetable, traffic mix, number of trains that should be able to stop at and pass the station simultaneously. Spatial limitations on specific locations. Requirements for additional tracks.
Platform and station dimensions	Length, width and height of platforms. Necessary distances between tracks and between tracks and objects.	Train length and width, expected number of people using the platforms, train speed.
Passenger safety on platforms	Safety measures to separate passengers from trains passing at high speed.	Speed of passing trains, required platform capacity, number of passengers on the platforms, available area.
Climate adaptation measures	Adaption to for example cold weather and snow.	Local climate and weather conditions.
Electrical, signalling and communication systems	Signalling system, power supply, communication system.	
Passenger service and comfort factors		
Station facilities	Building condition, waiting areas, weather protection, air quality, benches, shopping and eating facilities, toilets etc.	
Modal transfer	Possibilities for interchange to bus, car, bike, walking, taxi, other trains.	
Passenger security	Lighting, surveillance.	
Accessibility	Accessibility for disabled persons.	
Ticket selling and travel information	Ticket offices, ticket purchase machines, live information, signs, audible information, local maps, clocks etc.	
Environmental aspects		
Material choices	Material choices for station buildings and other constructions.	
Noise	Noise issues due to passing trains and noise reducing measures.	

The first category in table 1 includes aspects connected to market and economy. In early stages in the planning of a new railway line it has to be decided where stations should be located. That includes how many stations the line should have and in which cities, but also where in the cities the stations should be located. Those decisions are governed by factors such as population, labour market, city planning and travel time requirements (Atkins, 2011b). A difference between high speed rail traffic and conventional rail traffic is that high speed lines have fewer stations due to travel time requirements and curve radii restrictions. Station location is discussed thoroughly in the NHSRA and CCAIC and suggestions for locations for stations are presented in the different alternatives. This report uses the suggested station locations when the station designs are proposed and analysed. Costs and expected revenues is of course a very important factor that probably affects most of the other aspects, from the decision of how many stations to build and the number of parallel tracks to the choice of service level in station facilities. However, the focus of this report is rather on the discussion of different technical solutions than on profitability calculations.

The next category in table 1 is the track and platform technical aspects. That is an essential part of station design and it is also where the major focus in this report is. There are several important aspects connected to this which are mentioned in the table. The first four of them are the ones analysed in this report and they are described thoroughly in the following chapters. The last one, “Electrical, signalling and communication systems”, is beyond the scope of this report since these subjects are related to the railway system as a whole rather than to stations specifically. However they are important to consider when constructing or rebuilding such a system. An example of a difference between conventional railways and high speed railways is that the capacity of the signalling system has to be improved to manage higher speeds.

There are also other aspects that are not directly connected to the railway technology but are important for the travellers that are using the railway stations. Examples of such aspects are listed in table 1 under the headline passenger service and comfort factors (Atkins, 2011b). Some of these aspects are also affected by the high speed railway concept. One example is that the expectations on service on railway stations might be higher, especially if the high speed railway traffic is going to be able to compete with air transport. The possibilities for modal transfer is also important since high speed trains only stop at few large stations and travellers need to transfer to for example local trains or bus. This report focuses on the track and platform technical aspects but the aspects mentioned in this section would also have to be considered in a future planning of the railway stations.

Finally there are some important environmental aspects to station design that are described in the literature. Those are for example noise around stations and material choices for station buildings (Savastano, 2011). Noise issues can be more severe for high speed rail traffic since higher speed leads to more noise. To decrease the impact of noise around stations, noise reducing measures or reduced speed through cities might be necessary. However, these mentioned environmental aspects are not within the scope of this report.

4.2 Governing documents for railway station design

When dealing with design of railway infrastructure there are always certain rules and regulations to follow. In Norway the design of railway technical systems are governed by the Technical Regulations (TR) from the Norwegian National Rail Administration, Teknisk regelverk JD 5XX. The technical regulations cover requirements for design, construction and maintenance for all types of facilities within the railway infrastructure. Each subsystem is covered in separate chapters and as an example, requirements for platform and station design can be found in section JD 530 chapter 14 Plattformer og spor på stasjoner (Jernbaneverket, 2013c).

Besides the national regulations, there are the Technical Specifications for Interoperability (TSI) drafted by the European Railway Agency (ERA), which is one of the agencies of the European Union. Although Norway is not a member state of the European Union, they have agreed on adopting these regulations. The TSI´s are developed to enable interoperability in the Trans-European Rail network. This is an aspect which is particularly important on a line rail line like Oslo - Göteborg which actually crosses a national border. There are TSI´s for both high speed rail and conventional rail. The TSI for high speed rail was first released in 1996 as the EU directive 96/48/EC. In 2001 a TSI for conventional railways was also released as EU directive 2001/16/EC.

In the report Technical and Safety Analysis from phase 2 of the NHSRA a comparison between the Norwegian TR and the TSI was made. It shows that the main difference between the two systems is that the TR only covers requirements for speeds up to 250 km/h, while the TSI for high speed lines is valid for speeds up to 350 km/h. Among stated parameters for speeds up to 250 km/h there are only minor differences between the TR and the TSI, however in some cases the TR could have stricter requirements than the TSI without affecting the interoperability. The recommendation from the Technical and Safety Analysis report is to adapt the TSI for high speed for future Norwegian railways equipped for speeds over 250 km/h (Sweco et al. 2011).

Since a large part of the Oslo - Göteborg line is located in Sweden, Swedish design rules also has to be considered. Like in Norway there are national technical standards given by the Swedish Transport Administration. However, the railway design also has to meet requirements from the European TSI`s for high speed or conventional railway traffic which, in case of differences is superior to the national standards. There is no comparison between Swedish national requirements and TSI in the NHSRA.

4.3 Track and platform arrangement

Tracks and platforms are very basic parts of a railway station. For each station it has to be decided how many tracks and how many platforms there should be and also how the tracks and platforms should be arranged. It is hard to find any general guidelines for this part of the station design. Every railway line has its own unique conditions in terms of for example traffic mix and number of passengers.

4.3.1 Number of tracks and platforms

To decide the number of tracks required for a railway station it is necessary to know the planned traffic intensity and traffic pattern since that decides the required capacity of the station (Leander, 2011). The smallest stations on a double track railway might have only two tracks where the trains stop directly on the railway line. Larger stations can have one or more extra tracks that trains can switch to when they are going to stop. The main track can then be used by passing or other stopping trains simultaneously. Färnlöf [2] explains that the track design is also affected by the choice of concept for the railway system as a whole. An important difference is if a high speed train system is separated from or integrated with the conventional railway system. An integrated system has a more heterogeneous traffic with both high speed trains and slower trains such as regional and local trains and perhaps freight trains. Furthermore, regional and local trains stop more often which increases the differences in average speed. The differences in speed between train types make overtaking necessary which requires an extra track on some sections of the line. It can be beneficial to place this extra track on a station since it then also can be used by stopping trains and turning trains.

There are also other factors than traffic capacity that decides the number of tracks for a high speed railway station. Even if a simple double track station would give a sufficient capacity, a larger station can be beneficial for safety reasons, which is pointed out by Färnlöf. This issue occurs especially on high speed railways since a high speed train passing a platform might be dangerous for waiting passengers. A more safe solution is to build separate tracks for passing trains. This kind of safety measures are discussed more in depth in chapter 4.4.1.

The number of platforms required depends on how many trains that should be able to stop for passenger exchange simultaneously (Leander, 2011). This number might, just as the number of tracks, be larger on railway lines with heterogeneous traffic. It might happen that both high speed trains and for example regional trains stop simultaneously to allow train interchange for the passengers.

4.3.2 Placement of tracks and platforms

Another important question is the placement of tracks and platforms. There are two main concepts, island platforms with tracks on both sides and side platforms with only one side facing the track. These two concepts can be modified into many different alternative configurations. Some examples of this are shown in figure 6. There are benefits and drawbacks with both concepts and which design that is most suitable depends on the specific location and traffic concept. Island platforms have the advantage of providing possibilities for train interchanges over the platform (Savastano, 2011). This can be important since high speed trains often do not stop on all stations and therefore, many passengers have to change to a regional or local train. According to Löfving[3], island platforms are also beneficial for the flexibility on the stations. If for example a stopping train has to switch to a different track than the

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[2] Pär Färnlöf (Trafikverket) interviewed by the authors 2013-04-16.

[3] Christer Löfving (Trafikverket) interviewed by the authors 2013-04-08.

announced one, the passengers could be able to stay on the same platform. Side platforms on the other hand can be beneficial for platform safety. On for example a four track station, the platforms can be placed outside of all tracks and the two tracks in the middle can be used by passing trains with safe distance to the passengers on the platform as described above. According to a questionnaire sent to the railway authorities in some countries with high speed railway, both island platforms and side platforms are common on high speed lines (Savastano, 2011).

4.3.3 Layouts recommended in the Norwegian investigations

The track and platform arrangement on a possible high speed line between Oslo and Göteborg has been discussed to a varying extent in different investigations. The Norwegian InterCity investigation mostly discusses the location of the stations and whether the present stations need to be moved or rebuilt. There is no detailed discussion about the design of the specific stations but a general recommendation is that the stations should be designed with four tracks. The reason for that is that stopping and passing trains might occur simultaneously and that it is desired to provide flexible stations with possibilities for overtaking and turning of trains (Jernbaneverket, 2012b, Jernbaneverket, 2012d).

