HIGH SPEED RAIL ASSESSMENT PROJECT
CORRIDOR NORTH · OSLO - TRONDHEIM

DELIVERY 2 - PHASE 3

ALIGNMENT STUDY

RAMBØLL

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

This report describes how Rambøll envisages some scenarios for future railway development between Oslo and Trondheim. The main task has been to analyse and present High speed railway (HSR) solutions that can compete with air travel, i.e. with travel times Oslo-Trondheim below 2 hours 45 minutes.

This study is purely concentrated on finding the technically best HSR alignment from Gardermoen to Trondheim based on given design parameters and minimizing negative environmental and social impact. Our conclusions and recommendations are not based on any discussion of market impact except for reaching the end-to-end travel time.

All alternatives for HSR will have significant effects on society, the environment, the economy, public investments and travel patterns between Oslo and Trondheim. A new line will also have an impact on development of railway freight traffic. These factors are described in a separate report from a different consultancy company for Jernbaneverket.

Having analysed and discarded various possible railway alignments, Rambøll has studied three main alternatives for HSR Oslo-Trondheim: Gudbrandsdalen, Rondane and Østerdalen. All alignments start at Gardermoen and have a possible extension from Trondheim to Værnes.

	Distance Oslo-Trondheim (km)	Design speed (km/h)
Gudbrandsdalen	497	330
Rondane	462	330
Østerdalen	456	330

The Gudbrandsdalen route leaves the intercity line at Tangen and runs via Hamar, Lille-hammer, over Dovre and Soknedal to Trond-heim. The Rondane alternative turns north-east at Ringebu, continues in a long tunnel through Venabygdsfjellet, runs outside Rondane national park to Kvikne and Soknedal to Trondheim. The Østerdalen route branches off at Tangen, passing Elverum up Østerdalen valley to Tynset, where freight traffic is routed via an upgraded Røros line, and passenger traffic turns left over Kvikne and Soknedal to Trondheim. The freight line joins the new high speed line again at Lundamo.

As the new railway should be a viable alternative to air travel, 330 km/h has been set as the design speed for the assessments. This alternative is called D1/D2. We have also carried out an analysis showing how a 250 km/h alternative would impact on the major parameters (cost and travel time). For the Østerdalen alternative, the 250 km/h alternative (named 2* in this report) could be an interesting possibility. For Rondane and Gudbrandsdalen, 2* is considered to be similar to the D1/D2 alternatives, and are therefore not examined in detail. Stopping patterns would also obviously be of major importance for travel times and the end-to-end market possibilities.

For the Gudbrandsdalen and Rondane alignments, a 330 km/h alignment via Gjøvik is also presented as a possible future alternative to the route via Hamar, when the intercity train infrastructure has reached its capacity. For the Østerdalen alignment, a future alternative route designed for 330 km/h from Gardermoen to Tangen is also included for the same reasons.

Rambøll assumes that the on-going intercity rail planning and construction continues as planned. Planned intercity lines have been incorporated in this study where that is relevant.

Rambøll's corridor survey and mapping in our first report in this project documented that of the three potential corridors, Østerdalen has the least negative impact on the environment. The impact analysis in this document of the actual alignments also finds that Østerdalen has the least negative overall environmental impact.

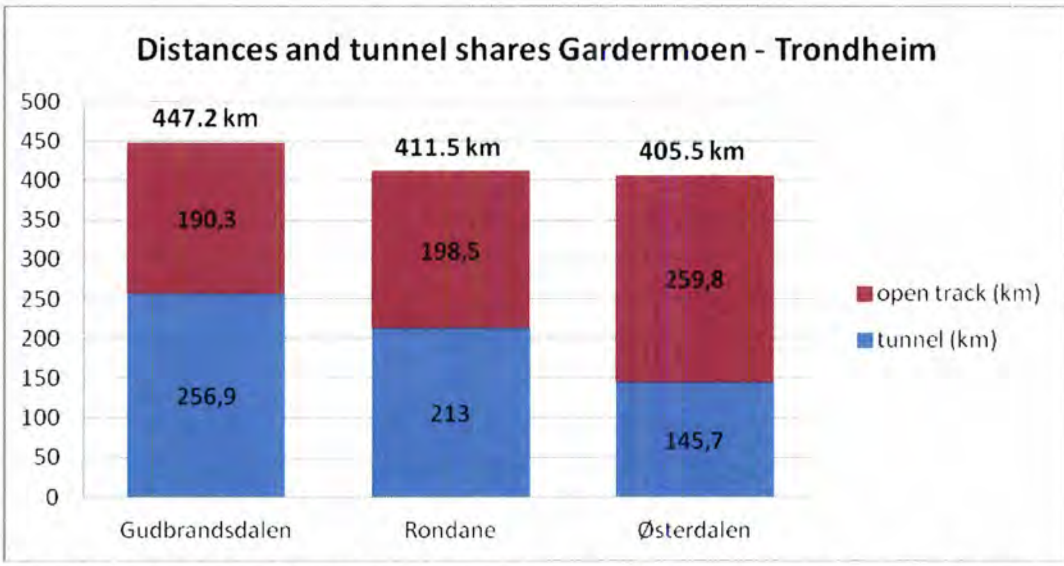
The construction period is estimated to between 9 (Østerdalen or Gudbrandsdalen) and 14 years (Rondane), and will have a number of consequences (mass deposits, road traffic disturbances, tunnels, environmental issues, etc). Tunnel constructions are the most time-consuming elements. Surplus masses are another interesting and important issue when analysing the tunnel construction. For Gudbrandsdalen, the surplus masses amount to more than 72 million cubic meters solid rock. This equals a queue of trailer trucks loaded with rock about 100 000 km long.

Rambøll has also investigated a non-high speed scenario, where the target was to reduce travel time by 20 % for passenger trains. This can be done, but we stress that this scenario (called scenario B) is not a high speed alternative, nor can it be a step towards a high speed railway.

It is important to note that capacity issues south of Gardermoen and at Oslo S are *not* part of this study, nor are any possible capacity problems related to local passenger traffic close to Trondheim studied. Also, geotechnical challenges in the Trondheim area, including a possible new station in Trondheim, will require considerable further study in the later phases, should Jernbaneverket decide to proceed with further planning for high speed rail Oslo-Trondheim. Some possibilities and considerations regarding Trondheim are described, for instance that Rambøll recommends Lerkendal as a new HSR station in Trondheim.

Rambøll's conclusions are as follows:

- It is technically possible to build all three HSR alignments presented in this report, but the differences between the alternatives are significant
- No particular exceptional risks for the construction of HSR lines in this corridor have been identified – well-known technology can be used
- Gudbrandsdalen is the longest route between Oslo and Trondheim, has the highest number of tunnels and highest tunnel share
- The Rondane alternative has a particular challenge in the very long Venabygdsfjellet tunnel
- Østerdalen is the shortest, and therefore the fastest, alternative between Oslo and Trondheim. It will also have the least amount of tunnels
- Østerdalen has the least negative environmental impact.



As the figure shows, the difference between the shortest and longest alignment is 41.7 km, and the longest alignment has 111.2 km more tunnels than the shortest one.

	GUDBRANDS-DALEN				RONDANE				ØSTERDALEN					
Section (Alternative)	Tangen - Lillehammer (D1)	Lillehammer - Ringebu (D1)	Ringebu - Soknedal (D1)	Soknedal - Trondheim (D1)	Tangen - Lillehammer (D1)	Lillehammer - Ringebu (D1)	Ringebu - Soknedal (D2)	Soknedal - Trondheim (D1)	Tangen - Koppang (D1)	Tangen - Koppang (2*)	Koppang - Tynset (D1)	Koppang - Tynset (2*)	Tynset - Soknedal (D2)	Soknedal - Trondheim (D1)
Total Length [km]	87,6	32,9	221,3	56,8	87,6	32,9	185,5	56,8	117,7	121,6	90,3	90,2	92,1	56,8
Total Tunnel Length [km]	45,6	27,1	134,6	39,9	45,6	27,1	90,6	39,9	23,6	23,4	38,1	27,3	34,4	39,9
TotalTunnel-Share [%]	52,0	82,3	60,8	70,3	52,0	82,3	48,8	70,3	20,0	19,2	42,2	30,3	37,4	70,3
Total Open Track [km]	41,9	5,1	80,5	15,5	41,9	5,1	90,3	15,5	90,8	96,9	50,2	61,9	55,4	15,5
Total Open-Track-Share [%]	47,8	15,6	36,4	27,2	47,8	15,6	48,7	27,2	77,2	79,7	55,7	68,7	60,1	27,2
Total Bridge Length [km]	0,1	0,7	6,2	1,4	0,1	0,7	4,6	1,4	3,3	1,3	2,0	1,0	2,3	1,4
Total Bridge-Share [%]	0,1	2,0	2,8	2,5	0,1	2,0	2,5	2,5	2,8	1,1	2,2	1,1	2,5	2,5
Max gradient [o/oo]	12,5	12,5	12,5	12,5	12,5	12,5	35,0	12,5	12,5	12,5	12,5	12,5	35,0	12,5
Enviornmental impact (overall)	**High/Medium**				**High/Medium**				**Medium**					
Landscape	High/Medium				High/Medium				Medium					
Cultural heritage	High				Medium/High/High				Medium					
Natural environment	Medium				Medium				High					
Natural resources	Medium/High				Medium				Medium/Low					
Community life and recreation	High/Medium				Medium/Medium/High				Medium					

Gardermoen - Trondheim	**Gudbrandsdalen**	**Rondane**	**Østerdalen**
Total Length [km]	447,2	411,5	405,5
Total Tunnel share [%]	57,4	51,8	35,9

2. INTRODUCTION

Jernbaneverket (The Norwegian National Rail Administration) was assigned the task of analysing a possible high-speed network in Norway as a part of the National Transport Plan 2010-2019. The project has to be finished before February 2012. Afterwards, relevant results and recommendations will be integrated in the National Transport Plan 2014-2023. The task is divided into three phases, of which Phases 1 and 2 have already been completed.

The Project Steering Group of Jernbaneverket chose Rambøll to do the analyses in Phase 3 for Corridor North Oslo – Trondheim. The final reports from Rambøll are:

- delivery 1 that consists of: Extracts from phase 1 and 2, methods and boundary conditions to be used in phase 3, defining the corridors between Oslo and Trondheim and survey of corridor North
- **delivery 2** (this document) that consists of: consideration of how to operate a High-speed Railway (HSR), drawings and descriptions of alignments of the different scenarios and prioritized alignments, market evaluations to localize stations, statistics of the routes, descriptions of tunnels, substructure and bridges, construction work and environmental impact (except energy-consumption and climate) of prioritized alignments.

The conclusions and recommendations in this document are developed by Rambøll, and do not necessarily reflect Jernbaneverket's view of the subjects at hand. The project team has consisted of experts in the various relevant fields from Rambøll and our partners IGV in Germany and ILF in Austria.

The analyses in phase 3 are made for different scenarios:

Scenario	description
B	**Upgrade:** A more aggressive development of the current infrastructure than existing plans, looking beyond the 'InterCity' area. The target travel time is a reduction of 20 % compared to scenario A.
2*	**Design speed of 250 km/h:** This is a scenario with mixed traffic, i.e. both passenger and freight traffic, but with a maximum speed of 250 km/h. (250 km/h is the lowest speed which is still defined as high speed rail.)
D	**Design speed of 330 km/h:** This involves the implementation of newly built, separate HSR lines with a maximum speed of 330 km/h. The scenario is divided into two sub-scenarios D1 and D2.
	D1, with freight traffic: This scenario is based on mixed traffic on HRS lines, i.e. both passenger and freight traffic using HSR lines.
	D2, only for passenger trains (without freight trains): The HSR lines are built only for passenger traffic; freight traffic uses the existing lines.

Figure 1. Overview of scenarios for phase 3.

Jernbaneverket will at a later stage put together recommended solutions for the corridor with a holistic view, taking all relevant information and other reports into account.

The aim of this report is to give an overview of the routes that might be possible for the various high-speed scenarios in the three corridors defined in Delivery 1. We have also defined a scenario B for possible development of the existing railway along the Dovrebanen (Dovre line), and thus, a reduction of travel times by 20 % along that line.

Furthermore, the report provides an overview of technical consequences and environmental impacts along the different routes. Technical impacts are studied in detail for the substructure, tunnels, bridges and construction work. The report also includes a preliminary analysis of an operational concept and the location of future high-speed stations.

3. BACKGROUND

Many countries have implemented and/or planned to construct high-speed railway lines. This is one of the reasons why the Ministry of Transport and Communications in 2005 gave Jernbaneverket the task of assessing the potential for high-speed railway lines in Norway. The results formed the basis for what the Ministry of Transport and Communications communicated in its Report No. 16 to the Storting (2008-2009): National Transport Plan 2010-2019.

The project was divided into three phases.

Phase 1:
The aim of this first step was to collect an overview of accessible competence in Norway as well as abroad. Various studies on high-speed rail in Norway were analysed. The conclusion was that these analyses could not be compared because of their different background and methods.

Phase 2:
The target of the second step was to have a common basis before going into a detailed analysis. It contained:

- Market analysis
- Railway planning and development
- Financial and socio-economic studies
- Commercial- and contract strategies
- Technical and safety analysis
- Environmental analysis

Phase 3:
The third step contains a detailed analysis for each corridor. This document is part of Phase 3 for the corridor North Oslo – Trondheim.

The background for Phase 3 was a request by the Ministry of Transport and Communications in 2010 for a detailed study on the future of Norwegian high-speed rail. The high-speed network was defined by the following six corridors:

- Oslo – Kristiansand – Stavanger
- Oslo – Bergen
- Oslo – Trondheim
- Oslo – Göteborg
- Oslo – Stockholm
- Bergen – Haugesund – Stavanger in combination with Oslo-Stavanger and Oslo-Bergen

The study is meant to provide advice for the development of future passenger transport in Southern Norway. The work is organised as a project which is managed by Jernbaneverket. The project has to be finished before February 2012 and will be an important part of the National Transport Plan 2014 – 2023.

Rambøll is the selected contractor of the assessment of high-speed rail in the Northern corridor, Phase 3, together with sub-consultants ILF and IGV Stuttgart.

4. DEFINITIONS OF THE DIFFERENT SCENARIOS

4.1 Introduction

We have examined three main corridors between Oslo and Trondheim:

- Gudbrandsdalen (GU)
- Rondane (RO)
- Østerdalen (OS)

In the three corridors, four Scenarios have been studied: B, 2*, D1 and D2.

- Scenario B is an upgrade of the existing tracks.
- Scenario 2* will start with the Intercity-project, and involves the construction of a new line further northward designed for 250 km/h, which will follow the existing corridors.
- Scenarios D1 and D2 are dedicated to a full high speed railway line, designed completely independently of the existing track, and with a design-speed of up to 330 km/h. The horizontal curvature is equal in D1 and D2, whereas the vertical curvature is maximum 12.5 ‰ in D1 and 25-35 ‰ in D2.

A more detailed description is presented below. Some sections may be assigned a lower design speed because of, for instance, major environmental consequences, by-passing urban centres, avoiding long tunnels, or for cost reasons. We assume that the Gardemoen line/Romeriksporten will be used for all alignments.

In Scenario 2* and D1/D2 with a totally new-built railway line, challenges already exist in realizing a feasible operating concept because of velocity differences between HSR and freight trains.

In Scenario B, these challenges are even more apparent because of the combination of new double track sections and the existing older sections in between. The new alignment sections chosen will probably cause a need for upgrading parts of existing sections as well. For this reason, the development of Scenario B has been carried out through an iterative process of alignment planning and planning of operational concepts, in order to provide a competitive and reliable railway infrastructure in the future.

Scenario	Design parameters	Mixed traffic (freight and passenger trains)	Design speed in the IC area	Design speed outside the IC area	Comments
B	20 % reduction in travel time, 2 hours frequency for passenger trains. Single track	Yes	--	--	Journey time Oslo-Trondheim shall be less than 5:20 hours for the Dovre line and 5:48 for Røros line.
2*	Design speed: 250 km/h. Double track	Yes	250 km/h	250 km/h	This shall be an upgrade of existing lines (equal to the IC KVU project). Some sections may be assigned a lower design speed in order to access the IC stops/towns.
D1	Design speed 330 km/h, max. gradient 12,5 ‰, double track	Yes	330 km/h	330 km/h	Journey time Oslo-Trondheim shall be less than 2:45 hours.
D2	Design speed 330 km/h. Double track. Max gradient 25-35 ‰	Passenger trains only	330 km/h	330 km/h	Journey time Oslo-Trondheim shall be less than 2:45 hours. It has to be described how capacity for the freight trains can be increased (existing line, electrification in Østerdalen, etc.) and associated consequences (including the need for maintenance). Gradient on line sections for freight trains should not be higher than on existing lines where freight trains run. (Approx. 18 ‰ for the Dovre line).
Prioritized Variants					Rambøll's proposed route combinations

Figure 2. Definitions of the different scenarios.

4.2 Scenario B

Scenario B involves an upgrade of the existing line in Gudbrandsdalen, to achieve a 20 % reduction in travel time. A 2-hour frequency for both passenger and freight trains is required. As for Østerdalen, it was challenging to decide the number of freight trains that should be allocated to an upgraded Østerdalen line and how many should remain in Gudbrandsdalen if we make significant improvements to the Røros line. We have therefore only looked very briefly into a Scenario B in Østerdalen.

4.3 Scenario 2*

Unlike in Scenario B, Scenario 2* will be designed for high speed. It consists of new alignments following the existing railway line (where possible) and allowing for a design speed of 250 km/h.

Corridor Gudbrandsdalen:

- IC -study Oslo – Lillehammer providing 160-200 km/h to Tangen , 200 km/h to Hamar and 250 km/h Hamar-Lillehammer
- New high-speed railway line with double-track and a design-speed of 250 km/h from Lillehammer to Trondheim via Gudbrandsdalen

Corridor Østerdalen:

- New high-speed railway line with double-track and a design-speed 250 km/h from Tangen to Trondheim via Østerdalen to Tynset, then via Kvikne and Soknedal
- IC study Oslo –Tangen providing 200 km/h to Tangen
- New bypass between Sørli and Elverum
- Upgrade of existing railway line (Røros line) between Tynset and Støren for freight traffic: electrification, extension of existing cross-sections/ new cross sections

4.4 Scenario D1/D2

Scenario D1/D2 is completely independent of the existing railway lines. The track will be designed for high speeds of up to 330 km/h. We have constructed the lines based on two scenarios: D1 for passenger and freight traffic with a maximum gradient of 12,5 ‰ and D2 for passenger traffic only with gradients in the range of 25-35 ‰.

Corridor Gudbrandsdalen:

- IC study, providing 160-200 km/h to Tangen
- New high-speed railway line with double-track and a design-speed of 330 km/h from Tangen to Trondheim via Gudbrandsdalen
- As a step 2: construction of a new section with double-track from Gardermoen to Lillehammer via Gjøvik with design speed of 330 km/h, designed for passenger traffic only. This section will only be needed at a very late stage when the capacity on the IC track has been exceeded.

Corridor Rondane:

- IC study, providing 160-200 km/h to Tangen
- New high-speed railway line with double-track and a design-speed of 330 km/h from Tangen to Trondheim via Rondane
- As a step 2: Construction of a new section with double-track from Gardermoen to Lillehammer via Gjøvik with a design-speed of 330 km/h, designed for passenger traffic

only. This section will only be needed at a very late stage when the capacity on the IC-track has been exceeded.

Corridor Østerdalen:

- IC study Oslo –Tangen providing 160-200 km/h to Tangen.
- New high-speed railway line with double-track and a design-speed of 330 km/h from Tangen to Trondheim via Østerdalen
- New bypass between Sørli and Elverum
- Upgrade of existing railway line (Røros line) between Tynset and Støren: electrification, extension of existing cross-sections/ new cross- sections
- As a step 2: Constructing a new section with single-track from Eidsvoll to Tangen (Vallset) with a design-speed of 330 km/h designed for passenger traffic only, but this will only be needed at a very late stage when the capacity on the IC-track has been exceeded.

4.5 Prioritized Variants

It will be possible to combine the different scenarios in the different sub-sections of the route. The Corridor North group has been engaged in a process studying the various scenarios and possible combinations. Our proposed route combinations are designated as "Prioritized Variants" and comprise a mixture of Scenarios D1, D2 and 2*.

5. SCENARIO B

Scenario B has been developed for the corridor of Gudbrandsdalen (Dovre-line) and is described in detail in the following chapters. For Østerdalen (Røros line), we have only discussed the situation briefly because it was problematic for Rambøll and Jernbaneverket to decide the boundary conditions for future service. Especially regarding freight traffic the B scenario has raised a discussion about which role is intended for the Gudbrandsdalen line in the case of a full upgrade of the Østerdalen line. The Østerdalen line is the shorter one and includes a lower maximum elevation. Hence it is normally a preferable freight route – if electrified and upgraded.

5.1 Boundary Conditions

5.1.1 General

Scenario B will combine improvements along the existing railway line and projects currently under development. The scenario shall not include new HSR-sections. However, the scenario shall be based on the planned upgrading of the IC-line Oslo – Lillehammer.

The following projects are handling optimization of transport on the Dovrebanen. Parts of the solutions can be implemented directly into scenario B:

- IC-study Oslo – Lillehammer, ongoing by Jernbaneverket
- Optimising existing "Dovre- and Rørosbane" given in "Strekningsvise Utviklingsplaner" (SUP), ongoing by Jernbaneverket
- Assessment "Godskapasitet Dovrebanen" (freight capacity), Jernbaneverket February 2010
- Utviklingsplan for Trønderbanen, ongoing by Jernbaneverket

Furthermore, measures for upgrading the two lines between Oslo and Trondheim are shown in strekningsvis Utviklingsplan (SUP, Jernbaneverket ongoing) in several scenarios.

South of Lillehammer, scenario B is based on the IC-study. North of Lillehammer, scenario B is based on optimising the existing railway line by:

- Upgrading passing and crossing tracks (new turnouts allowing higher speed and simultaneous entrance at station, lengthening of existing tracks)
- New double track sections based on 200 km/h alignment

At this stage, we have not gone into initiatives to reduce slow-speed sections such as removing level crossings, restoring track foundations and optimizing curves. Such actions will also reduce the journey time by several minutes, but must be studied more in detail at a later planning stage.

The target journey time for scenario B is set to 20 % lower than the current journey time for passenger trains. Scenario B does not include large new high-speed sections. Consequences from increased freight volume, shorter travel times and the additional trains/day for passenger services have been evaluated, as well as the impact on capacity.

A socio-economic goal in Norway is to transfer freight traffic from road to rail. Jernbaneverkets freight-strategy and the National Transport Plan (NTP 2010-19) indicate an increase of freight traffic by doubling by 2020 and triplication by 2040. If there is also to be an upgrading of passenger–service, prioritizing of one of the traffic modes is critical. From our point of view it is necessary to upgrade the line which presents optimal conditions for both freight **and** passenger services.

5.1.2 Operational concept for scenario B

Train frequency is an important boundary condition for evaluating necessary measures to reach the target travel time.

The SUP is working on three different scenarios for 2040 which are defined as:
1. Low level of service
2. Medium level of service
3. High level of service

Scenario 2 in SUP is quite close to the target travel time for scenario B. Therefore the same frequency for passenger trains is assumed for scenario B i.e. a two hour frequency. The current projects are all based on an increase in demand compared to today. It is obvious that the current frequency will not be enough to meet the higher demand in future.

Figure 3 compares travel time and frequency for scenario B HSR and scenario 2 SUP.

Oslo – Trondheim	Journey times			Frequency		Frequency freight
	2011	Long-distance Scen. B	SUP 2040 Scen.2	Long-distance Scen. B	SUP 2040 Scen.2	
via Dovre-line	06:40	05:20	05:00	2 h	2 h	2h
via Røros line	07:40	06:24	unknown	unknown	unknown	unknown

Figure 3. Frequency of passenger and freight trains of scenario B in this HSR assessment.

The assessment "Godskapasitet Dovrebanen" (JBV, January 2010) investigates necessary capacity enhancements to meet increased demand for freight traffic on the Dovre-line. The future demand expects up to 18 freight trains per day. Even if freight trains run on a higher frequency during night time, it is not possible to avoid freight trains during day time. This is not only a question of capacity of the railway-network but also capacity of the freight yards and the terminals and market demands.

In order to guarantee the expected number of freight trains, a two hour frequency for freight trains between Oslo and Trondheim during day time is assumed. Jernbaneverket confirms this assumption for future freight traffic demand. Therefore, scenario B is based on a two hour frequency of freight trains during the day. A higher frequency will be possible during night time, which will not affect passenger trains as they are not running during night time.

5.2 Scenario B in Gudbrandsdalen

The current journey time Oslo – Trondheim via Gudbrandsdalen is 6h 40 min. The target journey time is set to 20 % lower than today's travel time, hence 5h 20 min journey time has to be reached as shown in Figure 3. The projects listed in 5.1.1 will reduce the journey time significantly. It has to be evaluated which additional measures are necessary to reach the given target journey time.

5.2.1 Traffic Oslo – Lillehammer including the IC-line

The growing freight volumes and the needs to upgrade the line will also cause operating restrictions. This may result in additional needs to upgrade the line, for example constructing new or longer crossing sections if the passenger services are expanded. Another main restriction is caused by the upgraded IC-line Gardermoen – Hamar – Lillehammer. The planned IC train-frequencies allow limited and fixed departure times for long distance trains.

The upgraded IC-line Oslo – Lillehammer increases the top-speed between the airport Gardermoen and Hamar to 200 km/h. Construction of this section will start in 2012 (Langset-Kleverud). Between Hamar and Lillehammer there are still discussions about the practical maximum velocity. A discussion about practical design speed (200 or 250 km/h) may arise at a later stage, but in our calculations we have used 200 km/h design speed.

The travel time-calculations [Kjøretidsberegninger og kapasitetsvurderinger Dovrebanen JBV, 05.05.2011] made for the Oslo – Lillehammer line show that increasing the maximum speed between Hamar and Lillehammer hardly give any measurable effect for IC-trains, and only in the range of one or two minutes for long-distance trains. Graphic time tables also show that there is not enough capacity to cater for four IC trains and one long distance train during peak hours without constructing passing loops for the long distance trains. IC trains and long distance trains have different stopping patterns, resulting in long distance trains catching up with the IC trains and hence the need for passing loops to avoid being slowed down.

The IC-Study recommends a peak hour service of 4 IC-trains per hour and direction and outside peak hours 2 trains/hour and direction between Oslo and Hamar. Peak hours are defined as arriving Oslo between 07-09 o'clock in the morning and departing Oslo 15-17 in the afternoon. Transferred to a graphic timetable it is quite clear that several operational restrictions will arise. The obvious consequences are:

- no freight traffic in peak hours
- overtaking of IC-trains by long distance trains
- only one long-distance and one freight train per hour outside peak hours
- no slow/ordinary freight train during IC-operating-times without overtaking facilities between Eidsvoll and Lillehammer

4 IC trains/hour may also cause needs for upgrading or building of additional tracks or new lines/branches such as routing the freight trains via Solør/Rørosbanen or lengthening Gjøvikbanen to Lillehammer (Gudbrandsdalen) or an extra HSR-line from Gardermoen to Tangen (Østerdalen). Lengthening the Gjøvik-line northbound is not very useful for freight traffic, as the line has steep gradients.

However, based on knowledge about the IC market Oslo - Hamar/Lillehammer and benchmarking with comparable IC operations in Europe, Rambøll recommends basing the studies for the B scenario on **2 IC trains/hour in peak hours and 1 IC train/hour outside peak hours.** This adds up to **one slot per hour for long-distance trains using Gardermobanen and one for freight trains** operating on the existing single track-line from Alnabru terminal to Eidsvoll. We assume that there is enough capacity to run one freight train per hour between Alnabru terminal and Eidsvoll.

Nevertheless, the operation of IC-trains and the airport express trains may give restrictions to the long distance train departures because there are fixed slots at Oslo S for the long distance trains. Oslo S and Romeriksporten northbound from Oslo S to Lillestrøm, are also potential bottlenecks, but we assume that these capacity issues are handled in other projects.

In summary, in the Intercity-area Oslo – Lillehammer, we recommend the following operational concept for scenario B:

- Peak hour traffic: 0.5 long distance train, 2 IC and 0.5 freight trains per hour per direction.

- Non peak hour traffic: 0.5 long distance train, 1 IC and 1 freight train per hour per direction.

An example of a graphic timetable (Figure 4) is developed for the new IC-line Oslo – Lillehammer. It shows the operational concept within and outside peak hours.

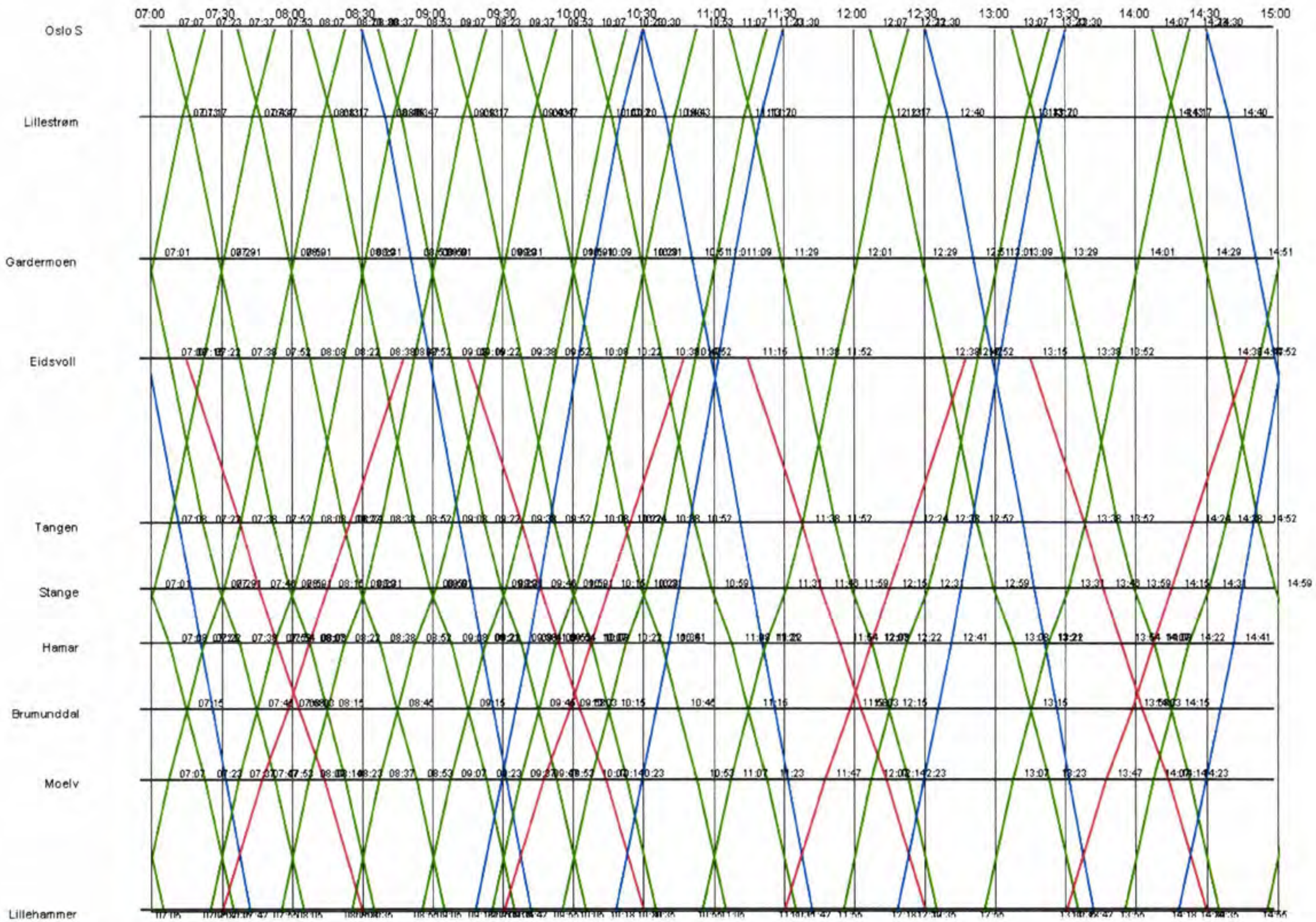


Figure 4. **Graphic timetable (scenario B) Oslo S – Lillehammer. Blue: Long distance. Green: IC. Red: freight.**

5.2.2 Lillehammer – Trondheim service

We recommend the following operational concept for scenario B between Lillehammer and Trondheim:

- Peak hour traffic: 0.5 long distance train and 0.5 freight trains per direction per hour
- Non peak hour traffic: 0.5 long distance train and 1 freight train per direction per hour

These assumptions are according to the definitions stated in 5.1.2. Furthermore, an increase of local trains in the Oslo and Trondheim area is <u>not</u> considered as part of this assessment. Obviously, potential increase of local traffic may cause need for additional upgrade of capacity.

The graphic timetables in Figure 4 and Figure 5 show a possible combination of long distance trains, IC and freight services along the entire line from Oslo S to Trondheim S.

Future restrictions on departure times or arrival times at Oslo S may lead to revised timetables. This will most probably cause demand for crossing sections and passing loops located elsewhere than indicated in our (example) graphic time table. Hence upgraded sections will have different locations and ground conditions. But in principle, the same kind of upgrading is needed.

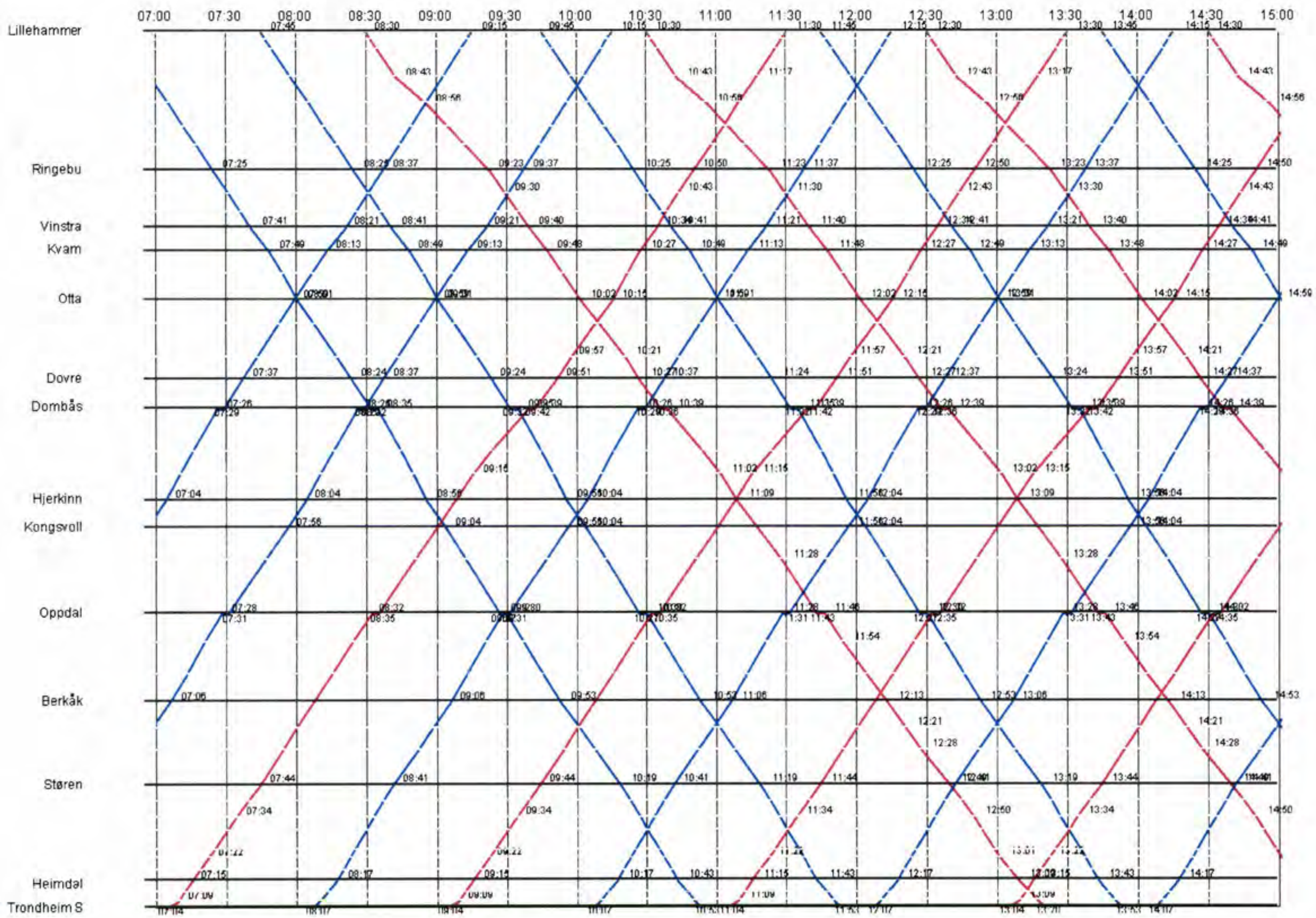


Figure 5. Graphic timetable (scenario B) Lillehammer – Trondheim S. Blue: long distance. Red: freight.

5.2.3 Stopping pattern

Several operating concepts have been studied and the recommendation is to use the existing stopping pattern in the IC-area which includes stops at Lillestrøm, Gardermoen, Eidsvoll, Tangen, Stange, Hamar, Brumunddal, Moelv and Lillehammer.

Travel time calculations show that a maximum speed of 250 km/h may be obtained only at very short sections when including these stops. Due to this fact the calculated travel time between Hamar and Lillehammer is very close to equal for top-speeds of 200 km/h and 250 km/h. Higher top speed than 200 km/h only benefits long distance trains stopping only at Hamar and Lillehammer. Rambøll's hypothesis is that a higher speed for relatively few long distance trains does not compensate for the disadvantage of higher investment cost.

For long distance trains in scenario B, the following stops are included: Oslo, Lillestrøm, Gardermoen, Hamar, Lillehammer, Ringebu, Otta, Dombås, Hjerkinn, Oppdal, Berkåk, Støren, Heimdal and Trondheim.

5.2.4 Measures to reach the target journey time

Upgrading the line between Gardermoen and Lillehammer in accordance with the IC-study reduces the travel time Oslo – Trondheim by 50 minutes. 30 more minutes of reduction is needed between Lillehammer and Trondheim in order to comply with the target travel time (-20 %) for passenger trains.

The freight traffic study for Dovre-line proposes several upgrading measures to reach the demanded capacity for future freight traffic. This includes upgrading of several crossing sections (lengthening, simultaneous entering and construction of new crossing sections) as well as double track-sections. As scenario B also demands a two hours frequency of freight trains, we have presupposed many of the same initiatives in this study.
Example: Length of upgraded crossing loops should comply with actual future length of freight trains, which is 600 meters according to the freight strategy in Jernbaneverket. Furthermore, upgraded crossing loops must cater for simultaneous entering without waiting time in- or outside the station. Therefore the length of crossing loops is calculated to 950 m. Figure 6 shows a possible design of an upgraded crossing station allowing simultaneous entering.

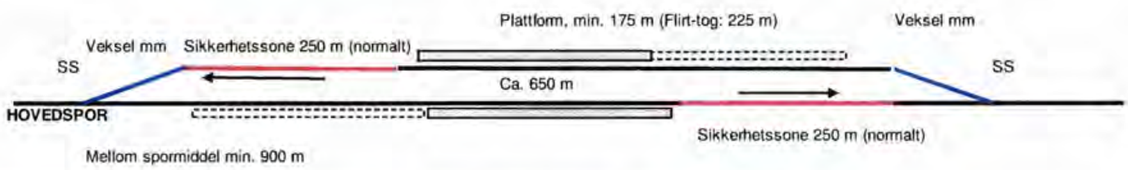


Figure 6. Layout of a crossing stating allowing simultaneous entering.

We have assumed that all crossing loops must be at least 950 meters, even if the graphic timetable example shows crossings with shorter passenger-trains. This will give a consistent standard of the crossing loops at Dovrebanen and a necessary operational flexibility when delays arise.

It is assumed that upgrading of crossing-loops in order to allow simultaneous entering of the station, reduces travel time by 2 minutes per upgraded crossing section.

The localisation of the measures mentioned in the freight traffic study depends on the chosen operational concept. Therefore a graphic timetable was developed for the whole line Oslo –

Trondheim via Gudbrandsdalen (Figure 4 and Figure 5). As described in 5.2.1, it is based on the IC-study and the possible slots between Oslo S and Lillehammer. Different operational concepts and time tables may lead to upgrades at other locations. This has to be studied in detail at a later stage. In this study the graphic time table in Figure 5 shows the need for **seven upgraded crossing loops**:

- Losna
- Hundorp
- Sel
- Berkåk
- Garli
- Ler
- Selsbakk

Some stations, such as Otta, do not need to be upgraded as the current crossing loop is sufficient because all passenger trains will stop here. According to the description above, these measures reduce travel time by 14 minutes.

Furthermore, the graphic timetable shows the need of **five double track sections** north of Lillehammer. These sections can theoretically be shorter (at least 1-5 km), but in our example they have a total length of 64.9 km:

- Øyer – Tretten (11.4 km)
- Fron – Vinstra (8.0 km)
- Kili – Dombås[1] (8.4 km)
- Hjerkinn – Drivstua (30.7 km)
- Driva Bp- Oppdal (6.4 km)

The distance between some double track sections and some upgraded crossing loops is low. This is the case of Øyer – Tretten and Losa as well as Fron – Vinstra and Hundorp. Instead of investing in an upgraded crossing loop it might be more future-oriented to extend the double track section. The effect on the travel time will be even higher than with an upgraded crossing loop.

New double track sections allow for a better alignment compared to the existing single track line. As part of the process we have designed a continuous new double-track from Lillehammer to Trondheim with a design speed of 200 km/h. Five sections have been extracted and incorporated in scenario B. Due to topographic reasons, some sections are significantly longer than needed according to the timetable. In particular, this is the case for Hjerkinn – Drivstua. Due to the local topographical situation, steeper gradients and the protected area in the national park it is recommended to build this section longer than needed.

In order to estimate the reduction of travel time, the double track section project Nykirke – Barkåker on the intercity Vestfold-line, was used as a basis. The section is similar to most of the above mentioned sections (e.g. curves, low speed). On this 12.6 km section travel time was reduced by 5 minutes due to higher speed and faster crossings. If similar reduction is calculated on the suggested double-track sections of 64.9 km between Lillehammer and Trondheim, one can reduce travel time by 26 minutes. However, this would be in the case of a continuous double-track designed for 200 km/h, which is not entirely the case in this study. We assume that 15- 20 minutes travel time reduction can be obtained by construction of the five suggested double-track sections designed for 200 km/h.

[1] This section has a gradient of 18 ‰, 12.5 ‰ is not achievable

Unfortunately, it is not possible to transfer solutions for these double track sections from other HSR-scenarios (2* and D), because those alignments are completely new lines planned completely independently of the existing track, and often located at some distance from the existing track.

If one of the proposed double track sections is not realised, the operational concept is highly affected and the proposed timetable would no longer be possible to operate. This affects freight traffic in particular, because freight trains would have to wait for crossings if passenger trains are given the highest priority. Consequently, upgrading of all crossing loops are necessary for reaching the target travel time for passenger train service and not affecting freight traffic negatively.

Step	**[min]**
New IC-line Gardermoen – Lillehammer	- 50
Upgrading of 7 crossing loops	- 14
5 double track sections (better alignment and crossing handling)	- 16
Sum	- 80

Figure 7. Steps to reach the target travel time in scenario B.

Overall, the reduction from today's journey time of 6h:40 min to 5h:20 min (-80 min) is possible with the measures described above. The estimated reduction of travel time through the five double track sections might be up to 26 minutes. Necessary reduction is calculated to 16 minutes. Due to different local conditions on the Dovre-line, the obtainable travel time reduction is somewhat lower than 29 minutes and probably closer to 16 minutes. However this indicates that there may be some reserves within our B scenario in order to obtain the required 80 minutes reduction. It also indicates that at a later planning stage, the length of one or more of the double track sections may be reduced in an optimizing process, but the track sections must never be shorter than approx. 1-5 km.

Although rolling stock is not a part of this study, it is likely that more powerful train sets will be normal in a longer perspective. Thus, an additional reduction of the travel time without any infrastructure measures is also possible.

