KTH Järnvägsgrupp
Trafik och logistik

2012-06-29
Till Jernbaneverket i Norge

Offentlig høring av "Høyhastighetsutredningen 2010-12"

Härmed överlämnar vi ett remissvar på den norska Høyhastighetsutredningen 2010-12. Bakgrunden är dels vår forskning inom järnvägsområdet på KTH, dels att Bo-Lennart Nelldal varit medlem i styrgruppen och Oskar Fröidh i expertgruppen för höghastighetsutredningen.

Utredningen har varit mycket ambitiös och grundlig och vi är imponerade av med vilken framfart den bedrivits hela tiden inte minst från projektledningens sida. Allt utredningsmaterial har redovisats och varit mycket transparent. Utredningen har klart redovisat att det går att bygga höghastighetsbanor i Norge.

På några punkter anser vi dock att utredningen behöver kompletteras. De viktigaste är:

- Att ta hänsyn till att även godstrafiken kan använda höghastighetsbanorna
- Att optimera utbudet för persontrafik genom att anpassa tågstorleken till efterfrågan och använda effktivare tåg
- Att ta hänsyn till att även tågtrafiken kan minska sin energiförbrukning och därmed även utsläpp av koldioxid i framtiden

Alla dessa punkter förbättrar såväl den företagsekonomiska, samhällsekonomiska som miljökalkylen. En del material som sammanställts tidigare redovisas i bilagor. Materialet är delvis på engelska för att kunna läsas av utredningens konsulter.

Slutligen vill vi framhålla de stora vinster i tillgänglighet som höghastighetståg kan ge i Norge och till Sverige. Det gäller både tjänsteresor över dagen med en restid under tre timmar och för daglig arbetspendling mellan många orter med en restid på 1 timme samt för godstrafik över natten.

När det gäller banorna mellan Norge och Sverige så bör de utredas i samverkan mellan norska och svenska intressenter. Författarna till detta remissvar svarar själva för framförda synpunkter.

Med vänlig hälsning

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Bilagor:

1. Ökad tillgänglighet med höghastighetståg i Norge
2. Some comments of the Norwegian High-Speed Rail Assessment according to the economic appraisal
3. Possibilities to handle freight trains on planned high speed lines in Norway

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Ökad tillgänglighet med höghastighetståg i Norge

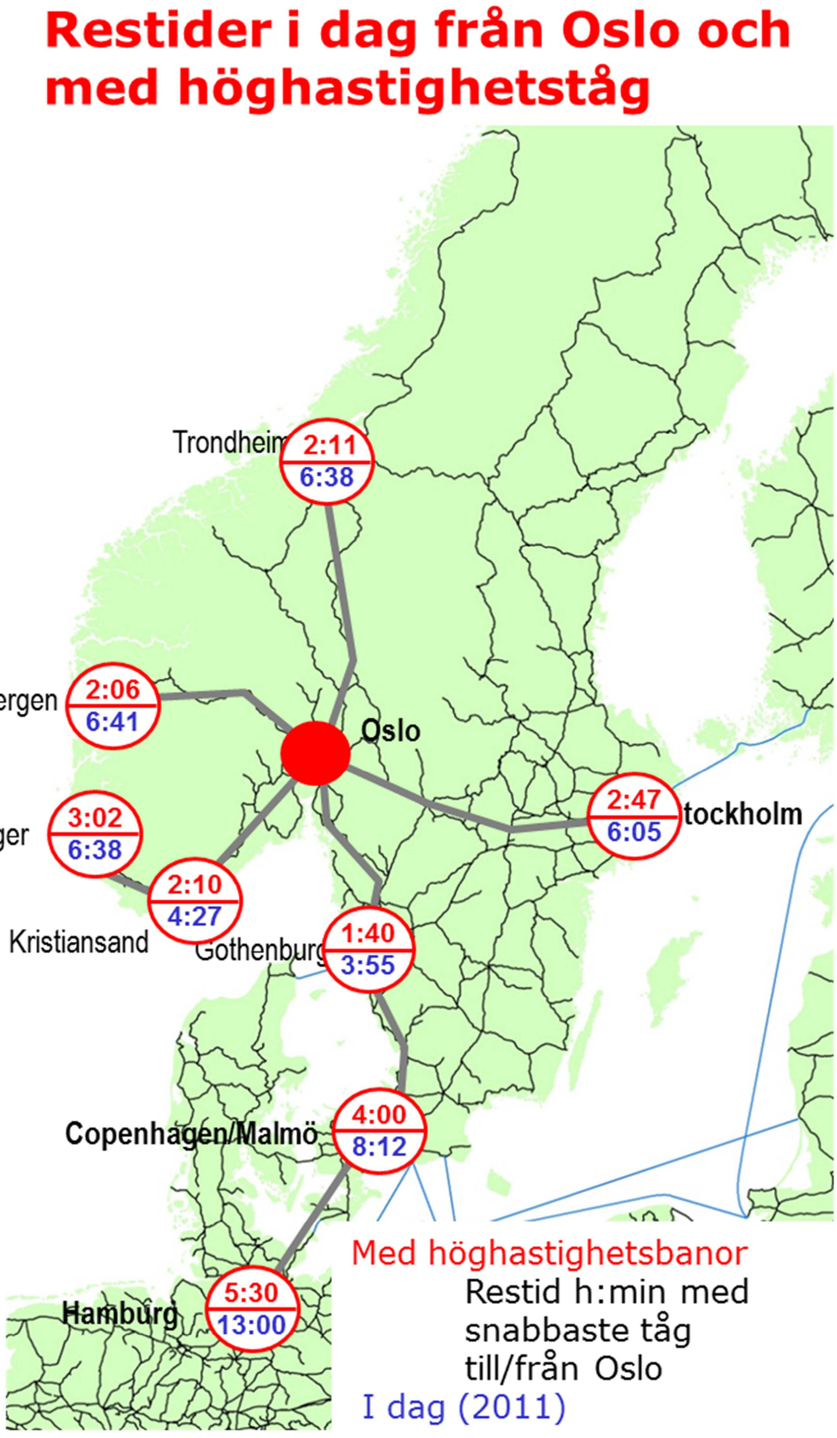
Tillgängligheten för persontrafik bestäms huvudsakligen av restiden. Det transportmedel som är snabbast skapar nya resmöjligheter och generar nya resor och blir marknadsledande. Viktigt för långväga tjänsteresor är att man kan resa fram och tillbaka över dagen. Det brukar vara möjligt vid ca 3 timmars restid. Med flyg kan man ta sig från och till Oslo inklusive matartransporter och terminaltid till de flesta större orter i Norge och några i Sverige. Motsvarande restiden med tåg i dag är i regel minst dubbelt så lång som med flyg och med bil minst lika lång som med tåg och dessutom är det ofta en krävande körning på det norska vägnätet. Pris, turtäthet och komfort har också betydelse men i ett långsiktigt perspektiv är det restiden som är avgörande för tillgängligheten.