In phase two of the High Speed Railway Assessment a number of possible traffic scenarios for high speed railway stations are presented (Leander, 2011). Then a set of station layouts that could be implemented for the different traffic scenarios are presented and their suitability are commented. There are nine traffic scenarios presented in the report where high speed trains and regional trains are operating with different frequency and speed. In the scenarios it is assumed that the distance between the stations is such that the travel time between them will be multiples of 30 minutes. This means that the trains will always cross each other at the stations. This is a simplification and will probably not be the case in the real situation which the report also points out. There are 27 station layouts listed in the report with varying number of tracks and configuration of tracks and platforms. The layouts are categorized after how many trains that can stop at and/or pass the station at the same time. Depending on this they are more or less suitable for the different traffic scenarios presented earlier which is commented in the station layout listing. The layouts that are recommended in phase two will be considered later in this report in the analysis of specific station locations.

In phase three of the high speed railway assessment the subject of track and platform layouts is not discussed to any great extent. Three different station layouts are presented and are recommended to be used for stations of different sizes. These three layouts are shown in figure 6. However, it is not explained what this choice of station layouts is based on, or specified which type of station that should be used in which specific city.

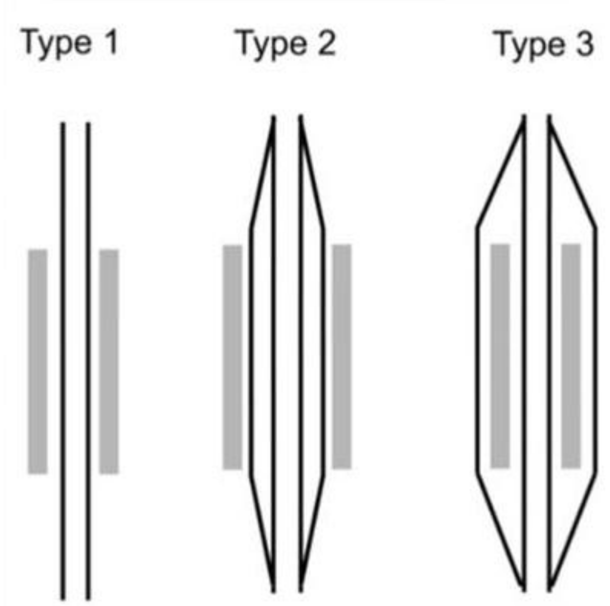

Figure 6 *Three types of station layouts that are recommended in the NHSRA. Types 1 and 2 have side platforms while Type 3 has island platforms (Norconsult, 2011).*

In one of the reports from “The Scandinavian 8 million city” project, the possibilities for a high speed railway between Oslo and Copenhagen via Göteborg are investigated (Ramböll, 2012). Regarding stations it is suggested that the stations should have separate tracks in the middle for trains that are passing and that there should be two or four side-tracks with platforms. It is worth mentioning that this report has studied higher speeds than the Norwegian investigations, up to 360 km/h

4.4 Platform safety - Risks and possible measures

One of the most important aspects in the design of high speed railway stations is safety for people waiting on platforms. Especially in cases when non-stopping trains pass through a station at very high speeds. This might occur on pure high speed lines where trains operate with different stopping patterns or on mixed traffic high speed lines where high speed trains only stop at a few stations. The latter option will likely be the case on the planned Oslo - Göteborg line. To maintain a high average speed on a high speed line it is important to drive as fast as possible through communities. Even short speed reductions are time consuming since the distances required for braking and accelerating are long.

Besides the obvious risk that someone can fall down onto the track and get hit by a train, the big issue with station passages at high speed is the air streams generated by trains and the forces on people and objects that they can exert. The velocity of these air streams increases significantly as train speed gets higher and may cause objects to be thrown up onto platforms. On the Oslo - Göteborg line this could be a problem especially in winter time in the Nordic climate when blocks of ice or snow could be thrown up by passing trains. Air streams from passing trains may also generate a so called slipstream effect which could cause people or objects to be sucked towards a passing train if they are situated too close to the platform edge. In an American study that summarizes research on how high speed trains affect people on platforms it is concluded that a train passage in 240 km/h (150 mph) could be a serious safety issue for a person standing 2 metres (6.6 ft.) away from the platform edge (Federal Railroad Administration, 1999). Besides the actual risk related to aerodynamics of passing trains, it is also important to consider the risk perceived by passengers waiting on platform. The perceived risk might appear and cause discomfort for people at speeds considerably lower than the speed associated with actual risks (Fröidh, 2010).

4.4.1 Separate passing tracks

According to Färnlöf[4] the common way in many HSR countries to prevent people on platforms to be exposed to the risks associated with passing high speed trains is to have separate passing tracks that are not located right next to a platform. Stopping trains will then reach the platforms by switching onto platform loops and passengers will have at least the width of one track between themselves and a passing train. To provide additional safety and sense of safety some kind of fixed barrier could be built between the passing track and the stopping track. This barrier could be some kind of wall or fence. A French example of such a barrier can be seen in figure 7 below. In the NHSRA, fixed barriers are advocated for stations with through tracks of 200 km/h or more (Leander, 2011).

Figure 7 A French station with separate through tracks and passive barriers (Leander, 2011)

[4] Pär Färnlöf (Trafikverket) interviewed by the authors 2013-04-16.

A significant negative aspect with separate passing tracks is of course the considerably increased construction and maintenance costs. The solution also makes the station more space consuming which might be a serious issue when fitting a new high speed station in the existing built environment (Fröidh, 2010). However, Pär Färnlöf at the Swedish Transport Administration says that no new station should be built in such a way that passengers on platforms could be exposed to trains passing at high speed. Further he argues that if it is not considered economically feasible to build a four track solution on a specific location, it might be considered whether to build a station there at all.

4.4.2 The use of traditional safety zones

On stations where separate through tracks are not feasible but high passing speed still desired, there are different possible measures that can be implemented on platforms in order to protect people from passing trains. These measures could be used on both new stations and when adapting old stations for high speed traffic. The traditional measure to prevent passengers on platforms to get too close to passing trains is to mark out a safety zone on the part of the platform closest to the platform edge. The zone is either marked with paint or with a paving that differs from the rest of the platform. Exactly how the marking of the safety zone is designed varies between Norway and Sweden but what is common though is that the width of the safety zone is dependent on the maximum allowed speed on the track adjacent to the platform. However, since there are no high speed lines in Norway or Sweden today, safety zone requirements are only valid for speeds up to 200 km/h and 240 km/h respectively. During train passages in Sweden at speed up to 200 km/h safety zones are used in combination with visual warnings on digital information screens. Visual warnings could also be enhanced by audible warnings when the passing train approaches the station. Compared with any type of barrier the solution with safety zones and warnings is relatively cheap to install with low operation and maintenance costs.

4.4.3 Different types of barrier solutions

As intentions point towards higher speeds on Scandinavian railways in the future, a need for new safety measures on platforms adjacent to high speed tracks might arise. However there are different opinions about from which passing speed that it would be appropriate with further measures in addition to safety zones. The TSI for high speed says in section 4.2.20.1 that passengers should not be given access to platforms at which trains passes in speeds ≥ 250 km/h (2008/217/EC). The policy of the Swedish Transport Administration says, based on test from the 1990s that passenger trains could pass platforms, equipped only with safety zones, in speeds up to 240 km/h (Fröidh, 2010). In the NHSRA as well as in the California High-Speed Train Project it is advocated that further safety measures should be taken when the speed through station exceeds 200 km/h (Leander, 2011, Parsons Brinckerhoff, 2010). However it should be mentioned that there are other parameters besides speed that affects the risks on platforms. Aspects such as available space on the platform and crowdedness could also be important.

A measure that have been tried on high speed lines in for instance Germany and Japan is to install some kind of platform safety fence with the purpose to prevent people from getting close to passing trains. Fences could be mounted right on the platform edge or at the edge of the safety zone depending on the maximum speed of passing trains. Fences could be made with openings in between or with automatic gates that opens when a train stops. On the German line Hamburg - Berlin, which is a conventional line that has been upgraded for high speed traffic, fences are built on several stations where trains pass in speeds up to 230 km/h. These fences, which can be seen in figure 8 are mounted two metres from the platform edge with openings distributed evenly along the platform. This solution does not provide a completely safe platform environment since it still possible to enter the safety zone while a train is passing but it will highlight the safety zone and make people stand further away from the platform edge. Platform fences would also likely provide a greater experience of comfort and perceived safety for passengers on platforms. The German fences are used in combination with visual and audible warnings and warnings signs (Banverket, 2009). It is a fairly cheap solution with no operation cost and little requirements of maintenance.

Figure 8 Example of fixed platform fences from Germany (Wikipedia, 2013a)

In Japan, platform fences are frequently used on Shinkansen high speed stations, both the type with openings but also fences with automatic gates that open when a train has stopped at the platform. The latter one can be seen in figure 9. This solution provides a high level of safety since the safety zone is completely blocked during train passage at high speed (Connor, 2011). However, the automatic gates make the solution more expensive to install and results in higher costs for operation and maintenance. There are also high demands on proper function of the gates since a failure could cause delays.

Figure 9 Platform fences with automatic gates in Japan. (Wikipedia, 2013b)

If implementing platform fences on Scandinavian rail lines the design must meet the requirements from the TSI and national regulations for platforms. This includes for instance enough space for snow removal between fence and platform edge and enough space on the platform for persons with reduced mobility and for service vehicles. This might increase the total area used for platforms. A facility with moving parts must also be guaranteed to be able to function properly in a Scandinavian winter climate. The TSI also requires that fence openings have to be at least 1600 mm wide which according to an assessment by the Swedish Transport Administration might be too wide to provide sufficient safety (Banverket, 2009).