Figure 8 gives an overview over the necessary measures for all steps of scenario B.

Scenario B: Gardermoen - Trondheim S	Need for measures along the existing track	length of existing crossing loop (m)	Crossing loops:Length of measures (m)	Double track-sections: Length of measures (m)	Need for new tracks (m)	Description of the measures/ remark
Gardermoen - Lillehammer	double track			103 000	103 000	The intercity KVU-project in Dovrebanen is a part of scenario B consisting a new double track Venjar - Langset and Kleverud - Lillehammer with a new station in Hamar following the existing track
Øyer - Tretten	double track			11 403	11 403	Straighten the line with double track in tunnels with one tube and some day zones
Losna	crossing loop 950m	579	950		371	
Hundorp	crossing loop 950m	690	950		260	
Fron - Vinstra	double track			8 017	8 017	Straighten the line with doubl -track in tunnels with one tube and some day zones
Otta	none (passenger trains are stopping)	667	0		0	
Sel	crossing loop 950m	740	950		210	
Kili-Dombås	double track			8 444	8 444	Straighten the line with double track in tunnels with one tube and some day zones
Hjerkinn - Drivstua	double track			30 737	30 737	The bad curvature of today will be replaced with a long tunnel. Vulnerable area: double track in day zones will probably not be permitted
Driva Bp- Oppdal	double track			6 363	6 363	The curvature is good today, a new track along the existing day zone is suggested
Berkåk	crossing loop 950m	569	950		381	
Garli	crossing loop 950m	780	950		170	
Støren	none (passenger trains are stopping)	822	0		0	
Ler	crossing loop 950m	459	950		491	
Selsbakk	crossing loop 950m	398	950		552	
Melhus - Trondheim	none	20780			0	Necessary if the number of local trains will be increased
Sum:			6650	167 964	170 399	

Figure 8. Overview of measures for scenario B in Gudbrandsdalen.

5.2.5 Recommendation for Scenario B in Gudbrandsdalen

Upgrading the Dovrebanen line to reach the target journey times for scenario B of 5h 20 min is achievable. This includes several upgraded and new crossing loops (seven) and at least five new double track sections. It also includes new alignment Gardermoen – Lillehammer in consistence with the Intercity line upgrading projects. Several slow-speed sections in a number of station areas have to be replaced. The described improvements will also allow for a future increase in freight service demand. Implications of enhanced local train service between Melhus and Trondheim have not been considered.

However, none of the described upgrades are feasible as a first phase towards a later High speed Rail line to Trondheim via Dovre. The B scenario could improve capacity, reliability and speed for existing and future ordinary train services somewhat, but would not be a step in the direction of a future HSR network.

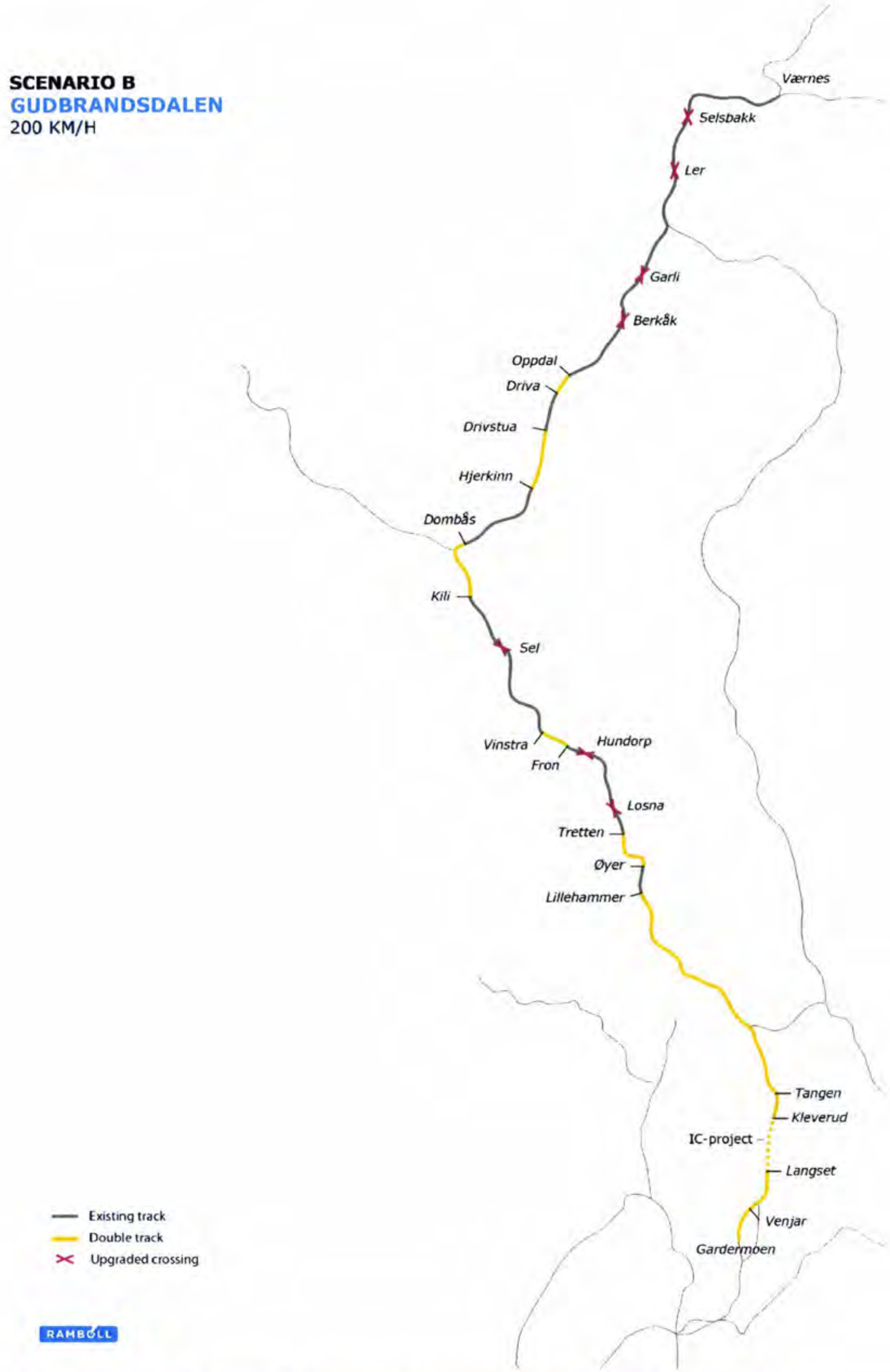


Figure 9. Geographical location of suggested measures for scenario B in Gudbrandsdalen.

5.3 Scenario B in Østerdalen

5.3.1 General situation

The Røros line through Østerdalen and further on via Røros and Gauldalen was the first line opened between Oslo and Trondheim. It is not electrified, but has a lower maximum gradient than Dovrebanen: 12 ‰ northbound and 14 ‰ southbound compared to 18 ‰ on the Dovre line. The passenger service is operated by light diesel-units combined with a few freight trains. Track condition is characterized by wear and tear, especially the superstructure. Due to the low importance of the line and the relatively low number of train services, the number of crossing sections is limited.

The alignment runs through a wide valley and includes long straight sections as well as sections with a wide radius, which give a potential for increased speed. This situation may include even greater improvements by removing a large number of existing level crossings.

5.3.2 Capacity, velocity and operations

The target journey time for passenger trains via Østerdalen is 20 % less than today's journey time which is 7h:40 min, i.e. scenario B via Østerdalen has to reach 6h:24 min.

As well as for scenario B Gudbrandsdalen, upgrading the existing line from Gardermoen northbound according to the IC-project already saves some 30 minutes in accordance to the IC project. To reach the target travel time, some 46 minutes additional reduction is needed.

Basis for a scenario B through Østerdalen is an electrified line. In addition it is assumed that the superstructure is rebuilt and level crossings removed. This gives passenger trains a maximum speed of 160 km/h for long sections without optimizing the alignment. It requires a modern signalling system. Some new crossing sections are also advisable.

The result of preliminary travel time calculations shows that the target journey time of 6h:24 min is easily within reach with the mentioned measures. The achievable travel time is calculated to 6h:00 min.

Upgrading the Røros line as described will open the possibility that all or almost all freight trains preferably may be operated via Østerdalen due to lower gradients. The maximum train load can be increased from 1,050t via Gudbrandsdalen up to 1,500t via Østerdalen given use of suitable traction equipment. Due to the higher maximum weight via Østerdalen, the necessary number of freight trains can be reduced in relation to a Gudbrandsdalen operation without reduction of freight capacity.

Nevertheless, we can assume that up to 13 freight trains per day and direction may operate via Østerdalen. The actual number cannot be determined without knowing which role the Gudbrandsdalen line will play in the case of an upgraded Østerdalen line. New crossing sections will be needed. As these consequences are not part of the current HSR-study and need detailed analysis, scenario B via Østerdalen is not presented as detailed as scenario B via Gudbrandsdalen.

5.3.3 Measures

The following measures will be necessary to reach the target journey time for scenario B in Østerdalen:

- New IC-line Gardermoen – Lillehammer (for Østerdalen only necessary to Hamar)
- Electrifying the line between Hamar and Støren, including power-supply-stations

- New superstructure ballast-track
- Reducing the number of level crossings. Removing level crossing sections with existing alignment theoretically permits 160 km/h
- Additional crossing sections
- New signalling system

Costs cannot be calculated as scenario B Østerdalen is not studied in detail, primarily due to the uncertainty of the consequences for freight traffic.

5.3.4 Recommendation for Scenario B in Østerdalen

The target journey time for scenario B can easily be reached by the measures mentioned above. Upgrading of the line gives high benefits to freight services by increasing the maximum train weight from 1.050 tons (Dovre line) to 1.500 tons for the Røros line. Hence the number of freight trains via Østerdalen will probably be lower than via Gudbrandsdalen.

Scenario B in Østerdalen is physically located quite close to scenarios 2* and D1/D2 which are high-speed lines. Hence, scenario B Østerdalen may more easily be developed as a step towards a future high-speed line.

5.4 Summary, scenario B

For both corridors (Gudbrandsdalen and Østerdalen) various enhancements are necessary to obtain the target travel time, such as double track sections, crossing tracks or even electrification of the line via Østerdalen. As freight traffic is important in the Oslo – Trondheim corridor, the enhancements will not only cater for increased passenger traffic, but will also allow increased freight traffic.

The target journey time is around the double compared to air traffic. Therefore, rail travel will not be competitive to air travel in scenario B. Furthermore, the investments cannot directly be considered as a step towards a future high-speed-line for Gudbrandsdalen, as the enhancements are not compatible with the other scenarios. For the Østerdalen line the B-scenario is somewhat closer to a 2* and D1/D2 scenario for some sections. Scenario B lines primarily have to be considered as an upgrading of the existing lines.

Scenario B in Østerdalen may highly affect the routing of freight trains. A probable distribution of freight trains between Gudbrandsdalen and an upgraded Østerdalen line has been discussed with Jernbaneverket without reaching any conclusion. And as this was not really a part of the current study, scenario B Østerdalen has not been analysed to the same detailed level as scenario B in Gudbrandsdalen.

Considering HSR, scenario B in Gudbrandsdalen is more or less a dead-end-project which improves the existing situation for train service but does not give any future options for HSR. If choosing scenario B, we strongly recommend analysing the line via Østerdalen in detail.

6. ALIGNMENT STUDY SCENARIO 2* AND D1/D2

6.1 Introduction

The following chapters describe Scenarios 2* and D1/D2 which have been evaluated in detail. This includes the different extension-levels and various alignment alternatives in the corridors Gudbrandsdalen, Østerdalen, Rondane and between Gardermoen and Lillehammer via Gjøvik or Hamar.

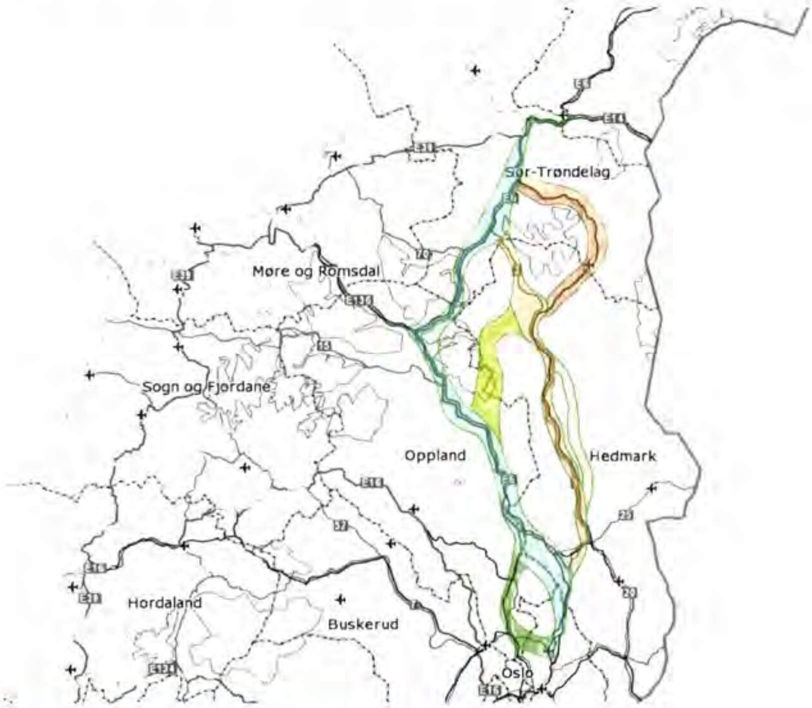


Figure 10. Corridors between Oslo and Trondheim.

Within Corridor North, a wide-spread range of alignments and variants has been evaluated. It is obvious that some of these variants could be discarded at an early stage because of too high tunnel shares, too long travel times, less potential and overly high investments compared with expected benefits. Other variants need to be studied in more detail as the argumentation for discarding was not sufficient at the early planning stage.

Based on the corridor investigations prepared in March / April 2011, several alignments have been designed for the Scenarios 2*, D1 and D2. During railway design, some of the scenarios could be discarded for specific corridors for a number of reasons. These reasons are described in more detail in the following chapters.

In Figure 11, all designed alignments are shown. In addition, several D1 and D2 alignments between Gardermoen and Gjøvik have been constructed. We have also looked at alignments going with slower speed than in the 2* Scenario. Based on additional investigations from the other involved disciplines, these alignments have been reduced to "prioritized alignments", shown in Figure 12.

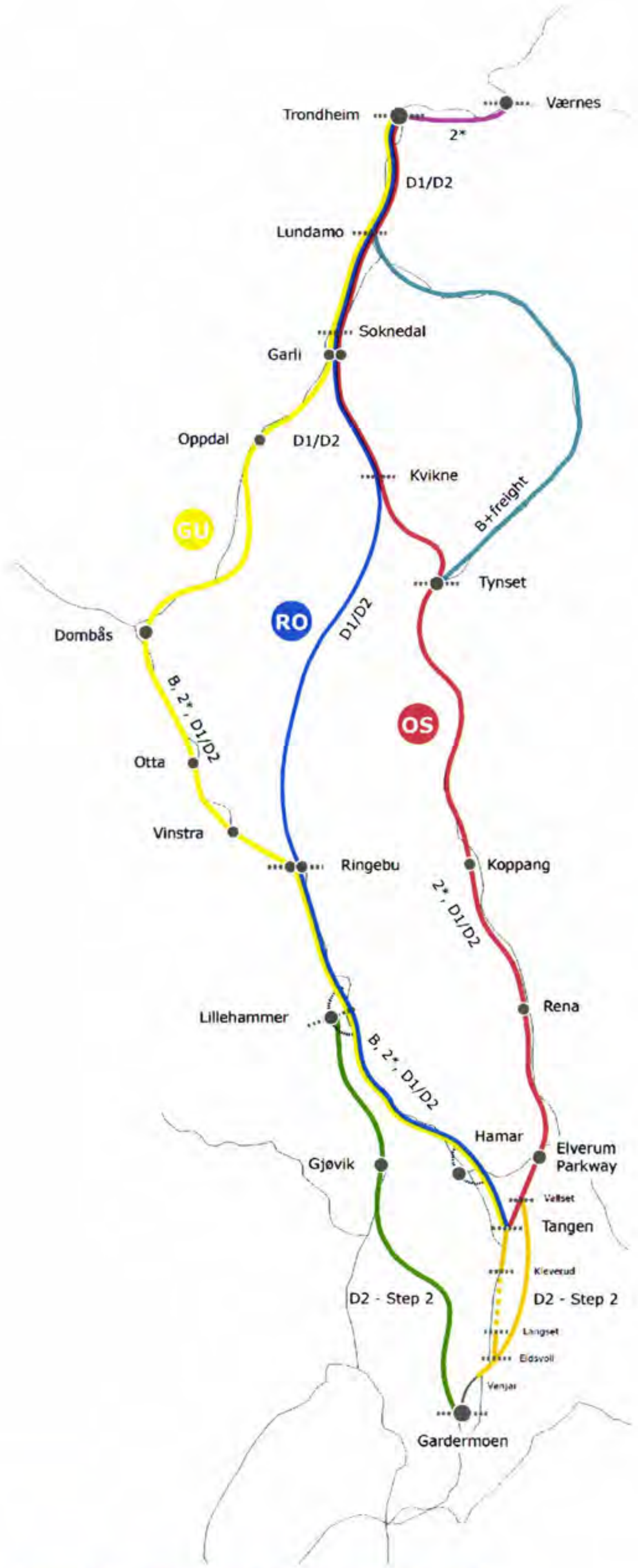


Figure 11. Designed alignments in phase 3.

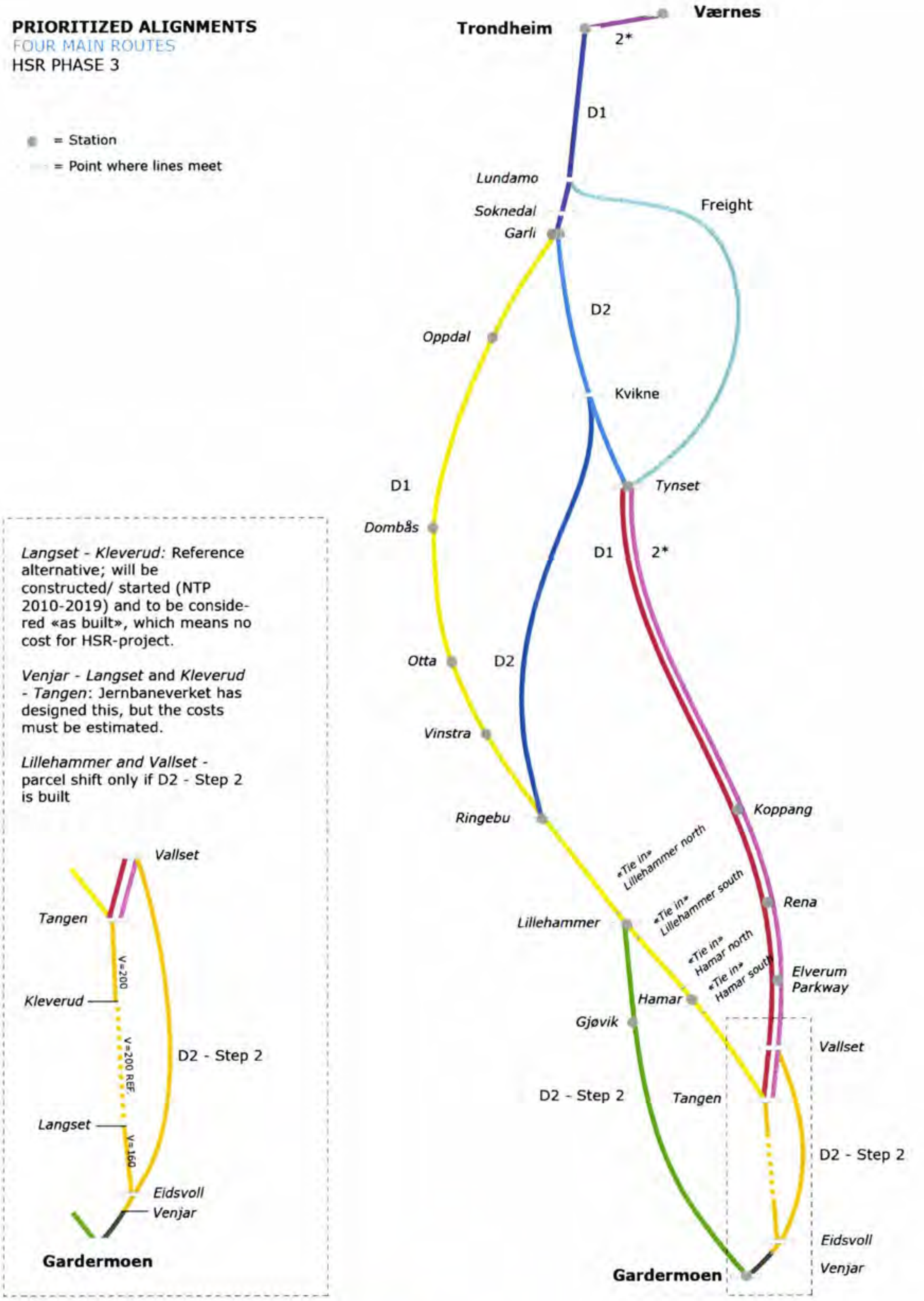


Figure 12. Prioritized alignments, October2011.

Three main routes and three sub-routes connecting Oslo (Gardermoen) and Trondheim, including Værnes, have been studied in more detail.

Main routes:

- GU-D1: Gudbrandsdalen, Scenario D1
- RO-D2: Rondane, Scenario D2
- OS-D1: Østerdalen, Scenario D1
- OS-2*: Østerdalen, Scenario 2*

Sub-Routes:

- GJ-D2: Gjøvik, Scenario D2
- GT-D2: Gardermoen / Tangen, Scenario D2
- VA-2*: Værnes, Scenario 2*

Concerning the construction of sub-routes two timeframes have been defined:

- **Step 1**: This includes the main route as well as the new railway line from Trondheim to Værnes.
- **Step 2**: After finishing step 1, the capacity of the existing IC line from Gardermoen (Eidsvoll) to Hamar might be exhausted. Therefore, a new line – designated for high-speed trains mainly – should be constructed. Depending on the main route, this could be either a third track between Gardermoen and Tangen, or a new line from Gardermoen via Gjøvik to Lillehammer. Both lines are designed for Scenario D2.

The following chapters describe each of these routes and the initial ideas behind the railway design in more detail.

6.2 The Intercity project Gardermoen-Lillehammer

The High-speed project will be affected by the Intercity Project. The IC-project has different scenarios for serving the center of Hamar, either through a new station or serving the existing station. Depending on which alternative that will be chosen, the HSR-routes Gudbrands-dalen/Rondane might have to be reconsidered in the section between Tangen and Lillehammer.

The Østerdalen route will be more or less independent from the Intercity-project, except in the section between Venjar and Tangen, where the HSR-project recommends following the IC-route.

6.2.1 Østerdalen

Two timeframes have been defined for construction of different scenarios in Østerdalen:

- **Step 1**: This includes the Intercity-project from Gardermoen to Tangen and further on with high-speed line to Trondheim
- **Step 2**: After finishing step 1, the new IC line from Gardermoen to Tangen may reach its capacity. A third track– designed for high-speed trains (scenario D2) is then needed between Gardermoen and Tangen (shown as yellow-green line in the figure).

When step 2 is completed, we have a continous line designed for high speed ($\geq$ 250 km/h) between Eidsvoll and Trondheim.

Figure 13. Østerdalen route: Construction of new double-track from Venjar and northwards starting with the IC-project (orange line) as step 1.

6.2.2 Gudbrandsdalen and Rondane

Two timeframes have been defined for construction of different scenarios in Gudbrandsdalen and Rondane:

- **Step 1-alternative 1**: This includes the Intercity-project from Gardermoen to Tangen and further on with high-speed line to Trondheim
- **Step 1-alternative 2:** This includes the Intercity-project from Gardermoen to Lillehammer and further on with high-speed line to Trondheim
- **Step 2**: After finishing step 1, the new HSR/IC line from Gardermoen to Lillehammer may reach its capacity. A third track – designed for high-speed trains (scenario D2) – is then needed between Gardermoen and Lillehammer. We recommend an alignment via Gjøvik (shown as green line in the figure).

Figure 14. Gudbrandsdalen route: Construction of new double-track from Venjar and northwards starting with the IC-project (orange line) as step 1.

The **Step 1-alternative 1** is our preferred high-speed line, scenario D1 from Tangen and northwards if the Intercity-project chooses a slow alternative for serving Hamar. To reach the target journey time to Trondheim, a faster high-speed line is needed, bypassing Hamar at Ridabu as shown in Figure 15. Our D1-scenario is bypassing both Hamar and Lillehammer with a fast alignment (330 km/h) with the aim of not losing much time for non-stopping high-speed trains passing these cities. Our 2*-scenario is similar to the 250 km/h-alternative in the intercity-project, hence we have not gone into details of a 2*-alignment in the Gardermoen-Lillehammer section.

The **Step 1-alternative 2** is our preferred high-speed line, scenario D1 from Tangen and northwards if the Intercity-project chooses a fast alternative for serving Hamar, e.g. the 250 km/h-alignment passing under the city-centre of Hamar in a tunnel. If this alternative will be constructed prior to the high-speed project, we think that the HSR by-pass east of Hamar (Ridabu) is no longer relevant.

Step 2 may be constructed after some years when market conditions and demands require more capacity between Gardermoen and Lillehammer. Our recommendation is to construct a third track via Gjøvik (for passenger trains only), since this will have more advantages than building a third track along the IC-route; Gardermoen -Tangen-Hamar-Lillehammer. A new Gjøvik-line will open a new and relatively big market, and will be an important link for the Toten/Gjøvik region both northwards and southwards including a new fast connection to Gardermoen. The Gjøvik route is also approximately 6 km shorter than the route east of lake Mjøsa. Final choice of route must, however, be decided through a cost-benefit analysis at a later stage.

Hamar:

Our main alternative is based on a tie in to the existing track, at Hamar south and north, and using the existing station at Hamar, as shown in Figure 15 (right). Depending on the conclusion in the intercity-project, the HSR-concept might have to be reconsidered. See also 8.5.1.

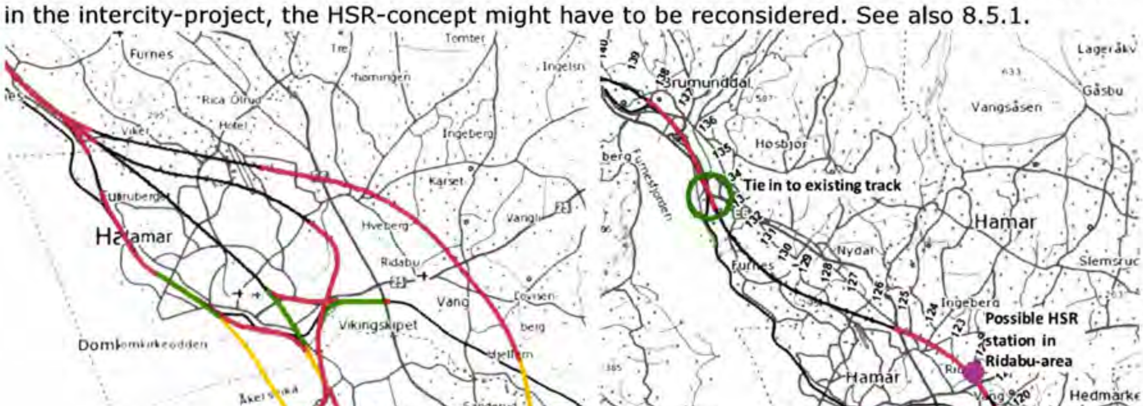
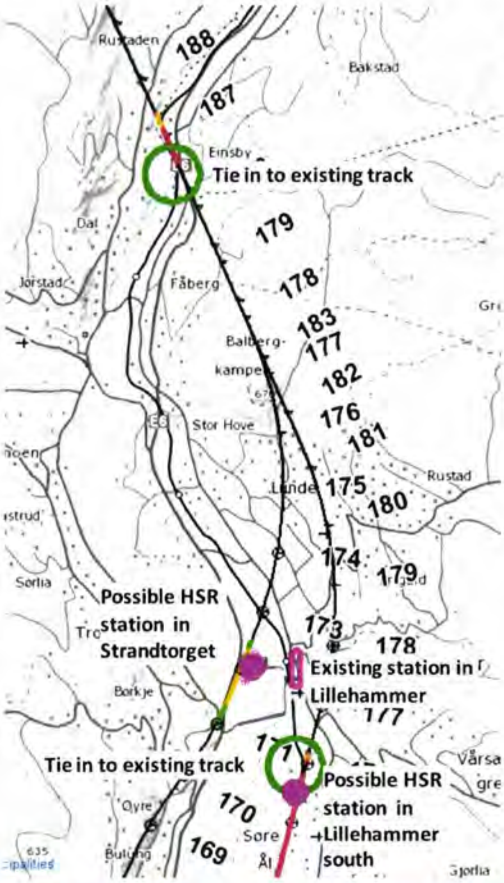


Figure 15. Intercity-project: Different alternatives to pass Hamar city. The eastern alternative is similar to the HSR-project alternative D. Source: Geovekst.

HSR-project D1-scenario with possible HSR-station at Ridabu

Lillehammer:



There are several opportunities for locating a new HSR-station in Lillehammer, depending on whether one will have some non-stopping trains passing Lillehammer serving the old station with some train-departures, constructing a new HSR-station in Lillehammer south or planning for a new HSR-line via Gjøvik. The last alternative will require a new, integrated station at Strandtorget, where both lines (Gjøvik and Hamar) are connected.

Our main alternative is based on a tie in to the existing track, in Lillehammer south and north, using the existing station at Lillehammer, as shown in the picture to the left.

See also Chapter8.5.2 about Lillehammer station.

Figure 16. HSR-project with different localities of possible stations in Lillehammer. Intercity-project plan to keep the todays locality of Lillehammer station. Source: Geovekst.

The following chapters describe in more detail the routes and the basic construction parameters for railway design combined with an optimum serving of the local markets.

6.3 Gudbrandsdalen

6.3.1 General

The corridor starts south of Hamar on the east side of Lake Mjøsa, and follows the existing railway line ("Dovrebanen" or "Dovre line") as well as the E6 highway to Trondheim. The corridor follows Gudbrandsdalen to Dombås and continues over the mountainous stretches of Dovre to Trondheim.

Figure 17. Lake Mjøsa near Lillehammer.

The whole corridor is characterized by a high density of constraints such as existing infrastructure (roads, railway, power transmission lines, hydropower stations etc.), settlement areas, national parks as well as rather difficult topographic conditions. Therefore, it was clear right from the beginning that the tunnel share for a high-speed railway line in this corridor would be greater than in the alternative corridors Rondane and Østerdalen.

Figure 18. Existing railway line near Kongsvoll Station.

Nevertheless, Gudbrandsdalen has always been mentioned during earlier discussions of building a high-speed railway by various groups and communities, as this is the main corridor for travelling by rail between Oslo and the northern parts of Norway today.

RAILWAY DESIGN		SOCIAL	ENVIRONMENT	COSTS
-	Difficult topographic conditions	Population density higher than in other corridors	National parks Reindeer habitat	High construction and maintenance costs

Figure 19. Overview of impacts, Gudbrandsdalen.

6.3.2 Alternative 2*

The initial idea of designing an alternative using Scenario 2* was to reduce the number of bridges and tunnels by using a lower speed limit of 250 km/h. However, the design of such railway alignments in Gudbrandsdalen showed that there is no significant difference between the Scenarios 2* and D1 / D2 in terms of the existing constraints (settlements, existing infrastructure, flood areas etc.) and the topographic situation. Only speed levels of 160-200 km/h could decrease the amount of necessary infrastructure (tunnels and bridges) and thus lower the costs of a high-speed railway line through Gudbrandsdalen.

6.3.3 Alternative D1

Between Lillehammer and Ringebu, the alignment runs mostly through tunnels due to the difficult topographic situation (narrow valley), flooding problems near the river and other constraints (Highway E6, settlement areas, hydropower plants etc.). From Ringebu northwards, the alignment continues with a series of tunnels until Dombås. To reduce the length of the tunnel up to Dovrefjell, a short section of open track was designed following the first approx. 6-7 kilometres of tunnel.

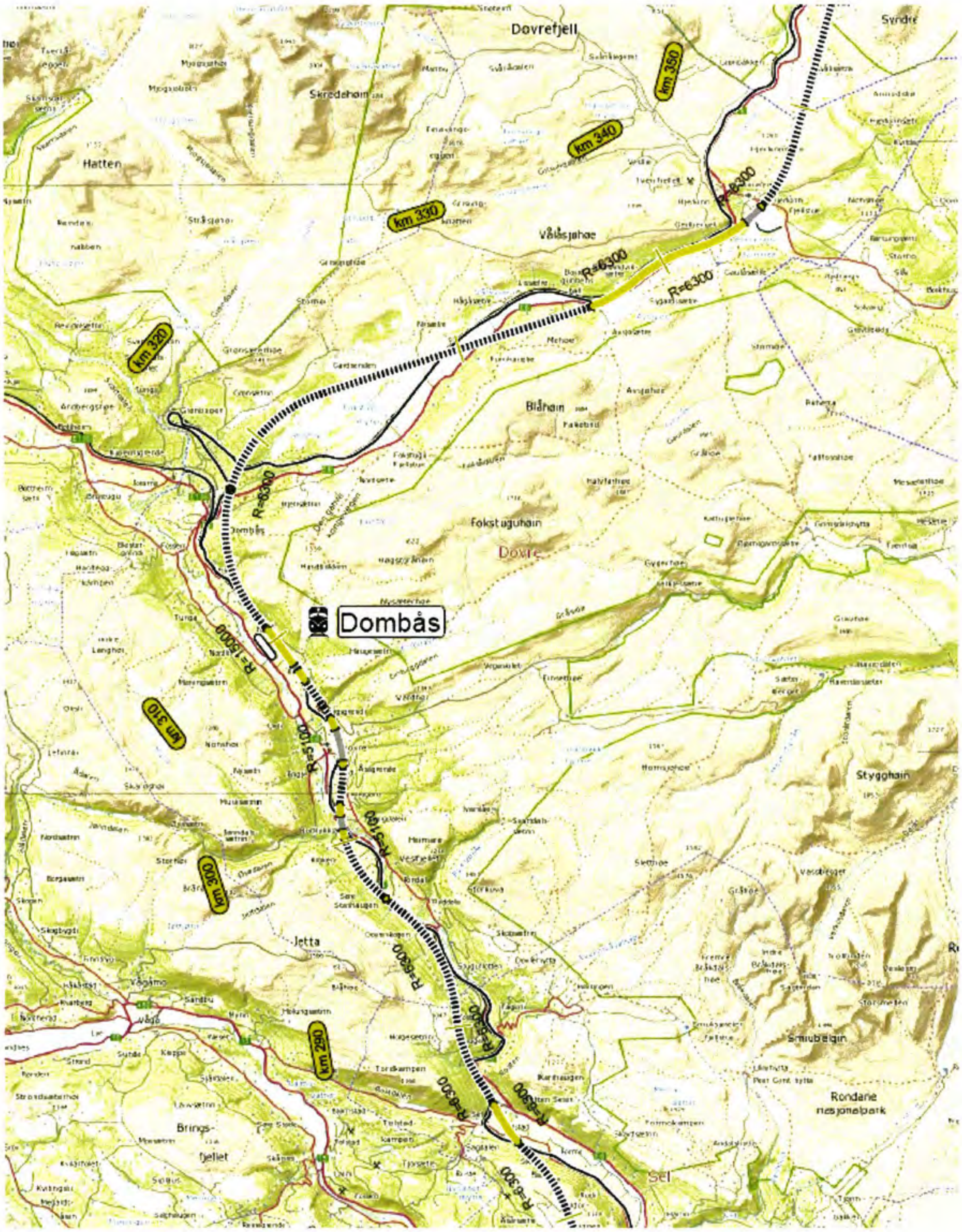


Figure 20. Excerpt from Avinet, showing the alignment GU-D1 near Dombås. Source: Geovekst.

After another long tunnel (approx. 19 km), the railway continues with more sections in open track. North of Oppdal, a more than 20 km long section in open track is one of the longest parts of the alignment in the Gudbrandsdalen corridor without tunnels and longer bridges.

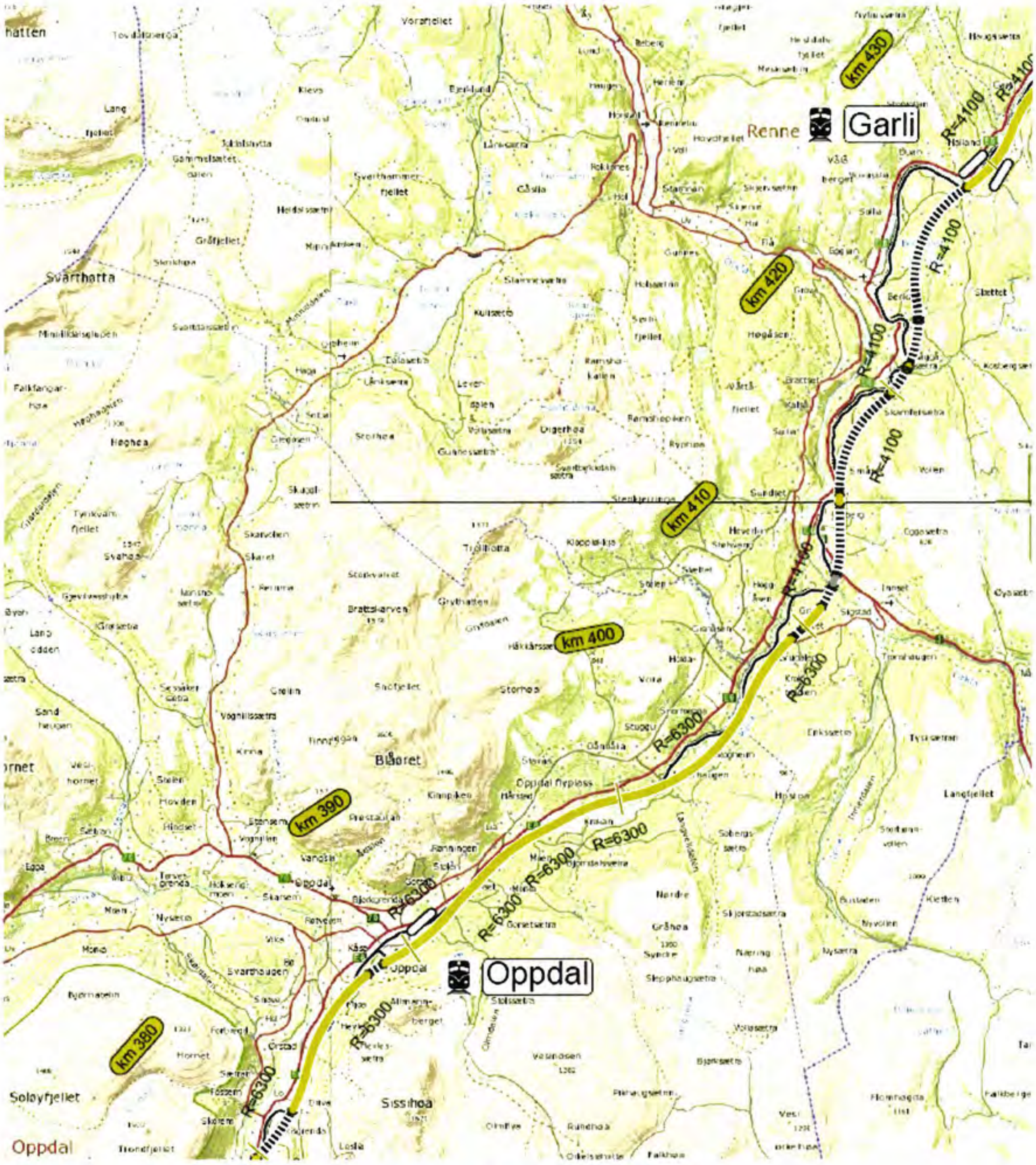


Figure 21. Excerpt GU-D1 between Oppdal and Garli. Source: Geovekst.

6.3.4 Alternatives 2* and D2

Alignments for the Scenarios 2* and D2 were tentatively designed as well, but quickly showed that there are no significant differences in tunnel share and quantity of bridges, as the design parameters for the horizontal alignment are the same for Scenario D1 as they are for D2. The design speed of 250 km/h in Scenario 2* also requires fairly large curves in the narrow valley of Gudbrandsdalen, giving very similar effects as D1/D2 curves. Therefore it was decided to include only Scenario D1 in the prioritized variants. In order to reduce the curves significantly, Rambøll has found that the design speed must be reduced to less than 200 km/h.

6.4 Rondane

6.4.1 General

From a topographic point of view, the Rondane area is a typical high mountain area with large plateaus, well-defined valleys and with only a few settlements in between. In general, it seems to be a place well suited for a high-speed railway line without overly long tunnels and bridges.

Figure 22. Rondane National park.

However, when constructing a high-speed railway line, two major constraints have to be taken into serious consideration in Rondane:
First of all, Rondane National park is the oldest national park in Norway, covering an area of 963 km² in the counties of Oppland and Hedmark. The whole area of Rondane is one of the few places in Scandinavia where wild reindeer can be found. Therefore, special measures have been installed to protect the reindeer population in their core area, such as removing or relocating walking paths, etc.

Figure 23. View from Savalen.

The high level of ecologic sensitivity of the corridor has influenced the design of the railway alignment in the Rondane corridor. Although, after entering the plateau through a long tunnel, the topographic situation seems to be advantageous for a high-speed railway line, many short and intermediate-length tunnels have been designed in order to avoid conflict with special reindeer and other wildlife areas. Of course, all open tracks are designed to be outside the National park boundaries.

Secondly, the Rondane plateau can only be reached by a very long tunnel starting somewhere near Ringebu in Gudbrandsdalen. Before the more detailed alignment design started, other possible routes up to Rondane were investigated, but all these routes have at least similar problems due to altitude difference and the presence of the national park.

Though aware of these challenges, the consulting team still decided to include the Rondane corridor in their investigations in order to provide a broader comparison of possible alignments for a high-speed railway line between Oslo and Trondheim. Due to the fact that no existing railway lines are presently crossing or running through the Rondane area, only alignments for the two D1/D2 Scenarios have been designed.

RAILWAY DESIGN		SOCIAL	ENVIRONMENT	COSTS
o	After reaching the Rondane area through a long tunnel, no further major problems can be expected from the railway design	There are no significant urban areas between Ringebu and Soknedal	Rondane National park Important reindeer habitat	High construction and maintenance costs

Figure 24. Overview of impacts, Rondane.

6.4.2 Alternative D1

Concurrent with the railway design for Scenario D2 (only passenger trains), an alignment for D1 (passenger and freight trains) was also studied for the Rondane corridor. As expected, the topographic conditions require a 31.5 km-long tunnel under Venabygdsfjellet (Venabygd Mountain) between Ringebu and the Rondane highlands.