För dagliga arbetsresor är en restid på ca en timme som är dimensionerande för daglig pendling. Det är i dag möjligt med tåg i Oslos närområde men tåget är sällan snabbare än bilen från dörr till dörr. Mellan en och tre timmar är det en glidande skala mellan daglig pendling och veckopendling men även här blir nya marknader tillgängliga för t.ex. tjänstesektorn om restiderna kortas.

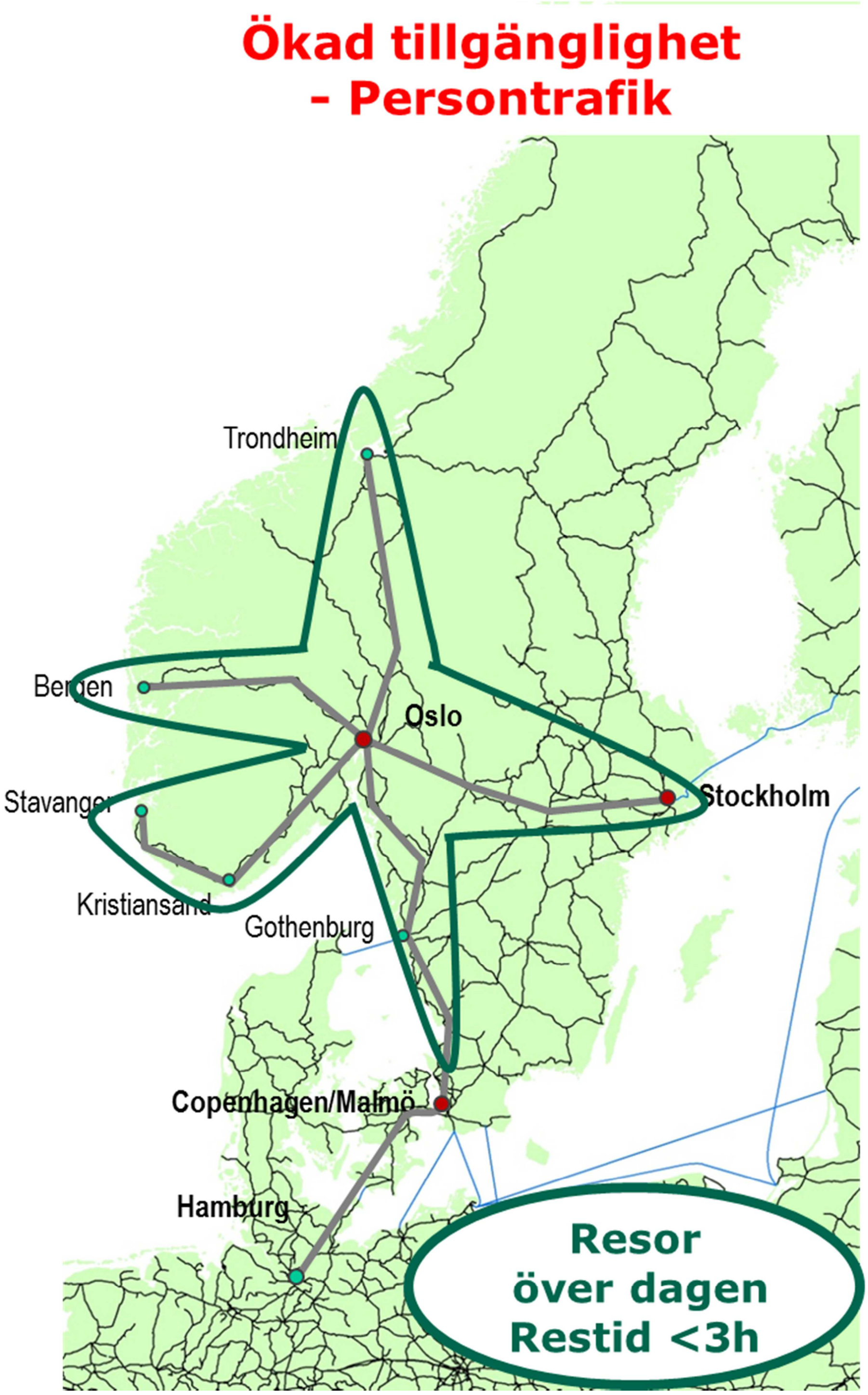
Det som händer om man bygger höghastighetsbanor är att restiderna förkortas radikalt så att helt nya resmöjligheter uppstår. Som framgår av figur 1 så blir restiden från Oslo till Trondheim, Bergen och Kristiansand drygt 2 timmar. Det är snabbare än med flyg från city till city i dag. Till Kristiansand och Stockholm omkring 3 timmar och till Göteborg 1 timme och 40 minuter. Dessutom når man många större orter längs höghastighetsbanorna på 1-2 timmars restid vilket ökar tillgängligheten både för arbetspendling och tjänstesektorns marknad. Det uppstår därmed helt nya resmöjligheter och ett helt nytt tidslandskap. Av figur 2 framgår det område som man når med mindre än 3 timmars restid från Oslo med tåg.