Another type of barrier that has not been tested on any high speed line is so called Platform Screen Doors (PSD). These are full height screens with automatic doors that create a solid separation between the platform area and the track. PSD:s are popular in metro systems around the world and in underground railway stations for conventional traffic but in these cases their primary function is to prevent people from accessing tunnels and to create a pleasant climate. In Sweden, PSD:s can be found on the Liseberg station in Göteborg, these can be seen in figure 10. PSD:s will also be installed on two underground stations on the new Stockholm City line (Trafikverket, 2010).

Figure 10 Example of Platform Screen Doors from Liseberg station in Göteborg (Wikipedia, 2013c)

PSD:s on high speed stations has to be very resistant against heavy aerodynamic loads and objects thrown up by passing trains. Since PSD:s are solid there is no need for a safety zone between the track and the screens and the PSD:s could be placed on the platform edge. However, since the screen doors have fixed positions, the distance between doors of stopping trains must match. This could be solved on a line with separated traffic and uniform rolling stock but the Oslo - Göteborg line and other potential high speed lines in Scandinavia will probably accommodate a more mixed traffic with different train types operating. In these cases a platform area outside the screens would still be required for people to make their way to the closest train door. However with such an area there must be some kind of system that detects people being stuck on the outside of the screen (Leander, 2011). A positive aspect with PSD:s, especially in Nordic winter climate is that they can be attached to the platform roof, creating a platform less exposed to the weather and disturbing noise with possibilities of controlling the platform climate. By creating a pleasant indoor climate it is also possible to integrate waiting hall and platform in the same space. PSD:s are considerably more costly than simple platform fences but much cheaper than building separate through tracks. Still they can offer a very high level of safety and comfort. Moving doors require maintenance and operational disturbances may cause delays in train traffic. The doors must also work properly in winter climate.

Besides different barrier systems, another solution could be to construct the station in such a way that passengers are not given access to the platform until a train has stopped at the station. When there is no train at the platform people have to wait in a separate waiting space. Such waiting spaces could be located on the platform if there is enough space but it could also be elevated and located on a footbridge between different tracks. Separate waiting spaces would be a very safe solution but it would require relatively extensive construction works, making it an unreasonable solution for stations with small passenger base. With separate waiting spaces there is a risk that train stops will have to be longer since passengers will not be able to spread out evenly along the platform before the train arrives. The waiting spaces have to be equipped with automatic doors that need to be extremely reliable. There also has to be personnel or a system that ensures that the platform is empty before the train leaves the station (Banverket, 2009).

4.5 Platform and station dimensions

There are guidelines for platform dimensions in the TSI as well as in the national railway regulations in Sweden and Norway. The guidelines contain standards for platform widths, heights and lengths as well as distances between different tracks and between tracks and objects on the platform. Platform dimensions are important since they affect the overall size of the station area. It is often desirable to minimize the land use of a station. If there is limited land available at a station location it might be necessary to choose a compact station layout. Platform heights are not discussed in this report but will be assumed to be 55 cm or 76 cm as recommended in the regulations.

4.5.1 Platform length

The platform length is one of the factors that determine the capacity of the railway system. Longer platforms allow longer trains and thereby more passengers per train. On the other hand, it is not desirable to build longer platforms than necessary due to economic reasons and land use restrictions. Platforms are often longer on high speed railways in Europe than on conventional railway lines in Sweden and Norway. The reason for this is not a conceptual difference in how the platform length is decided but rather because high speed railways are built where the demand is high and hence, long platforms are necessary to accommodate longer train sets.

The design rules for platform length vary in different governing documents. The different requirements are summarized in table 2. The European TSI specifies a minimum length for high speed traffic platforms but has also an exception for rail traffic in Sweden that allows shorter platforms (2008/217/EC). Sweden is sparsely populated compared to many European countries, thus it is likely that the demand in the railway transport system are lower. According to Färnlöf[5] the first high speed railway line planned for Sweden will have platform lengths of 320 metres for stations where high speed trains stop. 320 metres is the maximum allowed train length at Copenhagen station and trains coming from Europe to Sweden cannot exceed that length. However, he also points out that land should be reserved to allow a future extension of platforms up to 400 metres, which is the European standard for high speed traffic. The cost of arranging the tracks in a suitable way when constructing a new station is low compared to reconstructing them later on.

[5] Pär Färnlöf (Trafikverket) interviewed by the authors 2013-04-16.

The Norwegian National Rail Administration has regulations that states normal and minimum platform lengths for different cases in Norway (Jernbaneverket, 2013c). In phase three of the NHSRA it is suggested that stations where high speed trains will stop should have a platform length of 400m which is in line with the Norwegian rules (Norconsult, 2011).

Table 2 Platform length requirements in different regulations.

Regulation	Case	Minimum length	Normal length
European TSI	High speed traffic	400	
European TSI	Exception for Sweden	225	
Norwegian JD 530	Local traffic	220	250
Norwegian JD 530	Long distance traffic	220	350
Norwegian JD 530	Lines specifically constructed for high speed traffic	400	

4.5.2 Platform width

Platform width is in many aspects a matter of safety for the travellers. There must be enough room for passengers to move and reside on the platform without getting too close to the tracks (Leander, 2011). There are several different factors that affect the necessary platform width. To begin with, the expected amount of passengers that will use the platform simultaneously must be taken into account so that there is enough room. Island platforms are generally wider since they serve two tracks instead of one. The type and placement of obstacles such as benches, walls, lifts and stairs are also important as it has to be easy to move around them, also for people with reduced mobility. There must be sufficient space for suitable safety measures such as safety zones or screen doors which were described more in detail in chapter 4.4. A factor that is important to consider in the Nordic countries is the climate. There must be possibilities for snow removal machines to work on the platforms. The factors that decide platform width is the same for high speed rail and conventional rail but the result can vary. One example is that platforms on high speed railway stations where trains pass at high speed might be wider since there has to be room for a wide safety zone or other safety measures.

The regulations for platform width vary somewhat in the European TSI and the national rules in Sweden and Norway. However, the principles are basically the same. The minimum platform width is based on the necessary width of the safety zone, the expected number of passengers and the presence of obstacles and vehicle traffic on the platform. In some parts the TSI refer to the national regulations. Below follows a summary of the requirements (2008/217/EC & BVS 1586.26 & Jernbaneverket 2013b). For those parts where the Swedish regulations and the TSI differ, the TSI is superior.

- **Safety zone** - The width of the safety zone depends on whether there is any kind of safety barrier or not. Platforms without barriers are described in the national regulations but only for speed limits up to 200 km/h in Norway and 240 km/h in Sweden. In those cases, the minimum width is 1.5 and 2.0 metres respectively.

- **Minimum free path for passengers** - There should be a walking path for passengers that is free from obstacles. The minimum requirements are: TSI – 1.6m, Norwegian regulations – 1.8m, Swedish regulations - 2m.

- **Addition for maximum expected number of passengers** - For stations where many passengers are expected to use the platforms simultaneously additional width might be required. Both the Swedish and Norwegian national regulations have an addition of 0.5 metres width for every 100 passengers.

- **Addition for vehicle traffic** - Both the Swedish and Norwegian national regulations have an addition of 1 metre width if vehicle traffic will occur on the platform.

- **Minimum distance between obstacles and the safety zone** - The minimum distance stipulated in the different regulations vary between 0.8 and 2.5 metres depending on the size of the object and the presence of vehicle traffic.

- **Minimum total platform width** - In the TSI it is also specified a minimum total platform width of 2.5 metres for side platforms and 3.3 metres for island platforms. That is without addition for passenger flows and obstacles on the platform.

4.5.3 Distances between tracks and between tracks and platforms

Except for the platform dimensions, the overall dimensions of the station also depend on the distances between the tracks and between tracks and platforms. There is a difference in how the distance is decided for high speed rail and conventional rail. These dimensions are regulated in both national rules and the TSI. In the TSI, the distance between tracks is decided based on the speed limit of the track, at least for speeds over 230 km/h (2008/217/EC). For lower speed limits, smaller distances are allowed and it is based on the profile of the trains that will use the track. Table 3 shows the TSI requirements.

Table 3 Requirements for track distances.

Speed [km/h]	Distance between track centres [m]
< 230	Based on train profile
230 - 250	4.0
250 - 300	4.2
> 300	4.5

In the Norwegian regulations the distance is based on the curve radius of the track (Jernbaneverket, 2013c). The required minimum distance varies between 4.4 metres for radii above 5000 metres and 4.7 metres for radii below 350 meters. There is also a specific minimum distance of 4.7 metres between tracks on stations. In phase two of the NHSRA it is recommended that a distance of 4.5 metres is used for tracks on stations as long as the curve radius is at least 5000 metres (Leander, 2011). For station layouts with a barrier placed between the tracks a distance of 6.3 metres between the track centres has been used instead in the NHSRA.

The distance between tracks and platforms is not as much affected by the high speed concept and is decided similarly in all regulations. The distance is based on the height of the platform, the curve radius and the inclination of the track. The resulting distances are also similar for both the national and international regulations. As an example the track-platform distances for a straight track with the recommended platform heights are shown in table 4 (2008/217/EC & BVS 1586.26 & Jernbaneverket 2013b).

Table 4 Requirements for distance between track and platform.