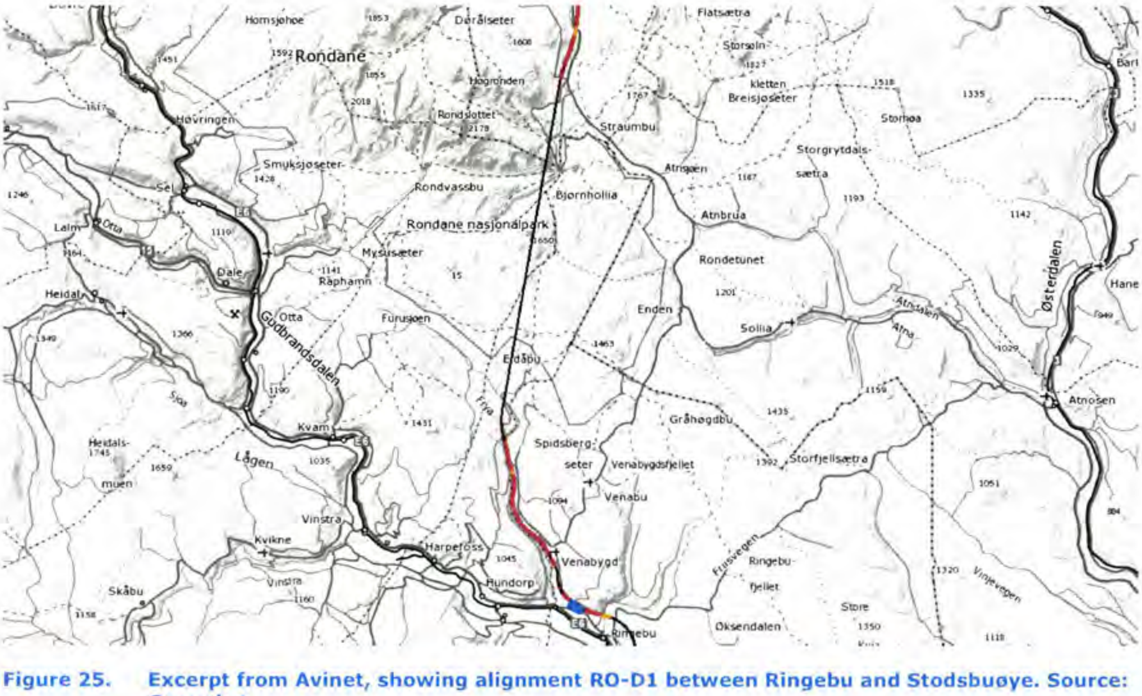


Figure 25. Excerpt from Avinet, showing alignment RO-D1 between Ringebu and Stodsbuøye. Source: Geovekst.

The tunnel has to be constructed continuously with a gradient of 12.5 ‰ in order to reach the mountainous plateau. It can be expected that aerodynamic effects will prevent the passenger trains from reaching the maximum operational speed of 300 km/h, although energy consumption is very high. Because the tunnel is crossing the National park, it is not possible to build access tunnels and/or construction sites in between the two portals for the purpose of reducing construction time.

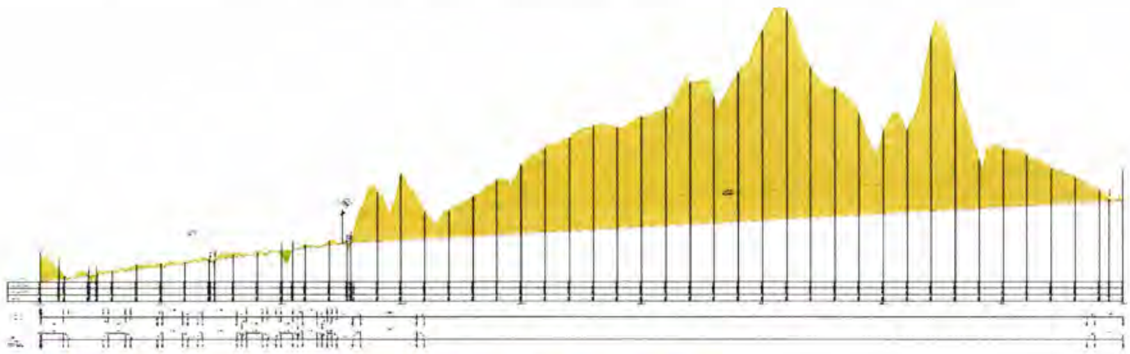


Figure 26. Tunnel between Ringebu and Morken, Scenario D1.

Although the tunnel share values for Scenarios D1 and D2 related to the section between Ringebu and Soknedal are quite similar, it was decided to discard Scenario D1 in Rondane. This is because it would be possible to save about 4 km of tunnel under Venabygdsfjellet with a D2 alignment. At the same time, it is possible to run freight trains on the existing track between Ringebu and Soknedal although the gradient on the existing track is a bit too steep in this section (17-18 ‰). This means that it would not be possible to increase the load of freight trains, i.e. freight trains will still have the same capacity as today. D2 could also offer the possibility of building some single-track sections, especially in the sensitive areas of Rondane. Rambøll has, however, calculated all volumes etc. with double track for the complete alignment.

6.4.3 Alternative D2

The alignment of alternative RO-D2 follows more or less closely the alignment of alternative RO-D1. Due to steeper gradients, the long tunnel between Ringebu and Rondane can be reduced to less than 28 km length. However, once the line reaches Rondane, there are no other significant changes in tunnel share.

Between Ringebu and Soknedal freight trains will continue to use the existing line.

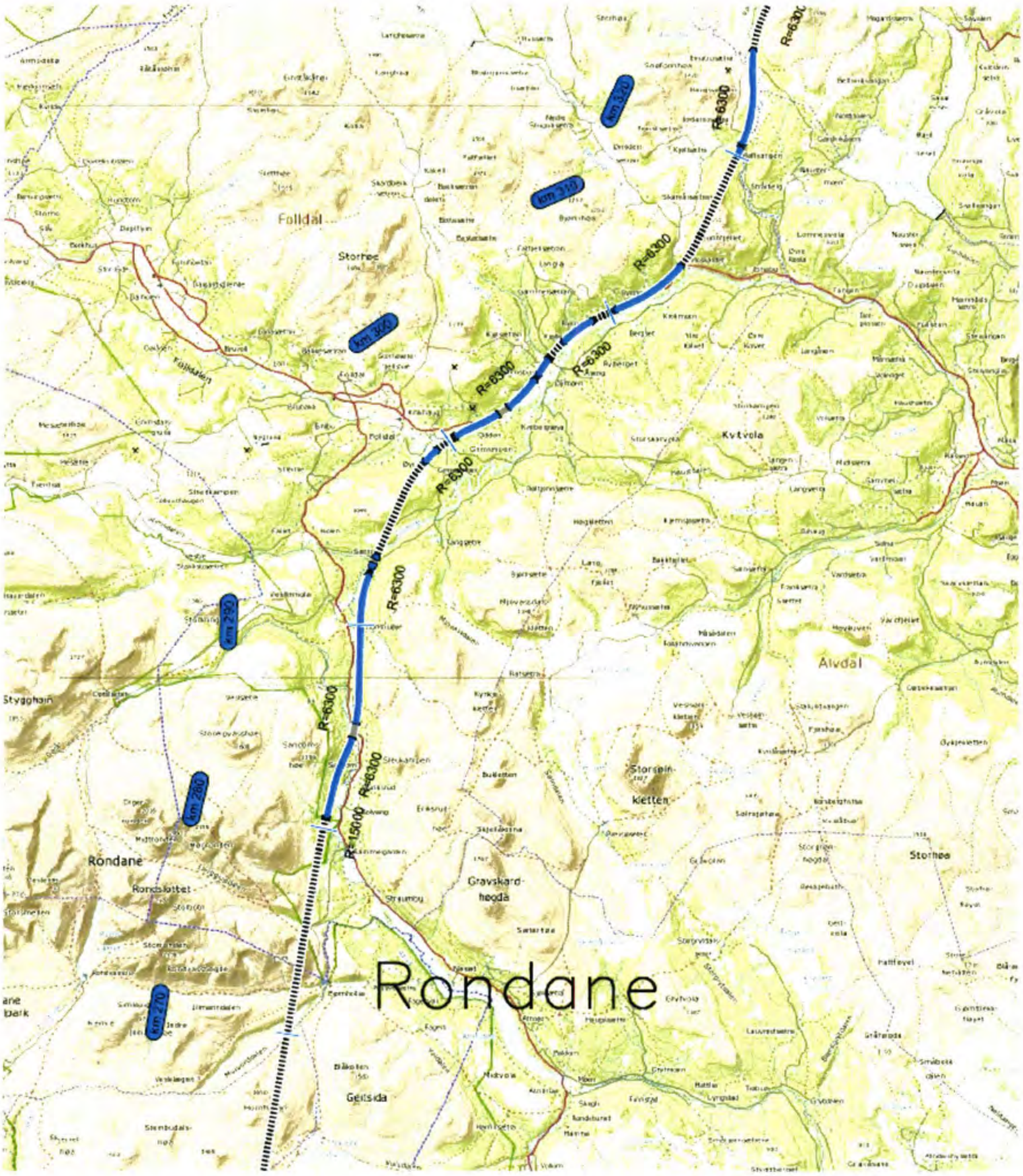


Figure 27. Alignment RO-D2 near Folldal. Source: Geovekst.

6.5 Østerdalen

6.5.1 General

The topography of Østerdalen is characterized by a wide valley with smooth slopes on each side. Most parts of the area are sparsely populated with some smaller scattered villages in between. Undoubtedly, the Østerdalen corridor is one of the places in Norway most suitable for building a long-distance high-speed railway line without extraordinary costs due to long tunnels and/or bridges.

Figure 28. Østerdalen as seen from Tronfjell.

In principle, there are two routing possibilities:

- Staying close to the existing railway track (Scenario 2*). This solution may have some advantages, e.g. it offers the possibility of building the new railway track "step-by-step", reduces use of still untouched areas, and more frequently connects the existing railway line with the new high-speed track. However, Scenario 2* also has disadvantages such as flooding problems, difficulties during the construction phase, and lower design speed.
- Building a completely new railway line (Scenarios D1 and D2), mostly on the opposite side of the river from the present line, and, in part, a bit higher than a 2* alignment.

In both cases, a new railway line has to be built between Tynset and Støren/Trondheim. A continuation of the high-speed railway line through Røros was not studied in detail, as the total length of the line would result in longer travel times as well as increased construction and maintenance costs. In addition, the topographic situation between Røros and Støren cannot be regarded as advantageous for constructing a high-speed railway line. Nevertheless, the existing Røros line railway track seems to be quite suitable to use by freight trains, provided some improvements (e.g. electrification, signalling, overtaking sections etc.) are made. As a consequence, the new high-speed railway line between Tynset and Støren can be constructed with shorter tunnels due to steeper gradients.

RAILWAY DESIGN		SOCIAL	ENVIRONMENT	COSTS
+	Best topographic conditions of all investigated corridors	Impact on settlement areas as well as agriculture can be reduced to a minimum; short travel time	Most parts of the new railway track run parallel to existing infrastructure; sensitive areas are not touched	By far the lowest tunnel share of all the studied corridors

Figure 29. Overview impacts Østerdalen.

6.5.2 Alternative 2*

Alternative 2* more or less closely follows the existing railway line through Østerdalen between Elverum and Tynset. It should be noted that due to the design parameters for a high-speed railway line, the existing railway line has to be rebuilt completely to accommodate trains with a maximum speed of 250 km/h.

Figure 30. Existing railway line in Østerdalen.

From Tynset to Trondheim, the high-speed trains will be using a new route, bypassing Soknedal. Freight trains would continue on the existing, but electrified, Røros line.

Nevertheless, Alternative 2* offers the possibility of building the high-speed railway line, Oslo – Trondheim, "step-by-step" in Østerdalen.

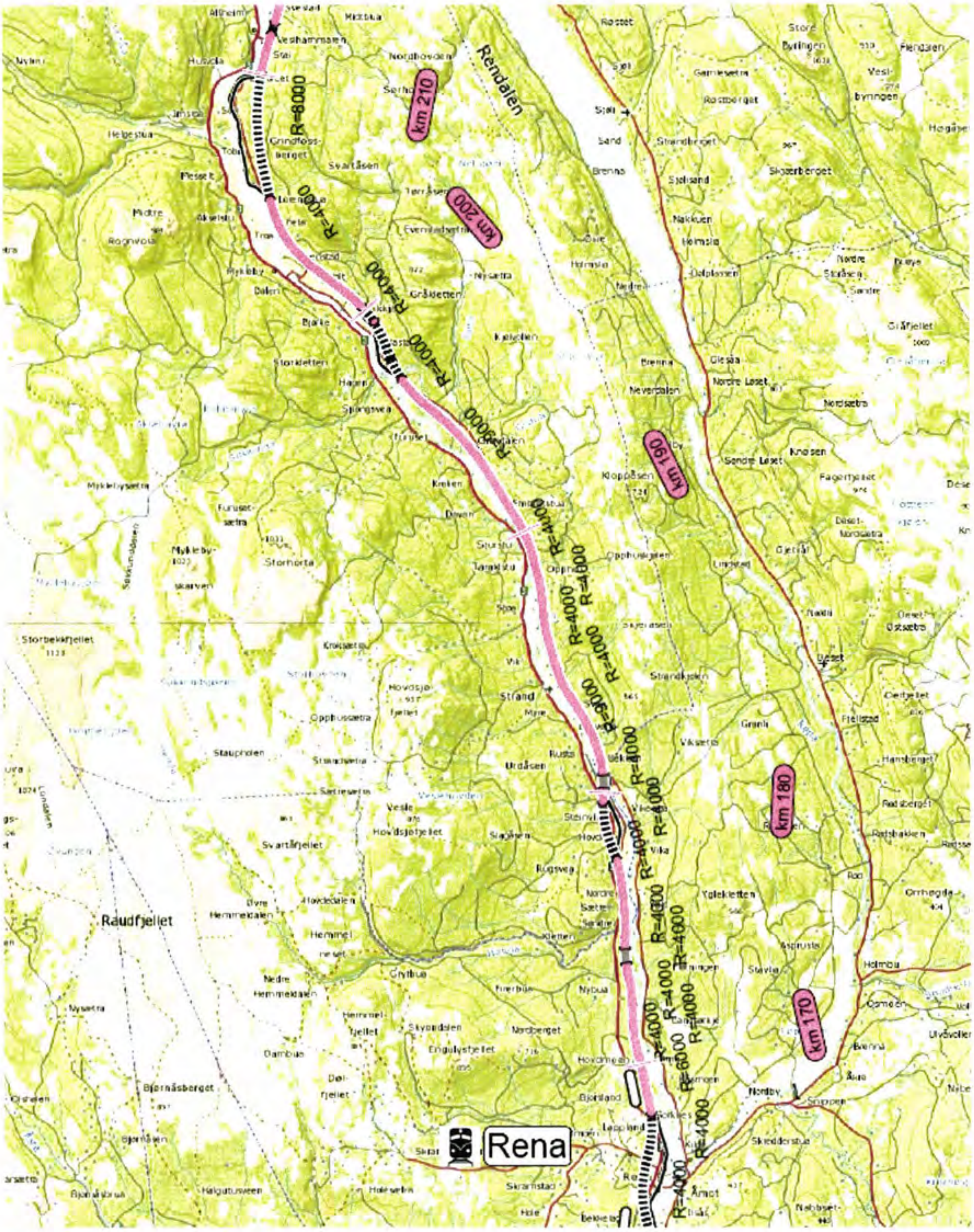


Figure 31. Excerpt showing alignment OS-2* north of Rena, running close to, or exactly on, the existing alignment. Source: Geovekst.

Due to topographic, as well as environmental and social constraints, the alignment has to deviate from the existing railway corridor in some places. One of these sections is in the Alvdal area, where it is proposed to bypass the settlement area by building a tunnel. As Alvdal is close to Tynset, it is not recommended to include a railway station for high-speed trains there.

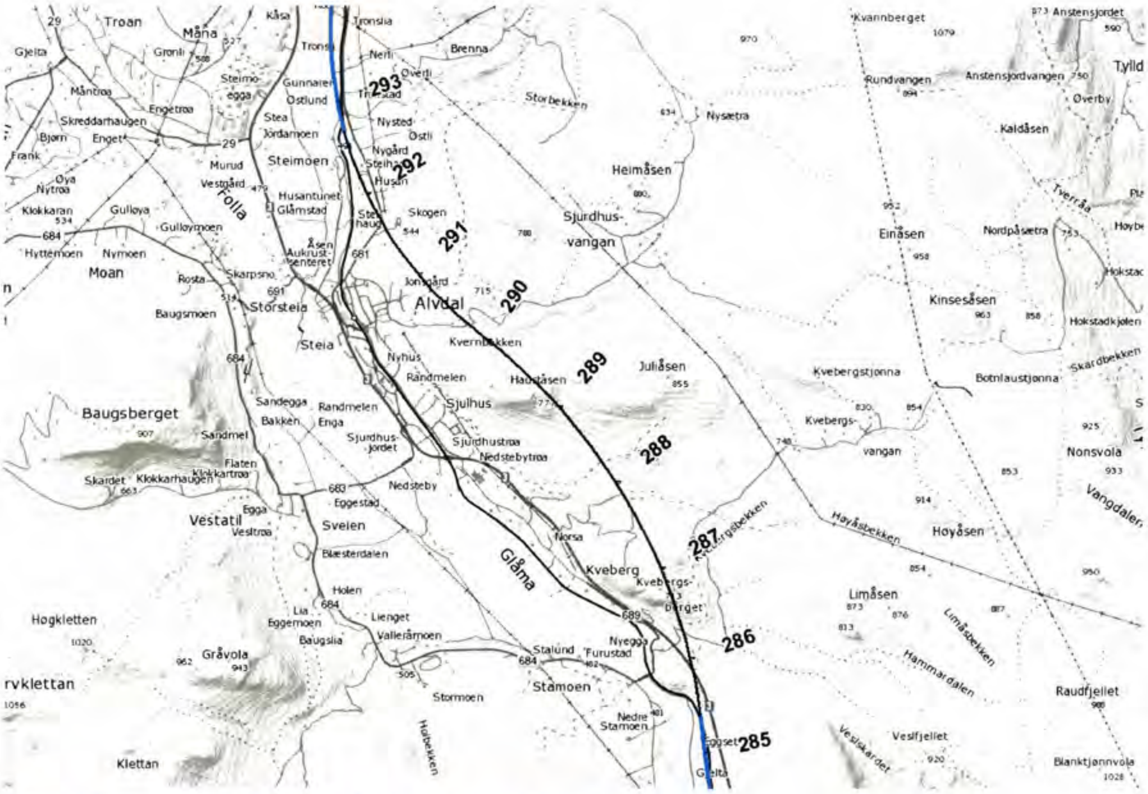


Figure 32. Excerpt alignment OS-2* near Alvdal. Source: Geovekst.

6.5.3 Alternative D

Concerning Scenario D, 4 possible options within the Østerdalen corridor have been studied:

a. D1 with mixed traffic Gardermoen-Trondheim
b. D1 with mixed traffic to Tynset, D2 from Tynset to Trondheim and freight traffic on existing alignment from Tynset to Trondheim via Røros
c. D2 with mixed traffic to Ulsberg, and separate traffic (high speed and freight) on existing alignment from Ulsberg to Trondheim
d. D2 with freight trains via Gudbrandsdalen. (Separate traffic from Tangen to Trondheim)

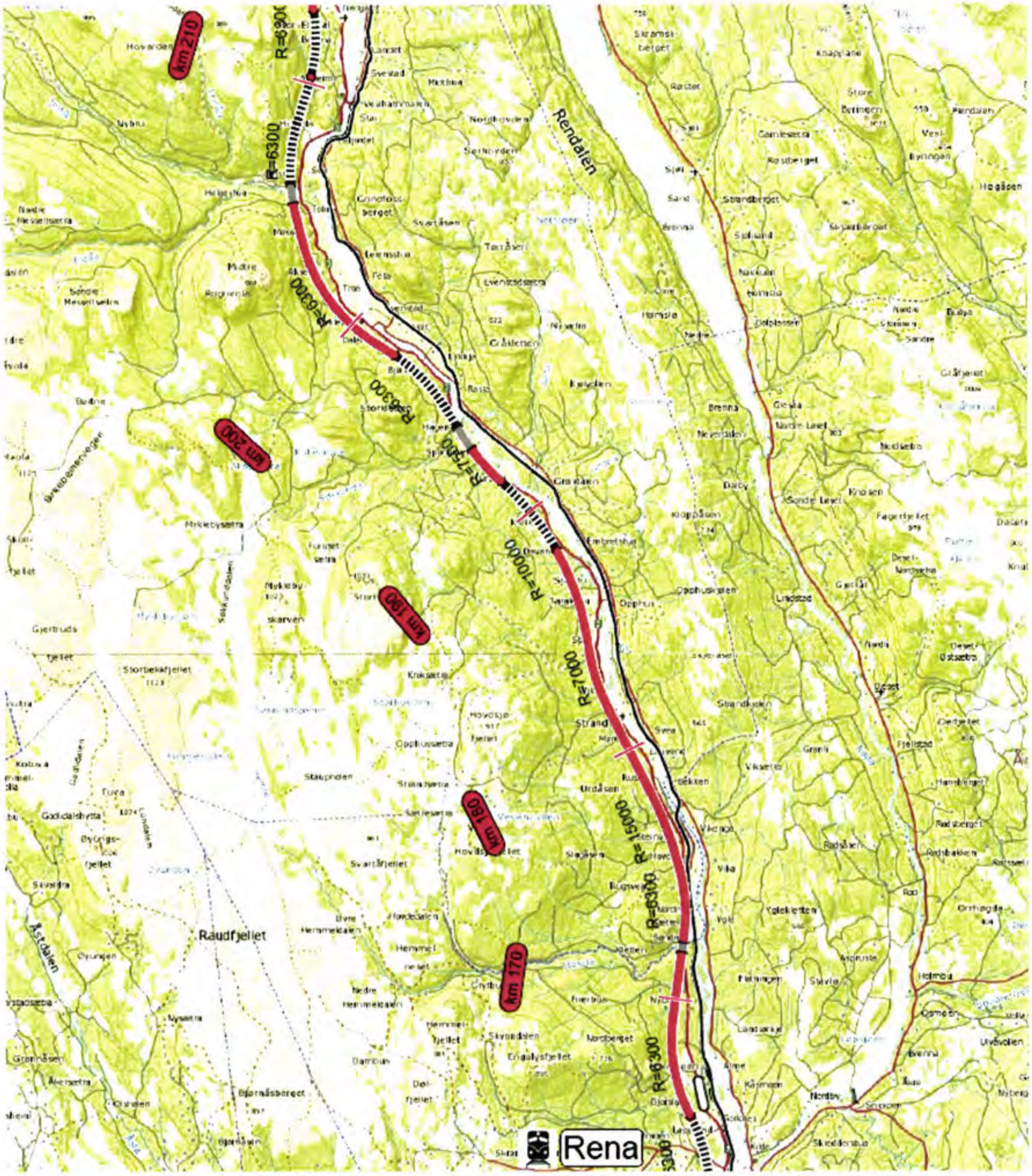


Figure 33. Alignment OS-D1/D2 north of Rena. Source: Geovekst.

It was decided to continue with alternative b. above (D1 with mixed traffic to Tynset, D2 from Tynset to Trondheim and freight traffic on existing railway from Tynset to Trondheim via Røros) for the following reasons:

- Between Tangen and Tynset, there is no significant difference between the alignments for Scenario D1 and that of D2. Scenario D1 gives more flexibility also for freight traffic, while the railway line for Scenario D2 can only be used by passenger trains, and freight trains have to use the existing railway track.
- Between Tynset and Trondheim, an alignment for Scenario D2 can be designed with significantly lower tunnel share than that for Scenario D1. This D2-section could in principle also offer the possibility of building some single-track sections. Rambøll has, however, calculated all volumes etc with double track for the complete alignment.

- The existing railway line through Røros is well designed (low gradients), and needs only minor improvements to provide sufficient capacity for freight traffic.
- It is assumed that the existing line via Røros will be kept for local passenger trains, so the maintenance costs there will remain, regardless.
- There are no further advantages in a continuous D1 alignment between Oslo (Gardermoen) and Trondheim through Østerdalen, but several disadvantages still exist (higher costs for construction and maintenance, higher environmental impacts, etc.).

6.6 Gjøvikbanen (the Gjøvik line)

6.6.1 General

The initial motivation for this corridor was to connect the urban areas of Gjøvik to the high-speed railway network. While there are plans to build an IC railway for speeds of 200 km/h up to Hamar and for 200 or 250 km/h to Lillehammer, there are no such concrete projects to do the same on the western side of Lake Mjøsa. Actually, Gjøvik is the end point of the Gjøvik line and a regional centre for the western side of the lake. Plans to extend the line northwards to Lillehammer have been put forward in the past, but were never realized.

As the new intercity alignment on the east side of Lake Mjøsa will be designed for freight traffic, it is not necessary to build a Scenario D1 between Gardermoen and Lillehammer through Gjøvik. Because of the local topography, the tunnel share can be reduced significantly from Scenario D1 to Scenario D2.

Figure 34. Lake Mjøsa south of Gjøvik.

6.6.2 Section between Gardermoen and Gjøvik

During the railway design process, 4 possible alignments between Gardermoen and Gjøvik were studied:

- A western alignment, running, in part, close to the existing Gjøvik line, Scenario D2
- Two central alignments (D1 and D2)
- An eastern alignment, running close to Lake Mjøsa and passing Skreia, Scenario D2

When designing a high-speed alignment close to Lake Mjøsa, numerous tunnels and bridges would have to be constructed on the slopes. This increases the costs and has a negative impact on the landscape. An alignment turning sharply to the west immediately after Gardermoen Airport might be designed to connect the settlement areas of Gran, Hadeland, Brandbu etc. to the railway network. However, this line would increase the total length of the high-speed railway line between Oslo and Trondheim, the potential for additional passengers is very low, and the additional stops involved would increase the journey time again.

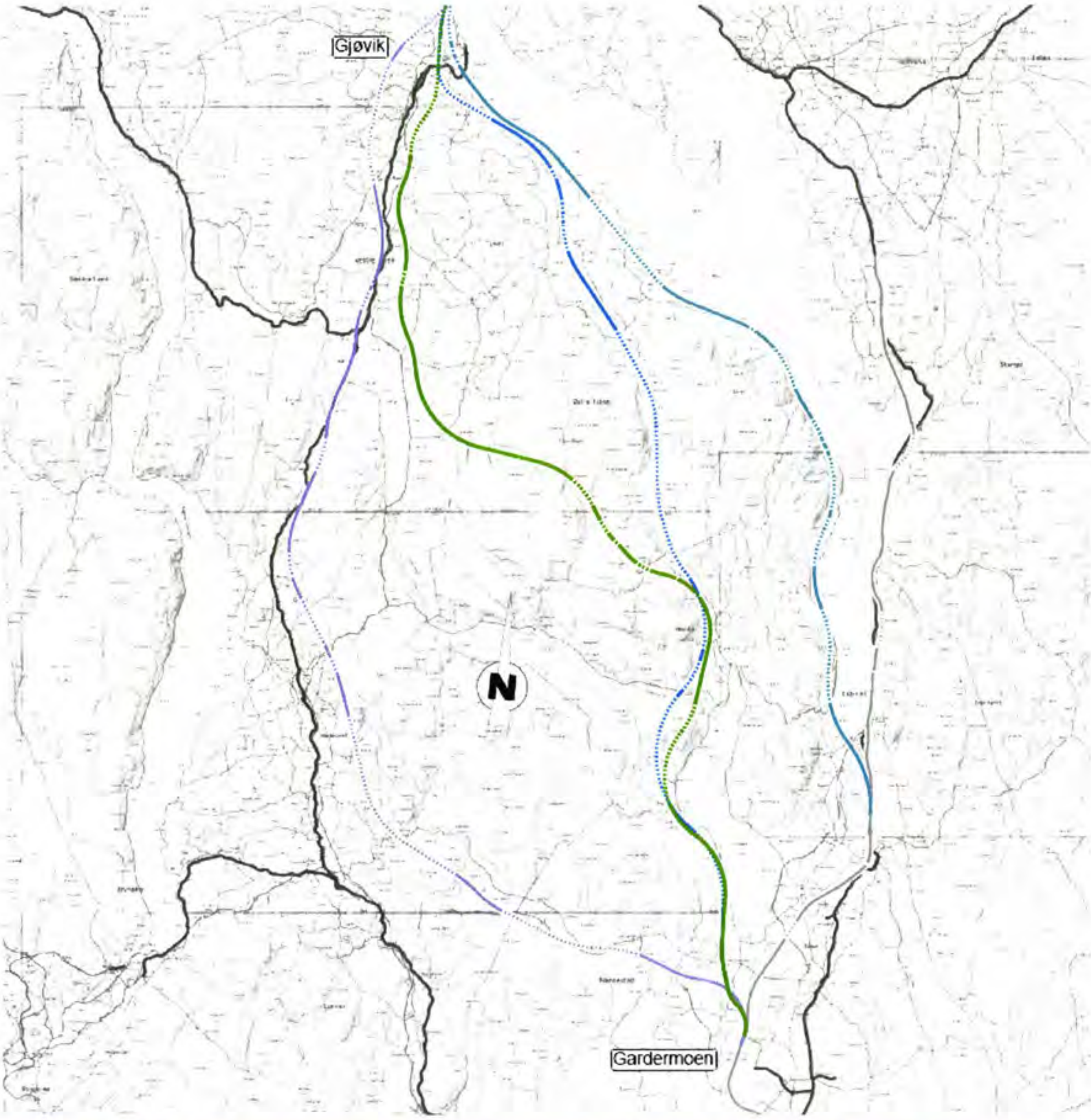


Figure 35. The four constructed alignments between Gardermoen and Gjøvik. Source: Geovekst.

The remaining direct connection between Gardermoen airport and Gjøvik can provide for a low tunnel share (Scenario D2) and would be the shortest connection between Oslo and Lillehammer.

6.6.3 Section between Gjøvik and Lillehammer

One of the major problems of this solution is the relocation of the new railway station in Lillehammer. The missing connection to the IC line Hamar – Lillehammer is a problem as passengers travelling from Hamar to Trondheim would have to change stations. The distance between the existing station in Lillehammer and the proposed new high-speed railway station is about 550 m.

Figure 36. Excerpt showing the distance between the new high-speed station (pink) and the existing railway station about 550 meters away. Source: Avinet.

Therefore, further investigations were made to design a railway line which connects the new railway station of Gjøvik directly with the existing railway station in Lillehammer. In principle, the following options could be identified:

1. Crossing of Lake Mjøsa south of Lillehammer
2. Building a short tunnel between the two railway stations

These possible options are shown in Figure 37.

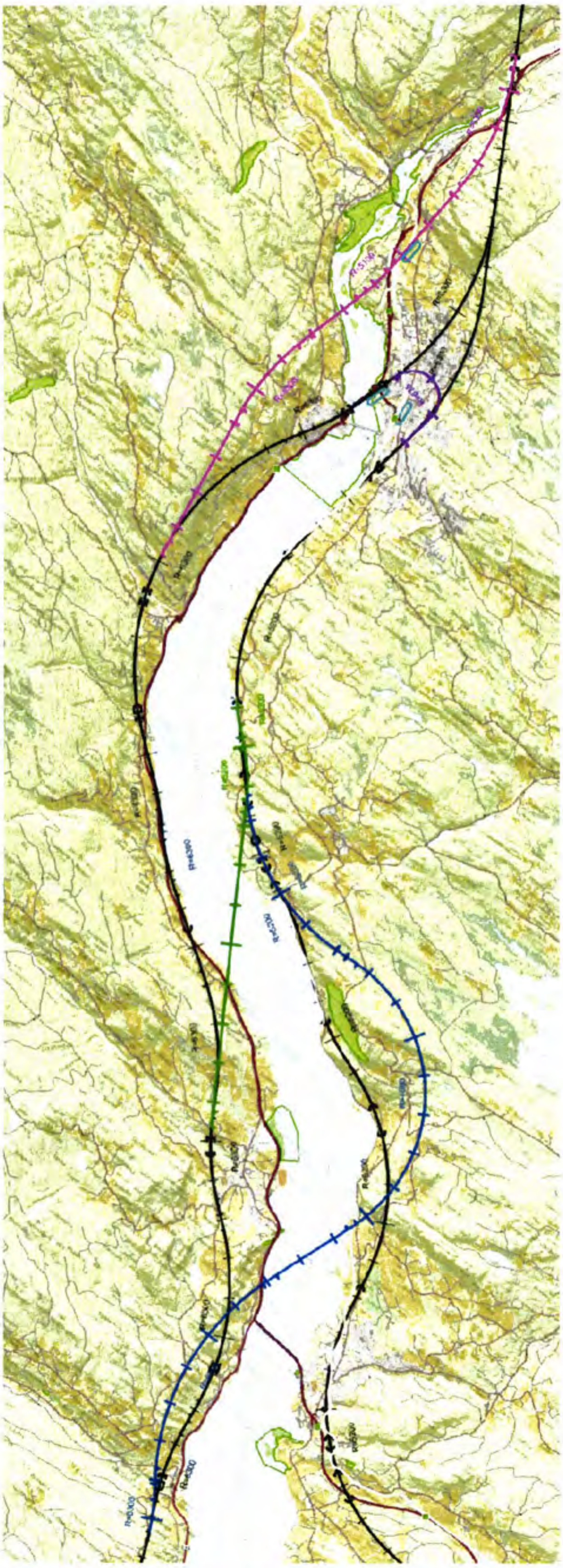


Figure 37. Possible alignments between Gjøvik and Lillehammer. Source: Geovekst.

Concerning the crossing of Lake Mjøsa, it should be noted that such a solution might have a number of risks:

- Negative impact on landscape
- Increased line and tunnel length (especially the alignment shown in dark blue). Due to design parameters for the high-speed railway line, the length of the bridge would exceed 2.5 km.
- High design-, construction-, and cost risks due to the great depth of Lake Mjøsa of about 80 to 500 meters.
- Last but not least, high construction costs and risk of uncertainties.
- Relocation problems with existing bridge (E6)

It was decided that, due to these unknown risks and possible high costs, the railway alignment and station in Lillehammer should remain at the proposed location as shown in Figure 36.

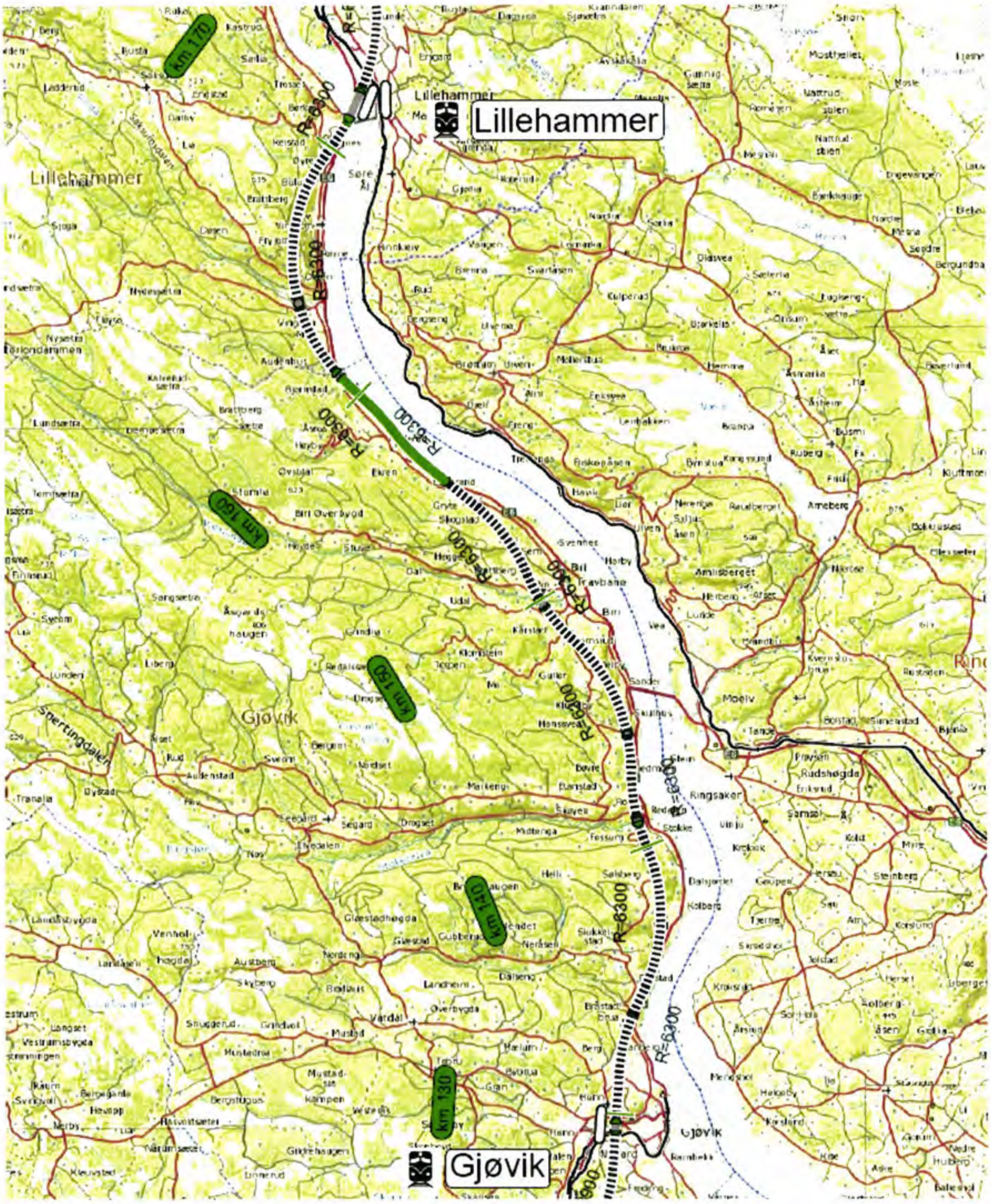


Figure 38. Proposed alignment GJ-D2 between Gjøvik and Lillehammer. Source: Geovekst.

6.7 Rørosbanen (the Røros line)

Today, the Røros railway line is not electrified; after the Nordland line, this is the second longest stretch of un-electrified railway in Norway.

When continuing with Scenario OS-D2 or OS-2*, it is proposed that freight trains run on the existing railway line between Tynset and south of Trondheim. This requires an upgrade of the railway infrastructure, including electrification and upgrading of signalling and passing loops to increase the capacity of the existing track. In addition, upgrading the Røros line would also provide a possibility for improved regional train services.

Figure 39. The Røros line. Source: Geovekst.

The identification of measures necessary for upgrading the Røros line was based on the following assumptions and conditions:

- 1h-frequency for freight trains at night / 2h-frequency for freight trains during daytime
- Existing freight trains to be run on the new freight paths
- Existing number of passenger trains to be maintained
- Passenger trains to be run in free slots during the freight trains' 2h-frequency
- Conflicts between passenger/freight trains in the morning and evening hours (when freight trains are running in 1h-frequency)
- Assumption to solve the conflict: Passenger trains use a freight path (i.e. no freight path Oslo – Trondheim, or freight trains run via Kvikne with lower weight)

section / station	existing track (m)	operation	measure	length needed (m)	to be built (m)	new station (m)	Tie-in to HSR
Tynset - Støren			- electrification and converting station	163,190			
Tynset - Støren			- centralized train control and installations for cables	163,190			
Tynset		- tie-in to HRS-line - crossing freight/freight on the tie-in tracks - freight trains wait on the tie-in before running on the HSR line - passenger trains run only to/from Tynset station (connection to HSR line to be evaluated, e.g. relocating HSR station, bus service, other connections) - freight trains "cross" passenger trains at existing Tynset station; no upgrading is necessary	- tie-in to/from HSR line and change from double track to single track - no measures on the existing station because passenger trains run only up to Tynset (length of the tracks is sufficient)				x
Tolga - Os		- crossing freight/freight during 1h-frequency freight traffic approx. 4.5 km south of Os - crossing passenger/freight(or passenger) if passenger train running instead of freight train	- new crossing station, length 950 m			950	
Glåmos	324	- crossing freight/freight - crossing passenger/freight (or passenger) if passenger train running instead of freight train	- upgrade station to cross freight/freight (simultaneous entrance, 600 m freight trains) - facilities to cross passenger/passenger (platforms)	950	626		
Glåmos - Haltdalen		- crossing freight/freight during 1h-frequency freight traffic approx. 9 km south of Haltdalen - crossing passenger/freight (or passenger) if passenger train running instead of freight train	- new crossing station, length 950 m			950	

section / station	existing track (m)	operation	measure	length needed (m)	to be built (m)	new station (m)	Tie-in to HSR
Singsås	385	- crossing freight/freight - crossing passenger/freight (or passenger) if passenger train running instead of freight train	- upgrade station to cross freight/freight (simultaneous entrance, 600 m freight trains) - facilities to cross passenger/passenger (platforms)	950	565		
Støren	631	- crossing freight/freight during 1h-frequency - crossing passenger/freight(or passenger) if passenger train running instead of freight train - longest track (810 m) only useable for Dovre line (no connection to Røros line)	- upgrade station to cross freight/freight (simultaneous entrance, 600 m freight trains) - facilities to cross passenger/passenger (platforms)	950	319		
Lundamo		- tie-in to HRS line - no crossings - measures for passenger traffic have to be evaluated	- tie-in to/from HSR-line and change from double track to single track - waiting area for freight trains before running on the HSR - facilities for passenger traffic may be necessary				x

Figure 40. Measures for upgrading the existing Røros line.

In total, 163 km of the existing railway line would have to be electrified and 2 new crossing stations with a length of 950 m will have to be built.

6.8 Værnes

Between Trondheim and Værnes (existing Trondheim Airport Station), an upgrade is planned for the existing Nordland line as a continuation of the new high-speed railway line, Oslo – Trondheim. When opened in 1994, Værnes Station was the first airport rail link in the Nordic countries. Due to the short distance (33 km) between the existing, as well as the planned, railway station in Trondheim and Værnes Airport station, only an alignment involving Scenario 2* was studied. It is furthermore assumed that all trains will stop in Trondheim, as well as at the airport, and would therefore not be able to utilize the design-speed.

6.8.1 Alternative 2*

The starting point of the new railway line between Trondheim and Værnes is the proposed new location for the main station in Trondheim – at exactly the endpoint of the straight line crossing the river in Trondheim at Lerkendal (see Chapter 8). The new alignment ends 1.8 km before the airport station at Hell Station. The length of the new high-speed rail line is 27.361 km up to near the airport, where it is connected to the Gevingåsen project. Between Hell and Værnes Airport, a railway project is currently under preparation with a new bridge over the river; therefore the high-speed railway line would end at Hell Station.

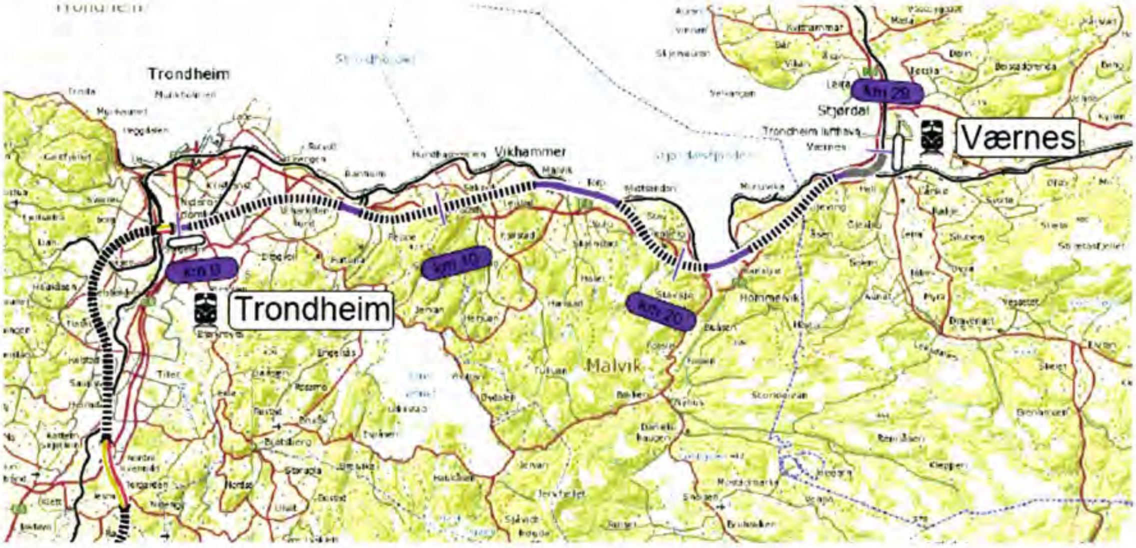


Figure 41. Excerpt from Avinet, showing the alignment Trondheim-Værnes. Source: Geovekst.

6.9 Trondheim area

6.9.1 Section Melhus - Trondheim

When starting the railway design, it was clear that there would be a number of possible solutions for entering Trondheim with a high-speed railway line, and that the location of the railway station had to be considered. Presently, the main station, Trondheim S, is situated in Brattøra.
Therefore, the whole area was studied in more detail to identify possible locations for a new main station and its feeder lines south (from/to Oslo) and east (from/to Værnes). Some aspects of the location of the new station are documented in more detail in Chapter 8.

In addition to the location of the new railway station, the railway design had to take care of other important constraints:

- Ground conditions / Geology
  If possible, quick clay deposits should be avoided. In particular, the areas around Melhus and Heimdal have multiple zones with high risk levels.