För godstransporter är det i regel transporter över natt som är dimensionerande. Många företag producerar på dagen och transporterar över natten för att deras varor ska kunna konsumeras nästa dag. Tidsfönstret mellan ca 18:00 till 06:00 är ofta dimensionerande, även om det finns en hel del mindre tidskänsliga varor som också kan transporteras på dagen. Eftersom persontrafiken huvudsakligen går på dagen så passar det bra att använda banan på natten åtminstone för det tidskänsliga godset. Transporttiderna för godstransporter blir 30-40% kortare än i dag på grund av att höghastighetsbanorna är rakare, dubbelspåriga så man slipper tågmöten samt att det går att köra fortare. Tillgängligheten för godstransporter ökar i och med att man kan nå ett större område övernatt. Av figur 3 framgår det område som man når från Oslo övernatt, vilket innebär att näringslivets marknad kan utvidgas.

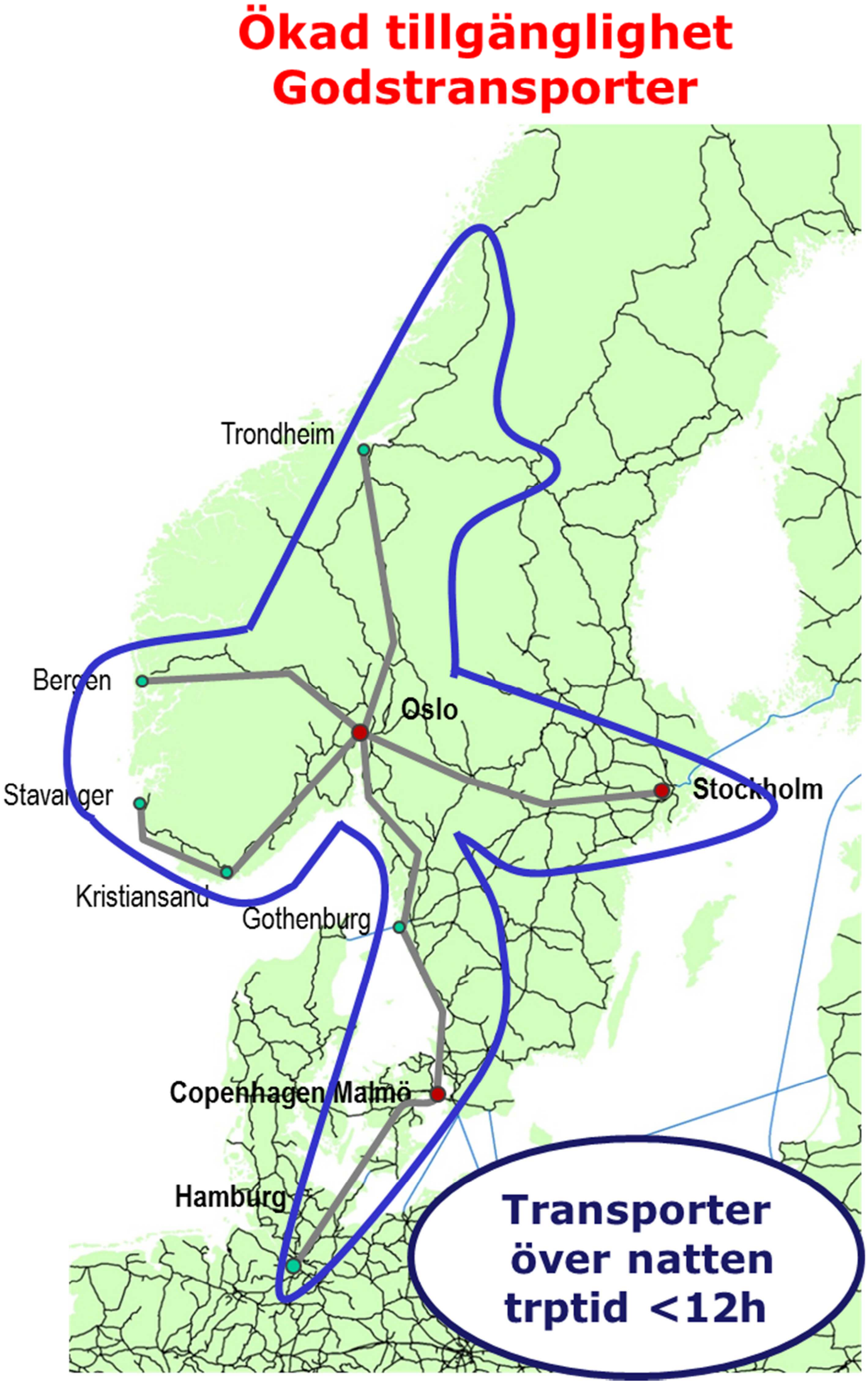
Det finns i dag inget annat transportmedel som kan öka tillgängligheten i så hög grad som en modern järnväg. Tåget blir snabbare än både bilen och flyget mellan många orter för persontrafik och kommer att generera helt nya resmöjligheter. För godstransporter blir det snabbare än lastbilen och skapar nya marknader för norsk industri. Det är också det energieffektivaste transportmedlet när det gäller stora volymer och långa avstånd som det här är frågan om som går att köra på elektricitet helt utan utsläpp..