Regulation	Track-Platform distance [m]
European TSI	1.65
Norwegian JD530	1.68
Swedish BVS 1586.26	1.70

4.6 Adaption to the Nordic climate

One important difference between Scandinavia and most other countries with high speed railway is the cold and snowy climate. There is only one country were parts of the high speed railway runs through areas where there is a lot of snow during winters, and that is Japan (Ramböll, 2012). Ice and snow on trains and infrastructure can cause disruptions in the train traffic. It is possibly even more important with a high reliability for a high speed railway service since the passengers have high expectations and the ambition is to compete with other long distance transport modes. According to Färnlöf[6] some winter related issues become worse at higher speeds and therefore new countermeasures might be needed on high speed railways. A part of the railway where it is particularly important to manage the snow and ice related issues are the railway stations. The tracks on stations have many sensitive movable parts such as switches. Some examples of preventive measures for issues caused by snow and ice are described below. No specific recommendations of which measures that would be most suitable in Sweden and Norway is given here since it is hard to do without a more detailed study of the efficiency and costs for the different alternatives.

[6] Pär Färnlöf (Trafikverket) interviewed by the authors 2013-04-16.

A common winter and speed related issue is flying ballast. Färnlöf explains that it consists of two phenomena. One is that snow accumulates on trains and when it falls off, ballast stones might be thrown up. The risk for this happening increases with speeds. The other phenomenon is that the speed itself can cause aerodynamic forces that lift ballast stones. Flying ballast can cause damage on equipment beside the track and on stations there is also a risk that passengers can be hit by stones. One way to avoid these phenomena is to choose a ballast free track solution. An example of this is shown in figure 11. A ballast free track is often some kind of concrete construction such as a slab track on the ground or a concrete viaduct which is the case in Japan (Ramböll, 2012). According to Färnlöf, future railways in Sweden with speed limits over 280 km/h will most likely be constructed as ballast free tracks. Another measure to avoid flying ballast is the use of ballast mats that cover the ballast. The NHSRA recommends that slab track is used for all parts of the line where possible, considering the ground conditions (Norconsult, 2011).

Figure 11 A slab track which is an example of a ballast free track solution (Wikipedia, 2013d).

At occasions with heavy snowfall, snow can accumulate on the track and on trains. Sensitive moving parts on tracks and trains such as switches and bogies can then malfunction. Snow accumulation on trains can also cause flying ballast as described above. One solution used is to create room for storage of snow along the track (Ramböll, 2012). In Japan, the track is built on a mound, as can be seen in figure 12, in order to create more space for snow below and between the tracks.

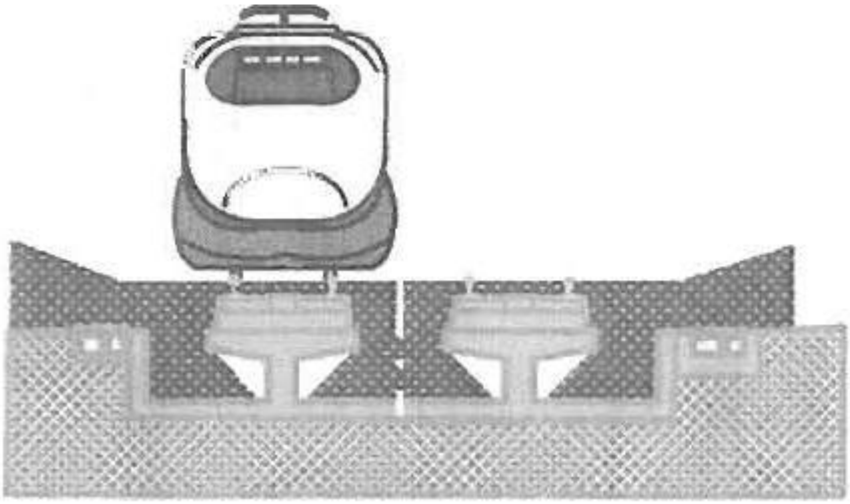

Figure 12 A Japanese track solution with room for snow storage below the track (Ramböll, 2012).

Another measure used in Japan to avoid accumulation of snow and ice on sensitive parts of tracks and trains is hot water sprinklers (Ramböll, 2012). This solution can be particularly suitable for stations since there is a lot of switches and other sensitive track details. According to Löfving[7] this method has been considered in Sweden, even though it is expensive, since it is considered to be very efficient. An example of a sprinkler facility can be seen in figure 13.

Figure 13 Hot water sprinklers that melt the snow at a switch (Ramböll, 2012).

Another important aspect connected to cold climate and railway stations is snow removal on platforms. It is important to consider the possibilities for this type of maintenance when the station is designed. For example it might be necessary to provide extra width on the platforms for snow removal vehicles. As explained in chapter 4.5.2 the Swedish and Norwegian regulations for platform width prescribes one extra metre of width for this purpose (BVS 1586.26 & Jernbaneverket 2013b).

[7] Christer Löfving (Trafikverket) interviewed by the authors 2013-04-08.

5 Suggested station designs for the Oslo - Göteborg line

The previous chapter was a review of literature on how railway stations can be suitably designed for high speed traffic. In this chapter that theory will be applied to three of the stations on the Oslo - Göteborg line. The concepts presented in the NHSRA and the CCAIC will be used as a basis and possible station designs will be presented and discussed.

5.1 Selection of studied stations

As described in chapter 3, two different alternatives were analysed in the NHSRA, alternative 2* and alternative D1. Alternative 2* is, for the part Oslo - Halden, identical to the recommended alternative, ØB 4B, in the CCAIC so in total there are two different concepts that are investigated in this report. The alternatives and their major stations are illustrated in figure 14.

Figure 14 The suggested route alternatives from Ski to Öxnered, alternative 2 in red and alternative D1 in green (Modified from Google Maps, 2013).*

Even though the design speeds for the two alternatives are 250 km/h and 330 km/h respectively, the speed limit along the lines vary due to track geometry and the fact that the old track is used at some parts of the line. Figures 15 and 16 illustrate the maximum speed in the two alternatives.

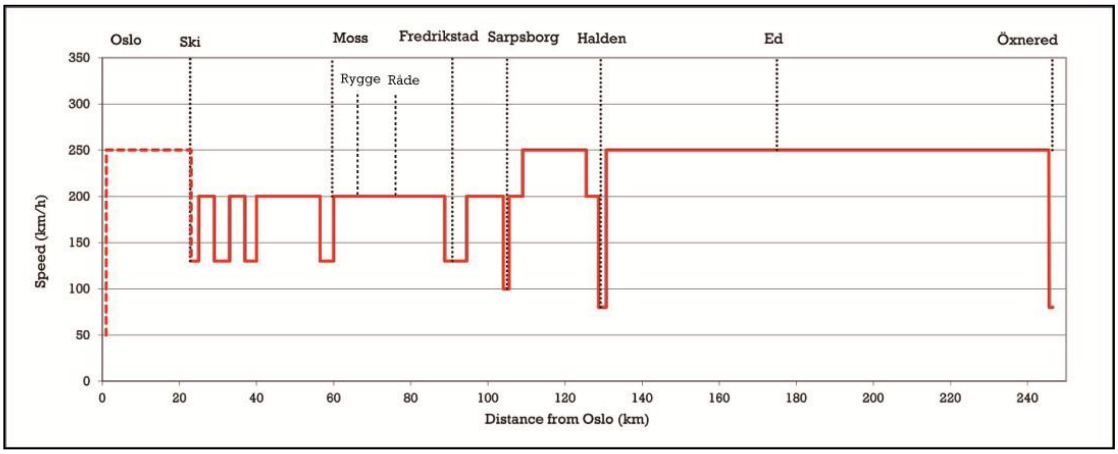

Figure 15 Speed profile for alternative 2 (Modified from Norconsult, 2011).*

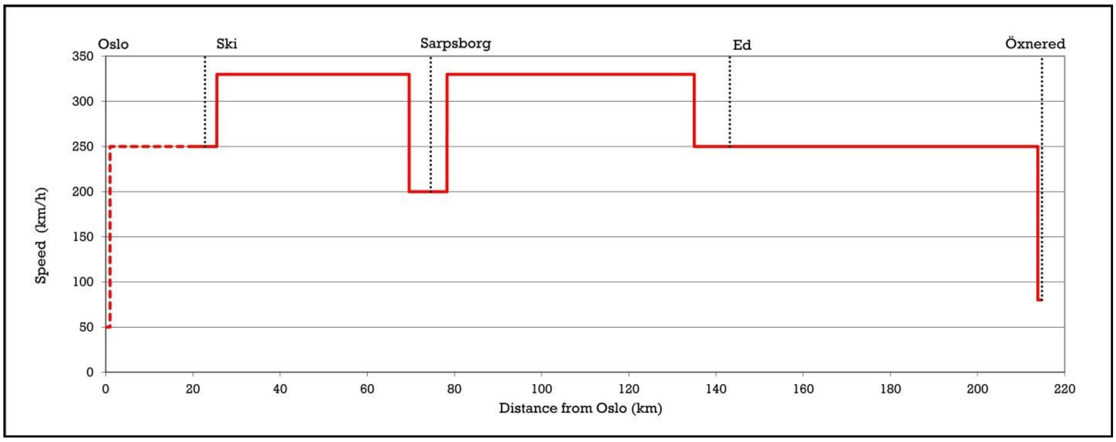

Figure 16 Speed profile for alternative D1 (Norconsult, 2011).

Since the focus in this report is on high speed railway stations it is interesting to choose stations where it can be expected that trains might pass at high speed. Since it is recommended in several assessments that additional platform safety measures are introduced for stations with speed limits of 200 km/h and above this was used as a criterion for the selected stations. Some stations are already planned to be rebuilt at present, e.g. Ski and Moss, and therefore those were not chosen for analysis. It was considered interesting to choose stations with varying prerequisites regarding location (Sweden/Norway), size and whether they were considered to need major reconstruction. According to these criteria three stations were selected, namely, Rygge, Sarpsborg and Ed. Ed is a small village in Sweden where it is suggested in the NHSRA that a station is built at a new location and where the speed of passing trains will be the highest. Sarpsborg is a relatively large town in Norway where a new station is suggested to be built at the same location as the existing one. Rygge is also located in Norway but is smaller than Sarpsborg and it is suggested that the station should be kept as it is today. For Rygge, some suggestions of how the station can be upgraded to be suitable for high speed traffic are presented in this chapter.