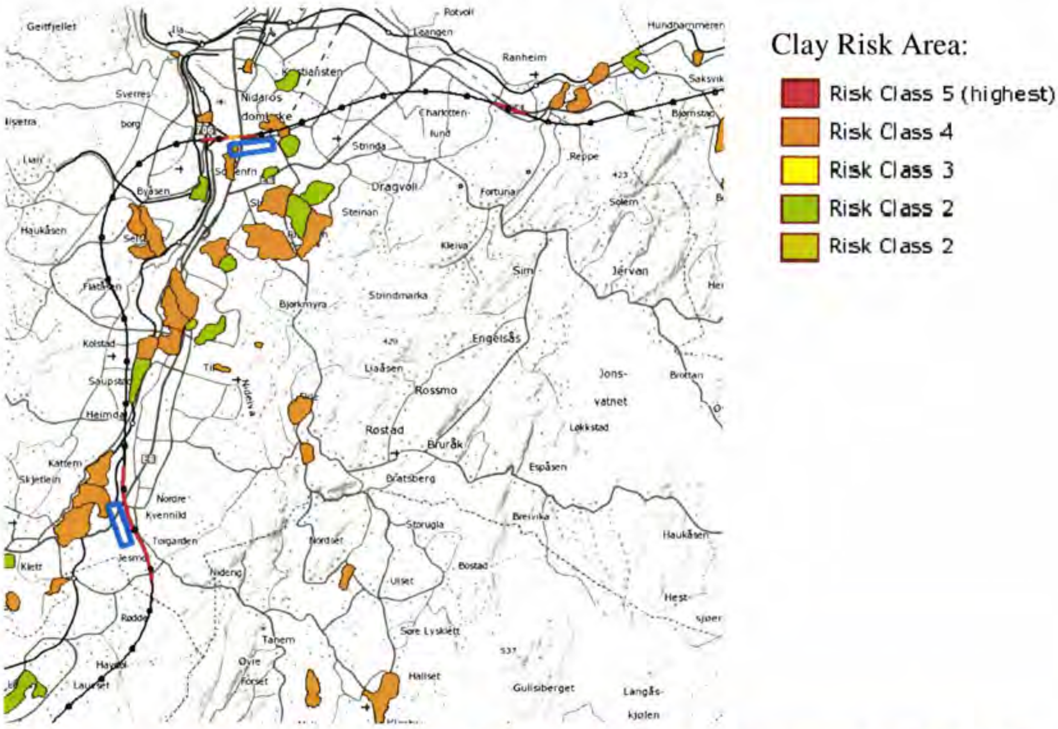


Figure 42. **Excerpt from Avinet, showing clay hazard zones in the Trondheim area, as well as the proposed alignment for the new high-speed railway line. Source: Geovekst.**

- **Agriculture**: Avoid crossing high quality agricultural areas (Gauldalen)
- **Environment**: Avoid the river banks from Melhus northwards due to high ecological sensitivity
- **Freight terminal**: If possible, connect the Sandmoen freight terminal to the new HSR network
- **Skansen Bridge**: Special care should be taken regarding sewer lines, the new north tangent and the new Ilabekken tunnel

As Trondheim is the end-point for the market, it could be assumed that all trains are stopping there; hence the design speed could be reduced, and thus allow for more flexibility in the railway design (smaller radii).

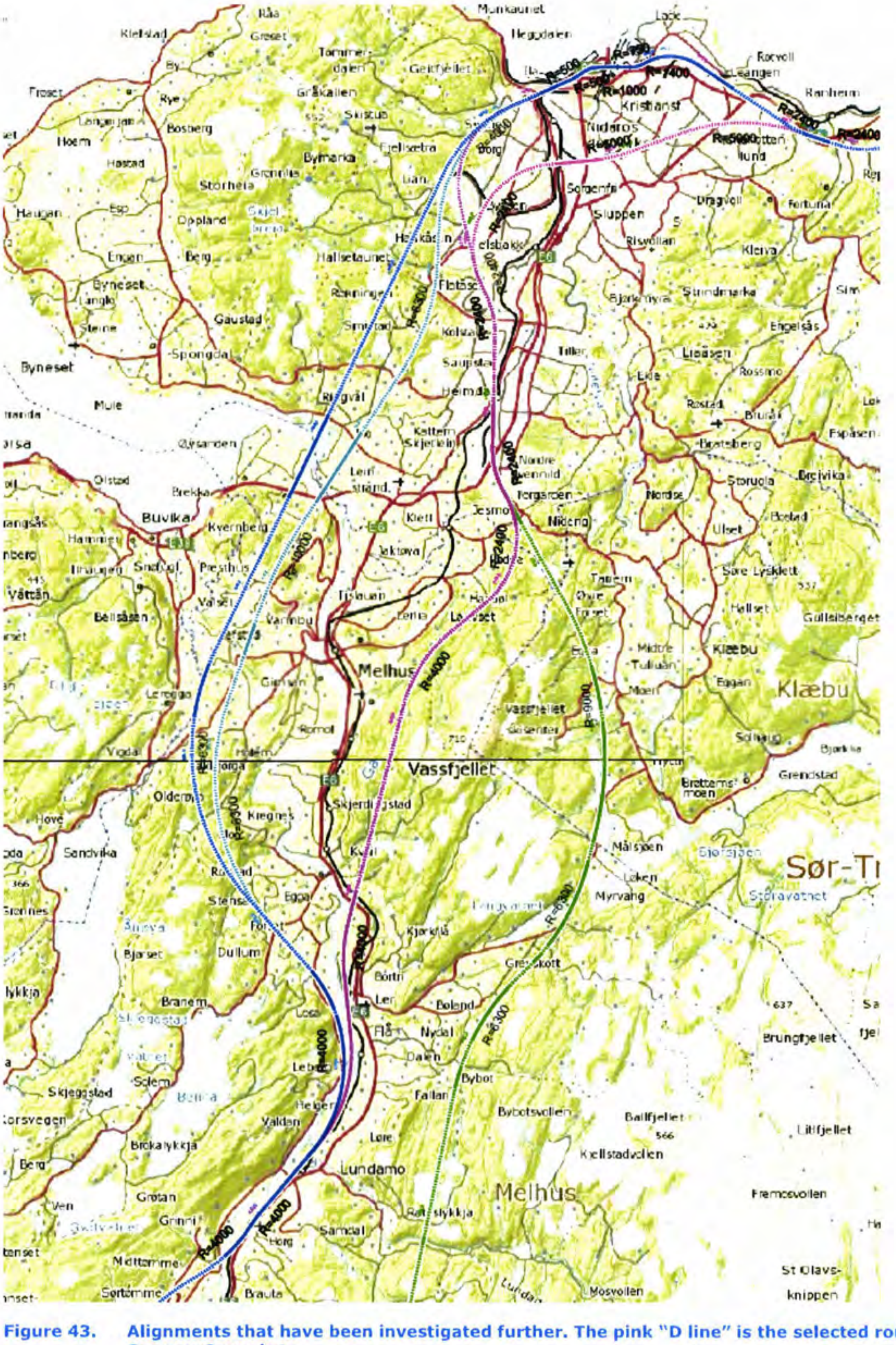


Figure 43. Alignments that have been investigated further. The pink "D line" is the selected route. Source: Geovekst.

Compared to the other railway routes, the selected line (shown in pink in Figure 43) is the straightest connection and has the lowest tunnel share.

Figure 44. Potential location of a freight terminal in Trondheim area. Source: Geovekst.

Concerning the linking of a new freight terminal to the railway network, three potential locations in the Trondheim area were studied:

- Trolla: Located directly on the coast, the structure has to be built directly into the rock. The most important disadvantages of this location are the non-availability of space as well as other infrastructure projects (e.g. road tunnel) directly in the surrounding area. A link to the existing railway line would incur considerable expense.
- Sandmoen: The freight terminal will be located close to Heimdal, with a direct link to the new high-speed rail as well as the existing railway infrastructure.
- Søberg: Generally, there are no severe issues against this location. The main problems lie in the considerable distance to Trondheim and the separate infrastructure that would be required to link the freight terminal to the railway network.

In conclusion, the Sandmoen location can be recommended for the new freight terminal.

6.9.2 Section Soknedal – Melhus

Between Soknedal and Melhus, various possible railway alignments for the Scenarios 2*, D2 and D1 have been designed. The following constraints had to be taken into consideration when designing the high-speed railway line:

- Location of a station at Støren
- Geological conditions
- Topographic situation: difference in elevation between Soknedal and Melhus

Finally, two options remained:

- Alignment D2 with a station at Støren
- Alignment D1 with an interchange to the existing railway line

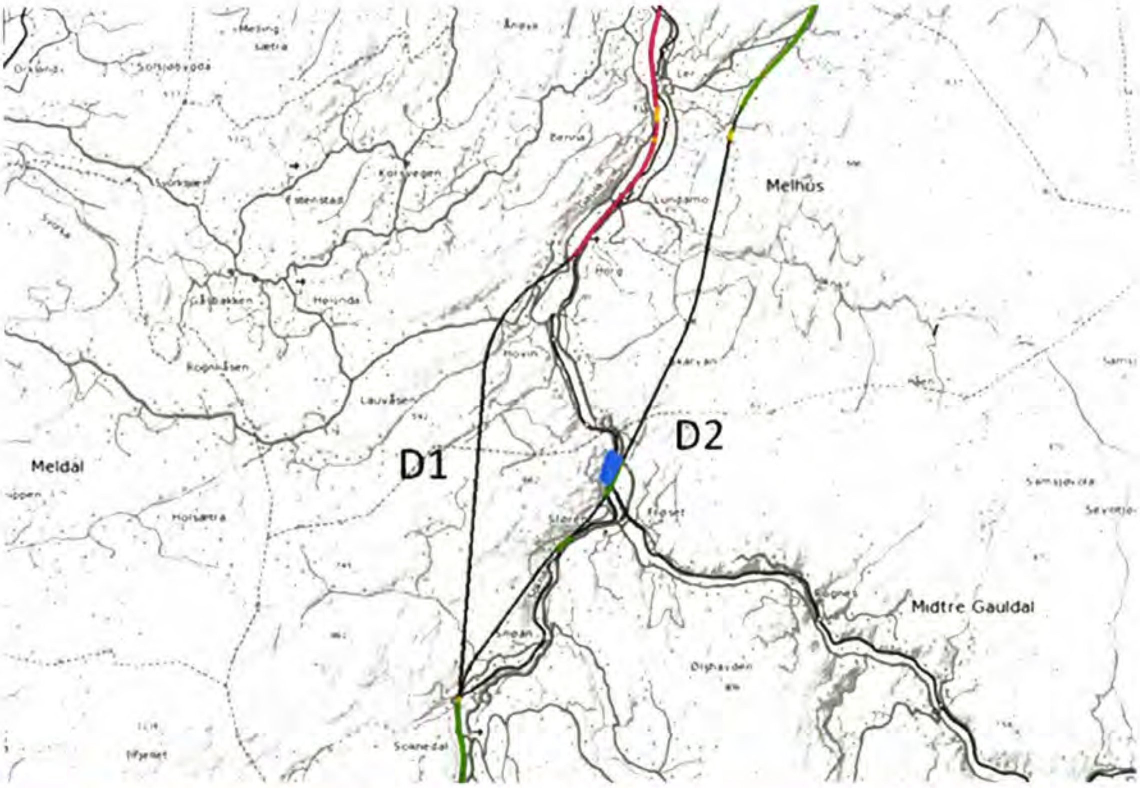


Figure 45. Excerpt from Avinet, showing the remaining options between Soknedal and Melhus (left: D1, right: D2). Source: Geovekst.

We decided to continue with D1 because this will provide reasonable flexibility for freight traffic and because the only advantage of D2 was the station at Støren where we believe an interchange could be provided to the north of Støren. Costs would also probably be lower.

For the D1 alignment, the design speed is slower than 330 km/h due to the fact that all trains have to stop at Trondheim, and trains starting from Trondheim heading southwards will not be able to reach 300 km/h in this section due to gradients and air resistance in tunnels. Therefore, the maximum speed for the interchange on the D1 alignment was reduced to 275 km/h, allowing for a section in open track.

It is also an argument for choosing the D1 alignment that the planned freight terminal at Torgård could then quite easily be connected to the D1 alignment.

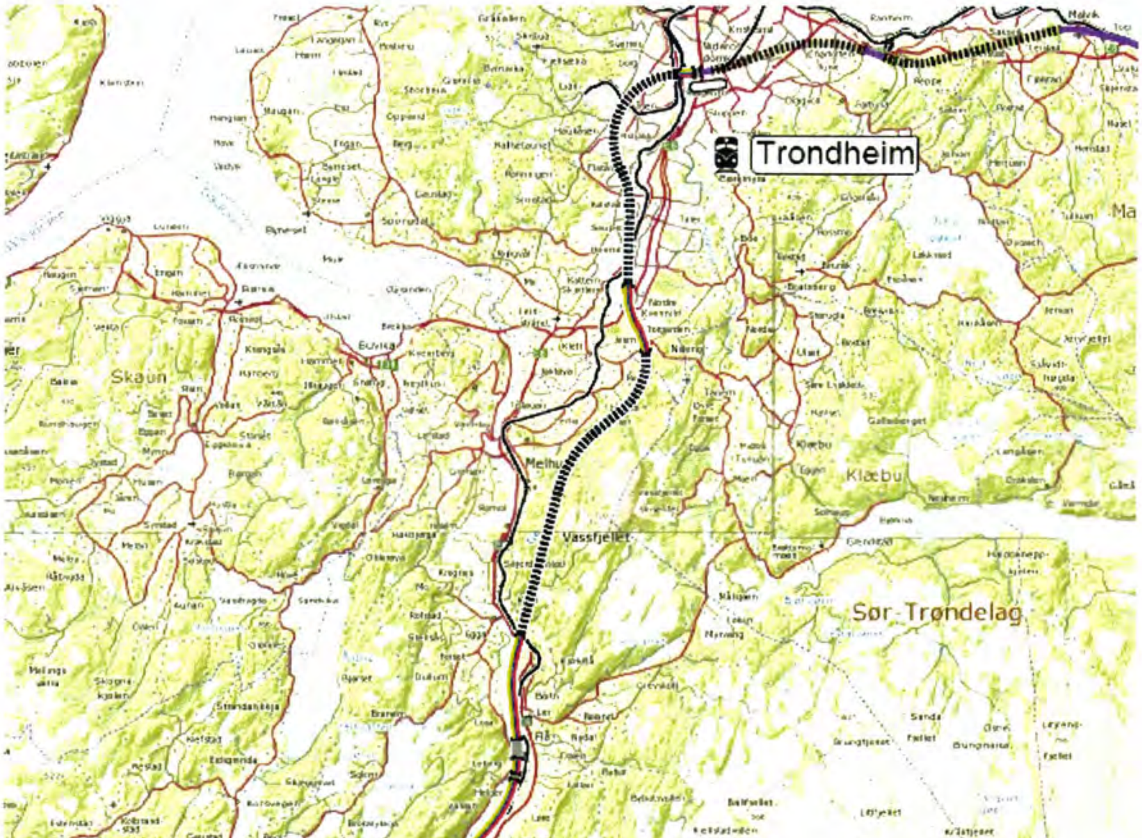


Figure 46. Proposed alignment between Soknedal and Trondheim. Source: Geovekst.

6.10 Gardermoen – Tangen

Due to capacity considerations it might be necessary to add a third track between Gardermoen and Tangen as part of a later so-called "Step 2" if the high-speed railway line ends up running through the Østerdalen corridor. It is assumed that this additional track will be built according to Scenario D2, as the freight trains would be able to continue using the IC alignment.

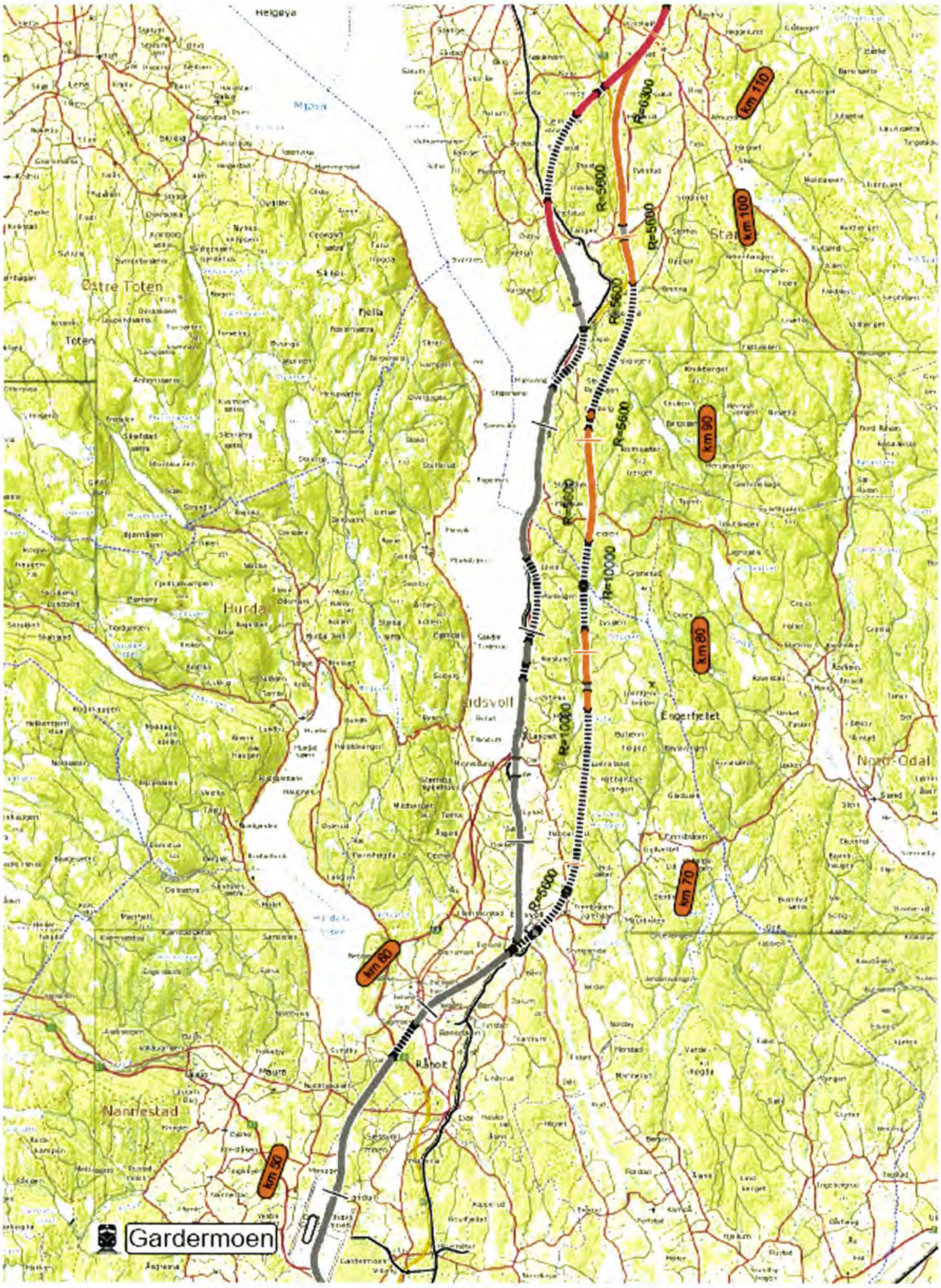


Figure 47. New D2-alignment between Gardermoen and Tangen (orange). Source: Geovekst.

6.11 Conclusion, alignment issues

From a railway engineering point of view, it is clear that only the corridor through Østerdalen allows for an alignment for a high-speed railway line with relatively low difficulty, reasonably few tunnels and a very high velocity of up to 330 km/h. All in all, from a railway engineering perspective, this corridor seems most suitable for constructing a high-speed railway connection with non-stop travel times between Oslo and Trondheim of around 2 hours.

7. DISCARDED ROUTES AND VARIANTS

7.1 Introduction

In the beginning of the study, all possible routes in the corridor Oslo – Trondheim were considered. After a first evaluation, several routes were discarded because they seem to be not feasible, too expensive, or because there are alternative and more useful routes.

Regarding the selected routes, several variants were evaluated as requested by Jernbaneverket. Based on topographical criteria, the number of variants was narrowed down for detailed evaluation.

7.2 Discarded Routes

7.2.1 Overview

The following routes were discarded and are no longer part of the detailed study:

a) Oslo – Gjøvik – Lillehammer (- Trondheim)
b) Lillehammer – Koppang (– Tynset – Trondheim)
c) Lillehammer - Ringebu – Atna (– Tynset – Trondheim)
d) Gudbrandsdalen – Folldalen – Oppdal (– Trondheim)
e) Østerdalen – Rendalen – Storsjøen (– Tynset – Trondheim)
f) Østerdalen – Tynset – Røros – Gauldalen (– Trondheim)
g) Østerdalen – Tynset – Røros – Værnes - Trondheim
h) Orkdalen
i) Gardermoen – Hadeland – Gjøvik (- Lillehammer)
j) Gardermoen – Skreia – Gjøvik (- Lillehammer)

The corridors are shown in Figure 48.

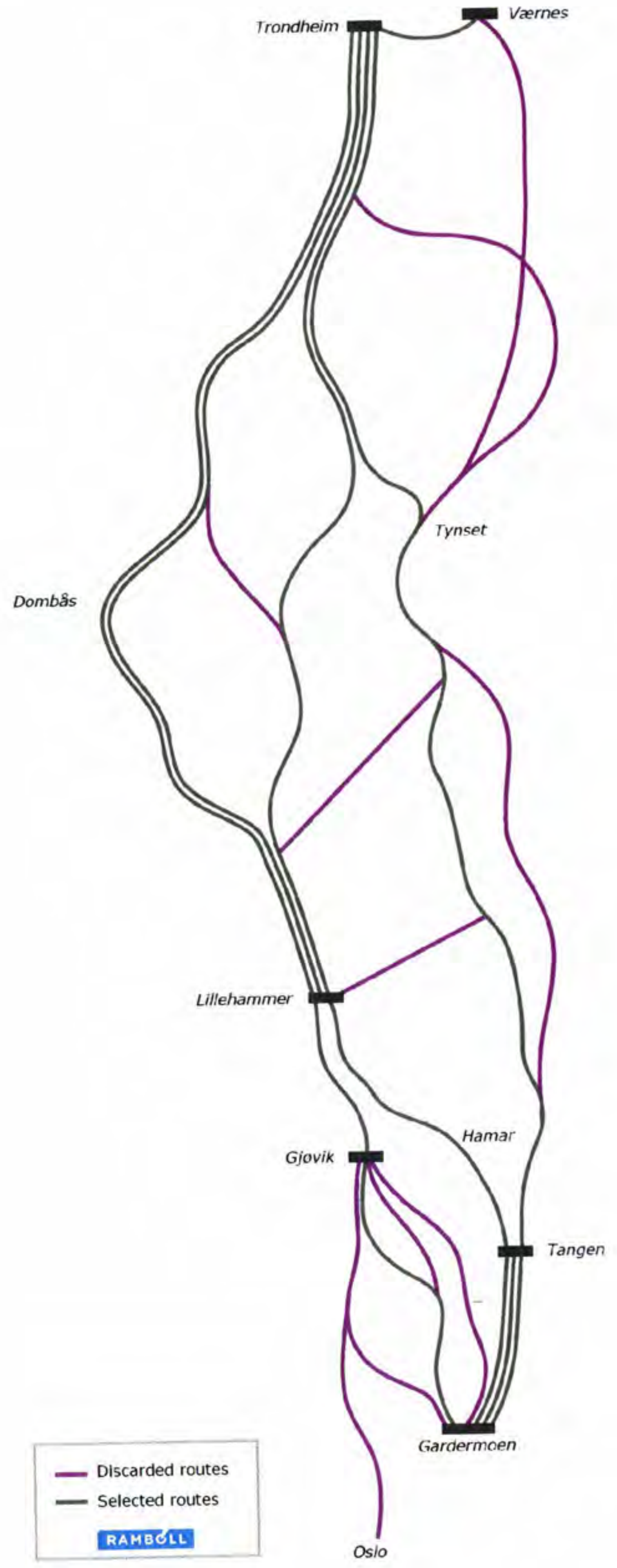


Figure 48. Discarded routes not to be investigated further.

7.2.2 Oslo – Gjøvik – Lillehammer (- Trondheim)

This corridor-variant involves the upgrade of the existing regional railway line between Oslo and Gjøvik, and continues from there to Lillehammer and Trondheim. As all high-speed lines in Corridor North must have a stop at Gardermoen Airport, this line had to be discarded. Other variants are dealing with a HSR connection to Gjøvik.

7.2.3 Lillehammer – Koppang (– Tynset – Trondheim)

As the greatest disadvantage of the line through Østerdalen is the missing connection with Lillehammer, attempts were made to find alternatives which connect Lillehammer with the Østerdalen line. The first possibility runs directly from Lillehammer to Østerdalen in the same corridor as the heritage road, Birkebeinerveien, and joins Østerdalen south of Koppang. As there is a mountain range in between both valleys, the alignment results in an approximately 50-km-long tunnel. The higher investment resulting from this tunnel should be compensated by additional demand compared with the direct Østerdalen line.

This demand contains only northbound potentials of Hamar and northwards, including Lillehammer, as the demand for stops at Hamar and Lillehammer in the Oslo direction is served by IC traffic. As the prognosis regarding additional demand from Hamar, Lillehammer, Stange, Løten and Elverum towards Trondheim is only about 500 passengers/day (source VWI study 2007), this will not compensate for the high investment associated with the long tunnel.
This corridor-variant will therefore result in a worse cost-to-benefit ratio than the alignment through Østerdalen, which is why we recommend discarding this route.

7.2.4 Lillehammer - Ringebu – Atna (– Tynset – Trondheim)

To obtain a better connection of Gudbrandsdalen and to avoid an alignment over Dovrefjell, we evaluated a corridor-variant which follows Gudbrandsdalen to Ringebu and then turns to the north-east to cross towards Østerdalen which will be joined close to Atna. This results in a tunnel with a length of about 40 km, i.e. one shorter than would be the case at the connection between Lillehammer and Koppang. However, the alignment through Gudbrandsdalen between Lillehammer and Ringebu is also very challenging, and involves, in fact, a series of tunnels with short daylight-zones where the line crosses valleys and rivers. For this reason, additional investment costs are very high compared to the Østerdalen line and the few extra passengers thus served would never justify the higher costs. We therefore recommend discarding this line.

7.2.5 Gudbrandsdalen – Folldalen – Oppdal (– Trondheim)

A high-speed-line following Gudbrandsdalen up to Dombås and over Dovrefjell will result in a series of (long) tunnels. Therefore, the consulting group considered an alternative alignment through Folldalen. This alternative includes two possibilities further north, i.e. a connection with the alignment of the Østerdalen line between Tynset and Kvikne, or a connection with the (upgraded) Dovre line south of Oppdal. The latter alternative crosses the mountain range east of Dovrefjell National park and would require long tunnel-sections. The alternative route towards Østerdalen would require fewer tunnels and (probably) lower investments and is therefore preferable. The line from Folldalen to Oppdal has therefore been discarded.

7.2.6 Østerdalen – Rendalen – Storsjøen (– Tynset – Trondheim)

A variant involving the eastern corridor through Østerdalen consists of a line east of Østerdalen branching off at Rena, following Rendalen, Lake Storsjøen and Tylldalen towards Tynset, with a connection further north via Ulsberg and Støren to Trondheim. This is the shortest and most direct line serving an area with even less population than in Østerdalen. The topography allows for a very straight line up to Øvre Rendal, but in the northern part of Tylldalen, a pass at an altitude of 710 m has to be crossed.

The disadvantages of this alternative line can be seen in the problematic alignment along Lake Storsjøen and the farming area between the lake and Øvre Rendal. But the final reason for discarding this alternative is that a high-speed line in this area would create a new border in unspoilt area. On the other hand, Østerdalen already has a major road (R 3) and an existing railway-line, which - depending on the level of upgrading - can be partly used for a new alignment.

7.2.7 Østerdalen – Tynset – Røros – Gauldalen (– Trondheim)

The existing railway line over Røros and through Gauldalen at the moment allows only rather low speeds due to difficult topographical conditions. The line is about 45 km longer than the alternative via Ulsberg. Upgrading is expensive, especially in the narrow valley of Gauldalen. Therefore, this is not a viable alternative for HSR (D alternatives).

A new line from Tynset via Ulsberg to Støren could provide a better alternative than the upgrade of the line via Røros. This applies for Scenarios B and, especially, for Scenario 2*, and should be discussed at a later stage. Another possible use for the (electrified) line is for freight services if HSR is developed only for passenger services. This will be studied during further work.

7.2.8 Østerdalen – Tynset – Røros – Værnes - Trondheim

This alternative follows the valley from Tynset to Røros and continues almost directly northward from Røros towards Værnes Airport. This alignment also causes a new border in an undeveloped landscape instead of following existing transport corridors. There is no straight valley to follow, so alignment planning will be rather challenging and will require a high tunnel share.

It passes by the airport before entering Trondheim. As the existing line, Trondheim – Værnes – Stjørdal (the Nordland line), crosses the airport in south-north-direction, the HSR can only access the airport from the north, via a big loop east of the airport, or from the south, although the latter requires a change of direction within the airport station. Neither of these solutions is useful for a very fast HSR connection Oslo – Trondheim. The line is around 50 km longer than the basic alternative via Østerdalen; therefore, travel times under 2:45 h, even without stopping at Værnes, are not realistic.

In a future upgraded railway network in Norway, the Nordland line from Trondheim to Bodø is expected, at least, to be electrified and upgraded to Steinkjer, and there are on-going discussions for reducing journey times between Steinkjer and Trondheim to one hour. That could also imply extending HSR service from Oslo via Trondheim to Steinkjer. An alignment from Røros directly to Værnes and then on to Trondheim does not fit well with such a scenario. Passengers from Steinkjer would have to change trains in Værnes or drive to Trondheim and then travel back to Værnes before they can continue towards Oslo.

So the main destination should be Trondheim and then an addition can be Værnes and not the other way round. Therefore, this variant is discarded.

7.2.9 Gardermoen-Hadeland-Gjøvik

As the railway-line from Gardermoen via Hamar to Lillehammer has limited capacity due to IC- and freight traffic, alternatives for HSR were considered via Gjøvik to Lillehammer. One of the possible routes for this branch line is via Hadeland. In addition to the town of Gjøvik, there is some potential for a rail connection to Gardermoen in this area. But as HSR lines are designed for very high velocities, there will never be a stop in both Gjøvik and Hadeland. And the potential for a separate local train service is considered not to be high enough. The rather densely-populated areas would necessitate additional tunnels for HSR due to noise problems. For the above-mentioned reasons and because there are much shorter alignments to connect Gardermoen with Gjøvik, this route was discarded.

7.2.10 Gardermoen-Skreia-Gjøvik

Another possibility for connecting Gardermoen with Gjøvik by HSR is to follow the west-bank of Lake Mjøsa to Skreia and then to Gjøvik. This line requires a high tunnel share and has to cross the environmentally-sensitive agricultural area between Skreia and Gjøvik. Therefore, this route was discarded.

7.2.11 Orkdalen

In the northern part of the corridor, there is an alternative to the Dovre line between Berkåk and Trondheim through Orkdalen. This alternative extends from Berkåk towards the northwest to Løkken and Orkanger, and then follows the coastline to Trondheim. The entire section is rather problematic for alignment planning because of topographical constraints and the settlement distribution between Løkken and Trondheim. Furthermore, it is more than 30 km longer than the direct line via Støren. Also, the area does not have a high enough passenger potential to compensate for this. Therefore, this route was taken out of further consideration.

7.3 Discarded variants

7.3.1 Overview

As described earlier in this report, a number of possible scenarios and variants within scenarios are possible. For each chosen route, several variant were considered.

After completing the alignment planning, the following variants were discarded:

- 2* and D2 in Gudbrandsdalen
- D1 in Rondane
- D1 to Gjøvik (Gudbrandsdalen and Rondane)
- D1 Gardermoen-Tangen (Østerdalen)
- 2* and D1 from Tynset to Støren (Østerdalen)
- D2 from Tangen to Tynset (Østerdalen)
- D1 and D2 Trondheim to Værnes
- D2 (eastern route) from Soknedal to Trondheim, all corridors

7.3.2 2* and D2 in Gudbrandsdalen

The alignments are drawn (see Attachment 1), but have not yet been brought to a full appraisal. The alignment shows that there is not very much difference in the tunnel share between alternatives 2*, D1 and D2. As 2* allows velocities only up to 250 km/h and D2 needs additional investments in order to accommodate freight traffic, which has to run on the existing line due to higher gradients in D2, the two variants were discarded from further work.

7.3.3 D1 in Rondane

The alignments are drawn (see Attachment 1), but they show that there is a significant increase in tunnel share. Due to the lower flexibility of D1 because of the rather low maximum gradient, the intrusions into the sensitive areas of Rondane would be much higher than in D2, and it is inconceivable that freight trains will be allowed to run along the Rondane National park. Therefore, this variant was not brought to full appraisal.

7.3.4 D1 to Gjøvik (for Gudbrandsdalen and Rondane routes)

This variant makes sense only if freight trains would go via Gjøvik. However, it must be assumed that freight traffic would use the new planned line from Gardermoen via Hamar to Lillehammer. Therefore, there is no need to go into detail with this variant because a D1 variant involves a much higher investment in this corridor than D2. Therefore, this variant was discarded. The alignments are shown in Attachment 1.

7.3.5 D1 Gardermoen-Tangen (for the Østerdalen route)

This branch line is an addition to the newly planned IC-line Gardermoen – Hamar – Lillehammer. It must be assumed that freight traffic will be using the IC line. Therefore, there is no need to plan using the new High-Speed-Line also for freight.

7.3.6 D2 from Tangen to Tynset (for the Østerdalen route)

The line goes from Tangen to, and along, Østerdalen and is almost flat. So the maximum gradient of 12.5 ‰ from D1 is sufficient to deal with the topographic conditions and there is no need for D2 along this line.

7.3.7 2* and D1 from Tynset to Lundamo

The basis for the operational concept of the Østerdalen corridor is that freight traffic will be using the HSR line from Eidsvoll to Tynset, and from there, will use the existing line via Røros to Lundamo (which has to be electrified). For this reason, there was no need for a D1 alignment between Tynset and Lundamo. The higher D2 gradients allow shorter tunnels, especially descending from Kvikne down to Lundamo. A 2* alignment has no significant advantages over D2 in this section. Therefore, both variants were discarded.

7.3.8 D2 (eastern route) from Soknedal - Trondheim

This variant was designed to provide HSR access to Støren. Due to the D2 gradients, this variant would require a connection from HSR to the existing railway line at Soknedal to switch freight trains from the HSR line over Dovre to the existing line. In addition, the D2 variant in this section has a significantly higher tunnel share compared to D1.

As the potential for HSR in the region around Støren is not very great and there would be a need for higher investments for longer tunnels and additional investments on the existing line for freight, this variant was discarded.

7.3.9 D1 and D2 Trondheim to Værnes

Because of the short distance between Trondheim and Værnes, where all trains will be stopping, we will not reach 330 km/h in the D1/D2 alternative. So there is no significant difference in travel time between the D1/D2 variants and the 2*-variant, but a much higher investment would be required for the D1/D2 variants. As there are no benefits for the D1/D2 variants compared to the 2*-variant, but higher investment, the D1/D2 variants can be discarded.

8. STATIONS

8.1 General

This chapter includes an overview of market evaluations, initial search of routes, station layouts, detailed layout for each station, a description of suggested locations including distances to local towns and villages and typical suggested service facilities. Some stations are given special attention.

Stations south of Hamar/Elverum parkway have not been evaluated. These stations are included in more detail in the intercity KVU project.

Discussing a preferred location of a high speed station in Trondheim has been an important issue. The location affects both journey time and cost. Therefore Trondheim has been studied in more detail than the other stations.

Stations layout:

	All	Gudbrandsdalen						Østerdalen				All alignments			
	Gardermoen	Hamar	Lillehammer	Ringebu	Vinstra	Otta	Dombås	Elverum parkway	Rena	Koppang	Tynset	Garli	Trondheim	Værnes	Gjøvik
Existing station	X														
Standard layout				X	X	X	X	X	X	X	X	X			X
Special layout		X	X										X	X	

Figure 49. Overview of stations layout.

At a standard station high-speed trains (HST) either stop or pass. When HST are passing a station, it is essential for achieving target end-to-end journey time that it passes without reducing speed from 300 km/h or 250 km/h. Speed limit for tracks serving platforms are 160 km/h. Hence, tracks serving passing trains have to be separated from tracks serving platforms. Standard stations must also cater for possible overtaking of freight trains. A standard station covers a length of 1 km. Standard layout includes sound barriers (blue) between HSR passing tracks and tracks serving platforms:

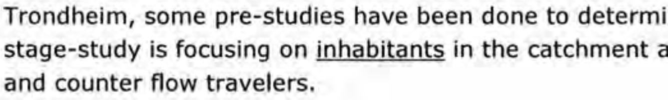


Figure 50. Standard High speed rail station for stopping and passing trains.

8.2 Potential catchment areas to intermediate stations

In order to get an overview of the intermediate markets not including Oslo, Gardermoen and Trondheim, some pre-studies have been done to determine local market potential. This early stage-study is focusing on inhabitants in the catchment areas, dividing them into parallel flow and counter flow travelers.

The total travel market depends on travel frequency, modal split and distribution of destinations. For many of these villages, travel habits are not found in the national travel survey. To base assumptions here on average numbers will not represent the nature of these existing travel markets as they lack main fast train connections and/or airports which are essential for extensive long distance travel to larger cities like Oslo. Intermediate stations in rural areas may nevertheless represent a significant catchment area when total travel time savings are large enough.

This preliminary market study has provided input to the alignment study on whether to locate stations north of, south of or close to existing towns. Stations included are from Hamar/Elverum in the south to Garli (replacing Berkåk/Støren) in the north.

The size of these markets is described by a hypothesis where:

- Potential for travel time savings (mode change included) increases with distance. Stations closer to destination attract fewer travellers to switch from car to train, and vice versa.
- Stations close to Oslo/Trondheim will to a larger extent have other transport available. The market for High Speed train is limited.
- Parallel flows with the high speed train are believed to have a 60 minutes catchment area (by car).
- Contra flows with the high speed train is believed to have a 20 minutes catchment area (by car).

8.3 Station location in Trondheim

8.3.1 Background

In order to study feasible ways to serve Trondheim in the different alignments, a brainstorming-meeting was arranged in Trondheim. Participants were representatives from Jernbaneverket Planning division north, the High Speed project in Jernbaneverket and experts from Rambøll with deep knowledge about local challenges, ongoing projects, geological and geotechnical conditions in the Trondheim area. Several possible locations were evaluated:

Location	advantages	disadvantages
Brattøra (as today)	- Close to city centre - New business area north of station - Connectivity to northbound rail - Easier track alignment northbound	- Narrow access from south though dense area with historical value. - Distance to residential areas - Triggers need for 2 stations (Heimdal) - Tunnelling north of Sluppen result in too many conflicts with existing infrastructure - Sum of technical complexity and conflicts with preserved area makes alternative nearly impossible
Lerkendal / Stavne	- Geographical gravity - Close to main road system - Close to high-frequency public transport - Close to planned business area - Excellent for connection to the Marienborg depot	- 2 km from city centre - Expropriation of parts of (low density) residential area necessary - Extension of HSR line into tunnel is challenging due to areas with quick clay (not applicable if HSR line terminates here)
Midtbyen (town centre, below ground level)	- Extremely close to city centre - Connectivity to other modes of transport	- Technically challenging (tunnelling in river delta below water level, and crossing river twice) - Expensive - Parking areas and car traffic undesirable downtown - Vulnerable historical area
Leangen	- Desirable hub for eastern and northern areas - Vacant areas - Connectivity to northern rail - Near business areas, existing and planned. - Relatively close to high-frequency public transport	- Undesirable hub for western areas - Distance to town centre - Triggers need for 2 stations
Tyholt (tunnel)	- Geographical gravity	- Residential area - Undesirable road network - Unfavourable public transport - Expensive station in solid rock
Dragvoll	- Easy access from south - Close to universities - Potential for denser population areas - Access to road network OK - Technically the less complex alternative	- Distance to town centre - Away from dense populated and business areas - Less frequent public transport
Sluppen	- Close to main road system - Close to existing and planned business area	- 4 km from city centre - Less frequent public transport

Figure 51. Evaluated localizations of a possible new HSR-station in Trondheim.

Three alternatives were regarded as the most interesting ones and were further assessed regarding technical complexity and market potential. These three alternatives were:

- **Brattøra** (blue line)
- **Lerkendal** (green line)
- **Dragvoll** (pink line)

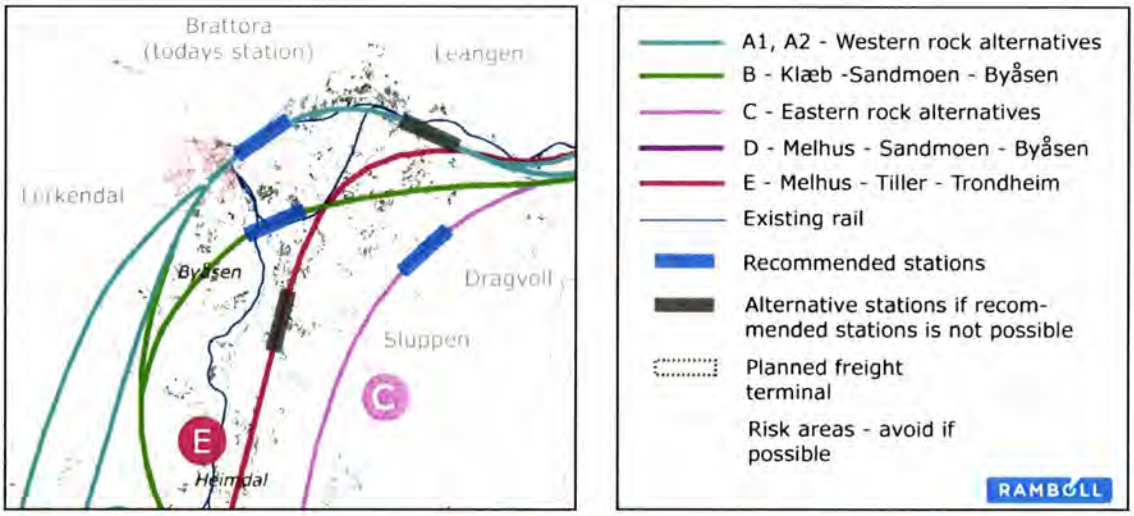


Figure 52. Alternative localization of terminus station for high-seed railway Oslo – Trondheim.

8.3.2 Market potential of alternatives in Trondheim

Recommended stations from brainstorming were Brattøra, Lerkendal/Stavne and Dragvoll. These stations were further analysed with the ATP[2] model to assess which to be the most desirable according to population and labor density. The calculation is based on today's data and for the modes walk and by car. Obviously, the results will not cover a future situation with new networks and build-up areas. However, the calculation will give an indication of the most favorable station allocation based on today's assumptions. The present situation will represent a majority of the future development, and the allocation of a new main rail station will affect new settlements so the correct future situation would be challenging to simulate correctly.

Method

The calculation is based on localised population and employment data on a detailed level, down to street addresses. Calculations of distance in time can be performed on several modes, in this case walk and by car is used, from chosen allocations. In this case two types of calculation are performed:

1. Distance along road network within time intervals (0 – 15 min and 15 – 30 min) for mode walk and by car
2. Analyse of nearest station to all population and employed within Trondheim boundaries for modes walk and by car.

Assumptions

Calculations are based on network-, population-, and employment data from 2009. The road network is based on "Elveg" which consist data for all drivable roads above 5 metres with speed

[2] GIS-based tool developed by Asplan Viak in the 1990s.

limits and restrictions included. For walking the data is supplemented with relevant walking routes. Every link is coded with speed 5 km/h.