Figur 1: Höghastighetsbanorna ger extremt korta restider i Norge. Restiderna blir endast en tredjedel till hälften av dagens restider med tåg och bil och i flera fall kortare än med flyg från city till city.



Figur 2: Ökad tillgänglighet för persontrafik vidgar människans revir. Restid på ca 3 timmar möjliggör resor över dagen.



Figur 2: Ökad tillgänglighet för godstransporter vidgar näringslivets marknad. Transporttider på 12 timmar möjliggör transporter över natten.

Some comments of the Norwegian High-Speed Rail Assessment according to the economic appraisal

We have reviewed preliminary information regarding the socio-economic analysis of possible Norwegian high-speed Railways. The results raises a number of questions regarding used assumptions, parameters and methodology. The High-speed investigation has emphasized transparency and involvement in the work. This has clearly been the case regarding railway line design, but to so far a lesser extent regarding the socio-economic analysis

We know that complete calculations will be presented later, but because of a very tight schedule it may be too late to discuss the result then. Based on what was presented in the December 12th 2011 seminar in Oslo we hereby present some questions we think is important to discuss and if possible also taken into account in the calculations. Perhaps we have misunderstood something that was presented on the seminar and perhaps some of these questions already have been clarified by the investigation, but anyhow it will be too late after the official presentation.

Economic risk and calculation period

Managing the economic risk

The combined effects of the economic risk management in the CBA mean a serious negative impact of the result. The components are:

- Discount rate, where 2.5% of a total 4.5% is motivated by risk [1]
- Calculation period, 25 years [1] for a long-term investment as high-speed lines with technical lifetime of 30-75 years depending on components [1]
- Risk premium of 20% added to the project cost in HSRA
- Optimism bias, where 28% extra is assigned to project costs in the CBA due to a hypothesis of a systematic underestimation of today's construction costs in Norway (although not proved).

Overall, this is a considerable risk premium which increases the costs, and the two first points also favours short-time projects (with a short pay-off like ERTMS signalling) over long-time (like new lines). Risk premium must be associated to the accuracy of the construction cost calculation, and there is always a most likely value (for example "doesn't exceed the most likely cost NOK 10,000 million with 50% probability").

Transportation infrastructure project (among other types of projects) have a reputation for cost overruns. As a response, contingencies are added to cost estimates. This has been included as a standard practice in the UK. What is less known, is that Norwegian governmental projects, including railways, during the last ten years have had an average cost under run of 2.3% [2]. It is therefore vital to make sure that 20+% optimism bias is not added to experience based cost estimates.

The investigation has shown that the costs per kilometres for building HSR in Norway is much higher than in other countries, but adjusted for the higher share of tunnel approximately the same. So the calculated costs do not seems to be too low according to international experience.

Calculation period

Provided a 1.3% annual increase in demand, will the benefits of 40 years calculation period be 27% larger than after 25 years and of 60 years 46% larger. Replacement costs (except rolling stock) occur after 30, 40, 60, or for the most costly part, the substructure, after 75 years [1] which have to be included, as well as the rest value. If no demand increase is expected, the difference will be smaller but still significant.

[1] This paper was written before the final report was presented so some facts may have changed after this.