5.2 Future traffic scenario for the Oslo - Göteborg line

In the High Speed Railway Assessment a traffic pattern has been assumed for the line and been used as a basis for the calculations. The stations on the line have been categorized by its size to be able to decide which stations should be selected as high speed train stops (Jernbaneverket, 2012a). According to the plans there should be one hourly high speed train in each direction, which stops at stations of category one and two. Those stations are Oslo, Ski, Moss, Fredrikstad, Sarpsborg, Halden, Trollhättan and Göteborg. Refer to figure 14 for the location of these stations. It should be noticed that some of these stations are only included in alternative 2*. The stations not mentioned here belong to category three and it is not planned for any high speed trains to stop there. In addition to the hourly train there are plans for one extra train per hour during peak hours, which would result in four extra trains per day and direction. These rush hour trains would only stop at category one stations which are Oslo, Moss, Sarpsborg, Trollhättan and Göteborg.

In the InterCity assessment there has also been made an assumption for the future traffic scenario. All InterCity trains will stop at the stations Oslo, Ski, Moss, Rygge, Råde, Fredrikstad, Sarpsborg and Halden (Jernbaneverket 2012c). It is planned for four trains each hour of which two goes from Oslo to Fredrikstad, one to Halden and one all the way to Göteborg. One train per hour and direction between Oslo and Göteborg is in line with the plans in the NHSRA as described above. In addition to the InterCity trains there will be four local trains per hour and direction between Oslo and Moss. The local trains will also stop at the smaller stations Ås, Vestby, Sonsveien and Kambo.

5.3 Ed station

Ed is a Swedish village situated in Dals-Ed municipality, about 80 kilometres north of Öxnered and 20 kilometres from the Norwegian border. The location of Ed is shown in figure 14. It is a small municipality with only 4700 inhabitants and the population is expected to decrease somewhat until 2040 (Statisticon, 2011). Ed is the only village in the municipality and it had 2932 inhabitants in 2010 (SCB, 2010). Since Ed is located on the Swedish part of the Oslo - Göteborg line it is not a part of the Norwegian InterCity assessment but it is included in the High Speed Railway Assessment. The routes of the two alternatives, 2* and D1 are identical for the section in Sweden and it is suggested that a new station is built outside of Ed.

5.3.1 Location of the station

The existing station is located in central Ed but in the NHSRA the railway line is proposed to be located some kilometres south of the village to avoid sharp curves as on the existing line, see figure 17. It is suggested that a new station should be built south of Ed, around 4 km from the existing station (Norconsult, 2011). In the municipal master plan for Dals-Ed the railway is discussed and it is important for the municipality that trains stop in Ed also in the future (Dals-Eds kommun, 2003). The master plan also suggests a straightening of the line but with the station kept in central Ed.

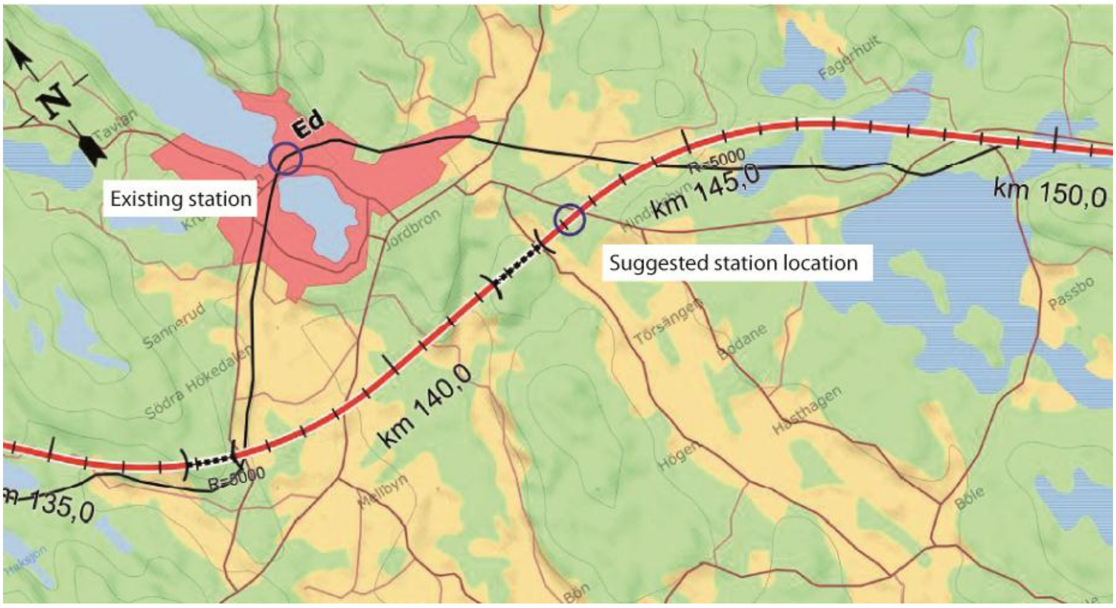

Figure 17 The existing and new suggested track through Ed with station locations (Modified from Norconsult, 2011).

The track geometry for the line suggested in the NHSRA allows a speed of 330 km/h almost all the way from after Halden down to Ed, but due to the two relatively sharp curves south of Ed seen in figure 17, the speed limit through the planned station is reduced to 250 km/h (Norconsult, 2011). This is still a rather high speed for passing trains and therefore this station is interesting to study.

5.3.2 Traffic situation

There is no intense traffic at this station today. The Oslo - Göteborg line has three passenger trains per day in each direction and they all stop at Ed station. In addition to this there are around 6-9 freight trains per day in each direction on the part of the line through Ed. Most of them just pass the station but some freight trains are turned at the station (Trafikverket, 2012). It is impossible to know exactly what the future traffic will be on this station but an assumption can be made based on the preliminary plans in the investigations. As explained above there will be 1-2 high speed trains per hour and direction on the Oslo - Göteborg line, but these will not stop in Ed. The Norwegian investigations do not include any discussion of other traffic concepts on this part of line. It is possible that there would be for example a local or regional train on the Swedish side from Ed to Trollhättan and further south, or a slower Oslo - Göteborg train that stop also at small stations. According to the NHSRA, the line is planned to be used for both passenger and freight traffic also in the future which has to be taken into account. It is likely that the number of freight trains will increase slightly on the new track since the travel time decreases.

5.3.3 Track- and platform arrangement and platform safety

The existing station in Ed has three tracks with side platforms on both sides of the track area and one island platform between two of the tracks. Even though the future traffic on Ed station is uncertain it is likely that it could be handled with a two-track station. If for example the freight traffic would increase to one train per hour and there would be one stopping passenger train each hour in addition to the passing high speed trains there would be in total 2-3 passing trains and 1 stopping train per hour. That amount of traffic is well within the capacity of a two track station, provided that no overtaking is planned to take place at this specific location (Leander, 2011). However, there are several reasons for building a station with more than two tracks which is discussed in the following text. Figure 18 shows three different station layouts that are recommended in phase 2 of the NHSRA for similar traffic scenarios. They have enough capacity and they allow both stopping trains and trains passing at high speed.

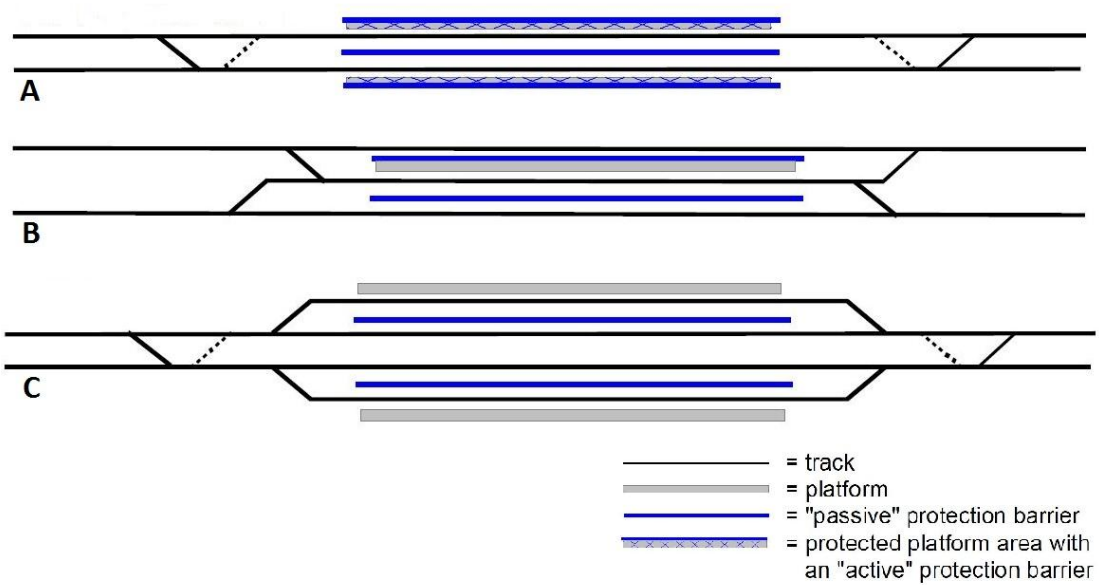

Figure 18 Potential layouts for Ed station (Modified from Leander, 2011).