Results:

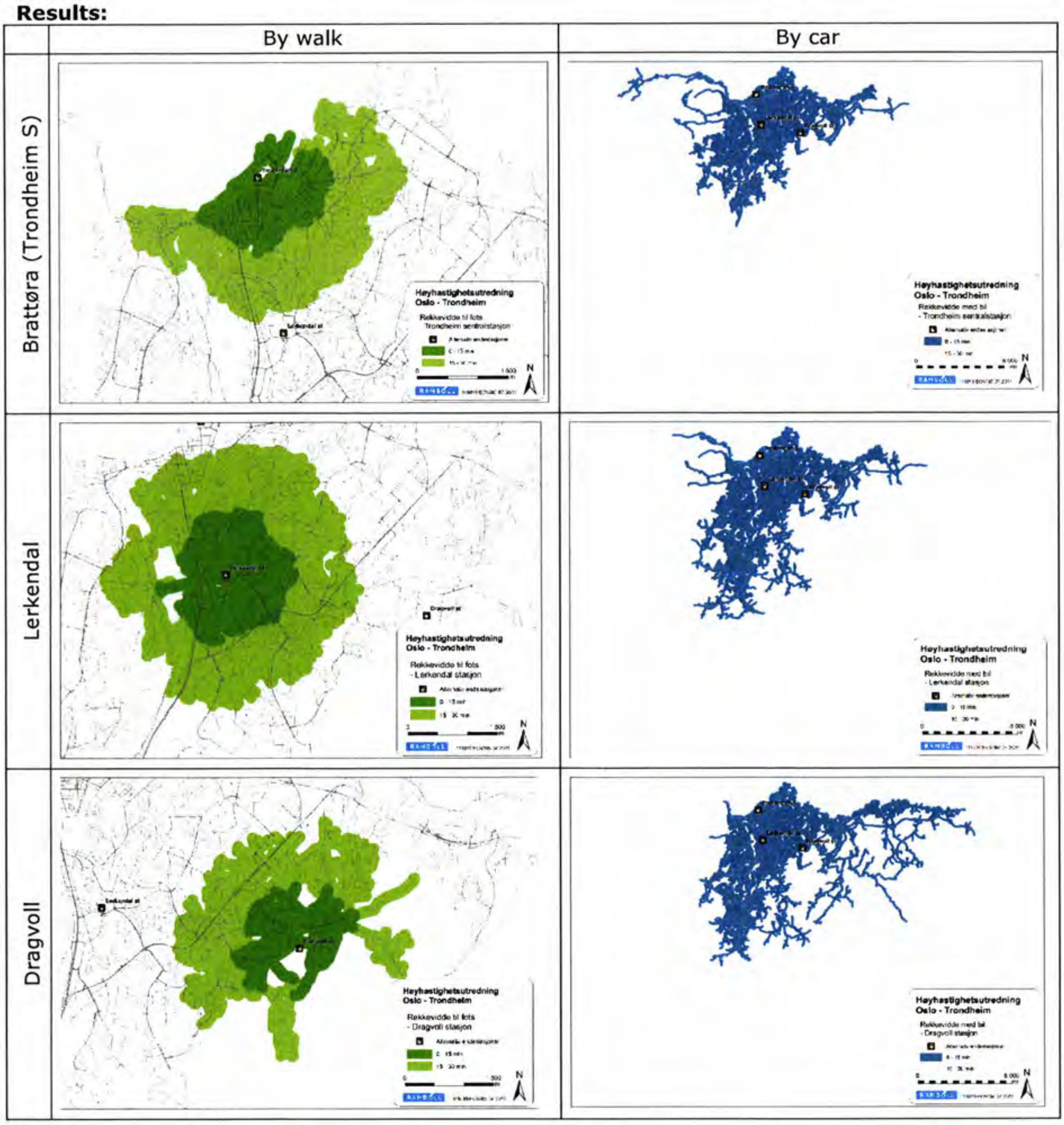


Figure 53. Catchment areas within 15 minutes and 15 to 30 minutes, by walk and by car.

		Brattøra	Lerkendal	Dragvoll
Residence	0 – 15 min	89 %	96 %	94 %
	15 – 30 min	11 %	3 %	6 %
Work place	0 – 15 min	93 %	96 %	95 %
	15 – 30 min	4 %	1 %	2 %

Figure 54. Percentage of population in Trondheim by car within 15 and 30 minutes.

Results indicate that Lerkendal is the most favorable location in matter of catchment area both walking and by car.
Another method "nearest point" shows which station that represents the shortest route from residence or workplace.

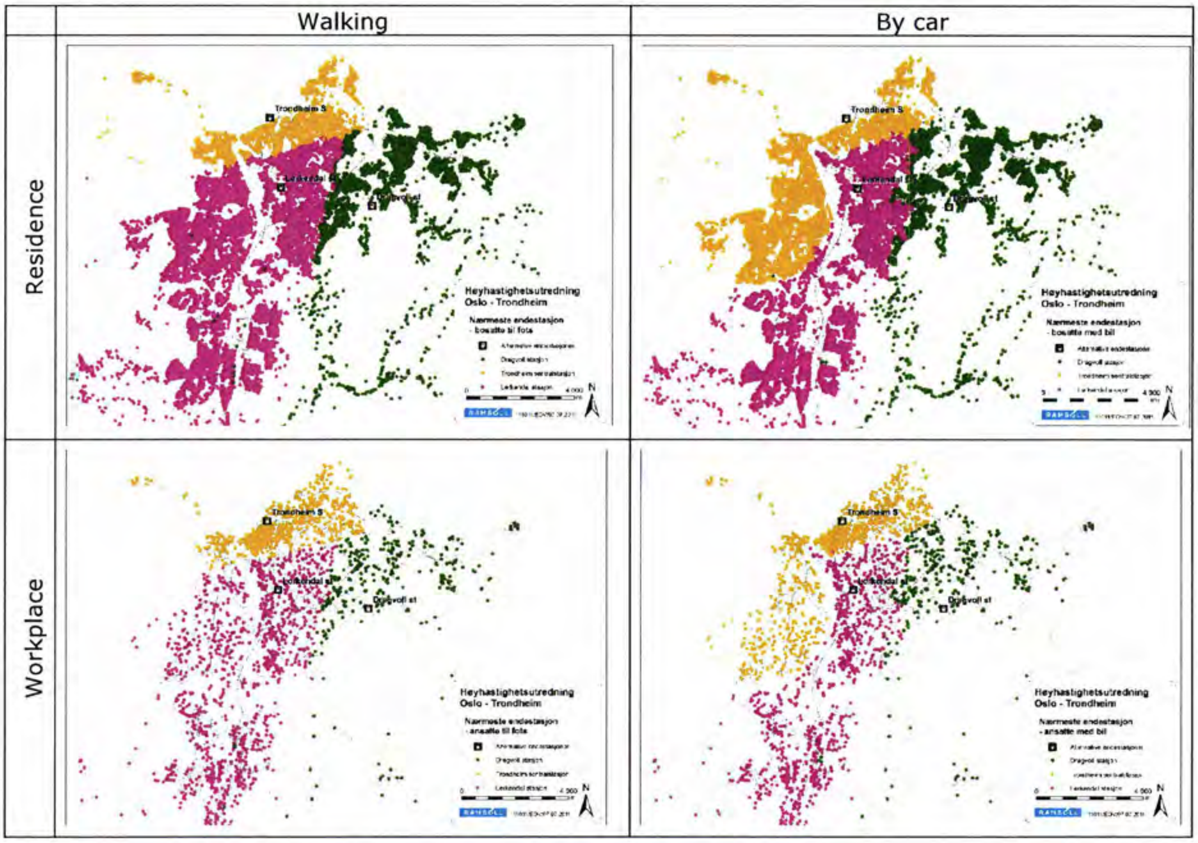
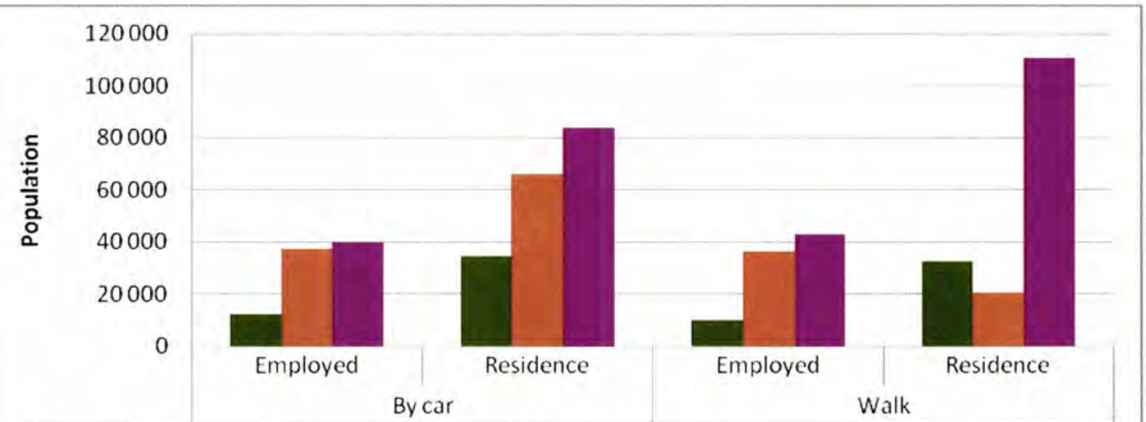
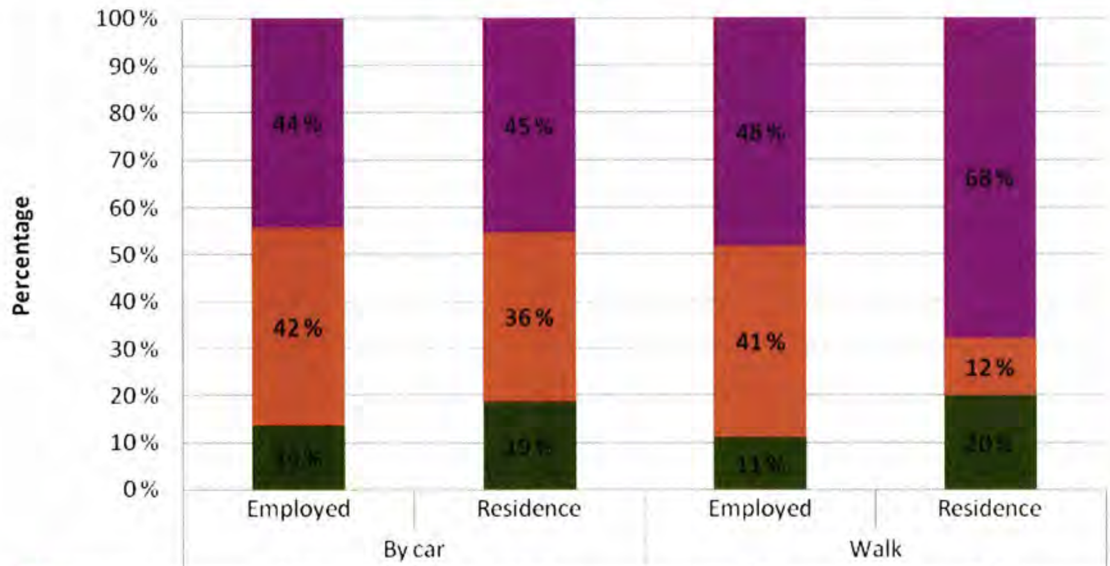


Figure 55. Nearest station from residence or workplace, by walk and by car.



	By car		Walk	
	Employed	Residence	Employed	Residence
Dragvoll st	12 240	34 265	9 799	32 480
Trondheim S	37 363	66 025	36 346	20 332
Lerkendal st	39 612	83 698	43 070	110 782

Figure 56. Number of residents and employed to nearest station location.



	By car		Walk	
	Employed	Residence	Employed	Residence
Lerkendal st	44 %	45 %	48 %	68 %
Trondheim S	42 %	36 %	41 %	12 %
Dragvoll st	14 %	19 %	11 %	20 %

Figure 57. Percentage of population to the nearest station divided on mode and residence/work place.

Within all categories and modes Lerkendal is found to be the most favourable location of station in Trondheim. The maps reveal a significant difference between walking and by car in the western region. This is due to the lack of sufficient road capacity between western and eastern regions of the city. This situation is better between the western region and Brattøra. However there are plans to improve this connection with a new tunnel, bridge and junction to the main road network close to the station Lerkendal.

An HSR station at Lerkendal seems also to be technically and environmentally feasible and can prove to be operationally beneficial due to close location to the Marienborg depot. Connection to the existing northern line in both ends of the station location adds flexibility to future operation.

8.3.3 Geological assessment in Trondheim area

Brattøra option

Areas east of Nidelva from Marienborg to Ila is today fully exploited with mountain halls and tunnels. This is a list of the actual in-mountain constructions today:

- New carriageway with built-in roundabout. (Nordre avlastningsveg)
- Power station /Transformer in mountain hall nearby Marienborg.
- Municipal sewage tunnel in wide profile
- Shelters in mountain by Roald Amundsens road (at higher level)
- Old railway in tunnel (Killingdalssporet) parallel to carriageway.
- Waterways in shaft and tunnels.
- Several drilled shafts for sewage to sewage tunnel also

In addition, the following limits in height:

- Access road to residential area of Byåsen
- Tramlink "Graakallbanen"
- Planned road tunnel link between Sluppen - Munkvoll

Most plausible implementation of high speed rail tunnel is in level above new carriage way and beneath access road to Byåsen out in free air at Marienborg. Bridge above Osloveg north of Marienborg close to old opening to now disused railway (Killingdalssporet). Further direction Ila in the existing double track alignment towards Skansen bridge. The double track culvert beneath Kongens gate (street), has to be raised, and new bridge along existing listed Skansen bascule bridge. Large cost and intervention with preserved areas. The line is assessed to have too many conflicts to be considered as plausible. (marked in yellow)

Figure 58. Conflicts with other in-mountain constructions in the Trondheim area.

Lerkendal option

New high-speed rail on bridge above Nidelva at Sluppen is needed. There are two possible alternatives:

1. High-speed rail terminates at Lerkendal
2. High-speed rail continues in tunnel towards north (as sketched)

Alternative 2 gives some complications. Tunnel opening will have to be in the area of existing tunnel opening (Stavne – Leangenbanen). This tunnel was a complex engineering task performed by the Germans during 2nd world war, but was not opened until 1956. This was one of the first projects where a frost technique was used to stabilise an area of clay around the tunnel opening. There might be some experience to be drawn from the ongoing Stindheim tunnel project (Statens vegvesen).

However, the actual area at Lerkendal has some technical issues:

- There is not sufficient documentation of mudslide hazards regarding new development
- Depth to solid bedrock is large
- The over layer of uncompacted material above is large and tunnel construction without excavation is more plausible.

A new tunnel will run under or close to newly reestablished student housing at Berg and in a dense residential area. Track and tunnel must be lowered compared to existing tunnel. New tunnelling is assessed to be complex and associated with high costs and high risks of damage to existing buildings nearby. Available information indicates that a new track alignment will not reach solid bedrock significantly earlier than the exsisting tunnel even if a deeper alignment is chosen. However, a new tunnel will be feasible but will include extensive protection works to secure suitable waterproofness. Overall the alternative with high speed track continuing northbound from Lerkendal is assessed as technically challenging and with high risks and costs.

Figure 59. Tunnel opening from Lerkendal-area and northwards is challenging.

Dragvoll option

Bridging is necessary crossing the river east of Heimdal nearby the power station at Leirfossen. There are substantial uncompacted materials at river banks. However it is no housing area nearby and this makes terrain adaption plausible. A tunnel under Lohove and tunnel station beneath Dragvoll is necessary. The alternative is assessed to be the less complex alternative as the alignment avoids the Trondheim city centre.

8.3.4 Initial search of routes into Trondheim

The alignment engineers have worked with the different proposals from the brainstorm-meeting, and concluded with the route seen in Figure 60 . The route is presented in detail in chapter 6.9.

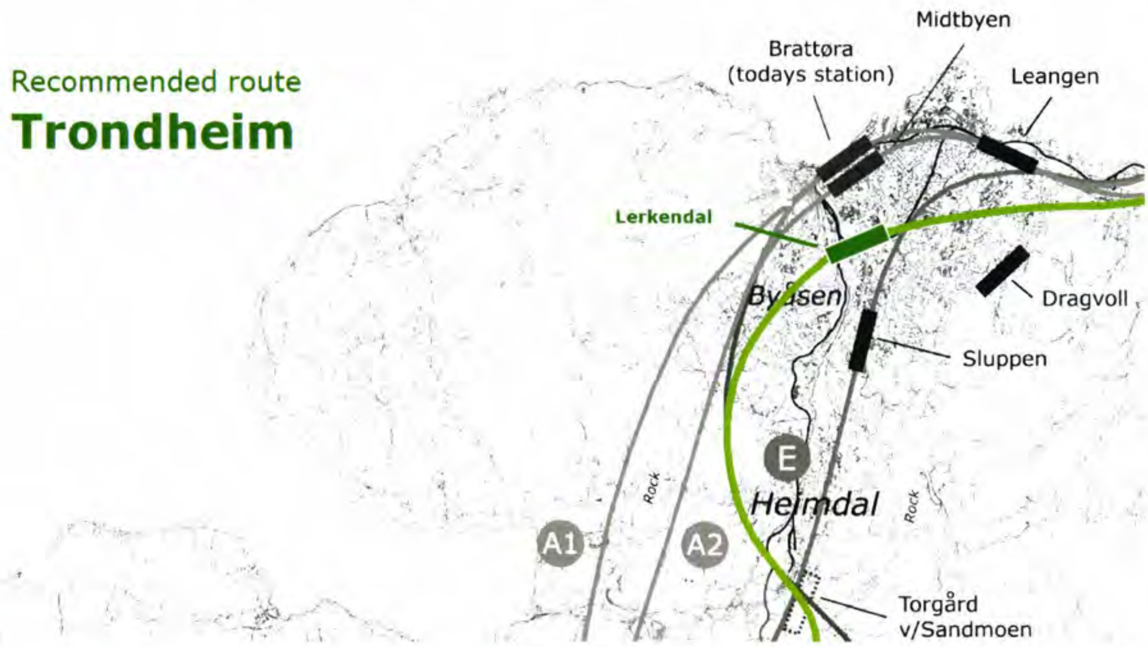


Figure 60. Recommended route (green line) into Trondheim and northwards.

8.3.5 Operational concept Trondheim station

As the HSR-service will have a departure rate of 2 trains per peak hour and there will be local-service north-/southbound with 2/1 train/peak hour plus single long-distance trains to Bodø, the station has to have at least 4 tracks, i.e. two platforms for HSR and two platforms for local and long-distance services. Single additional HST in peak hours can also be handled on the two tracks for HST as they are arriving from/departing to the depot area and subsequent with short stops at the platform.

Whether local trains shall serve the station can be decided at a later stage. It depends on which operational concept one chooses for local train operation. The Lerkendal station will, apart from a connection to the new HSR-line, have to be connected to the existing local line southbound to Heimdal and to the Marienborg depot area.

Figure 61. Possible rail-systems in Trondheim: Local rail 1 Lerkendal-Brattøra-Steinkjer (blue), local rail 2 Støren/Melhus-Stjørdal (red) and HSR Gardermoen-Trondheim-Værnes (dotted/magenta). Source: Geovekst.

As part of the study, an extention of the HSR-line to Værnes airport through a tunnel directly east of Lerkendal is studied. If this section will not be built, the local and the long-distance trains could use the existing freight-tunnel or could run via the existing central station. In this case Lerkendal will be the final station of HSR in Trondheim.

Figure 62. Possible rail-systems in Trondheim: Local rail 1 Lerkendal-Steinkjer and 2 Støren/Melhus-Stjørdal (red) and HSR Gardermoen-Trondheim-Værnes (dotted/magenta) in the same route. Source: Geovekst.

8.3.6 Station design - Lerkendal

Trondheim station is included in all scenarios and all alignments.

There are several possibilities for station design. HST can serve one platform (two tracks) and all other trains can serve another platform (two tracks). Another possibility is that HST stop at the two centrally located tracks and local and long-distance trains stop at the outer tracks. In this case, passengers may have direct access to corresponding trains on the same platform. The following figures show the principal possibilities.

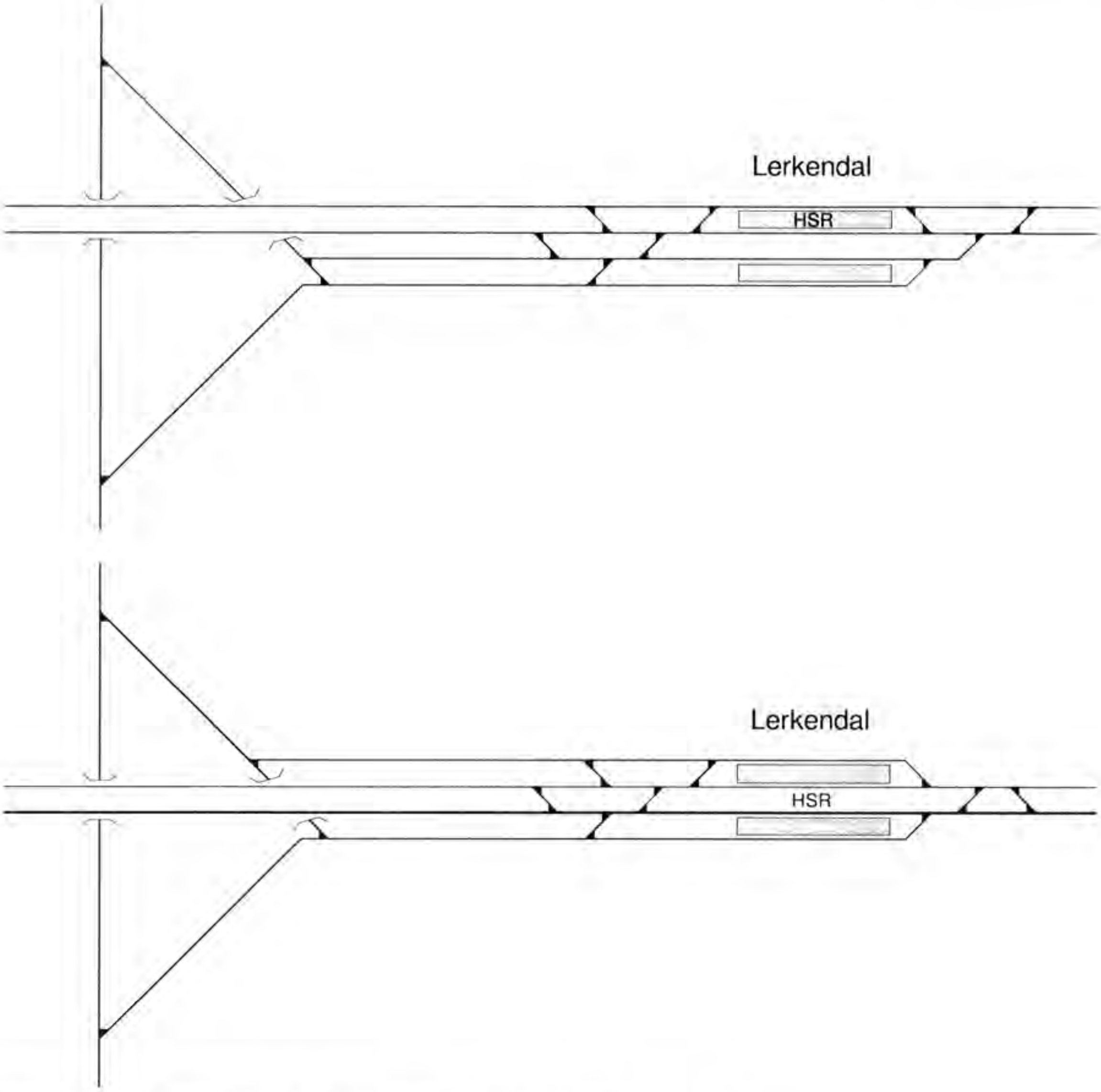


Figure 63. Two variants for design of Lerkendal Station in Trondheim.

Station layout is not essential at the current planning stage as long as 4 tracks and two platforms are included. If the HSR is not extended to Værnes, easy access to anticipated depot area Marienborg is essential. This area includes approximately 3,000 m of depot tracks which is sufficient for over night parking of up to 15-16 HST sets.

Also, detailed timetabling has to be carried out to determine the use of platforms. One ore two tracks should have a connection towards east, either through the existing tunnel or a new constructed tunnel. Using the existing tunnel requires a major reconstruction.

8.4 Existing stations, all routes

8.4.1 Gardermoen

Gardermoen station is a mandatory stop for all HST from Oslo to Trondheim. Capacity calculations for Gardermoen are not part of this project. As a result we do not make any recommendations for Gardermoen.

8.5 Special stations

8.5.1 Hamar

A High Speed Rail (HSR) solution for Hamar station shall be compatible with the IC project Oslo – Lillehammer which is investigating several options. One of the more likely alternatives is based on the existing line with some significant speed enhancements.

The HSR project is therefore proposing a tie-in solution to reach Hamar station with a bypass alignment for HST not serving Hamar. Services not serving Hamar could be direct zero stopping rush hour trains and trains serving Gardermoen only.

If a tie-in solution for Hamar station results in less than necessary speed enhancements to reach end-to-end target journey time with more than one stop, it is possible to locate an HSR station approximately 1 km east of Ridabu where the HSR is crossing classified road (Rv 25) Vangsvegen close to the interchange with county road (Fv 117) Hjellumvegen. This is around 3.5 km east of the centre of Hamar.

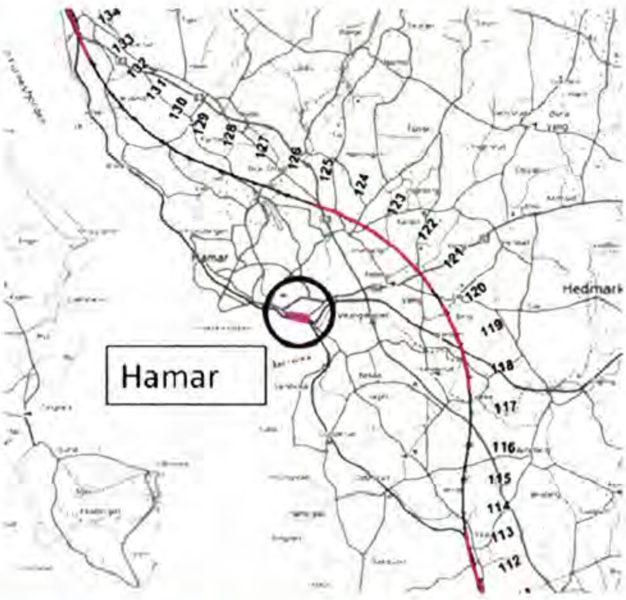


Figure 64. Hamar station based on a tie-in solution with a HSR bypass. Source: Geovekst.

Parking spaces:

- Tie-in: in accordance with IC-project.
- HSR station in the proximity of Ridabu: 400.

Standard facilities for a tie-in solution: In accordance with IC-project.
HSR station in the vicinity of Ridabu: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks and universal design. Furthermore ticket office/information desk, storage room/lockers, ATM (automatic teller machine), luggage carts, lost and found, and kiosk.

See also Chapter 6.2.2 about the intercity project.

8.5.2 Lillehammer

An HSR solution for Lillehammer station shall be compatible with the IC project Oslo – Lillehammer. Since Lillehammer is the IC end station, it is proposed to use the existing very centrally located station.

Hence the HSR project proposes a tie-in solution to reach Lillehammer station with a bypass alignment for HST not serving the city.

In a later step 2, a new HSR from Gardermoen to Lillehammer via Gjøvik could be constructed. Crossing Lake Mjøsa south of Lillehammer but north of Gjøvik is very challenging due to long crossing distances and a seabed with significant depth. The alignment is therefore following the west coast of Mjøsa and the only possible localisation of a station fairly close to the centre of Lillehammer is in the area of Strandtorget. Localisation of a new HSR station is preferably as close as possible to the existing station due to the fact that the (old) station will continue serving up to four IC trains per hour. Therefore, interchange between IC- and HSR operation is expected. Localisation of a HSR station where the Gjøvik alignment enters the Lillehammer area is very challenging. The solution indicates an elevated station some 10 to 15 m above the E6 road bridge/Strandtorget, approx. 800 m from the existing station.

Parking spaces: Tie-in, in accordance with IC-project. Elevated HSR station: To be determined.

Standard facilities for a tie-in solution: In accordance with IC-project.
Elevated HSR station: To be determined. A probable solution is continued service facilities at the existing station with a kind of high speed footpath link between the stations.

See also Chapter 6.2.2 about the Intercity project.

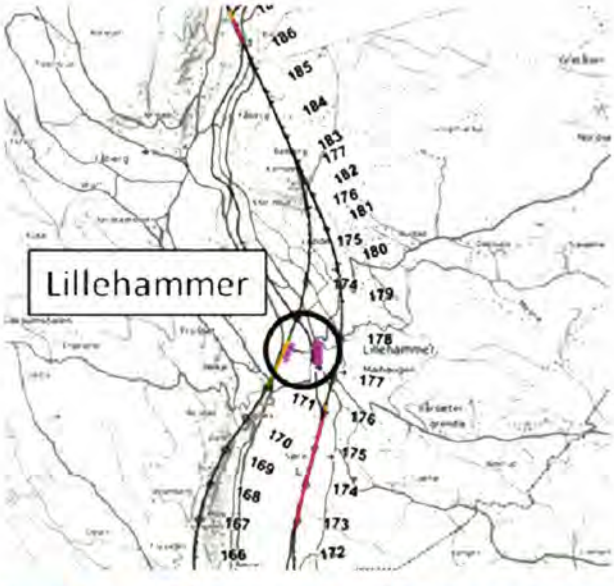


Figure 65. Lillehammer station with a tie-in solution and a possible future HSR station on the Gjøvik alignment. Source: Geovekst.

8.5.3 Værnes

Værnes will be the HSR end station if the HSR service is extended north of Trondheim. The HSR alignment is concurrent with existing alignment from Gjevingåsen tunnel to Værnes station.

Station layout should include two platforms with four tracks to platform. HST has to be turned around at the station which leads to a considerably longer platform time than at intermediate stations. The station shall also handle two or more local trains an hour and one long distance train an hour. Nevertheless a three track to platform solution may be considered.

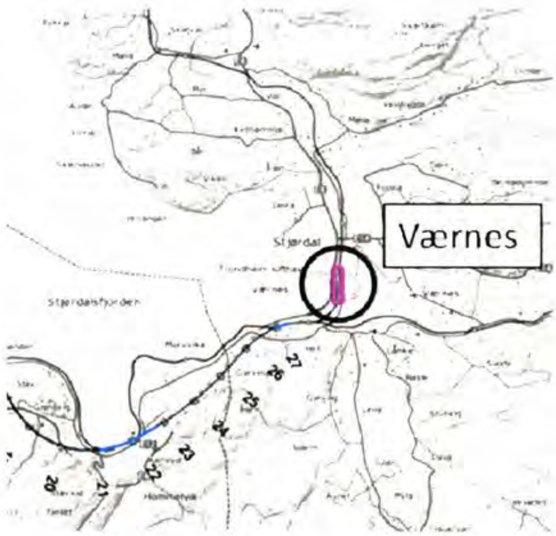


Figure 66. Værnes station. Source: Geovekst.

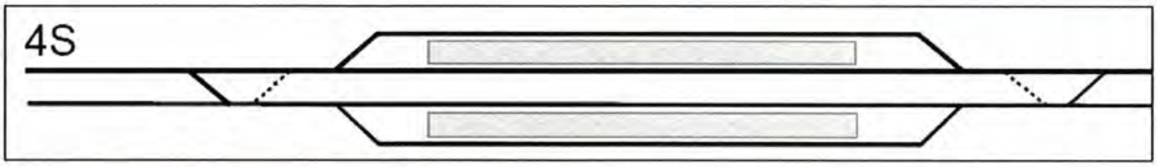


Figure 67. Preferred station layout.

Remark: There is only a single track north of the station running under the taxiway and main runway at Værnes airport (see Figure 68).

This limits the available area for a station, especially the length. The yellow line at Figure 68 marks an 800 m long track section. Platforms should preferably be located at the 470 m long section between the access road and the taxiway.

At the existing Stjørdal station there is available length for overnight parking of one or two HST sets. One or two of previously existing tracks will have to be reactivated.

Figure 68. Værnes station, close up. Source: Geovekst.

8.6 Stations in Gudbrandsdalen

8.6.1 Ringebu

Station layout: Standard

The station is situated approx. 0.4 km east of existing Ringebu station.

Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Figure 69. Ringebu station. Source: Geovekst.

8.6.2 Vinstra

Station layout: Standard

The station is situated approx. 5.3 km south of the centre of Vinstra, following the existing roads and bridges over the rivers. The crow fly distance is 1.8 km fairly straight south.

Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Figure 70. Vinstra station. Source: Geovekst.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

8.6.3 Otta

Station layout: Standard

The station is situated approx. 0.8 km west of the centre of Otta on a 330 m long bridge. Parts of the station will have to be integrated in the adjacent tunnels, which is a very challenging solution. This is the preferable location serving the local market. However, there are three other possibilities further away which most probably are less expensive, but not optimal considering the local market and long distance road system.

These are at Selsjord/Einangen some 2.1 km south of Otta, including a 600 m open track. A complete station including switches is approx 1.05 km long. Furthermore there are possible locations at Sandbu (across from Melemshaugen) approx. 6 km south of Otta or at Sel, approx. 12 km north of Otta

Parking spaces: 200

Figure 71. Otta station. Source: Geovekst

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

8.6.4 Dombås

Station layout: Standard

Due to a tunnel running from Hågå-Dombås-Dovrefjell, the only alternative for a new station is south of Dombås, near Korsvoll/Arnkleiv, approx. 6 km south of the centre of Dombås.

Parking spaces: 400

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Figure 72. Dombås station. Source: Geovekst.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

8.6.5 Oppdal

Station layout: Standard

We suggest a station approx. 1 km northeast of Oppdal. This is still compatible with the market potential towards the south.

Parking spaces: 400

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

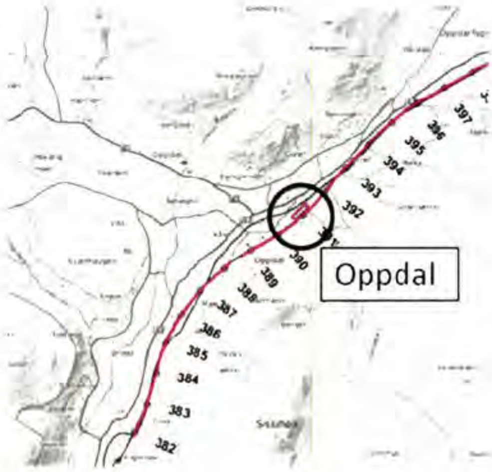


Figure 73. Oppdal station. Source: Geovekst.

8.6.6 Berkåk

Served by station at Garli, see below.

8.6.7 Støren

Served by station at Garli, see below.

8.6.8 Garli

Station layout: Standard

Due to difficult (steep, sloping) terrain in the area of Støren, and at Soknedal further south, we suggest a station located at Garli where the terrain is flatter. This station will be easily accessible from the highway, E6. Because of the tunnel at Berkåk, we suggest that Garli station is serving this area too, as it is within a reasonable distance. Garli station will be located approx. 20 km from Oppdal centre and approx. 12 km from Berkåk. The elevation of Garli station differs in the two alternative alignments for Gudbrandsdalen and Østerdalen, but has otherwise much the same localization.

Parking spaces: 200

Figure 74. Garli station. Source: Geovekst.

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found, kiosk.

8.7 Rondane

The Rondane route includes, with one exception, the same stations as the Gudbrandsdalen route south of Vinstra. In the northern part this route is similar to the Østerdalen route from Garli to Trondheim and Værnes.

8.7.1 Ringebu

Station layout: Standard

The station is situated approx. 3.6 km from the centre of Ringebu.

Due to difficult (sloping) terrain it will be difficult to establish a rail line and a station, as well as a parking area here. However, the best location for a station seems to be right after the tunnel near Høystad.

The height difference between the station and the location of Ringebu centre is approx. 175 m, where the station is located at a 375 m contour while the centre is at a 200 meter contour.

Figure 75. Ringebu station. Source: Geovekst.

Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

8.8 Stations in Østerdalen

8.8.1 Elverum Parkway

Station layout: Standard
Red: **Scenario D**. Blue: **Scenario 2***

The station is situated approx. 8.5 km west of the centre of Elverum and 22 km east of Hamar. Elverum Parkway is very close to the existing line between Elverum and Hamar and the locatin gives a possible co-localisation of a station on the existing line and the new HSR station. The HSR and the existing track will cross in two different levels having no track-connections.

Figure 76. Parking spaces: 400 Elverum Parkway station. Source: Geovekst.

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found, kiosk.

8.8.2 Rena

Station layout: Standard.
Red: **Scenario D**. Blue: **Scenario 2***

The station is situated approx. 2 km south (D) or 2 km north (2*) of the centre of Rena and approx. 5 km/3 km from Rena military camp.

Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

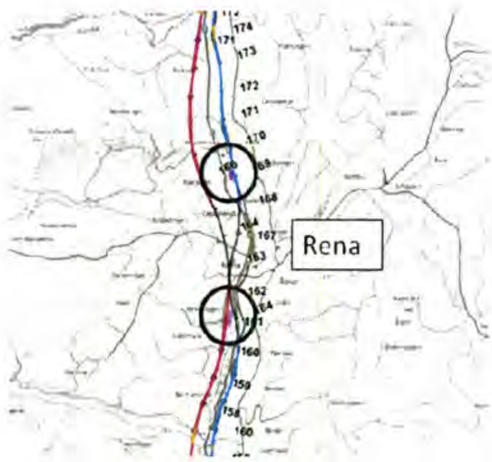


Figure 77. Rena station. Source: Geovekst.

8.8.3 Koppang

Station layout: Standard.
Red: **Scenario D**. Blue: **Scenario 2***

The station is situated at existing station area (2*) or approx. 5.6 km west (D) of the centre of Koppang using the existing road system. The crow fly distance is approx 3.0 km.

Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.
Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

Figure 78. Koppang station. Source: Geovekst.

8.8.4 Alvdal

Alvdal will be served by the station at Tynset.

8.8.5 Tynset

Station layout: Standard

The station is situated approx. 2.3 km west of the centre of Tynset.

There is a special tourist travel potential for the UNESCO town of Røros, situated some 55 km (50 minutes) north of Tynset.
Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.
Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found.

An alternative localization of Tynset station is some 4 km west southwest of Tynset. This gives a possible co-localisation with a new local station on the existing Røros line. See also chapter 8.10.1.

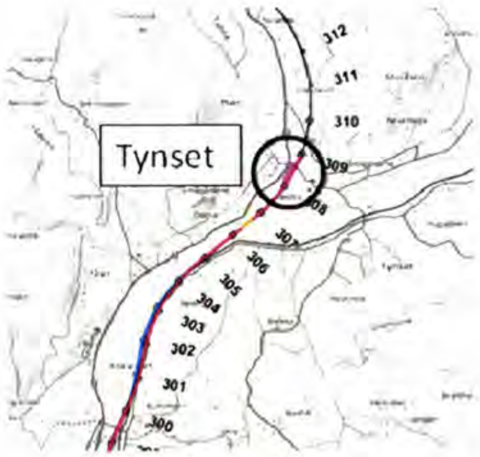


Figure 79. Tynset station. Source: Geovekst.

8.8.6 Garli

Station layout: Standard

Due to difficult (steep, sloping) terrain in the area of Støren, and at Soknedal further south, we suggest a station located at Garli where the terrain is flatter. This station will be easily accessible from the highway, E6. Because of the tunnel at Berkåk, we suggest that Garli station is serving this area too, as it is within a reasonable distance. Garli station will be located approx. 20 km from Oppdal centre and approx. 12 km from Berkåk. The elevation of Garli station differs in the two alternative alignments for Gudbrandsdalen and Østerdalen, but the localization is otherwise much the same.

Figure 80. Garli station. Source: Geovekst.

Parking spaces: 200

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departure and arrival boards, public announcement system, bus/taxi platform(s), bike racks, and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found, kiosk.

8.9 Gjøvikbanen

8.9.1 Gjøvik

Station layout: Standard

The rail line is raised above the Hunndalen valley, with a station on a bridge. This will be a central location for the inhabitants of Gjøvik and Raufoss (located south of Gjøvik). The bridge length is approx. 600 m including 400 m of platforms. Hence parts of the station area (remaining 400 m) must be constructed as parts of one or both adjacent tunnels.

Parking spaces: 400

Standard facilities: Ticket machines, toilets and baby care, waiting room, vending machines, departures and arrival boards, public announcement system, bus/taxi platform(s), bike racks and universal design.

Optional facilities: Ticket office/information desk, storage room/lockers, ATM, luggage carts, lost and found, kiosk.

Figure 81. Gjøvik station. Source: Geovekst.

8.10 Rørosbanen

8.10.1 Østerdalen alternative D2 with freight via Røros

The Østerdalen route also includes a D2 option from Tynset to Garli with a vertical alignment not suitable for freight, i.e. a gradient up to approx. 35 ‰. This option includes an upgraded, electrified Rørosbane with new crossing loops. This opens a possibility for a connecting local train service from Tynset to Røros as an extension of the local Trondheim – Røros train service. In this case the new Tynset station should be considered moved to a location some 4 km west southwest of Tynset.

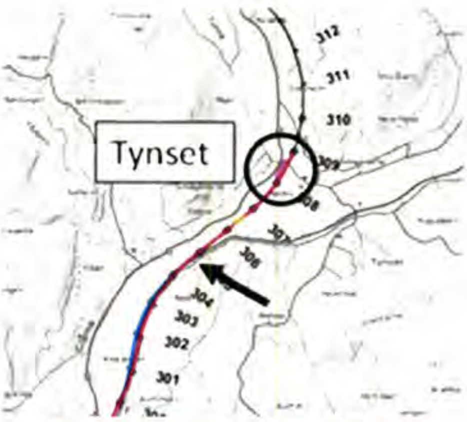


Figure 82. Alternative location of new Tynset station in the case of local passenger train service on an upgraded Rørosbane. Source: Geovekst.

9. OPERATIONAL CONCEPTS/STOPPING PATTERN

Final evaluations of stopping pattern and journey time calculations will be done by another consultant, Atkins. However, Rambøll has done some preliminary journey time calculations based on the proposed alignments and location of stations. This is to ensure that the proposed high speed operation is able to both serve the intermediate markets and obtain the target end-to-end journey time ensuring competitiveness with air traffic.

9.1 Introduction

In Scenarios D1/D2 and 2*, involving an entirely new railway-line, there are several challenges in creating a viable operating concept, particularly from the considerable speed differences between High-speed trains (HST) and freight modes.

In Scenario B, the challenges arise even more often because of the mixture of high-speed-sections and existing older sections with single track. The new alignment sections chosen will also generate a need for upgrades to parts of existing sections, such as lengthening existing crossing loops. The operational concept in Scenario B is dealt with in Chapter 5, so the rest of this chapter will discuss only Scenarios D1/D2 and 2*.

Total capacity (trains/h/direction) in a new high-speed line is estimated by WSP in Phase 2 as follows:

	Homogeneous High speed	Mixed traffic
Single-track	2	1 (1,5)
Double-track	12	4

Figure 83. Results from Phase 2 of number of trains per hour and direction with mixed traffic and homogenous traffic on single and double-track (from WSP Phase 2).

In order to allow for a minimum capacity of 2 HST and 1 freight train each direction per hour, a 100 % double-track solution is strongly recommended.

9.2 Operational concepts for Scenarios 2* and D

We have assumed the following boundary conditions for train operations in Scenarios 2* and D1/D2:

Upgraded IC line Gardermoen – Lillehammer with:

- Max. speed to Hamar 160/200 km/h
- Hamar – Lillehammer 250 km/h

The following traffic is assumed:

- 1-2 IC trains/h and direction all day
- Maximum speed 120 km/h for freight trains
- No freight trains during peak hours
- 1 freight-train/h during night time hours
- 1 freight-train/2h during daytime hours
- 1 HST/h during daytime hours
- 2 HST/h during peak periods

This adds up to a maximum of 4 trains/h, i.e. 2xHST + 2xIC or 2xHST + 1 freight. This is well within the capacity limits for a double-track HSR line. Overtaking stations will have to be established where HST can bypass freight trains.