An alternative socio economic analysis has to be carried out. Research has shown that the socio economic profitability of railway investments vary depending on the applied methodology [3]. British methodology includes a calculation period of 60 years, as well as an adjustment of future cost and benefits, based on assumed GDP growth. GDP growth is typically assumed to be between 1.5 and 2% annually. Until the full analysis is available, it is still unclear if these features are included in the socio economic analysis.

The period of appraisal is set to 40 years in the HEATCO recommendations [4]. Sweden have adapted to the period recommended by HEATCO, whilst Denmark and Britain still keep their old values of 50 and 60 years. France has 50 years, Germany 36 and an indefinite period is used in Switzerland.

In the Norwegian method [1] the period is recommended to be 25 years in general, but it is also stipulated that the period will be proved for each project. We think that investment in HSR is that kind of project which definitely had to take a longer period into account.

Freight transports

The effects on freight transports must be taken into account in the CBA. It is possible to operate freight trains even if the line is going to be built with 25‰ maximum incline (there are inclines on 20-25‰ already today in Norway). If the lines will be built with double track, which is proposed, there will be capacity left for freight trains in many cases. From a capacity point of view, it is possible to operate freight trains at night time and also at day time if the frequency of passenger trains are not too high i.e. one train per hour. On the lines to Sweden, which are not so hilly, it may be possible to build the lines with 12.5‰ maximum incline.

Freight trains on the high-speed lines will lead to:

- Decreased operational costs, if the freight trains use the HSR-lines because of shorter transport times and longer trains [5]. Longer trains will lead to fewer trains for the same quantity of freight.
- Higher market share because of lower cost and shorter transport times which also can widen the market or enable overnight transports in a larger geographical area.
- Less investments in longer crossings stations, more tracks and capacity in the conventional network.

Freight transports in Europe with rail and truck will increase with 29% in Europe from 2010 to 2030 and with 51% to 2050 in tonnes-kilometres [6]. Forecasts for Sweden are in the same order but international transports will grow faster than national.

A method to calculate freight is shown in the Norwegian handbook [1, p. 70] where it is possible to calculate the effects with an elasticity formula on the basis of the freight volumes of rail. Typical costs for freight trains are also shown, and these costs are in the same order as the costs used in the calculation of freight costs in [5].

Passenger transports

Adopt the supply to the demand

It seems that a standard 8-wagon ICE-train has been used in the calculation on all lines despite the actual demand. At first the train size must be adopted to the demand. There is possibility to use train-sizes in a range of 4-8 wagons and if necessary to multiple train sets at peak hours to handle the demand with a high average load factor. It is also possible to reduce the frequency at times with lower demand but this will also reduce the demand.

Train operating costs

Train operating costs have to be in line with the demand, and best technology at the time of opening should be used. Passenger numbers presented for Oslo-Trondheim indicated 161-184 passengers/departure, which means a high-speed train with approx. 300 seats if a 60% average load factor is assumed.

If a German ICE3 train with 444 seats as the standard high-speed train has been used for the calculation this is not optimal. This is a high-speed train with continental carbody, although the Norwegian reference gauge and TSI allows wider trains. Operation costs for the ICE3 is estimated by the Gröna tåget ("Green Train") cost model to NOK 170 per train-km, or NOK 0.64 per passenger-km at 60% load factor. The model is described in [7].

Estimates for Gröna tåget, an efficient wide-body high-speed train concept, suggest NOK 95 (4 cars) to NOK 140 (6 cars) per train-km, or NOK 0.52 per passenger-km at 60% load factor for a 300-450 seat version. This is almost 20% lower operating costs than for the ICE3. However, if a ICE3 444 seat train is used for 164-184 passengers, the resulting load factor would be approx. 40%, and the cost then increases to NOK 0.90 per passenger-km. A 300 seat Gröna Tåget would under those circumstances reduce the operating costs by 42%.

Yield management and high load factor

It has been said that a higher price will be more optimal because the total incomes will be higher. But with a modern flexible yield management pricing it is possible to both achieve a high demand and a high revenue and at the same time optimize the load factor.

In Sweden where this system has been adopted the average load factor on all X2000-lines now has reached 72% (passenger kilometres/seat kilometres) [8]. This means that the trains are full in peak-hours. This is despite the trains have stops on the line and that the demand is not equal in both directions.

This high load factor will be reached with a wide range of ticket prices and services. The cheapest ticket costs SEK 95 (NOK 80 or EUR 10) and the most expensive SEK 1,800 SEK (NOK 1500 or EUR 200). The average yield has at the same time not increased so much, but the total revenue has increased substantially. At the fiscal years 2006-2010 SJ's profit was SEK 400-800 million per year [9].

The importance of this is that it is possible to both reach a high demand and high revenues, and this will affect the socio-economic calculation in a positive way.

Saved costs for supply on conventional lines

Because the long-distance trains will move to the HS-lines the supply of conventional trains will be reduced on the conventional lines, and there is a possibility to save costs.

Demand and the train-air market

Demand calculations presented included for the rail-air market a general 60% HS train share and 40% air share. The flight mode will lose 50% of the present travelling without any decrease in frequency assumed.

This is in particular a questionable assumption. Economy of flight operations will be worse when half of the passengers leave in favour of the HS train, and to keep the same fares with the same (large) aircrafts requires subsidies, alternatively smaller aircrafts which will increase the air fares. Experiences from international markets strongly suggest that the flight frequency would be reduced, which increases the demand for HS train even more and gives lower operational costs per passenger-km alternatively demand for a higher frequency of HS train departures (a so called Mohring effect).