Layout A in figure 18 has only two tracks and therefore no overtaking is possible. As explained previously, a reason to build a station with more than two tracks is to provide possibilities for high speed trains to pass slower trains. The location of passing loops is not discussed in the NHSRA but it can be beneficial to place them at stations since overtaking and passenger exchange then can be combined. The extra tracks on the stations will also provide higher capacity and flexibility for a possible future increase of the traffic intensity. As mentioned there are also some freight trains that turns in Ed and that possibility will probably be needed in the future as well which is another argument against a two track station.

Another important aspect at Ed station is the platform safety, since passing trains have a speed of 250 km/h. As described in chapter 4.4.1, the Swedish Transport Administration advocates that such stations should be built with separate tracks for passing trains for platform safety reasons. In that case, layouts B and C in figure 18 are better options. It could probably be argued that it would be unnecessary to build a large station in a small village like Ed but as mentioned previously, Färnlöf considers that if it is too expensive to build a safe station at a specific location, it should be questioned if a station should be built at all. Both layout B and C have two separate tracks for passing trains but the difference between them is that layout B only have one track for stopping trains while in layout C, two trains can stop simultaneously. Since few trains are planned to stop at Ed station, layout C would probably be sufficient but the timetable would have to be adjusted so that trains from the two directions arrive at the station at different times. Station layout C would provide more flexibility for the timetable and in case of delays. Layout C is also much better from a reliability point of view, since if a train breaks down there is a second platform track which can be used instead. If a train would block the platform track in layout B, no other trains would be able to stop at the station. The recommendation from this report is to build a four track station with side platforms and separate tracks for passing trains in the middle. However, before making a final decision it would of course be necessary to study the differences in investments costs, which is not done in this report.

Another important aspect to consider when choosing a station layout is the land area available at the specific location. If there is limited space it is more important to build a compact station. The planned location of the new Ed station is outside of the village and there are few buildings in the closest surroundings. According to the municipal master plan for Dals-Ed, the station location lies in an area of national interest for cultural heritage that covers the whole village of Ed (Dals-Ed kommun, 2003). However, the station is located close to an industrial area and a road so it is probably not the most valuable part of this area. There are no other types of national interests at the location. Compared to building or extending a station in a more central area the suggested location will probably provide a less complicated situation and it is likely possible to construct a four track station there.

5.3.4 Platform and station dimensions

In chapter 4.5.1 it was found that the minimum platform length is 400 metres according to the European regulations but there is an exception for Sweden with a minimum length of 225 meters. 400 metres is probably unnecessary in this case since it is not planned for high speed trains to stop at Ed. The platforms at the existing Ed station are 250 metres long. Other stations on the line are for example Trollhättan where the platforms are 300 metres long today and the recently built stations between Göteborg and Trollhättan with platforms of 225 meters. It can be concluded that it is necessary to know more about the future rail traffic at Ed station before the platform length can be decided. Based on the assumptions made in this report it is recommended that the platforms in Ed should be 250 metres as today but that land should be reserved for a possible future extension.

The platform width is decided based on the European and national rules as described in chapter 4.5.2. Since a station with separate tracks is chosen for this station no trains will pass the platforms at high speed. Therefore the required safety zone is 1 metre according to the Swedish regulations (BVS 1586.26). The requirement for minimum width of the free walking path for passengers is 1.6 metres in the TSI and 2 metres in the Swedish regulations, therefore 2 metres is chosen. The future expected number of travellers from Ed station is not calculated in the NHSRA since high speed trains are not expected to stop there. A comparison can be made with Rygge station which is described in chapter 5.5. It is estimated there that the future number of waiting passengers will not exceed 100 and since Ed is an even smaller village it can be assumed that the maximum number of passengers on the platform in Ed won't exceed that number either. Therefore no additional width is necessary for that purpose. On the other hand, it is likely that vehicle traffic will occur on the platform and that requires one metre additional width. This results in a total platform width of 1+2+1= 4 metres which exceeds the required minimum total width of 2.5 metres in the TSI. The presence of objects on the platforms is not known in detail at this stage but it is likely that there at least would be stairs and an elevator or similar to allow passengers to cross the tracks in a tunnel or on a bridge. The impact of those depends on how they are placed on the platform but some extra width might have to be added for this purpose. The distance from the safety zone to the edge of an object like that has to be 1.6 metres according to the Swedish regulations (BVS 1586.26). According to the calculations above the platform should be 3 metres plus safety zone. If the object for example is 2 metres wide, those 3 metres have to be increased to 3.6 meters instead. If the platforms are constructed 5 meters wide including the safety zone, there will be some flexibility in the placement of objects.

In the NHSRA it is recommended that the distance between the tracks should be 4.5 metres for stations located on a straight section of the track which is the case in Ed and hence that distance will be used for the two passing tracks in the middle. The corresponding distance for tracks with a safety barrier between them is 6.3 meters. Since it is a straight part of the line where the planned station is located, the distance from the track centre to the platform edge should be 1.65 metres according to the TSI. The suggested station layout for Ed with dimensions is shown in figure 19.

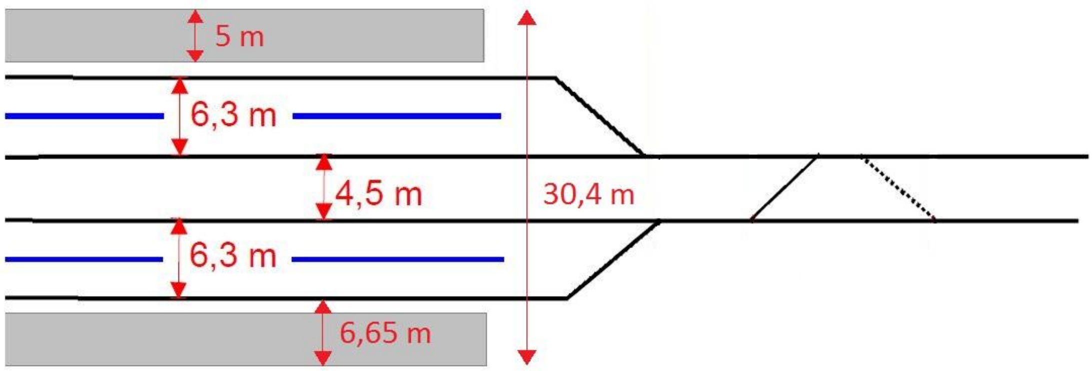

Figure 19 Suggested layout for Ed station with minimum dimensions (Modified from Leander, 2011).

5.4 Sarpsborg station

Sarpsborg is the second largest city along the Østfold line and had about 52 800 residents in 2011. It is located about 90 km south east of Oslo, see figure 14, from which it today takes 1 hour and 23 minutes to travel with the regional train. The future travel time is planned to be 56 minutes with for the Intercity based alternative 2* and 25 minutes with the pure high speed alternative D1. According to predictions made within the CCAIC the city will grow and house about 69 000 residents in 2040. The yearly number of passengers are today about 281 500 which is considered to be relatively few (Norconsult, 2012). However, with an expansion to a fast double track the number is assumed to increase to almost 600 000 passengers per year (Homleid et. al, 2012). These numbers are only based on an expansion of the IC-traffic and any pure high speed traffic is not included. However, it can be assumed that such traffic would give a further increase in travel demand on Sarpsborg station.

Sarpsborg is today one of the stops for the IC-trains between Oslo and Halden. The future plans for IC-traffic on the Østfold line from the CCAIC include Sarpsborg station which is suggested to remain in its present location. In the NHSRA Sarpsborg station is considered a potential intermediate stop for both of the assessed route alternatives. In alternative 2* the track through Sarpsborg and past the station is planned to follow the same corridor as the present track. A particularly tight turn just north of the station limits the speed through the station to only 100 km/h for this alternative. In alternative D1, the route alternative for 330 km/h, the tracks follows a new straight corridor north of Sarpsborg which enters the city in a tunnel that reaches the ground just north of the station area. With this alternative, tight turns are avoided and the speed through Sarpsborg would be 200 km/h. Since only alternative D1 includes relatively high speed, it is the only alternative for which station design will be discussed further.

In the CCAIC a number of alternative station locations are mentioned but the present location is the only one that has been included in the chosen routes. In the NHSRA the present location is the only location discussed. The station is situated in the north outskirts of the city centre, which can be seen in figure 20 and borders to industrial and recreational areas. The station has four platform tracks but only two of them are in use today. Today's platforms are between 120 and 250 metres long and very narrow with almost no safety zone at all. Thus major reconstruction work has to be done to be able to fulfil space related requirements from the technical regulations and the TSI. However, the total station area in Sarpsborg is quite large and a total of seven parallel tracks run past the station. Thus there is most likely space enough for a larger passenger station facility. The marshalling of freight trains that today is carried out along the station could probably be moved further south-east within the existing track area.

Figure 20 Location of Sarpsborg station, the new high speed line, the existing line and the connection to the eastern line (Modified from Norconsult, 2011).

5.4.1 Traffic situation

Today the passenger traffic at Sarpsborg station consists of the IC-service between Oslo and Halden/Göteborg. The trains depart hourly in both directions from Sarpsborg with two trains per hour to and from Oslo in rush hour. There are also about 9 trough going freight trains per day. In addition to these there are also some freight traffic going to and from destinations within Sarpsborg.

As mentioned earlier, both IC-trains and high speeds trains are planned to operate at Sarpsborg station. The CCAIC suggests two IC-trains per hour that will stop in Sarpsborg on their way to Halden and back to Oslo. Also potential long distance high speed trains are planned to stop in Sarpsborg with a frequency of one train per hour and with extra trains in rush hour. In the two assessments no train concept with passing passenger trains has been presented. However, if a future train service could reach a travel time competitive with air traffic there might be a market for direct trains between Oslo and Göteborg with no intermediate stops.