We believe that the operational concept suggested is sufficient for a long time into the future. If, at some point in the future, the demand for (parts of) the operation exceeds a double-track capacity, the construction of one or two extra tracks from Gardermoen to Stange will be priority number one. If HSR operation is to be via Gudbrandsdalen, then construction of one or two more tracks from Stange to Hamar and further on to Lillehammer may be a preferred solution. As an alternative to HSR operations in Gudbrandsdalen, the construction of an entirely new HSR line west of Lake Mjøsa through Gjøvik is also a possible solution. If HSR operation is to be via Østerdalen, then new tracks from Gardermoen to Stange will be sufficient.

The operational concept within the IC area from Oslo-Lillehammer (HSR in Gudbrandsdalen)/Oslo-Stange (HSR in Østerdalen) is as follows:

- Peak hour traffic: HST and 4 IC per hour per direction, no freight trains. 4 IC trains only at a later stage
- Non-peak hour traffic: 1 HST, 2 IC and one freight train per direction per hour

The operational concept Lillehammer (Gudbrandsdalen)/Stange (Østerdalen) to Støren:

- Peak hour traffic: 2 HST per hour per direction, no freight trains
- Non-peak hour traffic: 1 HST and one freight train per direction per hour

The operational concept Støren-Melhus:

- Peak hour traffic: 2 HST per hour per direction, 2 local-trains, no freight trains.
- Non-peak hour traffic: 1 HST, 1 local train and one freight train per direction per hour

The operational concept Melhus-Trondheim:

- Peak hour traffic: 2 HST and 4 local-trains per hour per direction, no freight trains.
- Non-peak hour traffic: 1 HST, 2 local trains and one freight train per direction per hour

The operational concept Trondheim-Værnes:

- Peak hour traffic: 2 HST and 2 local-trains per hour per direction, no freight trains.
- Non-peak hour traffic: 1 HST, 1 local train and one freight train per direction per hour

A general study shows why it is necessary to construct several overtaking sections on an HSR route even with a double-track alignment. Figure 84 indicates that a non-stop HST (blue) typically has to bypass a freight train (red) three times from Eidsvoll to Tynset. A stopping HST (green) may have to bypass freight trains twice on the same section. However, these are just examples.

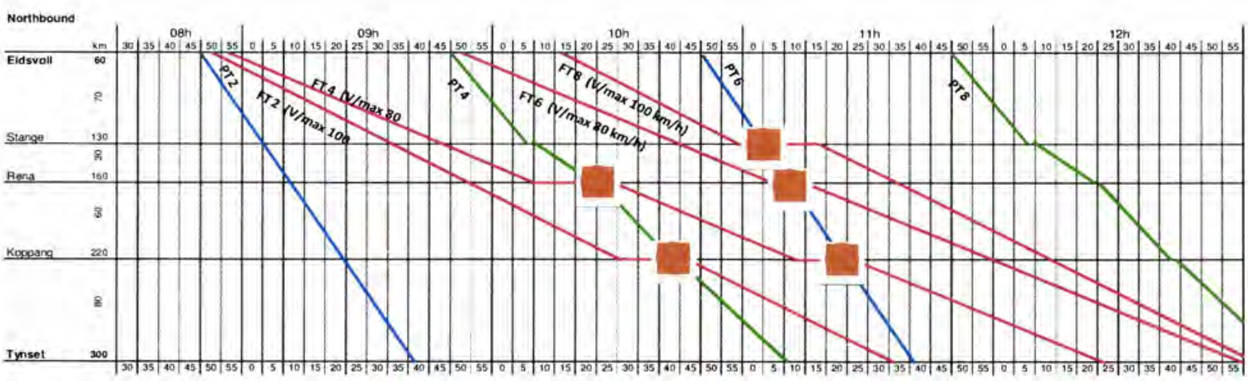


Figure 84. HST overtaking freight trains.

Remark: Forcing a freight train to come to a complete stop with a subsequent restart is very energy-consuming due to the weight of the train. Hence construction of overtaking sections every 10 or more km might be an energy optimal solution for areas where HST trains are bypassing freight trains running at close to normal speed. (This would require quite long passing loops.)

9.3 Journey times

The final journey times will be calculated by Atkins with basis in the final alignments and their recommended stopping pattern. However, some preliminary calculations have been done based on the final alignments, to determine whether the target journey times are obtainable within those proposed alignments including the required number of stations.

For these rough calculations, the following boundary conditions are used:

- 7 min standard addition per stop per station (both for the 2* and the D-alternatives)
- Reduced obtainable top speed as follows:
  - Design-speed 330 km/h (D1/D2-alt.): average speed is 270 km/h.
  - Design-speed 250 km/h (2*-alt.): average speed is 230 km/h.

Preliminary calculations show that all scenarios obtain end-to-end journey times well below the target end-to-end journey time of 2h 45m with one stop or few stops. Østerdalen reaches the target end-to-end journey time stopping at all stations. Gudbrandsdalen exceeds the target end-to-end journey time when stopping at 6 or more stations.

Final and official journey time calculations can be found in the Atkins report.

9.4 Stopping pattern

There are numerous combinations of stopping patterns in the corridor based on market surveys. One possibility is to alternates between serving all stations, and serving only some of the intermediate stations. We also think one should serve the major end-to-end market with at least one non stopping train (also excluding Gardermoen) each direction in the morning and afternoon. It is possible to obtain a travel time close to two hours for scenario D1/D2 and some 10-15 minutes more for scenario 2*.

In Østerdalen it makes sense not always to serve the smaller stations. Skipping for example three small stations will reduce the Oslo – Trondheim journey time by around 20 minutes (The time amendment is approx 7-8 minutes per station.) Alternating between three stops and six stops Gardermoen included, opens the possibility of running one direct non stopping rush hour train Oslo – Trondheim and v.v. within a fixed departure time model. A fixed departure time model with a 30 minutes frequency includes departures at fixed hours, for example 0705, 0735, 0805, 0835 etc.

In Gudbrandsdalen, the number of stations is too high for the end-to-end target journey time to serve all stations. For this reason, some services would have to bypass some of the smaller stations. The boundary conditions state that Gardermoen is a compulsory stop. Nevertheless, the Oslo – Trondheim market may demand at least one none stopping train in both directions during rush-hour, reducing travel time to slightly more than 2 hours. For the Gudbrandsdalen line this is not possible within fixed time table. Due to the number of stations to be served one have to extend the time gap between the trains to avoid the non stopping train to catch up with the previous train, given the requirement of a 30 minutes frequency (two departures per hour) during the rush periode. it is possible to compile an operating model where a non stopping train is overtaking a stopping high speed train in the Hamar area. The time difference between a train stopping at Hamar using the tie in solution and a non stopping train using the new high speed alignment around Hamar, is some 10 minutes. This is enough time for a safe bypass of the stopping train given a requirement of minimum five minutes headway between high speed trains.

As a result one will have to deviate from the strict 30-min. headway in order to provide a non-stop service during the rush hour.

A more detailed study will be carried out by Atkins, both on the need for passing loops, as well as for the stopping pattern of a HSR service between Oslo and Trondheim, both for the Østerdalen line and the Gudbrandsdalen line.

Designing the alignments for each line has been an iterative process taking into consideration the required number of stations, as well as formulating an operational concept to serve all or some stations within the constraints of the end-to-end journey time and the required design speeds for each scenario. Some of the smaller stations will then be served only by every second train.

10. ENVIRONMENTAL IMPACT

10.1 Introduction and summary

The environmental impact assessment for different alignments consists of a value assessment (delivery 1) based on corridors, an effect and an impact assessment. The main objective of the environmental impact assessment is to find out to what extent the different alternatives are expected to have a negative impact on the environment. Alternative alignments are thereafter ranked according to their scores on the impact assessment.

The results of the environmental impact assessment show that the alignment alternative through Gudbrandsdalen by Dombås has the most negative impact, and Østerdalen (alignment D) has the least negative impact on the environment. The alternative through Gudbrandsdalen will have higher impact then Østerdalen (alignment D) for following measurements: natural resources, cultural heritage, landscape and community life and recreation.

The impact on agriculture is one of the central differences between the alternatives through Gudbrandsdalen and the alternative that goes through Østerdalen. While the alignment through Gudbrandsdalen will have great impact on high quality agriculture land near Mjøsa, the alternatives through Østerdalen will mainly have impact on forested areas. Agricultural areas also have a higher value as cultural heritage sites, and tend to have a more dense population in its surrounding area. These characteristics contribute to the relatively high impact on cultural heritage and community life for the Gudbrandsdalen alternative.

Taking into consideration the size and scope of the project it is relevant to discuss whether or not the environmental impact can be justified. An overall evaluation of the assessment results leads to the conclusion that the alternatives through Østerdalen are more acceptable than the alternatives through Gudbrandsdalen and Rondane. In addition to the negative impact on agriculture the wild reindeer habitats in the Dovre and Rondane area contribute to a high value for these alternatives. Norway has an international responsibility to protect the wild reindeer and its habitat. In addition there is a political agreement to protect agriculture land in order to maintain a cultural landscape as well as to feed an increasing world population.

A conclusion to this chapter is that the alignment alternatives through Gudbrandsdalen and Rondane will have high impact on the environment. This could make it difficult to justify the benefits of the project. If these alternatives are chosen, it will probably require the implementation of several impacts reducing measures. The need for these kinds of measures will be significantly lower for the alternatives through Østerdalen. The Østerdalen alternatives are likely to receive greater justification from both a scientific and political point of view.

10.2 Method for the environmental impact assessment

The magnitude of effect and conflict potential are measured by means of a quantitative GIS-analysis. The assessment analyses are based on information that has been accessible through a web-based database. Only the most crucial parts of this information will be presented in this report. Readers interested in extensive overview are asked to contact Jernbaneverket for further information. The value assessments presented in delivery 1 were based on corridors, whereas the calculations of potential environmental effects of the high-speed railway are based on the designed alignments within the corridors.

The calculations are conducted for the main corridors along Gudbrandsdalen (alignment GU-D), Rondane (alignment RO-D), and two alternative alignments through Østerdalen (OS-D1 and OS-2). The corridors are divided into four sections, where the first and last sections of the Gudbrandsdalen and Rondane corridor are the same. For the two alternative alignments through the Østerdalen corridor the last section from Soknedal to Trondheim has the same alignment. In addition to the four alternative alignments within the main corridors three additional sections are included in the impact assessment (Gardermoen – Tangen, Gardermoen – Gjøvik – Lillehammer, and Trondheim – Værnes).

The area calculations are based on the thematic mapping that was conducted in the value assessment for the five landscapes and environmental topics: Landscape, Cultural heritage, Natural environment, Natural resources and Community life and outdoor recreation. The mapping consists of 2-7 subjects for each topic. For example, the natural environment topic is divided into five subjects: wild reindeer, wildlife species, nature types, protected areas and wildlife habitat.

The high-speed railway line will go through tunnels several places along the line, including both shorter and longer sections. These tunnel sections are removed from the dataset prior to calculating the magnitude of effect, considering that sections where the railway goes through tunnels will not conflict with the landscape and environment.

A buffer zone of 25 metres on each side of the alignments determines the areas that are directly affected. The scope of these different areas is calculated. The calculations are done in square metres, which are converted into hectares. Some of the subjects, for example the pilgrim path are shown as lines and not polygons, while subjects like cultural monuments will appear as points. These subjects are measured in terms of the length in kilometres or number of points, instead of square meter area.

In addition to the landscape and environmental topics the magnitude of effect and conflict potential of noise is measured. The quantification of noise impact is based on the number of houses that fall within calculated noise areas of 75 metres, 100 metres and between 100 and 300 metres.

The magnitude or effect represents the type of changes that the project may cause for the areas or environments of interest. The value of an element and the magnitude of the same element results in the measured impact. The effect and impact are based on consideration between pros and cons of the project in different sections of the corridor.

The different sections are not equally long. The effect is therefore described as number of hectares per kilometre that will be affected by the railway. These calculations are done for all subjects for each topic. The final impact assessment consists of an overall assessment of all effects per kilometre, and for every section. The impact is set as either low, medium or high (green, yellow or red colours in the map). The following maps and figures illustrate the impact for each topic and each section. Finally the total impact for each of the four alternative alignments is summarized and ranked from lowest to highest impact on the environment.

The main alternatives are ranked from (1) least impact to (4) most impact on the environment. A calculation has been conducted in order to separate alternatives that have the same total impact. The calculation is done by quantifying the categories low, medium and high on a scale from 1 to 3. The numbers for each alternative alignment are summarized to get a total sum that will accordingly be the basis for ranking of the alternatives.

10.3 Environmental impact assessment

10.3.1 Summary

The total results of the environmental impact assessment are shown in Figure 85. The alignment alternative through Gudbrandsdalen has the highest (most negative) impact on the environment. Østerdalen has the lowest (least negative) impact on the environment.

Alignments	Gudbrandsdalen D	Rondane D	Østerdalen D	Østerdalen 2*
Landscape	H/M	H/M	M	H/M
Cultural heritage	H	M/HH	M	MM/H
Natural environment	M	M	H	H
Natural resources	M/H	M	M/L	M
Community life and recreation	H/M	MM/H	M	L/M
Total impact	**H/M**	**H/M**	**M**	**MM/H**
Ranking	**4**	**3**	**1**	**2**

Figure 85. Main results of the environmental impact assessment for the main alternatives.

The results of the environmental impact assessment for the sections that are not included in the main alternatives are shown in Figure 86.

Sections	Gardermoen-Tangen	Gardermoen-Gjøvik-Lillehammer	Trondheim-Værnes
Landscape	L	M	M
Cultural heritage	M	M	M
Natural environment	M	M	M
Natural resources	M	H	H
Community life and recreation	M	M	M
Total impact	**M**	**M**	**M**

Figure 86. Results of the environmental impact assessment for the sections not included in the main alternatives.

10.3.2 Landscape

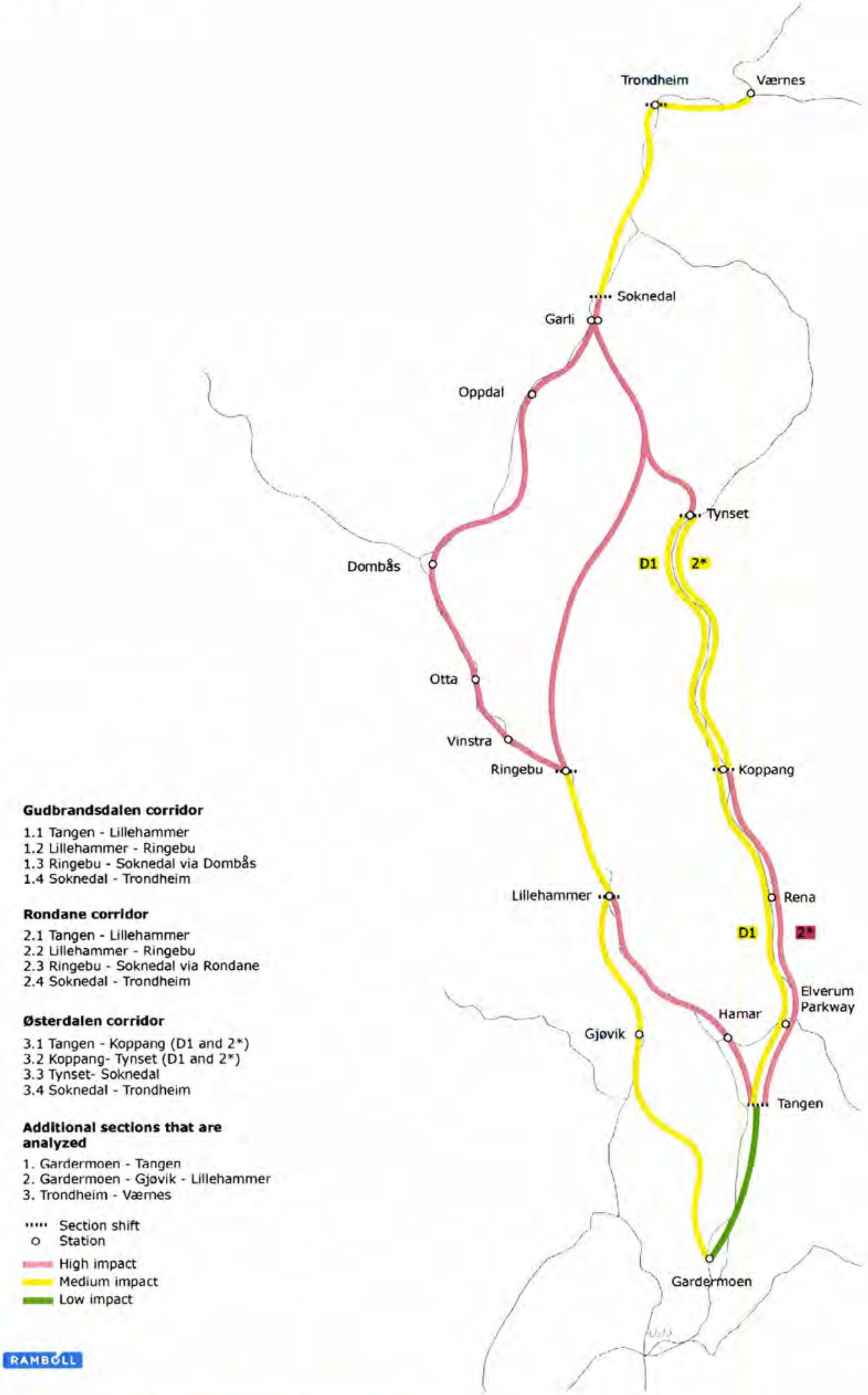


Figure 87. Landscape, impact of four alignments.

The impact assessment for landscape is shown in Figure 88 and Figure 89. This includes the value, effect and impact for each section. The effect is shown as effect per kilometre for each subject in Figure 88. The total impact for each main alignment alternative is shown in Figure 89.

Landscape		Low landscape value (hectares)	Medium landscape value (hectares)	High landscape value (hectares)	Very high landscape value (hectares)	
SECTIONS	CORRIDOR VALUE	CALCULATION PER KM LINE				LINE IMPACT
Gardermoen - Tangen	Medium	0,0	1,2	0,1	0,0	Low
Gardermoen - Gjøvik - Lillehammer	Medium/High	0,0	1,6	0,3	0,0	Medium
Tangen - Lillehammer	Medium/High	0,0	1,5	1,0	0,0	High
Tangen - Koppang (D1)	Medium	2,7	0,8	0,0	0,2	Medium
Tangen - Koppang (2*)	Medium	0,8	0,8	1,6	0,3	High
Lillehammer - Ringebu	Medium	0,0	0,1	0,5	0,2	Medium
Koppang - Tynset (D1)	Low/Medium	1,0	0,4	1,6	0,0	Medium
Koppang - Tynset (2*)	Low/Medium	0,4	0,3	2,7	0,1	Medium
Ringebu - Soknedal (via Dombås)	Medium/High	0,0	0,8	0,8	0,4	High
Ringebu - Soknedal (via Rondane)	Medium/High	0,0	1,7	0,9	0,1	High
Tynset - Soknedal	Medium	0,0	2,4	0,3	0,4	High
Soknedal - Trondheim	Medium	0,0	0,3	1,4	0,0	Medium
Trondheim-Værnes	Medium/High	0,0	1,2	0,0	0,0	Medium

Figure 88. Impact assessment for landscape, shown for each section.

Alignment	**Gudbrandsdalen D**	**Rondane D**	**Østerdalen D**	**Østerdalen 2***
Sections	Tangen-Lillehammer (H)		Tangen-Koppang D1 (M)	Tangen-Koppang 2* (H)
	Lillehammer-Ringebu (M)		Koppang-Tynset D1 (M)	Koppang-Tynset 2* (M)
	Ringebu-Soknedal via Dombås (H)	Ringebu-Soknedal via Rondane (H)	Tynset-Soknedal (H)	
	Soknedal-Trondheim (M)			
Impact	**H/M**	**H/M**	**M**	**H/M**
Ranking	**2**	**3**	**1**	**4**

Figure 89. Summarized impact and ranking for landscape for the four main alignment alternatives.

10.3.3 Cultural heritage

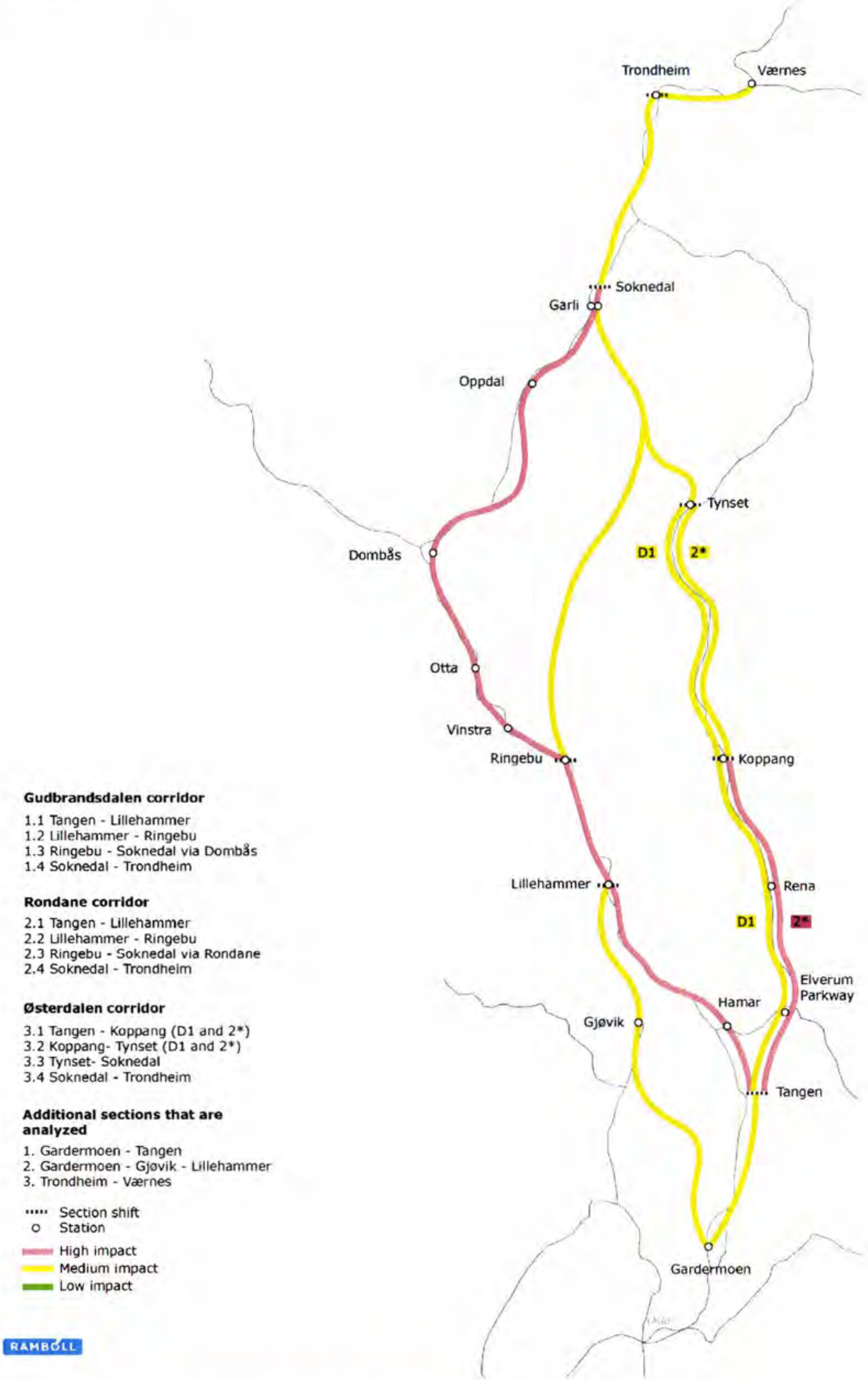


Figure 90. Cultural heritage, impact of four alignments.

The impact assessment for cultural heritage is shown in Figure 91 and Figure 92. This includes the value, effect and impact for each section. The effect is shown as effect per kilometre for each subject in Figure 91. The total impact for each main alignment alternative is shown in Figure 92.

Cultural heritage		Protected cultural areas (hectares)	Important cultural landscapes (hectares)	Pilgrim walk (kilometres)	Cultural heritage (no. of points)	Sefrak - Old buildings (no. of points)	World heritage (no. of points)	
SECTIONS	CORRIDOR VALUE	CALCULATION PER KM LINE						LINE IMPACT
Gardermoen - Tangen	Medium/High	0,0	0,0	0,0	0,0	0,1	0,0	Medium
Gardermoen - Gjøvik - Lillehammer	Medium/High	0,0	0,0	0,0	0,0	0,0	0,0	Medium
Tangen - Lillehammer	Medium/High	0,0	0,0	0,0	0,1	0,2	0,1	High
Tangen - Koppang (D1)	Medium/High	0,0	0,2	0,0	0,0	0,0	0,0	Medium
Tangen - Koppang (2*)	Medium/High	0,0	0,2	0,0	0,1	0,3	0,1	High
Lillehammer - Ringebu	Medium/High	0,0	0,0	0,0	0,1	0,1	0,1	High
Koppang - Tynset (D1)	Medium/Low	0,0	0,2	0,0	0,0	0,3	0,0	Medium
Koppang - Tynset (2*)	Medium/Low	0,0	0,3	0,0	0,1	0,2	0,1	Medium
Ringebu - Soknedal (via Dombås)	Medium/High	0,0	0,1	0,0	0,1	0,1	0,1	High
Ringebu - Soknedal (via Rondane)	Medium	0,0	0,0	0,0	0,0	0,1	0,0	Medium
Tynset - Soknedal	Medium	0,0	0,0	0,0	0,0	0,1	0,0	Medium
Soknedal - Trondheim	Medium/High	0,0	0,0	0,0	0,0	0,0	0,0	Medium
Trondheim - Værnes	Medium/High	0,0	0,0	0,0	0,0	0,0	0,0	Medium

Figure 91. Impact assessment for natural resources, shown for each section.

Alignment	**Gudbrandsdalen D**	**Rondane D**	**Østerdalen D**	**Østerdalen 2***
Sections	Tangen-Lillehammer (H)		Tangen-Koppang D1 (M)	Tangen-Koppang 2* (H)
	Lillehammer-Ringebu (H)		Koppang-Tynset D1 (M)	Koppang-Tynset 2* (M)
	Ringebu-Soknedal via Dombås (H)	Ringebu-Soknedal via Rondane (M)	Tynset-Soknedal (M)	
	Soknedal-Trondheim (M)			
Impact	**H**	**M/HH**	**M**	**MM/H**
Ranking	**4**	**3**	**1**	**2**

Figure 92. Summarized impact and ranking for natural resources for the four main alignment alternatives.

10.3.4 Natural environment

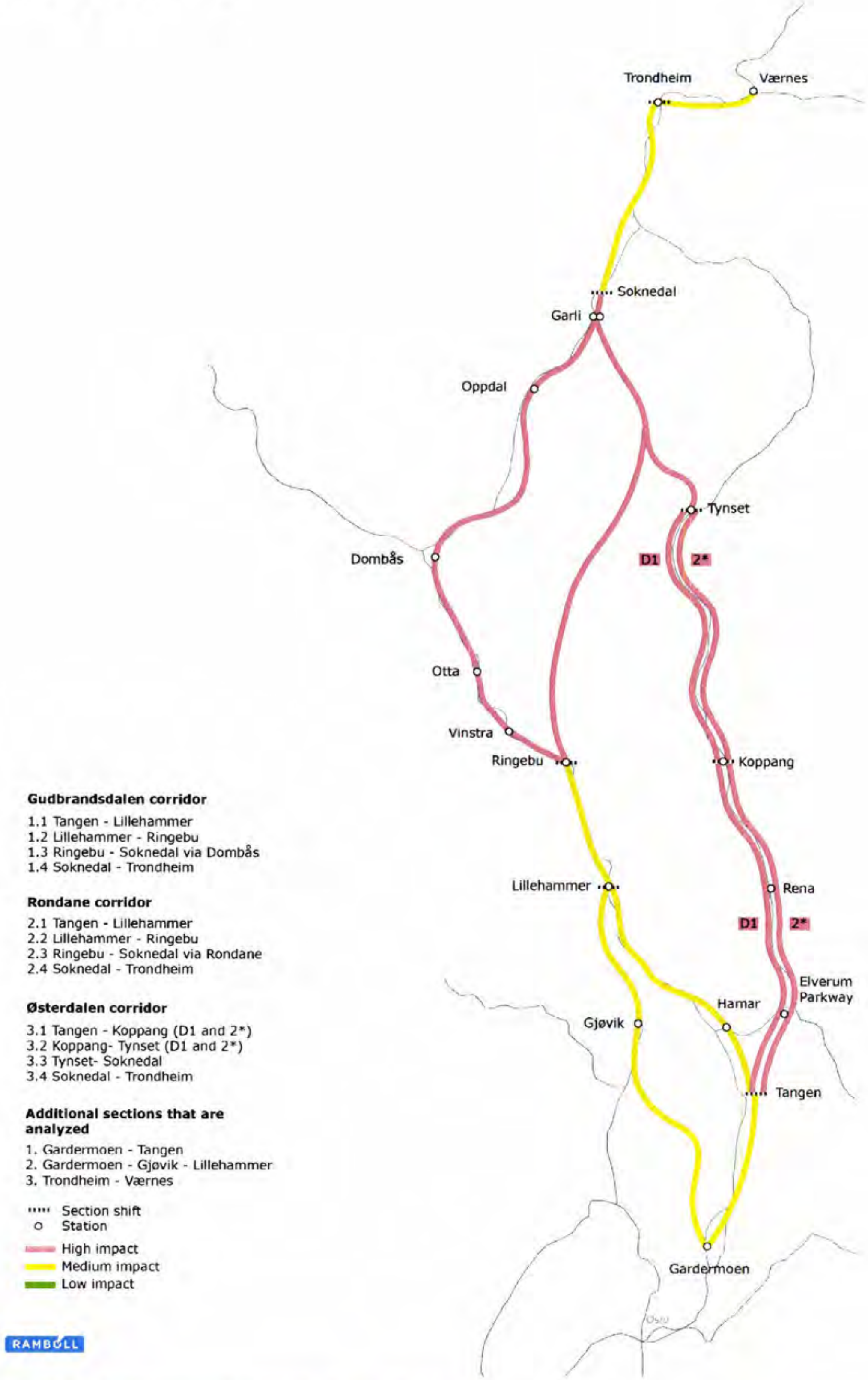


Figure 93. Natural environment, impact of four alignments.

Natural environment		Reindeer - main areas (hectares)	Reindeer - living areas (hectares)	Reindeer paths (kilometres)	Important habitats (hectares)	Important species registrations (no.)	Wildlife corridors (kilometres)	Very important nature type (hectares)	Important nature type (hectares)	Very imp. nature type spot (no. of points)	Important nature type spot (no. of points)	Protected areas (hectares)	Protected spots (no. of points)	> 5 km from human intervention (hectares)	3-5 km from human intervention (hectares)	1-3 km from human intervention (hectares)	
	Corridor Value	**Calculation per km line**															**Line Impact**
Gardermoen - Tangen	Low/Medium	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	Medium
Gardermoen - Gjøvik - Lillehammer	Medium	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Medium
Tangen - Lillehammer	Medium/High	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Medium
Tangen - Koppang (D1)	Medium/High	0,2	0,0	0,0	3,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	High
Tangen - Koppang (2*)	Medium/High	0,0	0,0	0,0	1,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	High
Lillehammer - Ringebu	Medium/High	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Medium
Koppang - Tynset (D1)	Medium/High	0,3	2,5	0,0	1,2	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	High
Koppang - Tynset (2*)	Medium/High	0,1	1,1	0,0	1,6	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	High
Ringebu - Soknedal (via Dombås)	High	0,2	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	High
Ringebu - Soknedal (via Rondane)	High	0,3	1,1	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	High
Tynset - Soknedal	Medium	1,8	0,3	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	High
Soknedal - Trondheim	Low/Medium	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Medium
Trondheim-Værnes	Low/Medium	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Medium

Figure 94. Impact assessment for natural environment, shown for each section.

The impact assessment for natural environment is shown in Figure 94 and Figure 95. This includes the value, effect and impact for each section. The effect is shown as effect per kilometre for each subject in Figure 94. The total impact for each main alignment alternative is shown in Figure 95.

Alignment	Gudbrandsdalen D	Rondane D	Østerdalen D	Østerdalen 2*
Sections	Tangen-Lillehammer (M)		Tangen-Koppang D1 (H)	Tangen-Koppang 2* (H)
	Lillehammer-Ringebu (M)		Koppang-Tynset D1 (H)	Koppang-Tynset 2* (H)
	Ringebu-Soknedal via Dombås (H)	Ringebu-Soknedal via Rondane (H)	Tynset-Soknedal (H)	
	Soknedal-Trondheim (M)			
Impact	M	M	H	H
Ranking	2	1	4	3

Figure 95. Summarized impact and ranking for natural environment for the four main alignment alternatives.

10.3.5 Natural resources

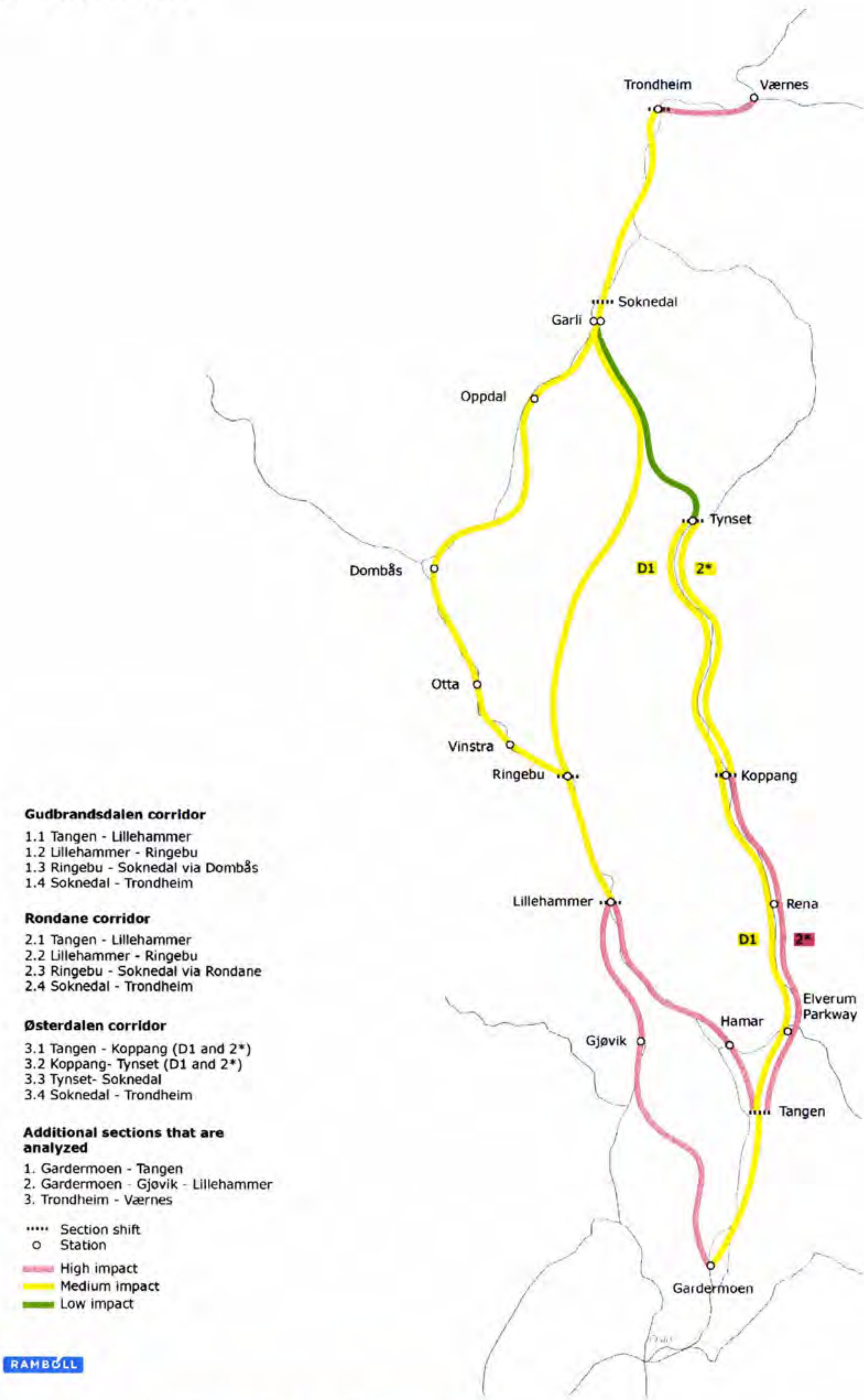


Figure 96. Natural resources, impact of four alignments.

The impact assessment for natural resources is shown in Figure 97 and Figure 98. This includes the value, effect and impact for each section. The effect is shown as effect per kilometre for each subject in Figure 97. The total impact for each main alignment alternative is shown Figure 98.

Natural resources		Rock aggregate value 1 (hectares)	Rock aggregate value 2 (hectares)	Sand and gravel value 1 (hectares)	Sand and gravel value 2 (hectares)	Forest, unclassified (hectares)	Agriculture, unclassified (hectares)	Ground water sources (no. of points)	
SECTIONS	CORRIDOR VALUE	CALCULATION PER KM LINE							LINE IMPACT
Gardermoen - Tangen	Medium	0,0	0,0	0,0	0,0	1,2	0,2	0,0	Medium
Gardermoen - Gjøvik - Lillehammer	Medium/high	0,0	0,0	0,0	0,0	1,4	0,3	0,0	High
Tangen - Lillehammer	High	0,0	0,0	0,0	0,0	1,0	0,9	0,0	High
Tangen - Koppang (D1)	Medium/high	0,0	0,0	0,0	0,1	3,8	0,1	0,0	Medium
Tangen - Koppang (2*)	Medium/high	0,0	0,0	0,1	0,0	3,1	0,6	0,0	High
Lillehammer - Ringebu	Medium	0,0	0,0	0,0	0,0	0,4	0,3	0,0	Medium
Koppang - Tynset (D1)	Low/medium	0,0	0,0	0,0	0,0	2,1	0,7	0,0	Medium
Koppang - Tynset (2*)	Low/medium	0,0	0,0	0,0	0,0	2,4	0,8	0,0	Medium
Ringebu - Soknedal (via Dombås)	Medium	0,0	0,0	0,1	0,0	1,0	0,5	0,0	Medium
Ringebu - Soknedal (via Rondane)	Medium/high	0,0	0,0	0,0	0,1	1,8	0,4	0,0	Medium
Tynset - Soknedal	Low	0,0	0,0	0,0	0,0	2,4	0,3	0,0	Low
Soknedal - Trondheim	Medium	0,0	0,0	0,1	0,0	0,3	0,9	0,0	Medium
Trondheim - Værnes	Medium/high	0,0	0,0	0,0	0,0	0,1	0,5	0,0	High

Figure 97. Impact assessment for natural resources, shown for each section.

Alignment	**Gudbrandsdalen D**	**Rondane D**	**Østerdalen D**	**Østerdalen 2***
Sections	Tangen-Lillehammer (H)		Tangen-Koppang D1 (M)	Tangen-Koppang 2* (H)
	Lillehammer-Ringebu (M)		Koppang-Tynset D1 (M)	Koppang-Tynset 2* (M)
	Ringebu-Soknedal via Dombås (M)	Ringebu-Soknedal via Rondane (L)	Tynset-Soknedal (L)	
	Soknedal-Trondheim (M)			
Impact	**M/H**	**M**	**M/L**	**M**
Ranking	**4**	**3**	**1**	**2**

Figure 98. Summarized impact and ranking for natural resources for the four main alignment alternatives.

10.3.6 Community life and outdoor recreation

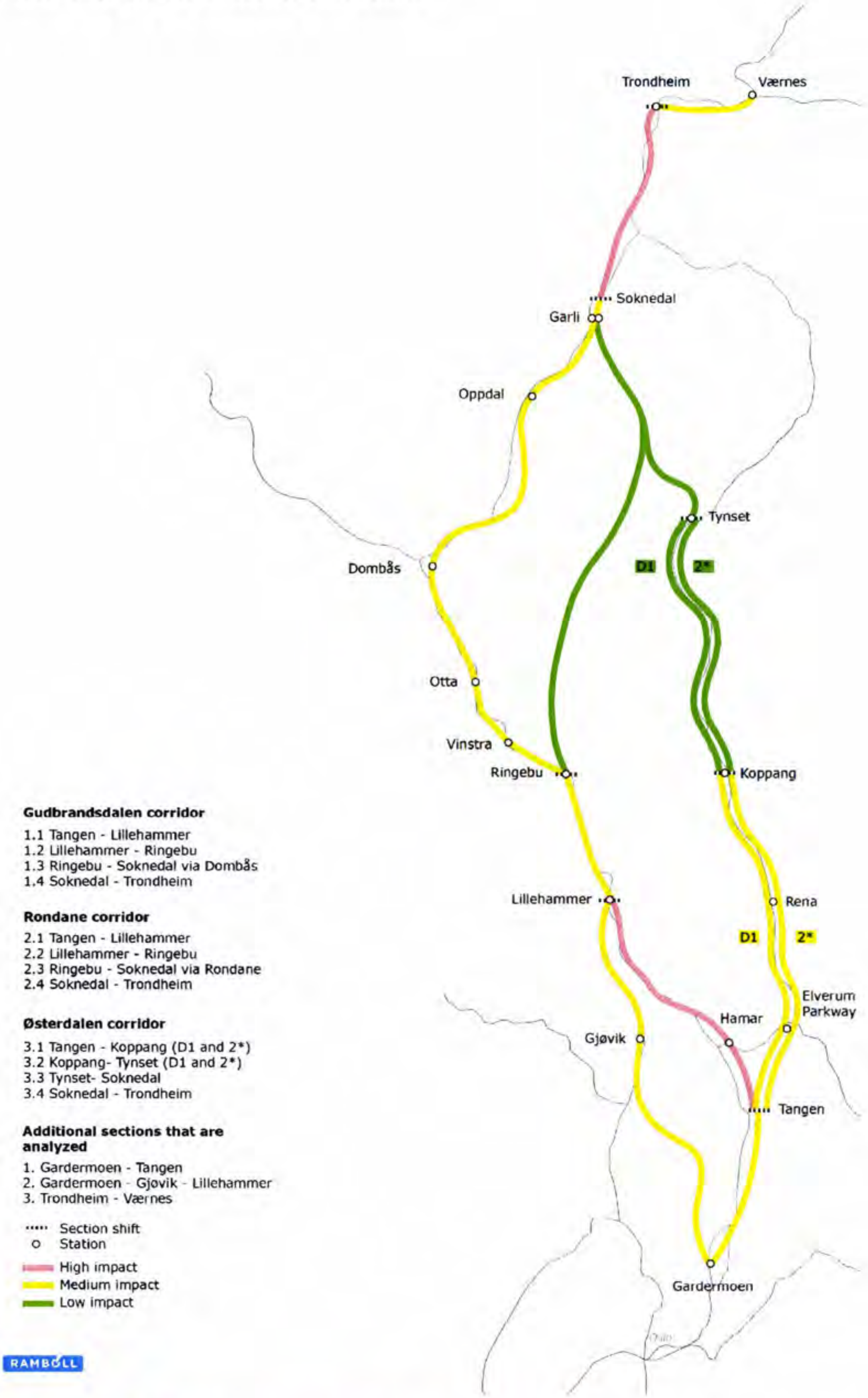


Figure 99. Community life and outdoor recreation, impact of four alignments.

The impact assessment for community life and outdoor recreation is shown in Figure 100 and Figure 101. This includes the value, effect and impact for each section. The effect is shown as effect per kilometre for each subject in Figure 100. The total impact for each main alignment alternative is shown in Figure 101.