Conclusions

We suggest that a socio-economic calculation will be figured out with these revised prerequisites:

- Calculation period 60 years to match the long-time benefits
- No extra risk on costs
- Adjustment of future cost and benefits, based on assumed GDP growth
- Adopt the supply to the demand according to the train size
- Taken freight transports into account

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[6] EU-project TOSCA: http://www.toscaproject.com

[7] Fröidh, O., 2010. Resande och trafik med Gröna tåget. KTH, Stockholm (An English version is scheduled for late January, 2012)

[8] Compendium in Railway Traffic Planning (KTH), statistics from SJ.

[9] SJ Annual report, financial report 2010.

Bo-Lennart Nelldal

Possibilities to handle freight trains on planned high speed lines in Norway

Train types

The question of how handle freight trains in Norway if there will be built real high speed lines is important because today´s lines are single track and have rather short meeting stations and high grades. To build them with 12,5 ‰ grade just to handle freight trains will be very expensive because a higher share of tunnels but if they can be built with 25 ‰ grades the investment cost will be lower. So the question is if it is possible to operate freight trains on high speed lines with 25 ‰ grades.

We can assume that there are three segments of freight trains in Norway:

1. Heavy wagon load trains, mostly unit trains with a maximum speed of 100 km/h.
2. Intermodal trains of normal weight, today mostly with a maximum speed of 100 km/h and tomorrow probably 120 km/h.
3. High speed freight trains with almost the same speed as the passenger trains.

Category 1 I think in general will use the conventional old railways and they will be even heavier and longer in the future. Maybe they can use some sections of the HSR links under special conditions.

Category 2 I think can use most part of the HSR links if sufficient capacity is available. I think there is a rather big market for this and 120 km/h is technically possible already today for most locos and many newer wagons.

Category 3 can of course use the HSR but here I think the market is small so even if it will be established it will be few trains. An alternative dedicated high speed freight trains might be to provide a small freight compartment in the high speed passenger trains, to be loaded and unloaded from the passenger platform.

If you study the incremental development of freight trains you can see that there has been a successive increase of both speeds and axle loads. In the 1970s the normal freight train speed was 80 km/h but increased to 100 km/h in the 1990s, while axle loads have risen from 20 to 22,5 tons and are now being raised to 25 tons for some commodities such as logs in Sweden and Norway. Technical development of tracks and vehicles has made this possible.

Already today many wagons are built for 120 km/h. If high speed lines are going to be built in Norway they will not be completed before 2020 and it is possible that at that time many intermodal trains have a maximum speed of 120 km/h. There are several precedents of locomotive-hauled freight trains operating at 160 km/h in Europe, including France, Germany and Sweden, but perhaps too expensive with today´s technology and market. At this speed and today's normal signal distances there must be disc-brakes on the wagons.

The Swedish mail trains have a top-speed of 160 km/h but this can be categorised as category 3.

Cost and market effects

If freight trains will use double track high speed lines the average speed will be higher than on the old single track lines and the transport time will be shorter. The high speed lines are often shorter and with higher top speed possible because of no restrictions for curves. Also the average speed will be higher because of the double track there is no need to stop for meets, but sometimes there is a need for high speed trains to overtake freight trains. This will be common in day-time but not so common at night-time.

One example: Oslo-Trondheim is today 553 km with HSR 483 km in Østerdalen route. Transport time today is 8:15 with 100 km/h top speed and an average speed 65 km/h. With HSR route and 483 km an average speed of 92 km/h with top speed 120 km/h and transport time 5:15; this is 40% reduction in transport time.

When the customers and operators say it does not matter because the transports are overnight so it is enough that it will reach Oslo in the morning. But shorter transport time will reduce the cost for train staff and will raise equipment utilisation. In this case it will also be possible to have two trips per night; from Trondheim 18:00 to Oslo 23:15 and from Oslo 00:15 to Trondheim 5:30 and this will really give a lower cost because the capital will be used two times instead of one. At the freight terminals, later departure and earlier arrival will also reduce load peaks, and will create margins to handle more freight with the existing capital assets.

From a market perspective shorter transport time will also widen the over-night-market. In this case from Trondheim it will be possible to reach Gothenburg overnight and also Malmö-Copenhagen, and this is very important for the industry.

There are also other possibilities; today the crossing stations restrict the train length to 450 m on many lines in Norway. With a double track the restriction is the overtaking stations and the marshalling yards and it is possible to build them for 750 m trains ore even longer in the future. This will also reduce cost per transported wagon significantly and will increase capacity because it will reduce the number of trains needed for transporting a certain quantity.

The alignment problem

If we want to have freight trains on HSR we say we must have maximum gradients of 12,5 ‰. This is advantage because you only need one engine (El16 or Rc) to operate a train with1300-1400 tonnes, with a new TRAXX-engine it may be possible to operate at least 2200 gross tonnes trains. If you build the line with 25 ‰ grades it is not impossible to operate freight but in principal you need two engines instead of one or you can haul half the gross tonnes with one engine. That means one modern locomotive can handle 1100 gross tonnes.