In the recommended route alternative in the CCAIC freight traffic through the Østfold region is planned to go on the eastern line of the Østfold line, which merges with the main line south of Sarpsborg. This means that only freight traffic with destination in or close to Sarpsborg will pass the station. However, due to increased capacity and track standard it is reasonable to think that this traffic will increase in the future. In summary there will be 3-4 passenger trains per hour plus the freight trains aimed for Sarpsborg.

5.4.2 Track- and platform arrangement and platform safety

With alternative D1 there will be a clear division of long distance high speed traffic and the regional IC-traffic in Sarpsborg since high speed trains will use a new route north of the city station while the IC trains will use the existing route towards Fredrikstad. This means that there has to be separate platforms for IC and high speed traffic. In the NHSRA a schematic solution is proposed with the IC-platform elevated in relation to the high speed platforms, this can be seen in figure 21.

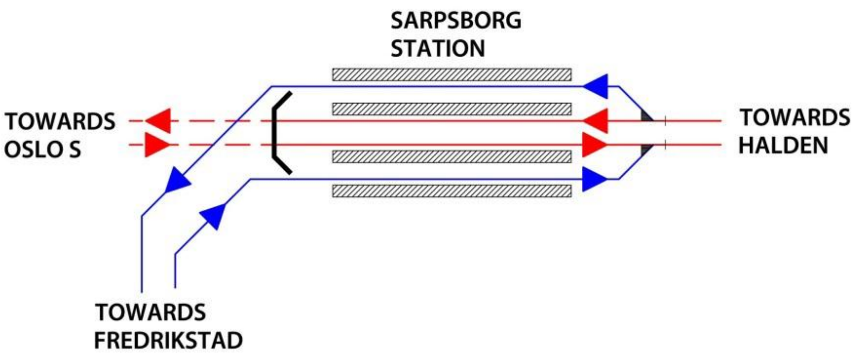

Figure 21 Possible station layout for Sarpsborg station from the NHSRA with high speed tracks in red and tracks for other traffic in blue (Norconsult, 2011).

As can be seen no through tracks are suggested meaning that any passing train has to pass on a track adjacent to a platform. Thus, with a design speed of 200 km/h Sarpsborg station is right on the limit for when platform barriers are recommended. However, since there probably will be no or very few trains passing the station in high speed, any special facility for that purpose might not be motivated. What could be done is to make the new high speed platforms wide enough to permit a possible future installation of any type of platform barrier. Until then the platform safety arrangement on high speed platforms could consist of a 1.5 m safety zone combined with visual and audible warnings. On the outer platforms for IC-trains, the suggested track layout does not permit platform passage at high speed due to a tight curve in the north and switches to the main track in the south. Thus, the platform safety arrangements on those platforms could be designed for low speed.

Regarding through tracks, it would of course increase safety and flexibility of the station, but since the high speed tracks are suggested to be lowered to enter a tunnel north of the station extra tracks would result in much more extensive construction works. The increase in cost that such works would result in is not considered reasonable in relation to the small need of through going tracks.

5.4.3 Platform and station dimensions

With separate platforms for high speed traffic and other traffic only the high speed platforms has to be designed according to regulations in TSI for high speed. Platforms for conventional traffic can be designed according to Technical Regulations (TR) from the Norwegian National Rail Administration. When it comes to platform lengths, the TSI for high speed, TR, as well as the NHSRA states that high speed platforms should be 400 metres long. If considering only the interoperability with the high speed network in the rest of Europe, it can as mentioned in chapter 4.5.1 be discussed whether it has to be 400 metres since Copenhagen central station only can provide platforms of 320 metres. On the other hand on the Swedish long distance route between Göteborg and Stockholm some departures are run with multiple units with total length of more than 300 metres (SJ, 2013). Thus, there could be a demand for very long trains between major cities in Scandinavia. If a competitive high speed train service is developed on the Oslo – Göteborg line such a demand might arise even there. The suggestion is therefore to build high speed platforms of 400 metres in Sarpsborg. The platforms for conventional traffic could be built 350 metres according to TR for long distance traffic.

With an allowed passing speed of 200 km/h the safety zone on high speed platforms in Sarpsborg has to be 1.5 m according to the TR. Since Sarpsborg would be a major stop if alternative D1 is realised, it is assumed that platforms should be adapted for service vehicle traffic. This means that the waiting zone has to be at least 2.8 metres wide. Prognoses from the NHSRA show maximum number of expected travellers at Sarpsborg station in 2043 of 3222 passengers (Jernbaneverket, 2012a). With 16 departures per direction and day this makes an average of about 100 passengers per train that will use Sarpsborg station. If 100-200 passengers could be expected to be on the platform at the same time the waiting zone should be increased with 1 metre. Totally this gives a waiting zone of 3.8 metres which also should be enough to fulfil requirement on free space between fixed objects and the safety zone. What will distinguish the non-high speed platforms from the high speed platforms is that the safety zone could be allowed to be narrower. The add-on for crowdedness might also be smaller but this has not been investigated further since it is considered to be beyond the scope of this report.

To summarize this chapter the layout suggested in the NHSRA is found appropriate. Precise dimensions of the station are hard to suggest since the design of the level separated construction is not known. However, the platforms are suggested to be 400 metres long and at least 5.3 metres wide plus extra space for any future safety improvements.

5.5 Rygge

Rygge is a quite small municipality located about 70 km south of Oslo along the existing Østfold line. The Rygge railway station is located in the municipal centre Halmstad, see figure 22 where about 2500 of the total 14400 municipal residents live. Until 2040 Rygge is expected to grow to about 17000 residents. Today Rygge is one of the stops for the IC-trains between Oslo and Halden/Göteborg and with 120.000 passengers per year it is the least used station on the IC-line (Norconsult, 2012). According to the CCAIC the passenger numbers could double until 2025 if the new double track is built and the travel time to Oslo is reduced from 50 to 34 minutes (Homleid et. al, 2012). The Rygge station is located only about 3 km from the Moss Airport Rygge and shuttle busses operates between the railway station and the airport with timetables that corresponds to the IC-trains. Today's traffic at Rygge station consists of one hourly IC-train in each direction with one additional departure per hour in during peak hours. There are also about 9 through going freight trains per day.

Figure 22 Location of the station in Rygge (Norconsult, 2011)

In the CCAIC Rygge is suggested to be kept as one of the stations in the IC-service. In alternative D1 of the NHSRA the line will not go through Rygge but since the 2* alternative of the same assessment is identical with the suggested route choice of the CCAIC, Rygge station is also affected by the high speed railway assessment. However, since Rygge station serves relatively few people it is not reasonable to think that long distance high speed trains will ever stop there. According to the CCAIC and the NHSRA a possible future traffic scenario for Rygge station could be four stopping IC-trains plus one or two passing long distance high speed trains every hour during peak traffic.

A short section of the existing line through Rygge station was upgraded to double track in 2000. Thus, the track geometry already permits a speed of 200 km/h even though speed limit is 130 km/h today. Based on that, the NHSRA suggests that the track and the station in Rygge are kept as they are today but with the difference that the speed limit will be increased to 200 km/h (Norconsult, 2013). The present station, seen in figure 23 is a two-track station with side platforms along both tracks. This means that through going trains will be able to pass in 200 km/h on tracks adjacent to platforms. The NHSRA recommended that some kind of physical barrier should be used on stations with passing speeds above 200 km/h so technically Rygge station would not require any barriers according to the assessment. Nevertheless, the risk perceived by passengers is probably very much the same whether a train passes in 200 or 210 km/h. Since the IC-trains are suggested to depart every fifteen minutes it is likely that there will be passengers standing on the platform when a high speed train passes. So for the comfort of passengers on platforms a simple barrier system might be considered. A fixed fence at the edge of the safety zone could most likely provide an increased sense of safety for passengers without resulting in any extensive reconstruction of the station. A fence with automatic gates would of course be the safest alternative but since the number of passengers is quite low and the passing speed not extremely high, a fence with openings might be a reasonable solution.

Figure 23 Present station in Rygge (Wikipedia, 2013e)

Regardless of whether platform fences are installed or not, an increased passing speed will require a widened safety zone. According to the technical regulations from Jernbaneverket the safety zone has to be 1.5 m wide at speeds of 200 km/h. In addition to the safety zone the waiting zone has to be at least 1.8 m wide or 2.8 m if platform trucks are to be used. If it could be expected that more than 50 (n>50) will wait on the platform at the same time there should be an increased waiting zone according to the formula n/200 = extra space (m). However, it is unlikely that more than 50 people will wait at the same time even with a doubled number of travellers (Based on 240 000 travellers, 4 stopping trains/hour and direction, 1 year equivalent to 320 working days), and even if an extra half a metre would be needed, today's approximately 5 m wide platform would be enough for both also in the future. An important consideration to make if fences are installed is to ensure that snow removal from platforms will work properly. Regarding platform length, the approximately 220 m of today will likely be enough also in a future traffic scenario since only IC-trains will stop in Rygge. However, if platforms have to be prolonged for some reason there is free space according to aerial photography. Since the station is suggested to be kept it has been assumed that the distance between the tracks is enough as it is today. However, that distance is not affected by speed until the speed exceeds 230 km/h which will not be the case in Rygge.

Another issue that comes with a two track solution is decreased capacity and robustness. This is particularly a problem when trains operate with different stopping patterns and different top speeds, just as the case of the future the Østfold line. Faster trains will need passing loops to pass slower trains and if Rygge station would be a four track station it could be used also for this purpose. However, since the next station in both directions, Moss and Råde are suggested to be rebuilt as at least four track stations and are located only 6 and 5 minutes away respectively, there will most likely be enough overtaking opportunities.