Community life and outdoor recreation		**Protected areas (hectares)**	**Local recreational areas (hectares)**	**Marked hikers trails (kilometres)**	**Pilgrim walk (kilometres) - see "cultural heritage"**	**Vårstigen (kilometres)**	**Hikers cabins (no. of points)**	
SECTIONS	CORRIDOR VALUE	CALCULATION PER KM LINE						LINE IMPACT
Gardermoen - Tangen	Low	0,1	0,7	0,0	0,0	0,0	0,0	Medium
Gardermoen - Gjøvik - Lillehammer	Medium	0,0	0,6	0,0	0,0	0,0	0,0	Medium
Tangen - Lillehammer	Medium	0,0	1,2	0,0	0,0	0,0	0,0	High
Tangen - Koppang (D1)	Low/medium	0,0	0,4	0,0	0,0	0,0	0,0	Medium
Tangen - Koppang (2*)	Low/medium	0,0	0,5	0,0	0,0	0,0	0,0	Medium
Lillehammer - Ringebu	Medium	0,0	0,3	0,0	0,0	0,0	0,0	Medium
Koppang - Tynset (D1)	Low	0,0	0,3	0,0	0,0	0,0	0,0	Low
Koppang - Tynset (2*)	Low	0,1	0,4	0,0	0,0	0,0	0,0	Low
Ringebu - Soknedal (via Dombås)	High	0,0	0,6	0,0	0,0	0,0	0,0	Medium
Ringebu - Soknedal (via Rondane)	High	0,0	0,1	0,0	0,0	0,0	0,0	Low
Tynset - Soknedal	Medium	0,0	0,0	0,0	0,0	0,0	0,0	Low
Soknedal - Trondheim	Low/medium	0,0	1,4	0,0	0,0	0,0	0,0	High
Trondheim-Værnes	Medium/high	0,0	0,9	0,0	0,0	0,0	0,0	Medium

Figure 100. Impact assessment for community life and outdoor recreation, shown for each section.

<table>
<tr><th>Alignment</th><th>Gudbrandsdalen D</th><th>Rondane D</th><th>Østerdalen D</th><th>Østerdalen 2*</th></tr>
<tr><td rowspan="4">Sections</td><td colspan="2">Tangen-Lillehammer (H)</td><td>Tangen-Koppang D1 (M)</td><td>Tangen-Koppang 2* (M)</td></tr>
<tr><td colspan="2">Lillehammer-Ringebu (M)</td><td>Koppang-Tynset D1 (M)</td><td>Koppang-Tynset 2* (L)</td></tr>
<tr><td>Ringebu-Soknedal via Dombås (M)</td><td>Ringebu-Soknedal via Rondane (L)</td><td colspan="2">Tynset-Soknedal (L)</td></tr>
<tr><td colspan="4">Soknedal-Trondheim (H)</td></tr>
<tr><td>Impact</td><td>H/M</td><td>MM/H</td><td>M</td><td>L/M</td></tr>
<tr><td>Ranking</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
</table>

Figure 101. Summarized impact and ranking for community life and outdoor recreation for the four main alignment alternativesLandscape

11. SUBSTRUCTURE

11.1 Introduction

The evaluation is based on the following data from NGU:

- Quaternary maps giving top layer deposits
- Quick clay risk map and danger maps showing known quick clay zones that should be given special attention.
- "skrednett" showing registered sliding activity

No detailed evaluations have been performed. The depth to bedrock is unknown and only rough evaluations are done to estimate the cost categories and possible special challenges concerning ground conditions.

11.2 Route Gudbrandsdalen

11.2.1 General

The main impression is that the ground conditions in Gudbrandsdalen are good as foundation for a railway fill, but at the steep slopes rock fall, flooding of small rivers and snow melting could cause problems. However, this should be evaluated based on local knowledge and a field study and have to be evaluated in a later phase when the corridor has been chosen. Where the line is situated close to the river on river deposits, there may be softer sediments below the upper river deposits.

Marine coastal clay deposits are surveyed from the sea line and up to a level where the land previously was below sea level. From south this goes up to Eidsvoll, and in the north this starts south of Soknedal and continues further up to Værnes. Marine deposits could be positioned below river deposits as well, and may be quick clay.

Especially in the southern part (south of Lillehammer) there are some occurrences with peat and bog that may give some additional measures and costs.

11.2.2 Alternative D1 from Tangen to Lillehammer

There are some occurrences with peat and bog. Extra cost for mass replacement and possible measures for settlement reduction are given for a 0.25 km long distance. The quaternary map shows mainly glacial deposits / moraine indicating good ground conditions for foundation.

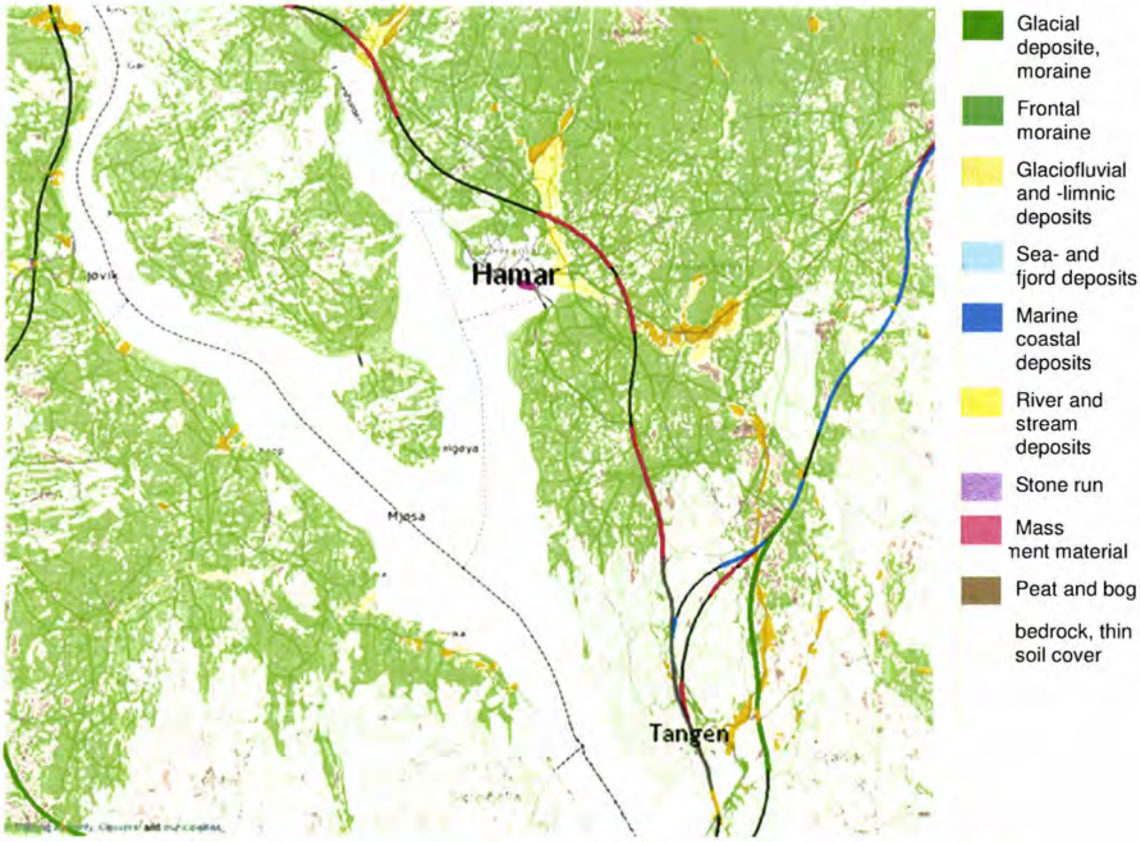


Figure 102. Quaternary in the Mjøsa region The map inclueds the lines for the Gudbrandsdalen Østerdalen and Gjøvik alternative. Source: Geovekst.

11.2.3 Alternative D1 Lillehammer to Ringebu

The quaternary map shows mainly firm glacial deposits, but only small parts of this section are not in tunnel. These parts will mainly be on glaciofluvial deposits and river deposits that have probably got more varying quality.

11.2.4 Alternative D1 Ringebu to Soknedal

The quaternary map shows mainly firm glacial deposits, but only small parts of this section are not in tunnel. Up to Dombås these parts will mainly be on glaciofluvial deposits and river deposits that probably got more varying quality. Special challenges may be in Drivdalen with very steep slopes. Some extra costs are included for crossing some peat and bog as e.g. north of Oppdal. A total length of 2.9 km is estimated in a higher cost category because of registered peat.

Figure 103. Area with sliding mass / Rock fall mass in Drivdalen. Source: Geovekst. Legend see Figure 104.

11.2.5 Alternative D1 Soknedal to Trondheim

The quaternary map shows mainly firm glacial deposits and river deposits on the first part and sea -/marine deposits (=clay and quick clay) closer to Trondheimfjorden. However, there may be marine deposits below the river deposits as well. The line is close to or crossing several quick clay zones. Passing areas with quick clay may give challenges and excessive costs. These parts will mainly be on glaciofluvial deposits and river deposits that have probably got more varying quality.

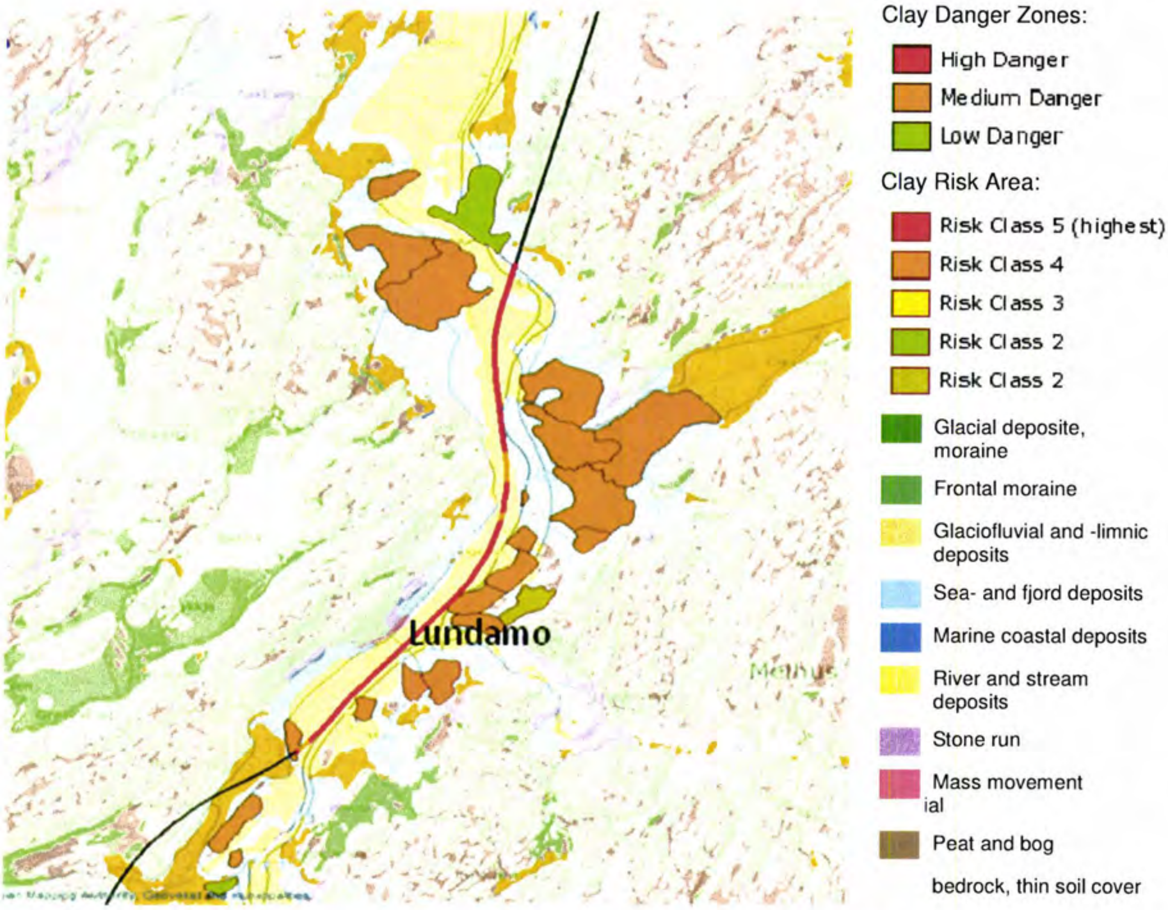


Figure 104. Quick clay zones around Lundamo in Sør-Trøndelag. Source: Geovekst.

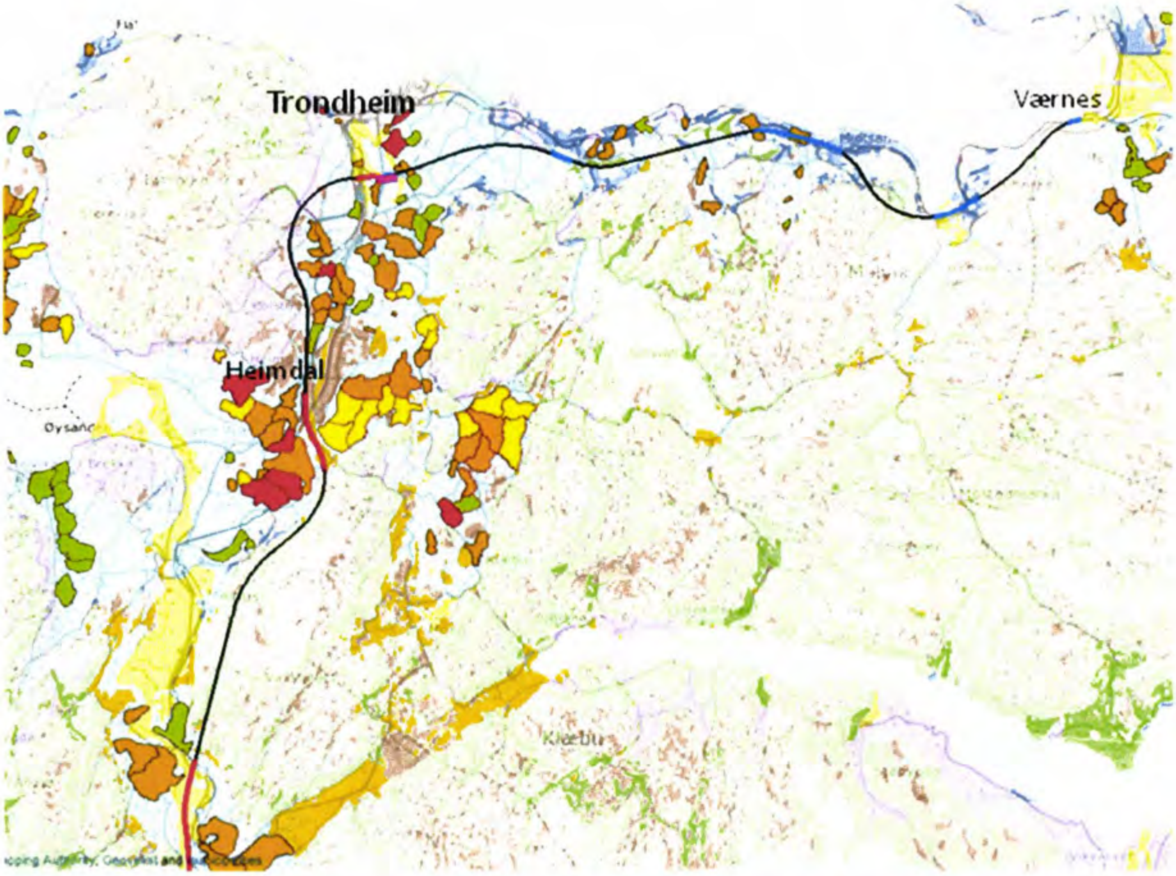


Figure 105. Known quick clay zones and Quaternary in the Trondheim area / Trøndelag. Source: Geovekst. Legend see Figure 106.

11.2.6 Alternative 2* from Trondheim to Værnes

The most challenging parts are the tunnel portal through the quick clay zone at Lerkendal /Berg in Trondheim and at Jonsborg in Malvik. These two small sections could cause excessive costs. There is also known to be soft soil and quick clay in Hommelvik.

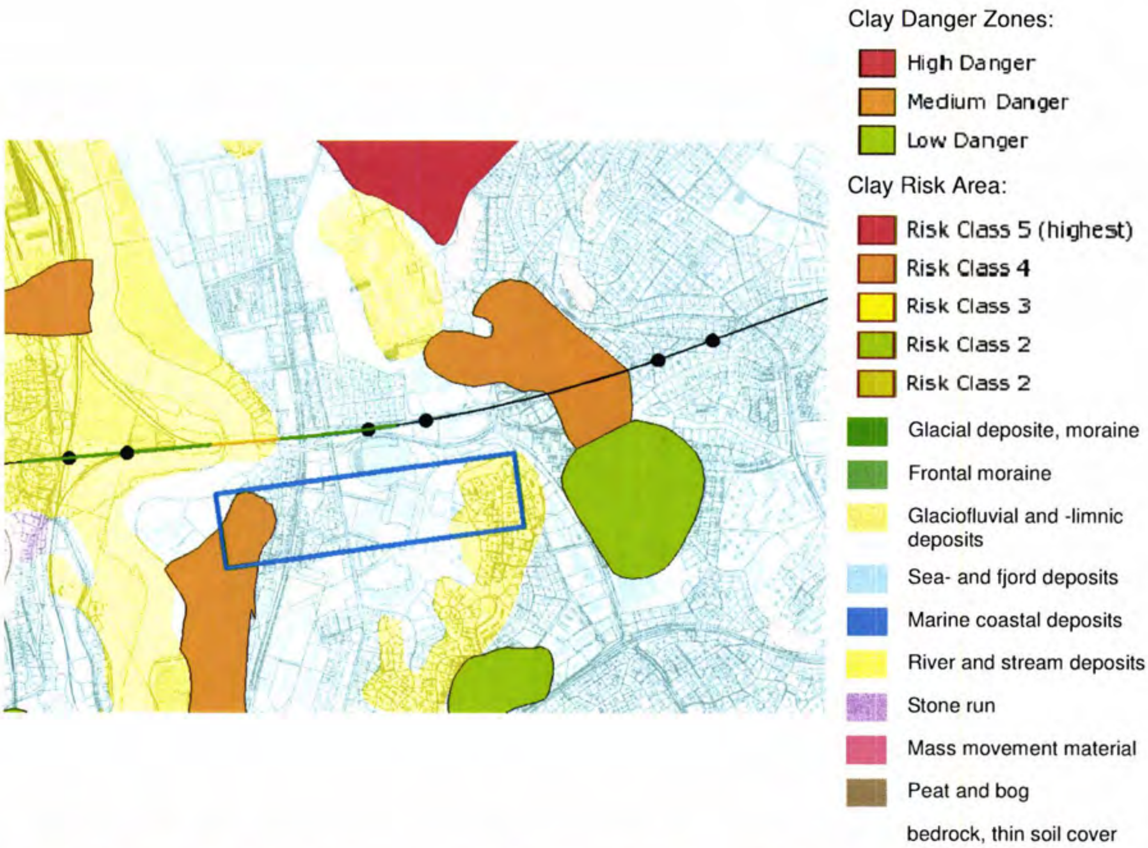


Figure 106. Difficult cutting/tunneling in the Berg quick clay zone in Trondheim. Source: Geovekst.

Figure 107. Diffucult part (tunnel, cutting and filling) in Jonsborg quick clay zone in Malvik. Source. Geovekst. Legend see Figure 106.

11.3 Route Rondane

11.3.1 Reference to the route sections already described

The route is subdivided into sections. Some sections are equal to route sections described for Gudbrandsdalen. These are:

- Tangen-Ringebu (as described in 11.2)
- Soknedal-Værnes (as described in 11.2)

11.3.2 Alternative D2 from Ringebu to Soknedal via Kvikne

The quaternary map shows mainly firm glacial deposits and river deposits and only some small parts with peat and bog (a total of 0.8 km) that will not constitute any particular challenges.

11.4 Route Østerdalen

11.4.1 Reference to the route sections already described

The route is subdivided into sections. Some sections are equal to route sections described for Gudbrandsdalen and Rondane:

- Kvikne-Soknedal (as described in 11.3)
- Soknedal-Værnes (as described in 11.2)

11.4.2 Alternative 2* from Tangen to Tynset

From Tangen to Elverum there are some large areas with peat and bog, especially south of Ebru (2.2 km).

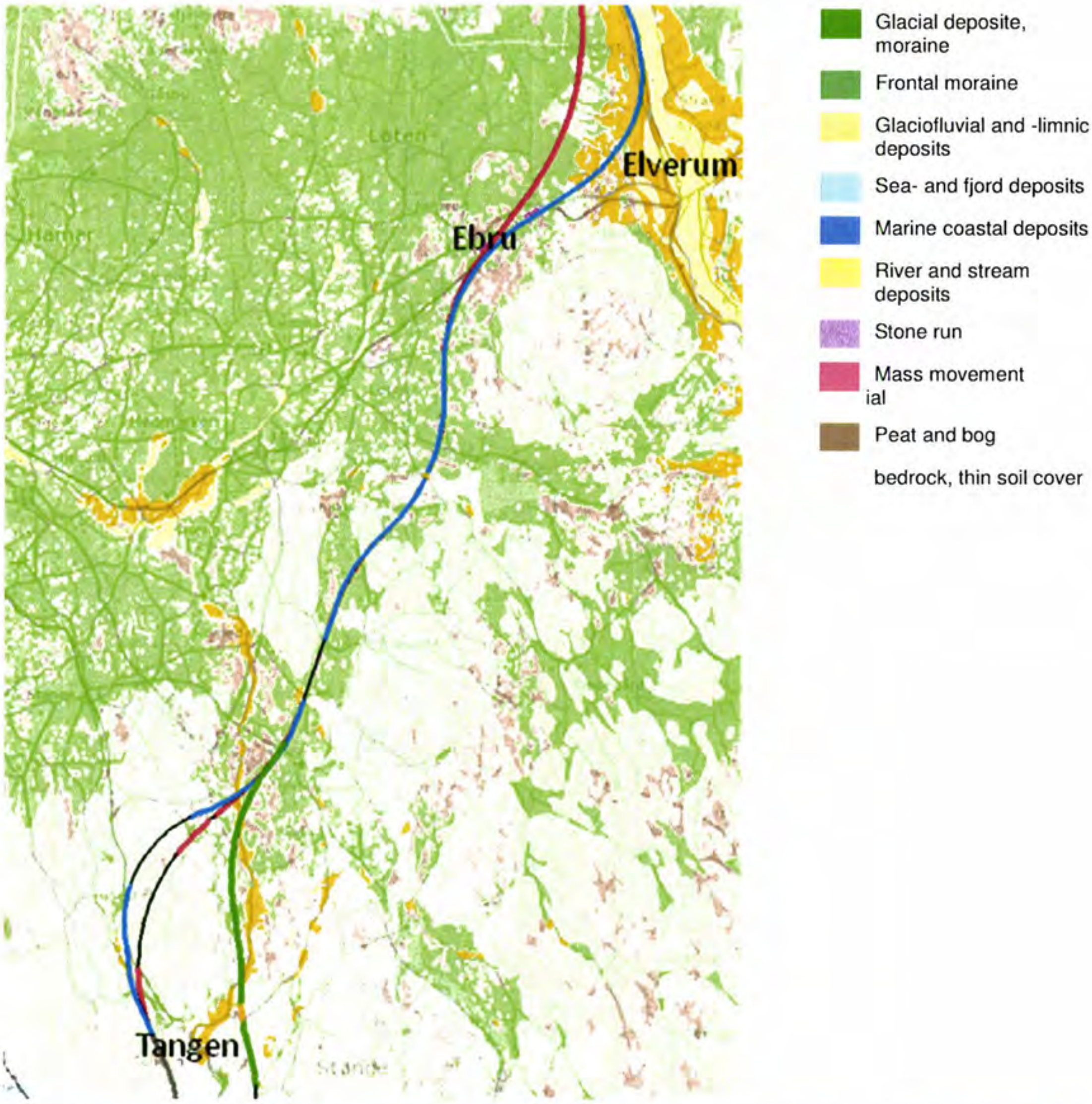


Figure 108. Quaternary east of Mjøsa includes larger peat areas between Tangen and Elverum. The blue line is the 2*-alternative. Red is the D-alternative, green is Gardermoen-Tangen D2 step 2. Source: Geovekst.

Further northwards there are mainly firm glacial deposits / moraine indicating good conditions for foundation. Closer to the river Glomma there will be river deposits that could be layered with softer materials below, but is not expected to cause special problems. However, sections where the fill is ending close to or in the river should be evaluated more closely. Outside Tynset the line crosses a river delta. The ground conditions are expected to vary and to include some softer layers. This area could also be flooded. The frost intensity is extreme in the Tynset area and necessary frost insulation should be evaluated as a special case for this area. A total length of 5.5 km is estimated in a higher cost category because of registered peat from Tangen to Tynset.

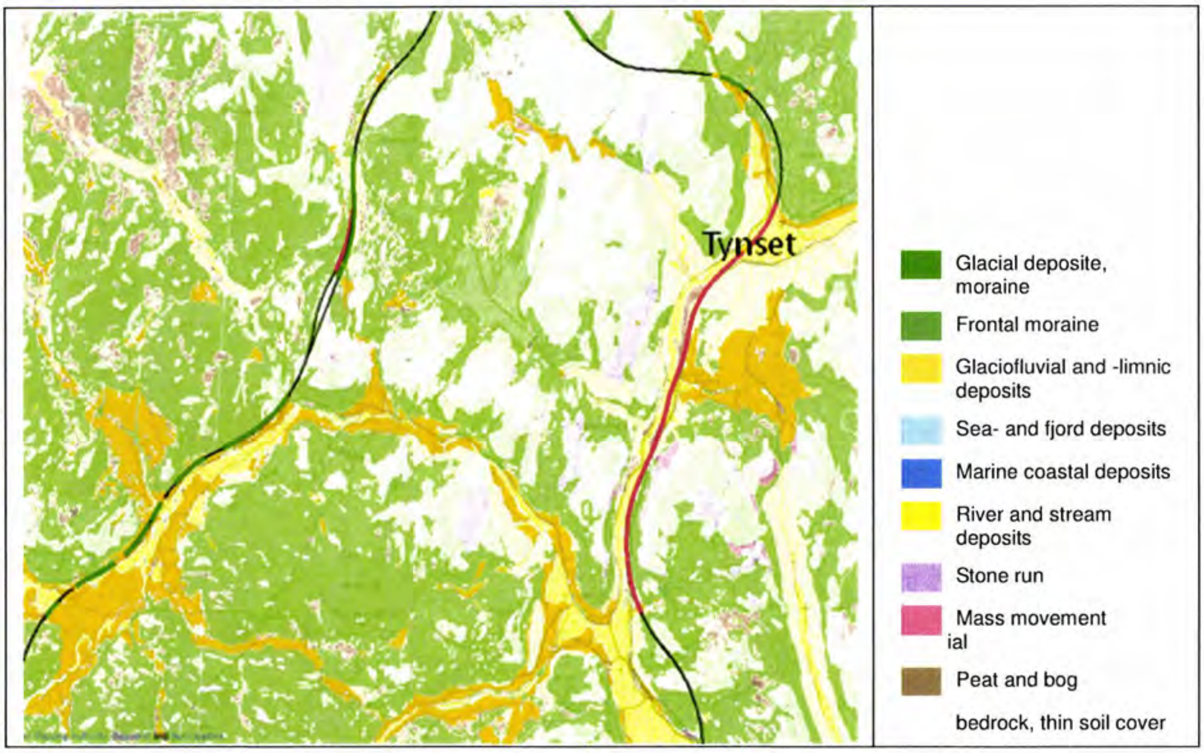


Figure 109. Quaternary in Tynset area with river delta vest of Tynset. The map is also including the line for the Rondane alternative in the west. Source: Geovekst.

11.4.3 Alternative D1 from Tangen to Tynset

The D1-alternative is like alternative 2*. A total length of 4.0 km is estimated in a higher cost category because of registered peat from Tangen to Tynset.

11.4.4 Alternative D2 from Tynset to Soknedal

The quaternary map shows mainly firm glacial deposits / moraine. There are some areas with peat and bog.

11.5 Step 2 sections when the IC-line is saturated

11.5.1 Gjøvik - D2 for Gudbrandsdalen and Rondane

This is section is planned to be built at a later stage (step 2), when the intercity section from Gardermoen to Lillehammer has no capacity left.

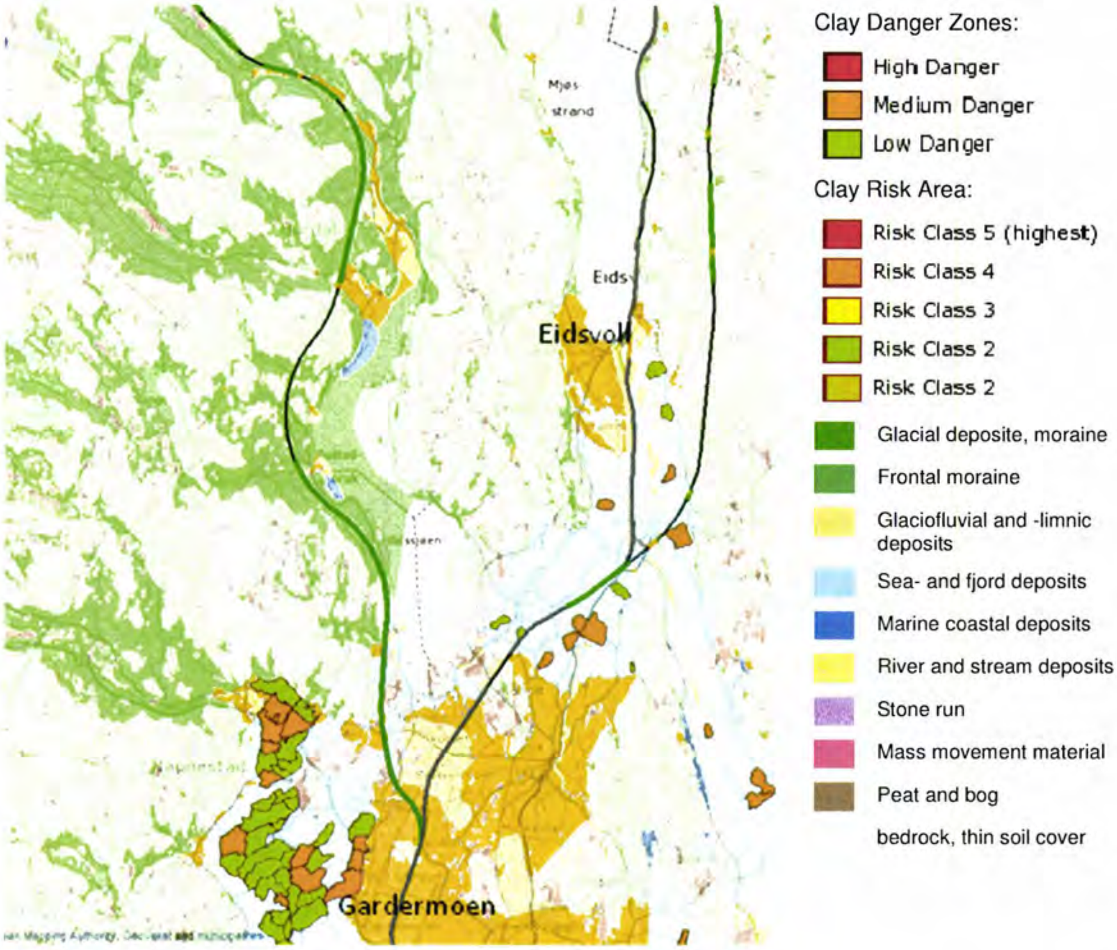


Figure 110. Quaternary north of Gardermoen. Source: Geovekst.

There are some areas with soft soil north of Gardermoen and the line is also crossing some peat and bog. Most of the line is on firm glacial deposits, but occasionally there are minor areas with peat and bog. A total length of 3.8 km is estimated in a higher cost category because of registered peat.

11.5.2 New D2 section Gardermoen to Tangen for the Østerdalen route

This section is planned to be built at a later stage (step 2) when the intercity-section from Gardermoen to Tangen has no capacity left.

In general, there are mostly good ground conditions for foundation on firm glacial deposits in this route section. However, there are sea-/marine deposits of silt and clay in the Eidsvoll area including some quick clay zones. A total length of 1.6 km is estimated in a higher cost category because of registered peat.

12. TUNNELS

12.1 Introduction

12.1.1 References

- NGU: Bedrock map and descriptions with the proposed alignments drawn in (Avinet).
- Quartary deposits and descriptions of the track with the alignments drawn in (Avinet).
- Topographical maps.
- Longitudinal sections with topographical overburden.
- Google earth with the alignments included.
- Google maps combined with the proposed alignments.
- Some known experiences from earlier tunnels in similar formations.
- NGU/Statens strålevern: Maps showing Alum schist.

12.1.2 Tunnel categories

The categorization of the tunnels is based on desktop studies, where different aspects of the tunnels have been investigated.

Main criteria were rock cover, rock type, tectonical structures and sensitive areas.
Rock cover of the tunnels has been based on longitudinal sections which have been produced by Rambøll and based on topographical map. Profiles perpendicular to the longitudinal sections have not been produced here. Tunnels with a length smaller than 0,3km have been turned into rock slopes.

At this stage a distribution of bedrock and thickness of soils has not been taken in consideration. And there has been no estimation of profiles perpendicular to the longitudinal sections. It might therefore turn out that after closer investigations and field studies, especially the shorter tunnels, preliminary cuts and portals of the tunnels turn out to have a different design and length than shown in the descriptions which are presented in this study.

Rock types have been estimated according to the maps from NGU. Especially rock sequences containing alumschist can lead to unfavourable building conditions of the tunnels.

Alumschists occur in the region from Oslo to Lillehammer and mainly west and east of Mjøsa. Loose masses from alumschists must be properly removed from all foundations. The occurrence of alumschists will demand for special solutions for rock support constructions in the tunnel and special solutions for foundations and track stability. Masses containing alumschist must have special deposits and special treatments for the leakage water from tunnels.

Many of the tunnels follow the valleys, which may lead to non uniform rock stress situations, caused by high vertical rock cover and low rock on the valley side of the tunnel.

The rock conditions are classified in three classes according to the Q-system and the classifications from Statens vegvesen.

<u>Categories</u>
Category 1: No important weakness-zones; Q=B/C with low injection scale
Category 2: Average difficult rock conditions, intermediate injection, smaller weakness-zones
Category 3: Difficult rock conditions, high injection scale, more weakness-zones

Cost estimate for elements and lengths are mainly based on the longitudinal profile combined with topographical maps and bedrock map.

We have mainly used category 1 and 2. Tunnel category 3 has in this section been chosen for some settings, like:

- low rock cover (<15m) in combination with porous sediments, which might lead to intense groundwater flow
- weakness zones with large amounts of heavily crushed materials and water
- large amounts of clay
- tunnel runs under buildings and high density areas
- tunnel runs under protected watersheds

At this stage we have not spent much effort evaluating amounts of loose deposits near portals and costs of support constructions in slopes.

12.1.3 Tunnel methods

Final choice of the tunnel method, conventional vs. TBM (tunnel boring machine), has to be taken at a later point of planning and after more precise field work. TBM might be used for the tunnels which are longer than 4km. There are many circumstances which might influence the choice of tunnel methods, like rock quality, distribution of soils in the portal areas, rock cover over the tunnel, building site facilities and access conditions.

12.1.4 Description of the routes

The routes Gudbrandsdalen, Rondane og Østerdalen (alternative 2* and D) partly run in similar lines. They have been splitted in several sections to avoid repetitions. Since the line Soknedal-Værnes is similar for all routes, it has been described only once and an independent statistic of the section has been carried out. Statistics for the other lines has been carried out for the section from Tangen to Soknedal, since this is where the lines meet for the section Soknedal-Værnes.

Symbols of the geological map

- Unconsolidated sediments
- Sandstone
- Conglomerate, sediamentary breccia
- Breccia
- Mylonite, Phyllite
- Sedimentary rocks (unspesifed)
- Schist, sandstone, limestone
- Sandstone, schist
- Limestone, schist, marl
- Limestone, dolomite
- Granite, granodiorite
- Diorite, monzonite
- Syenite, quartz syenite
- Monzonite, quartz monzonite
- Mangerite syenite
- Rhyolite, rhyodacite, dacite
- Rhomb porphyry
- Metabasalt
- Igneous rocks (unspesified)
- Mangerite til gabbro, gneiss and amphibolite
- Gabbro, amphibolite
- Keratophyre
- Quartz diorite, tonalite, trondhjemite
- Olivin rocks
- Eclogite
- Anorthosite
- Charnockitic and anorthositic plutonic rocks
- Amphibolite and mica schist
- Greenstone, amphibolite
- Metasandstone, schist
- Quartzite
- Mica gneiss, mica schist, metasandstone, amphibolite
- Phyllite, mica schist
- Calcareous mica schist and calcareous mica gneiss
- Marble
- Dolomite
- Dioritic to granitic gneiss, migmatite
- Augen gneiss, granite, foliated gneiss
- Banded gneiss (amphibolite, hornblende gneiss, mica

Figure 111. Symbols of the geological map used in this chapter.

12.2 Route Gudbrandsdalen

12.2.1 Gardermoen – Tangen

The alignment between Gardermoen and Tangen follows the proposal for the new Intercity line. This section has already been planned in detail by Jernbaneverket.

The route runs through metamorphic rocks, like gneiss, micaschist, metasediments, amphibolites and granitic and pegmatitic bodies of the Romerikscomplex, gabbro with ultrabasic bodies of the Oslo-area and different gneisses of the Solør-complex.

Figure 112. Route between Gardemoen and Tangen. This route section is the same for all four main routes: Gudbrandsdalen, Rondane and Østerdalen D1 and 2*. Source: Geovekst.

12.2.2 Tangen-Lillehammer

Between Tangen and Lillehammer 15 tunnels with a total length of ca. 35.3 km are planned. The tunnels are to be built in low (<30 m) to moderate (<150 m) rock cover. Just at one ridge near Ringsaker is the rock cover over the tunnel up to 200 m. The tunnels are placed in sediments, like for example different types of sandstones, schist and conglomerates of the Oslo- and Hedmarkgroup.

Tunnels of the Oslogroup might run in sediments containing alumschist which might lead to difficulties during building. Two of the smaller tunnels (<4 km) in the South of the section run through sediments which might contain alumschist.

Some of the tunnels run under buildings. Low rock cover (<15 m) in combination with porous sediments might lead to difficult groundwater conditions and might cause difficult building situations. There are several weakness and thrust zones crossing the tunnels.

Some of the shorter tunnels have, due to low rock cover (<15 m), category 3. It might turn out to be more feasible to turn those tunnels in rock-slopes.

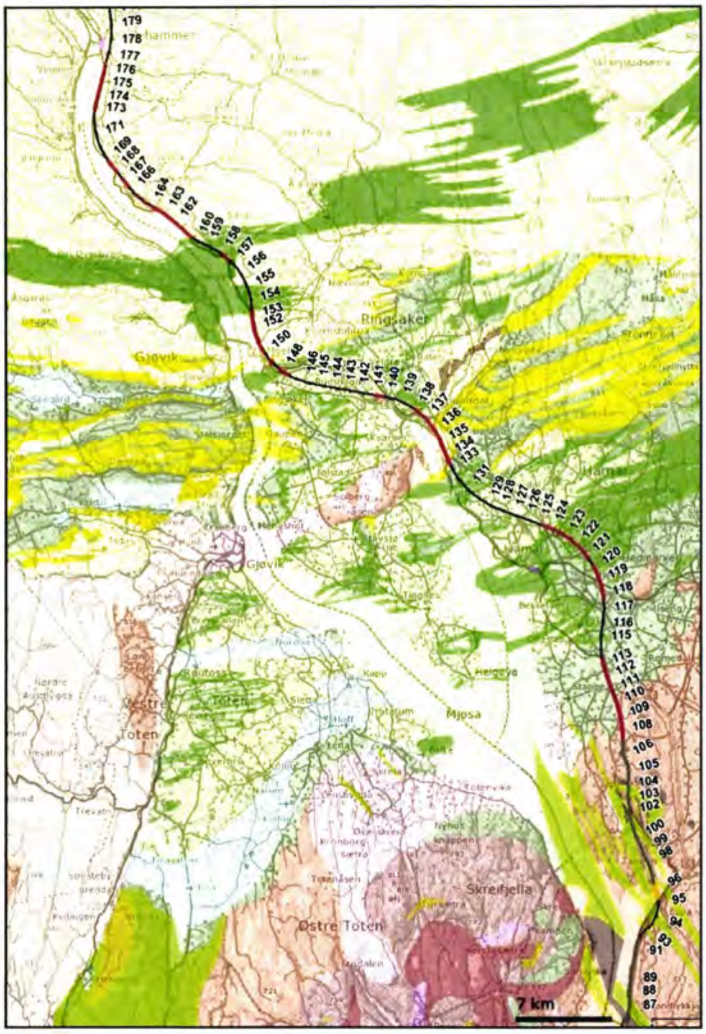


Figure 113.

Route between Tangen and Lillehammer. This route section is the same for the main routes Gudbrandsdalen and Rondane. The tunnels are marked in black color along the line. Source: Geovekst.

12.2.3 Lillehammer-Ringebu

Along a valley, which follows lake Losna, 7 tunnels are planned. Their total length is 37.5 km. Most of the tunnels in this section have rock cover from 25 to 400 m. The two longest tunnels are in Lillehammer and north of Lillehammer and each ca. 10 km long.

The tunnels are running in diverse sediments, like sandstone, schist, conglomerate and limestone of the Hedmark-group. One of the longer tunnels in this section runs under the high density area of Lillehammer, the other under the family park Hunderfossen, which can lead to different design conditions and restrictions during building phase. The sediments have presumably varying rock quality and ground water conditions.

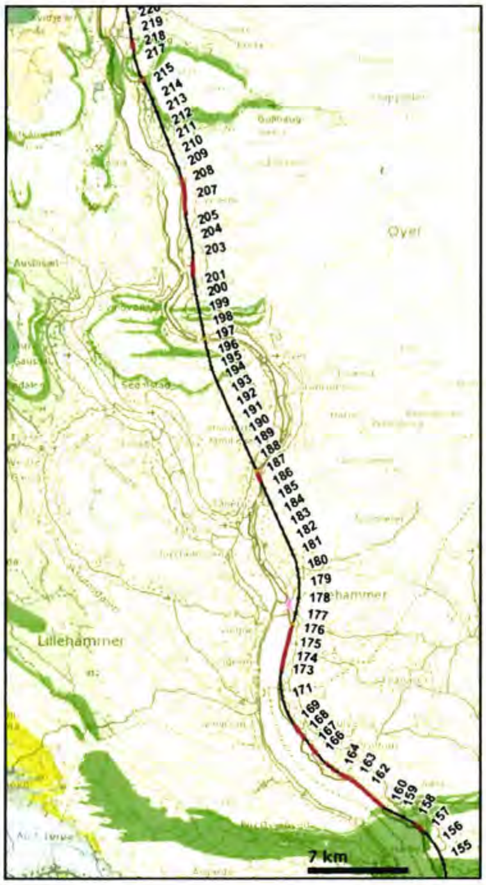


Figure 114.

Route between Lillehammer and Ringebu. The tunnels are marked in black color along the line. Source: Geovekst.

12.2.4 Ringebu-Soknedal

Between Ringebu and Soknedal 32 tunnels with a total length of 134.6 km are planned. Most of the tunnels have moderate rock cover of ca. 30-200 m. The two longest tunnels are each 18 km, and are placed in the area of Dovre. They have a rock cover of 650 m and run partly under protected watersheds. In some areas mining activity occurs.

The tunnels are placed in mixed rock types:

- Sediments of the Hedmark- and Engerdalsgroup.
- Metamorphic rocks, like augengneiss, quartzite, mica schist and granitoide of the Middle Allochton.
- Metamorphic rocks of the Trondheim Nappe (Upper Allochtone), like for example greenstone, phyllite, mica schist, amphibolites and metasediments.

The tunnels are running parallel to thrust- or weakness zones or are crossing them.