You must also take into account braking performance for freight trains going downhill. But this can be handled with longer braking distances and on a future HSR line the ERTMS signalling system L3 will be implemented so this is no principal problem.

The energy consumption will not increase with 25 ‰ instead of 12,5 ‰ if the height difference between the lowest and the highest point of the line is the same. You need approximately the same amount of energy to “lift up” the train 1000 m on a shorter (40 km) 25 ‰ grade as on a longer (80 km) 12,5 ‰ grade. Actually the running resistance and the air resistance will be the same so it will in practice use less energy but that is not a major question.

The cost for train operation with different strategies

Today CargoNet's intermodal trains are usually 450 meters with an estimated average weight of 1100 gross tonnes which varies depending of the number of empty containers. Today´s lines in Norway have grades of up to 20 ‰ – 25 ‰ so it is not unique to operate under these circumstances. So it must be clarified that it is absolutely not impossible to operate freight trains in 25 ‰ grades.

Anyhow the cost will be affected and therefore the cost for operating freight trains in different cases will be presented here. The cost has been calculated with a cost model developed at KTH. It includes capital costs for engines and wagons and all the operating costs: engineer, energy, maintenance, risk and track access fees in Sweden.

The prerequisites for distances and possible time tables are shown in Figure 1. The cost per TEU (20 foot equivalent container) versus train length is shown in Figure 2. At first, the cost for transportation on today´s line with one loco is presented as a reference. The cost with a 450 m train, which is maximum today, is 900 SEK/TEU and train gross weight approx. 1100 tonnes. With a new shorter line and shorter transport time the cost will be 800 SEK/TEU with the same train length and gross weight that means approx 10% lower.

But on a double track line it is possible to handle longer trains. The length depends on the length of the tracks in overtaking stations and in the terminals. We here assume that the stations will be planned for 750 m trains. A 750 m intermodal train will have a gross weight of 1700 tonnes and that means you must have two locos. With two locos the cost for a 750 m trains on a HSR line will be 825 SEK/TEU that means approx. 10 % lower than today.

However, with the shorter transport time it is possible to use the locomotive for two trips per night. The wagons are probably not possible to use two times because it takes time to unload and load them and the time window is not enough on this line for that. In this case, the capital cost for the locomotive will be halved per trip and that makes a cost of 650 SEK/TEU ore 30% lower than today.

With two modern locomotives it is possible to handle 2200 gross tonnes in 25 ‰ grades and that means that the train length will be 1000 meters and the cost will be 575 SEK/TEU or 30% lower with two trips per night for the locos. This is optimal from the traction point of view but in this case there is also a need for investments in longer overtaking tracks and additional cost which has to be calculated from a socioeconomic point of view. But that means also that two trains today with 1100 tonnes gross weight will be replaced with one train on HSR.

The capacity problem

Today most freight trains are operated at night because the industry produces during day time and transports at night. But there is also demand for transports at day time, especially for international transports that will take more than one night. Also there is a wish both from the industry and the operators to use their resources more effectively 24 h per day.

Anyhow there will be a lot of free capacity for freight on HSR at night. There is also a need to maintain the track but there are possibilities to do that at weekends and there is also a possibility to close and maintain a section of one of the double tracks. This is a complication but it is not impossible to handle it like it is done on all double track lines with 24 h traffic in the world today.

It is also possible to operate freight trains on day times under the right conditions. Olov Lindfeldt has shown in the report about passing loops (WSP 20/12 2010) that it is possible to operate 4 freight trains per hour if there is one HST every hour in 300 km/h stopping every 100 km with a passing loop distance of 60 km and a freight train top speed of 140 km/h (this is only one example of many).

Figure 1: Transport times on today´s and new HSR line Oslo-Trondheim

Oslo-Trondheim				
	Distance	Time	km/h	Max speed
Todays line	553	8:15	67	100 single track
HSR line	483	5:15	92	120 double track
Time table examples				
Todays line				
Dep	Trondheim		19:00	
Arr	Oslo		3:15	
HSR line				
Dep	Trondheim		18:00	
Arr	Oslo		23:15	
Dep	Oslo		0:15	
Arr	Trondheim		5:30	