In summary the present Rygge station seems to be able to accommodate a future traffic with stopping IC-trains and high speed trains passing in 200 km/h. Length and width of platforms are most likely enough but platform fences are suggested to be installed in order to create a safer environment for passengers on the platforms.

6 Discussion

The preceding chapters present the results from the literature study and the implementation of the theory for three stations but there are several parts in the results that could be analysed further which is discussed in this chapter. The discussion also involves how the implementation of the method succeeded and how the choice of scope definition affects the results in the report.

6.1 Consequences of the scope definition

During the initial work with this thesis it was concluded that there is a large number of aspects that should be taken into consideration when a railway station is designed. There are more relevant aspects than what can be covered in a report of this extent and hence a limitation has to be made. This report focuses on the track and platform technical aspects but there are many other interesting aspects that would have to be analysed if the suggested Oslo - Göteborg line and its stations would be built in the future. One example is the costs for construction and maintenance of different parts of the railway stations. Economic aspects are very important since they affect decisions at all levels, especially when public funds are used. Some cost calculations have been carried out for the planned railway lines in the Norwegian investigations but a more detailed study would have to done to compare different station layouts and safety measures.

The group of aspects called "Passenger service and comfort factors" in table 1 is also worth mentioning here. According to Färnlöf, several of the important differences between high speed railway stations and conventional railway stations are related to these aspects. One example is that it is common to have a more commercial approach to the station services on HSR stations with more shopping and eating facilities. Since the major competition to a high speed railway line often is air transport it might be necessary to provide the same high comfort as in an airport. Other examples are the information to passengers which has to be sufficient and comprehensible as well as highly developed possibilities for modal transfer. To be able to influence the development of the transport market in the desired direction it is necessary to change people's behaviour and their view of railway transport. In that process, the aspects mentioned here are important since they probably are perceived as more important by travellers than for example the track layout on the station.

Another delimitation in this report is that it only studies the Oslo - Göteborg corridor and the concepts that are presented by the NHSRA and the CCAIC. Some of the results are unique for the chosen case such as those depending on the planned traffic pattern and the local conditions of the studied stations. However, there are also several results that are valid for other cases as well, particularly in Scandinavia. Many of the results from the literature study apply to high speed railways in Scandinavia in general such as the design regulations and the challenges connected to the winter climate.

6.2 Implementation of the method

A major part of the information used in this report has been gathered from different types of literature. One of the aims was to study literature from different countries where high speed railways are found today. Some such literature has been found but not to the extent that was desired. It has been particularly hard to find literature dealing with station design specifically. A good method to find more literature of this kind might have been to contact railway authorities in relevant countries. One reason to why literature on high speed railway systems is hard to find can be that those who have developed a technical system might not want it to be easily accessible by others. It is common that technical systems are sold to other countries that are interested in developing their own high speed railway system.

Another important part of this study is the interviews with experts within the high speed railway field. The original plan was to have meetings with representatives from both the Swedish and Norwegian railway authorities to be able to compare the opinions on different issues. Unfortunately it has not been possible to arrange such a meeting with someone from the Norwegian authority. When contacted, they referred to the written information in the NHSRA reports and their homepage. However, since a large part of the literature used in this investigation originates from Norwegian Ministry of Transport and Communications, the interviews with Swedish experts were more important to broaden the perspective.

6.3 Comments on the results

The result from the literature study showed that, for some of the design aspects that were studied, there is no fundamental difference between high speed rail traffic and conventional rail traffic. One example is that several parameters governed by national or international regulations are decided in the same manner and based on the same input data whether it is high speed rail or conventional rail but the outcome may vary depending on for example speed limits. However, it is important to mention that many of the regulations are minimum requirements and it is allowed to exceed them if necessary. It might be a good idea to strive for a higher standard in general when new high speed railway stations are built since that can increase the level of comfort and attractiveness. It is important to attract many passengers to achieve profitability for the railway transport system. The level of difference between a high speed railway system and a conventional railway system also depends on what type of HSR system that is considered. The system studied in this report has a fairly low speed limit compared to many other HSR systems in the world. It is also an integrated system where high speed trains and conventional trains are planned to use the same track. A HSR system with very high speed limits and where the high speed trains have a separate track is likely to become more specialized with greater differences to the conventional rail system.

Regarding platform safety, it has been shown to be one of the aspects for which high speed has a major effect on station design. But as well as for station design as a whole, the platform safety arrangements are also dependent on the type of HSR system. It can also be said that the speed limits for when trains passing adjacent to platforms can be considered a safety issue is a bit vague and different railway authorities has different recommendations for limit values. Another interesting aspects of platform safety is that high speed station design can be a difficult balance between safety gains and aspects like travel time and construction costs.

Chapter 5 presents suggestions for three different stations on the Oslo - Göteborg line but it is important to remember that these suggestions are based on several assumptions. The future traffic pattern on the line, the number of passengers that will use the stations and the construction costs are examples of parameters that are not known in detail. The Norwegian investigations on which this report is based are still in a very early idea stage and therefore all conditions have not been examined in detail. That is of course something that would have to be done if the plans are to be realized in the future. However, chapter 5 presents plausible future station layouts and the development of the suggestions shows what different parameters that would have to be taken into consideration and which fundamental challenges that will be encountered in the process.

The suggestion for Ed is to build a station with a high safety level since the speed of passing trains will be high. Since Ed is a relatively small village it can be discussed if a high speed railway station for passenger traffic should be built there at all. At present, three trains stop there each day but in the NHSRA it is suggested that future high speed trains will not stop there at all. Today it is the long distance trains between Oslo and Göteborg that stop in Ed. If the HSR plans will be implemented as suggested it has to be investigated if there is a sufficient market for other trains to stop in Ed, such as local trains, regional trains or Oslo - Göteborg trains that stop also at smaller stations. Another issue with the suggested station in Ed is that its location outside the village leads to a need for feeder traffic, for example busses, to and from central Ed, which is an additional cost. If the question of a possible closure of the station would arise, then the consequences of that would have to be analysed thoroughly before such a decision can be made.

The station layout for Sarpsborg that is suggested in the NHSRA is a rather complicated station that should serve several types of traffic. The solution with high speed tracks lowered under ground level requires more extensive construction works which might make it more difficult to implement safety arrangements. On the Rygge station the balance between costs and safety gains becomes clear. For safety reasons a new station with separate through tracks for high speed trains would have been the optimal choice. But since the existing station already allows high speed while it also has quite few passengers a total reconstruction would not be economically justifiable. The suggested measure with platform fences would likely make the platform environment feel safer but how the solution would be perceived by passengers is hard to predict since it has not been tried in Norway or Sweden before.

7 Summary and conclusions

This report is based to a major part on the railway concepts that are presented in the Norwegian High Speed Railway Assessment and the Concept Choice Assessment for InterCity. Two alternatives for the Oslo - Göteborg route are presented in the investigations and these alternatives have different numbers of stations and different design speed. There are some main features of the alternatives that affect the design of the stations. The planned lines have mixed traffic with freight trains, local trains and HSR trains which requires that trains can overtake each other on the line. On some parts of the line, existing tracks are to be upgraded while on other parts a completely new track will be built. This means that some stations have to be constructed in new locations and some only needs to be rebuilt slightly and hence there will be different challenges. The speed limits past stations will also vary which require different safety measures at different stations.

From the literature study it was concluded that there are many different aspects to consider when designing a railway station. Some of them are extensively affected by the high speed rail concept compared to a conventional railway concept while other aspects are more or less unaffected. Some possible differences regarding station design on high speed railways and conventional railways identified in this report are summarized below:

- The increased need for platform safety measures due to high speed is one of the major differences.

- The placement of the platforms in relation to tracks and the number of parallel tracks are affected by the platform safety requirements on HSR stations, since separate passing tracks might be necessary.

- HSR systems that are integrated with the conventional rail system will have a more heterogeneous traffic which can affect for example the required number of tracks on a station.

- Some issues with snow and ice become more severe at higher speeds.

- Station dimensions can be larger for HSR stations for several reasons:

    - The required platform width can be higher since there has to be room for appropriate safety measures.

    - The required distance between the tracks increases with the speed limit.

    - Long platforms can be necessary on HSR lines since longer trains often are used due to the high travel demand.

An important question to answer in the planning of a future HSR system in Sweden and Norway is what differentiates these countries from others where high speed railways are common. One answer to that is the Nordic climate with all the challenges that it brings as described above. Another important thing is that Sweden and Norway is sparsely populated which makes it harder to construct a profitable system. The economic calculations in the NHSRA concluded that the suggested HSR lines in Norway wouldn't be socioeconomically profitable. However, there are major uncertainties in the calculations at this early stage and the result also depends on what factors that are taken into account and how they are weighted.

The final recommendation for the three analysed stations includes a four track station in Ed with separate tracks for passing trains and an installation of platform fences in Rygge where the station otherwise will be kept as today. For Sarpsborg, the layout presented in the Norwegian investigations is considered to be suitable and it is suggested that the platforms are built wide enough to enable a future installation of platform fences. From the work with the station suggestions, it can be concluded that there are several alternative station layouts that can be suitable for the stations that are analysed in this report, especially in this early stage in the planning process. More input data is needed to make a definite recommendation but the presented suggestions are possible options. There are also several important aspects of station design that are not included in this report. A deeper analysis of those aspects would be an essential extension to the type of results presented in this report if the planning for high speed railway in Scandinavia is to be continued in the future.

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