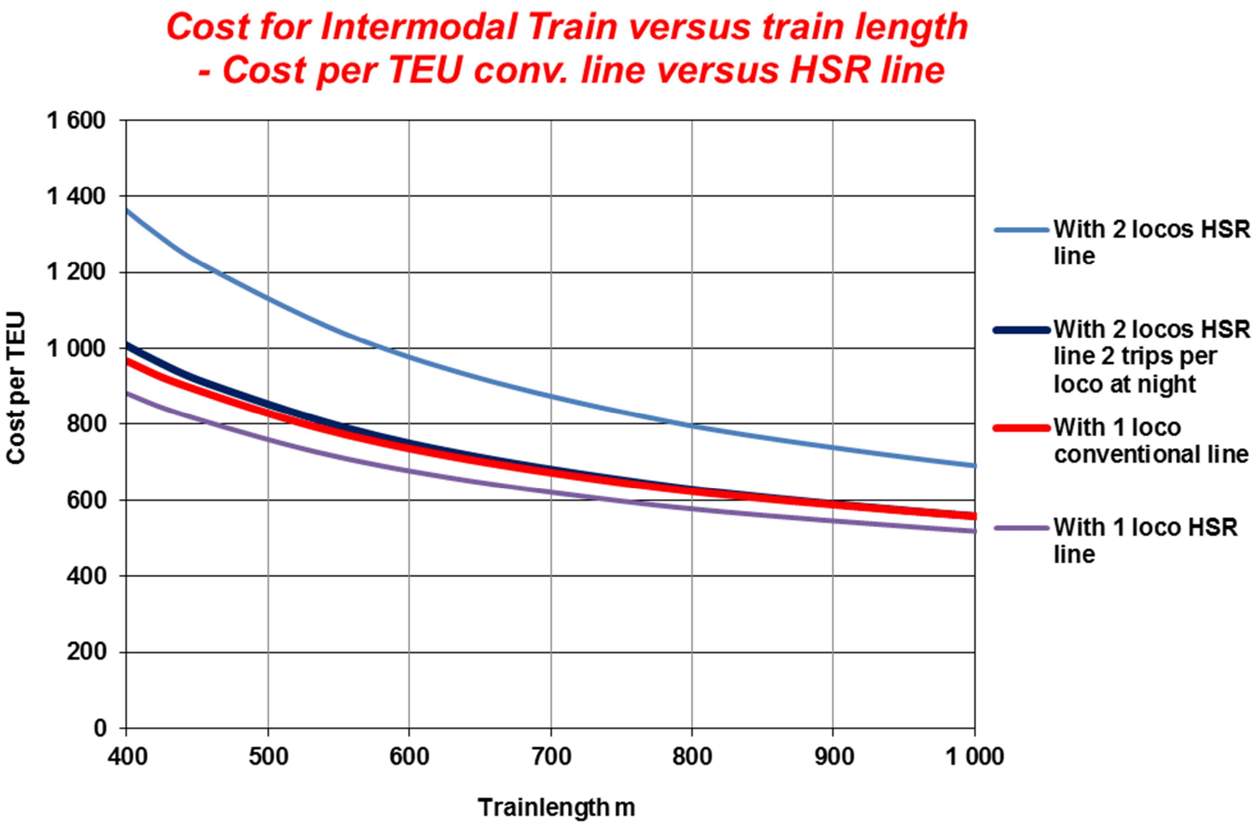

Figure 2: Cost for operating intermodal trains on a conventional line versus HSR-line under different operating conditions.

It is more complicated to combine regional trains and high speed trains especially if both have high frequency because they are more dependent on exact stopping times at the stations and overtaking will be more negative for the passengers than for freight which only has one origin and one destination to reach on time. Then to combine both HSR, regional trains and freight trains on the same line and at the same time it will be more complicated. That is what we do now in Sweden and this will force us to build real high speed lines beside our double track lines, so in that case you might sooner or later build four tracks instead of two.

Conclusion

Today intermodal trains in Norway are 450 m long and with approx 1100 tonnes gross weight and the grades on the old lines are up to 20-25 ‰. That means that it is possible to operate intermodal trains also on a HSR with 25 ‰ grades in the future. Of course there is an advantage for freight to build new HSR lines with only 12,5 ‰ grades as stipulated in TSI, but if this will cost too much money because higher tunnel share length this must carefully be proven.

The advantage to operate freight train on a HSR line compared with today´s lines are that they are planned to have double track that means that you can avoid crossings with other trains and that it will be possible with longer trains. On the other hand freight trains have sometimes to be overtaken by high speed trains and in this case the length of overtaking stations will be the dimensioning criteria. In Norway there is a strategic target to prolong the crossing stations to 600 m on most lines but on Oslo-Kornsjö and Oslo-Charlottenberg the target is 750 m as in Sweden.

From a capacity point of view it is possible to operate freight trains on a HSR line if the frequence and mix of passenger trains is not too high. With one HSR per hour it will be rather easy. Raising top speed from 100 to 120 km/h which is technically possible already today will make it easier to combine with passenger trains, but will reduce the maximum load that can be handled per train. Operating most freight trains at night time will also reduce these problems on more congested lines.

With a modern locomotive with 5,6 MW it is possible to operate a train with one loco on a line with 25 ‰ with 450 m length and 1100 gross tonnes. Because of shorter distance and transport time on HSR compared with today´s line the cost per container will be reduced by 10 %.

To handle 750 m train length with 1700 gross tonnes in 25 ‰ grades you must have two locomotives. This will be more costly but with the extended train length the transportation cost per container will decrease. If the engine can be used for two trips per night, which is possible with the shorter transport time, the cost will be reduced by 30%. That also means fewer trains than today for the same transport weight which is positive also from a capacity point of view.

The conclusion is that it will be possible to operate intermodal freight trains also on future high speed lines with 25 ‰ grades. It will be more efficient than to use today´s single track lines both from the capacity point of view and from the customers point of view because of shorter transport times and lower cost. It will also make it possible to avoid some investments in the conventional network and to release capacity for regional trains and heavy freight trains on these lines.