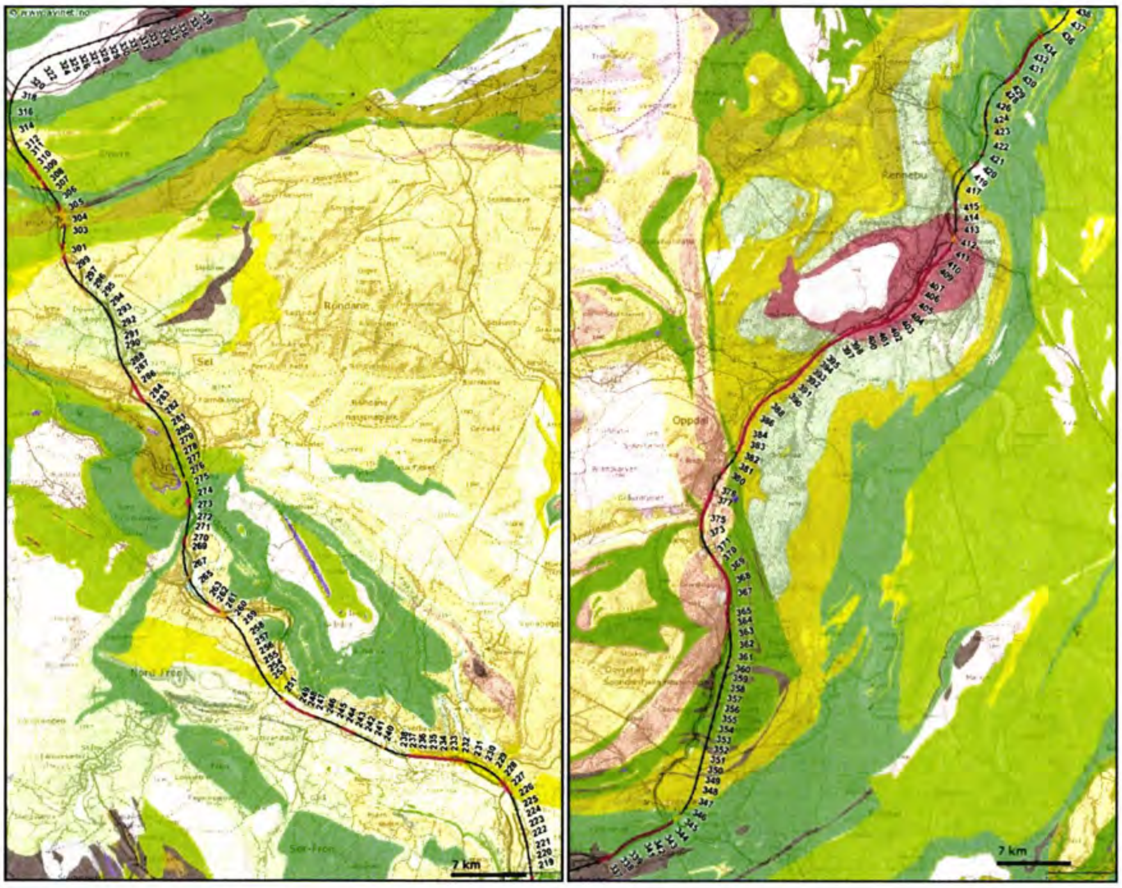


Figure 115. Southern part of the route Ringebu-Soknedal (left picture), north part of the route (right picture). The tunnels are marked in black color along the line. Source: Geovekst.

12.2.5 Statistics of the route Gudbrandsdal: Tangen-Soknedal

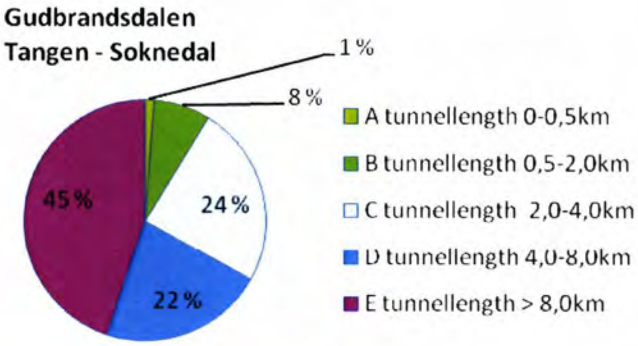


Figure 116.

Distribution of tunnels referred to the total length (ca. 207 km) of all tunnels in this section.

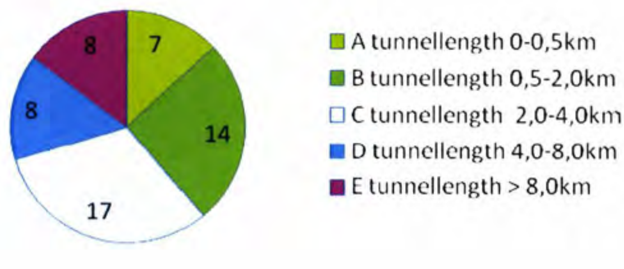


Figure 117.

Number of tunnels in this section.

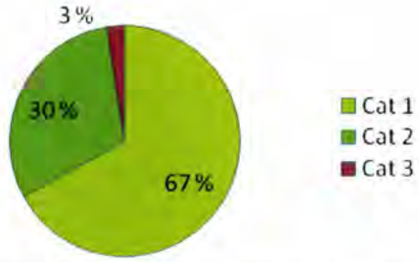


Figure 118.

Distribution of categories referred to total length (ca.207km) of all tunnels in this section.

-Category 1: No important weakness-zones; Q= B/C with low injection scale

-Category 2: Average difficult rock conditions, intermediate injection, smaller weakness-zones

-Category 3: Difficult rock conditions, high injection scale, more weakness-zones

12.2.6 Soknedal-Trondheim

Between Soknedal and Trondheim 3 long tunnels (>8 km) with a total length of 39.9 km are planned. Rock cover of the tunnels ranges between 35 and 400 m. One of the tunnels runs under a high density area in the city of Trondheim. They are placed in metamorphic rocks of the Trondheim Nappe (Upper Allochtone), like for example greenstone, phyllite, mica schist, amphibolite and metasediments. Most of the tunnels run parallel to thrust- or weakness zones or are crossing them. Nearly all tunnels have 500 m and more of their length in category 3.

Figure 119.

Route from Soknedal to Trondheim. This route section is common for all main routes described in this report. The tunnels are marked in black color along the line, without chainage.

12.2.7 Statistics of the route Soknedal-Trondheim

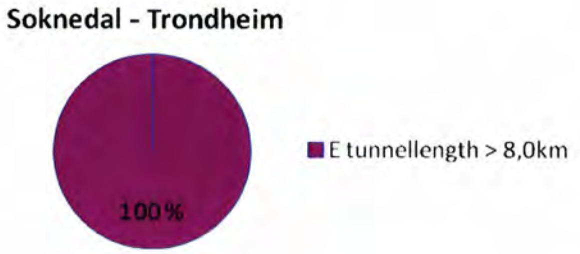


Figure 120.

Distribution of tunnels referred to the total length (ca. 40 km) of all tunnels in this section.

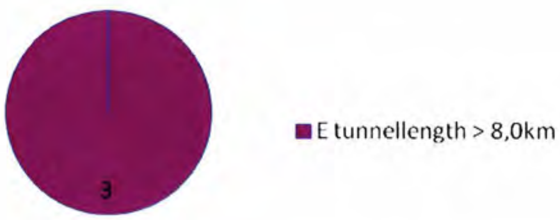


Figure 121.

Number of tunnels in this section.

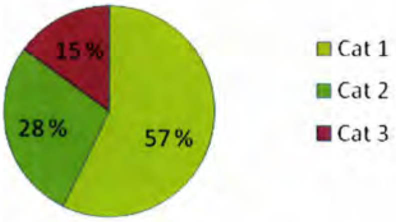


Figure 122.

Distribution of categories referred to total length (ca. 40 km) of all tunnels in this section.

12.2.8 Trondheim-Værnes

Between Trondheim and Værnes 4 longer tunnels (>4 km) with a total length of 20.8 km are planned. Rock cover of the tunnels ranges from 20 to 250 m. The tunnels run partly under high density areas. They are placed in metamorphic rocks of the Trondheim Nappe (Upper Allochtone), like for example greenstone, phyllite, mica schist, amphibolite and metasediments. Most of the tunnels run parallel to thrust- or weakness zones or are crossing them. Nearly all tunnels have more than 100 m of their length in category 3. The only exception is the tunnel before Værnes. One tube of that tunnel already exists and has just ca. 50 m in category 3. For the second tube similar conditions are expected.

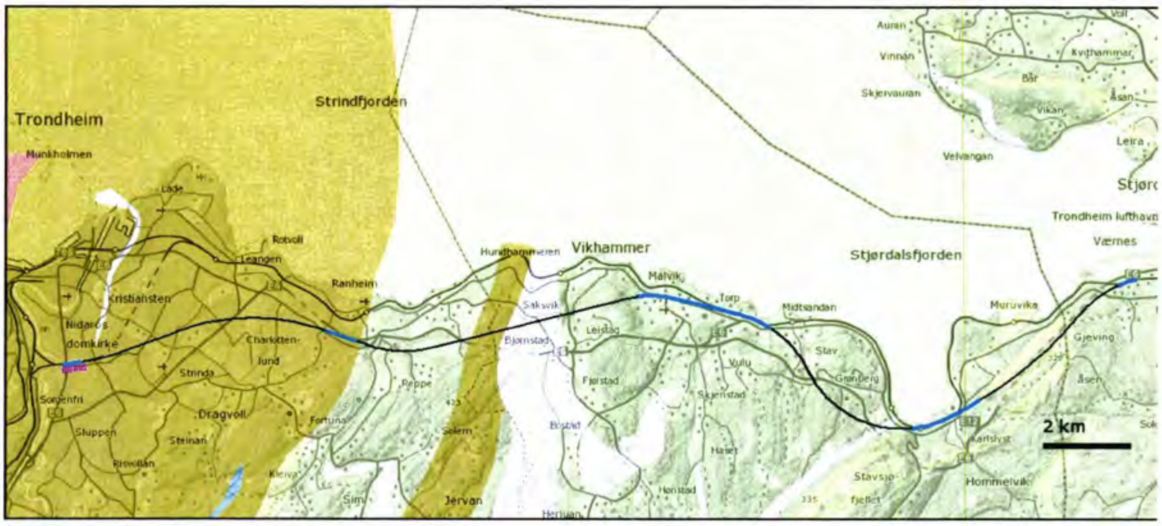


Figure 123. **Route from Trondheim to Værnes. All routes described share that line. The tunnels are marked in black color along the line, without chainage.**

12.2.9 Statistics of the route Trondheim-Værnes

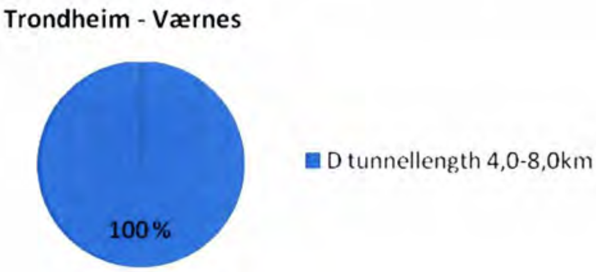


Figure 124.

Distribution of tunnels referred to the total length (ca. 21 km) of all tunnels in this section.

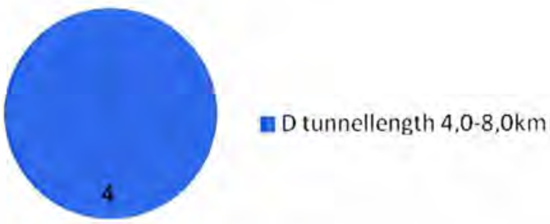


Figure 125.

Number of tunnels in this section.

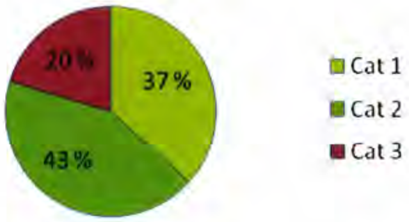


Figure 126.

Distribution of categories referred to total length (ca. 21 km) of all tunnels in this section.

12.3 Route Rondane

12.3.1 Reference to the route sections already described

The route is subdivided into sections. Some sections are equal to route sections described for Gudbrandsdalen in 12.2:

- Tangen-Ringebu (as described in 12.2)
- Soknedal-Trondheim (as described in 12.2)
- Trondheim-Værnes (as described in 12.2)

12.3.2 Alternative D2 from Ringebu to Kvikne

Between Ringebu and Kvikne 12 tunnels with a total length of ca. 68,5 km are planned. The tunnels have a moderate rock cover of mostly 30 to 300m. The longest tunnel has a length of approx. 27 km and a rock cover of nearly 900 m. It runs under a protected watershed and the Rondane national park.

Many tunnels in the South of this section are placed in an area of protected watersheds and the area of Rondane national park, which might lead to high demands concerning water management of the tunnel.

The tunnels in the South of this section are placed in sediments, like sandstones, quartzites and conglomerates of the Hedmark- and Engerdalsgroup. The tunnels in the North are run through metamorphic rocks, like greenstone, amphibolite, gneiss, phyllite and schist of the Trondheim Nappe.

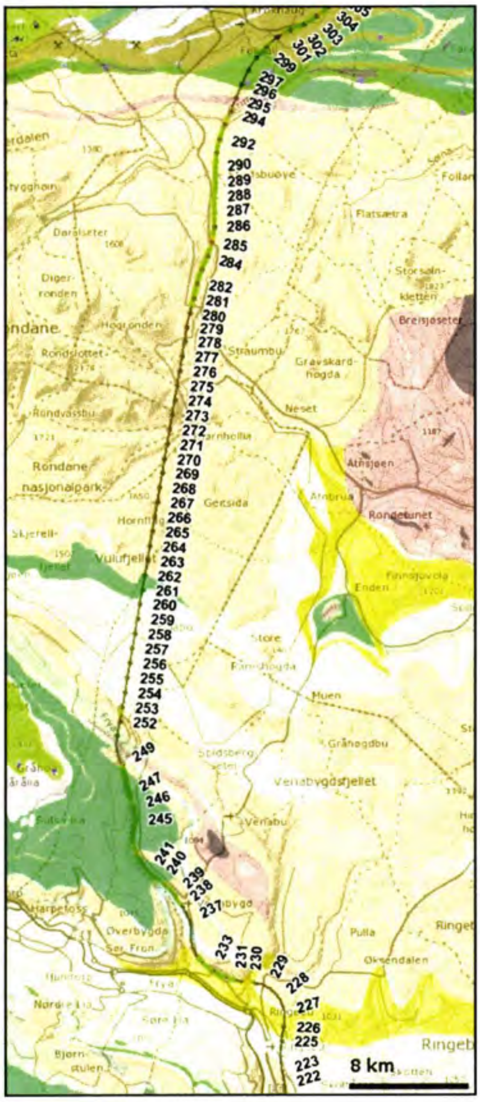


Figure 127.

Route from Ringebu to Kvikne. Picture to the left: southern part, picture above: northern part. The tunnels are marked with gray color along the line. Source: Geovekst.

12.3.3 Alternative D2 from Kvikne to Soknedal

Between Kvikne and Soknedal 8 tunnels with a total length of 19.0 km are planned. The tunnels in this area have moderate rock cover of 20 to 180 m. They are mainly placed in phyllite, schist and biotittmyllit of the Gula Nappe, Upper Allochtone.

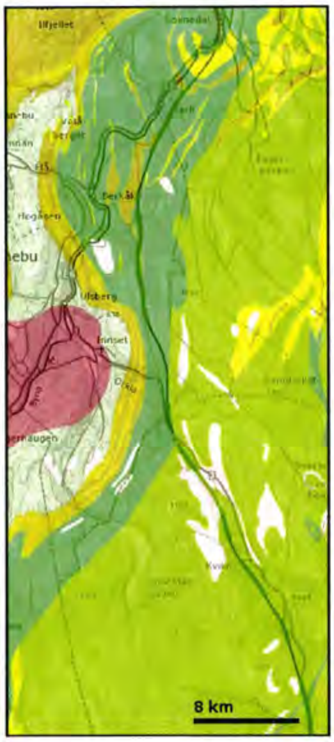


Figure 128.

Route from Kvikne to Soknedal. Route Rondane and Østerdalen share that route.The tunnels are marked in grey color along the line and without chainage. Source: Geovekst.

12.3.4 Statistics of the route Rondane: Tangen-Soknedal

Statistics for the section Tangen-Soknedal are given in the following.

Statistics for the route sections Soknedal-Trondheim and Trondheim-Værnes are described in the chapter of the route Gudbrandsdal (12.2).

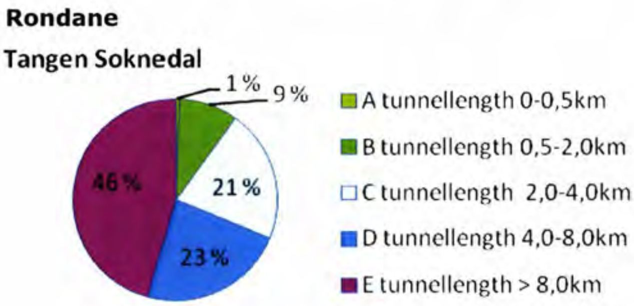


Figure 129.

Distribution of tunnels referred to the total length (ca. 163 km) of all tunnels in this section.

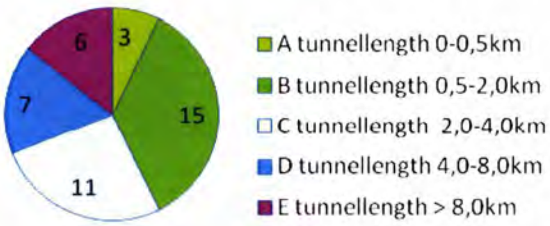


Figure 130.

Number of tunnels in this section.

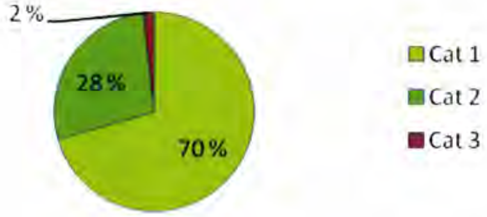


Figure 131.

Distribution of categories referred to total length (ca. 163 km) of all tunnels in this section.

12.4 Route Østerdalen

12.4.1 Reference to the route sections already described

The route is subdivided into sections. Some sections are equal to route sections described for Gudbrandsdalen and Rondane:

- Kvikne-Soknedal (as described in 12.3)
- Soknedal-Trondheim (as described in 12.2)
- Trondheim-Værnes (as described in 12.2)

The lines following Østerdalen have many short tunnels through ridges in the landscape. This gives many portals and tunnels with low rock overburden. That means lower rock quality near portals and bridges over the large weakzones that form depressions or valleys.

12.4.2 Alternative 2* from Tangen to Tynset

Between Tangen and Tynset 16 tunnels with a total length of ca. 50.2 km are planned. Many tunnels in this section have a low rock cover of up to 50 m, some up to 100 m. The longer tunnels have rock cover up to 350 m. The longest tunnel under Månsæterkletten has a length of 10 km and a rock cover up to 500 m. Most of the tunnels are running in mixed sediments of the Hedmark- and Engerdalgroup. The most frequent sediment is sandstone, but schist, slate, limestone, dolomite and conglomerate can also occur.

Metamorphic rocks, like augengneiss, gneiss, metasediments, metagabbro and amphibolite occur in the South of the section, where they are of the Oslo rift and Cambrium to Ordovicium, in the middle of the section they are belonging to the Kvitvolacomplex.

One smaller tunnel in the South of the section might run through sediments containing alumschist.

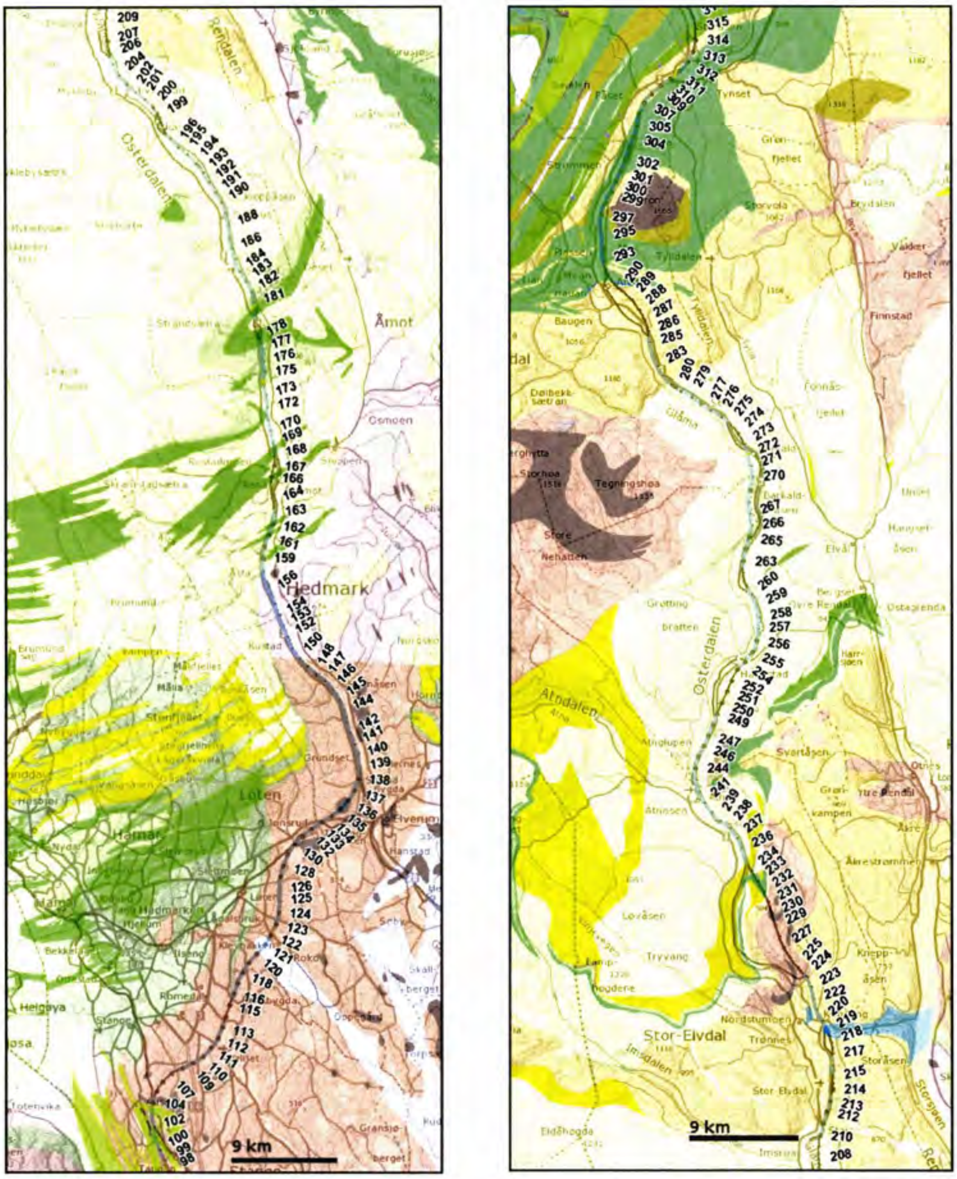


Figure 132. Southern (left picture) and northern (right picture) of the route Tangen to Tynset of the route Østerdalen 2*. The tunnels are marked in grey color along the line. Source: Geovekst.

12.4.3 Alternative D1 from Tangen to Tynset

Between Tangen and Tynset 19 tunnels with a total length of 61.4 km are planned. Most of the tunnels have low rock cover of around 30-50 m, but there are also some with a rock cover up to 200 m. The longest tunnel under Juliåsen is around 7 km long and has a maximal rock cover of 350 m. The main part of the tunnels in that area is running in sedimentary rocks, like sandstone, limestone, schist, slate, conglomerate and quartzite, of the Hedmarkgroup. The tunnels in the South of the section are running through metamorphic rocks, like augengneiss, gneiss, metasediments and amphibolites of the Oslorift and the Cambrium til Ordovicium.

One of the smaller tunnels in the South of the section might run through sediments containing alumschist.

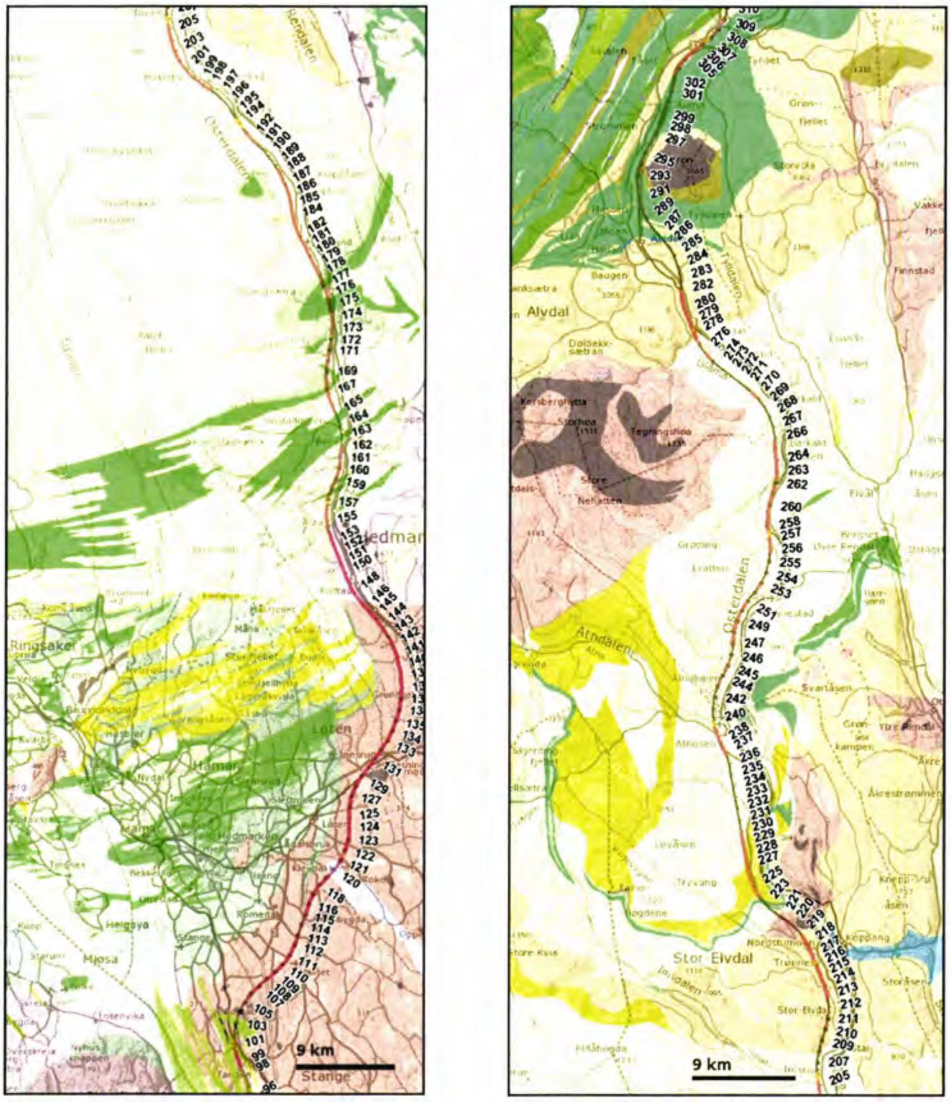


Figure 133. Southern (left picture) and northern (right picture) of the route Tangen to Tynset of the route Østerdalen D1. The tunnels are marked in dark grey color along the line. Source: Geovekst.

12.4.4 Alternative D2 from Tynset to Kvikne

Between Tynset and Kvikne three tunnels with a total length of 15.3 km are planned. The tunnels have moderate length and rock cover of 30 to 250 m. The first to tunnels run in different metamorphic rocks, like phyllite, greenstone, amfibolite, micaschist and gneiss of the Trondheim-, and Rørosnappe (Upper Allochton). The second tunnel runs partly, the third tunnel completely in metamorphic rocks, like phylite, quartzmicaschist and biotitschist of the Gulanappe.

Figure 134.

Route between Tynset and Kvikne. The tunnels are marked in grey color along the line, without chainage. Source: Geovekst.

12.4.5 Statistics of the route Østerdalen: 2* Tangen-Soknedal

The complete route Østerdalen, Alternative 2*, from Tangen to Værnes can be put together by pieces from sections described here and that have been named earlier in the report:

- Tangen-Tynset, alternative 2*
- Tynset-Kvikne, alternative D2
- Kvikne-Soknedal, as described in the chapter of the route Rondane (12.2.6)
- Soknedal-Trondheim, as described in the chapter of the route Gudbrandsdal (12.2)
- Trondheim-Værnes, as described in the chapter of the route Gudbrandsdal (12.2)

Statistics for Østerdalen, Alternative 2*, from Tangen to Soknedal are given in the following. Statistics for the other sections are given in 12.2.

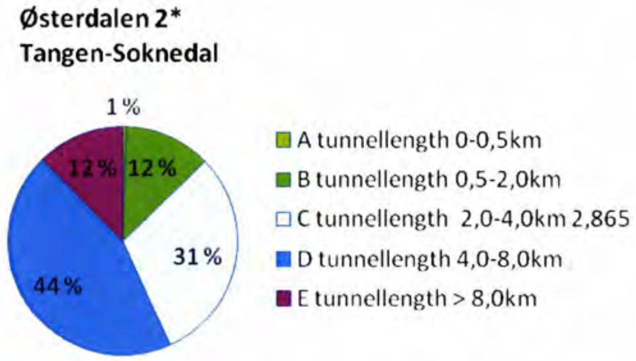


Figure 135.

Distribution of tunnels referred to the total length (ca. 85 km) of all tunnels in this section.

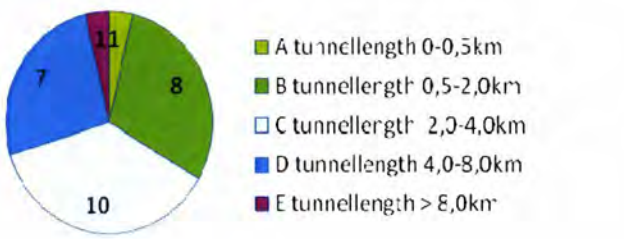


Figure 136.

Number of tunnels in this section.

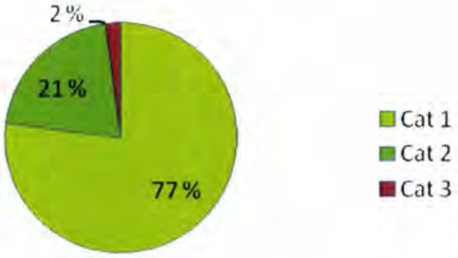


Figure 137.

Distribution of categories referred to total length (ca. 85 km) of all tunnels in this section.

12.4.6 Statistics of the route Østerdalen: D1/D2 Tangen-Soknedal

The complete route Østerdalen, Alternative D1/D2, from Tangen to Værnes can be put together by pieces from sections described here and that have been named earlier in the report:

- Tangen-Tynset, alternative D1
- Tynset-Kvikne, alternative D2
- Kvikne-Soknedal, as described in chapter of the route Rondane (12.2.6)
- Soknedal-Trondheim, as described in the chapter of the route Gudbrandsdal (12.2)
- Trondheim-Værnes, as described in the chapter of the route Gudbrandsdal (12.2)

Statistics for Østerdalen, Alternative D1/D2, from Tangen to Soknedal are given in the following. Statistics for the other sections are given in 12.2.

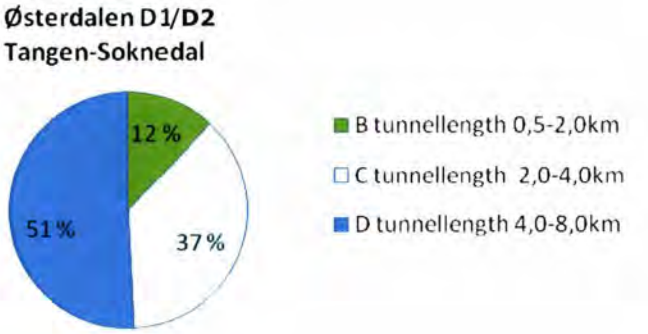


Figure 138.

Distribution of tunnels referred to the total length (ca. 96 km) of all tunnels in this section.

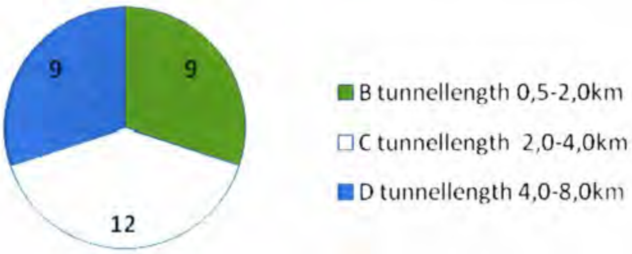


Figure 139.

Number of tunnels in this section.

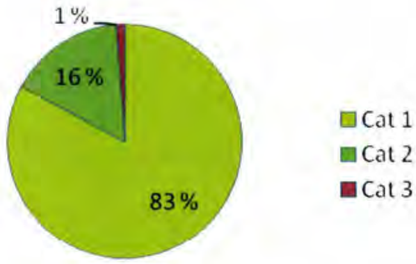


Figure 140.

Distribution of categories referred to total length (ca. 96 km) of all tunnels in this section.

12.5 Route D2 – step 2: Gardermoen – Gjøvik - Lillehammer.

On this route 18 tunnels with a total length of 64.3 km are planned. The tunnels from Hurdalssjøen to Østre Toten are running through granite and gneiss.

The tunnels south of Gjøvik are placed in sedimentary rock as sandstone, schists and limestone. The tunnel passing Gjøvik is situated in granite and gneiss, while the tunnels towards Lillehammer in quartzite, limestone and sandstone. The tunnels around Gjøvik are running through sediments that may contain alumschist.

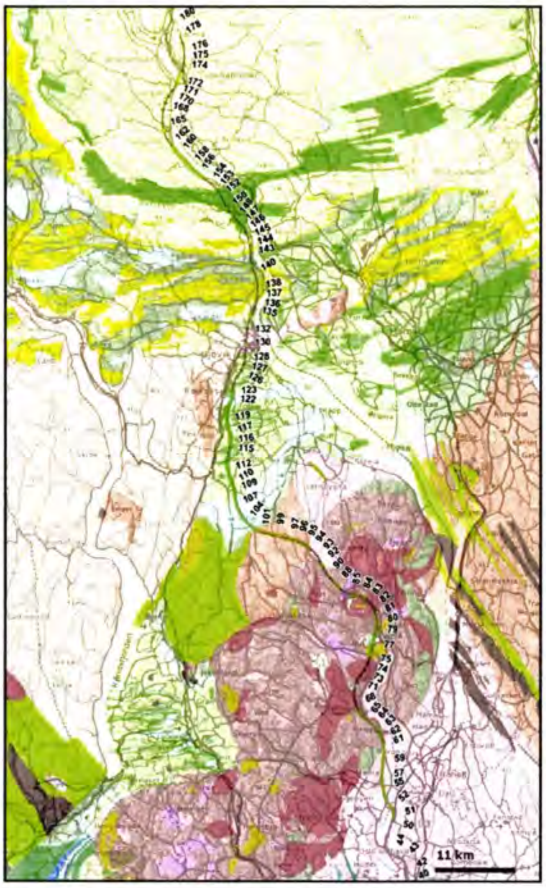


Figure 141.

Route between Gardermoen and Lillehammer. The tunnels are marked in grey color along the line. Source: Geovekst.

12.6 Route D2 – step 2: Gardermoen – Venjar - Vallset.

Between Venjar and Vallset 8 tunnels with a total length of 21.8 km are planned. They run through metamorphic rocks, like gneiss, micaschist, metasediments, amphibolites and granitic and pegmatitic bodies of the Romerikscomplex, gabbro with ultrabasic bodies of the Osloarea and different gneisses of the Solørcomplex.

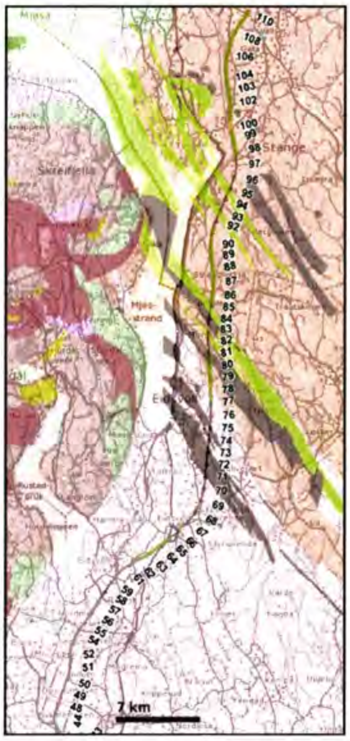


Figure 142.

Route between Gardermoen and Tangen. The tunnels are marked in grey color along the line. Source: Geovekst.

12.7 Statistics summary – tunnels

We have shown statistics from Tangen where the lines splitt in different routes to Soknedal where all lines join. In this way the differences of geological characteristics between the routes are shown. Furthermore we have shown the tunnel characteristics all the way to Trondheim as well as further on to Værnes. As for the section Gardermoen – Tangen we refer to the Intercity project where more detailed data are available.

12.7.1 Quantity of tunnels

		Gudbrandsdal	Rondane	Østerdal D	Østerdal 2*
Tangen-Soknedal	length of all tunnels	206.9	160.2	95.7	84.5
	number of tunnels	54	42	30	27
	number of tunnels > 8km	8	6	0	1
Tangen-Trondheim	length of all tunnels	246.8	200.1	135.6	124.4
	number of tunnels	57	45	33	30
	number of tunnels > 8km	11	9	3	4
Tangen-Værnes	length of all tunnels	267.7	221.0	156.5	145.3
	number of tunnels	61	49	37	34
	number of tunnels > 8km	11	9	3	4

Figure 143. Overview: Quantity of tunnels.

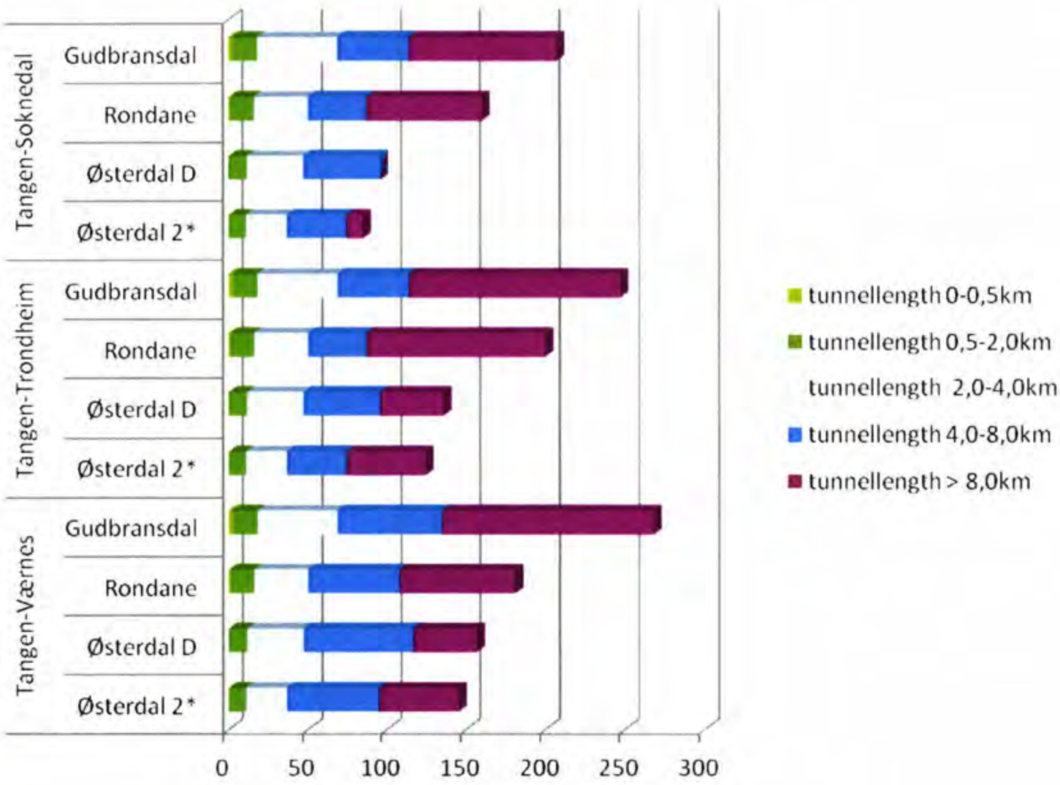


Figure 144. Length of the tunnels in the different sections.

12.7.2 Summary of tunnel quality

			Gudbransdal	Rondane	Østerdal D	Østerdal 2*
Tangen-Soknedal						
	rock quality	cat 1	139.8	118.1	79.4	65.1
		cat 2	63	46	15	18
		cat 3	4	3	1	2
Tangen-Trondheim						
	rock quality	cat 1	162.7	140.9	102.2	87.9
		cat 2	74	57	26	29
		cat 3	10	9	7	8
Tangen-Værnes						
	rock quality	cat 1	170.3	148.5	109.8	95.6
		cat 2	83	66	35	38
		cat 3	14	13	11	12

Figure 145. Overview: Summary of tunnel quality.

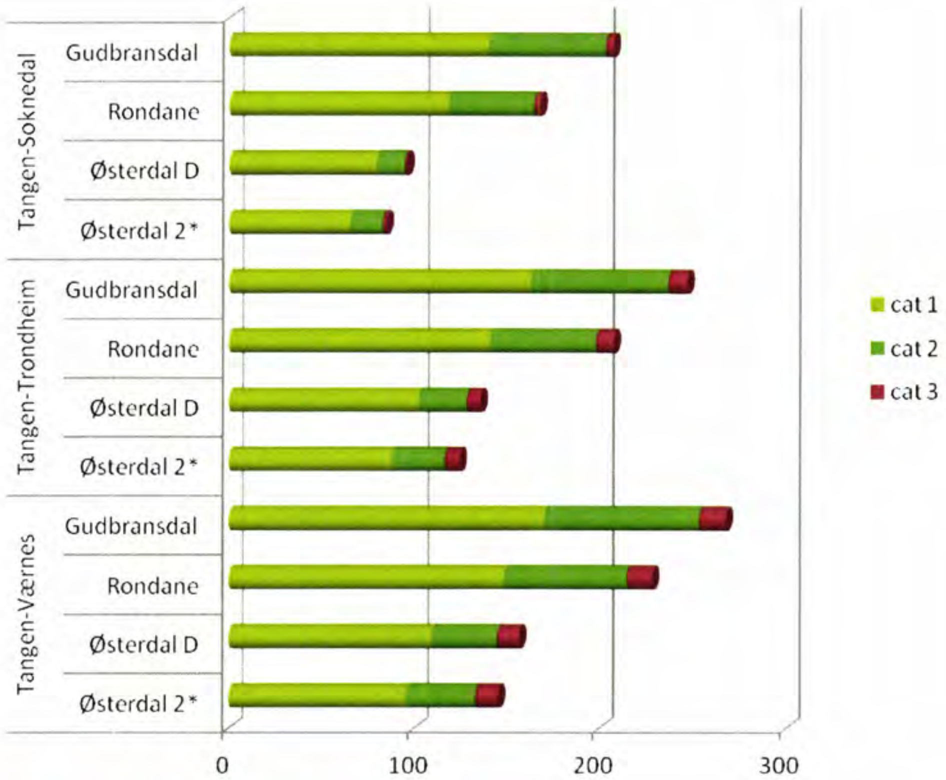


Figure 146. Tunnel categories in the different sections.

13. BRIDGES AND OTHER CONSTRUCTIONS

13.1 General

13.1.1 Bridge categories used in the cost calculations

Railway bridges

Related to the cost calculations, there are four categories of railway bridges:

- Category 1: Bridges with span less than 50 meters
- Category 2: Bridges with span between 50 and 100 meters
- Category 3: Bridges with span above 100 meters
- Category 4: Special bridges

Comment:
The unit cost (pr km) related to the various categories are relevant for ordinary double track bridges with limited challenge for the construction of the bridges.

For many bridges a more expensive category than indicated by the span widths is chosen, due to special construction challenges and cost increasing bridge elements, such as:

- Bridges close to tunnels (due to the distance between tunnels, two bridges or wider bridges must be constructed)
- Bridges with pillars founded in rivers or in areas with poor soil conditions.
- Bridges high above the ground

Crossings

In addition to the railway bridges of Category 1-4, crossings between the new railway and existing roads and railways are included by unit prices pr crossing. The unit price also includes the cost for the adjacent road work.

Categories of crossings:

1. Crossing between the railway and existing highway (4-lanes)
2. Crossing between the railway and 2-lane roads
3. Crossing between the railway and small roads
4. Crossing between the railway and existing railway

Comments:
There are very few crossings of category 1, only a limited number of categories 2 and 4, and a very large number of category 3 crossings. Some crossings of category 1, 2 and 4 are given some comments in the following route survey. Crossings of category 3 are not given any further comments.

In some sections the new railway alignment has approximately the same alignment as existing roads and railway, shown on the map as several crossings of the existing infrastructure. This situation requires an adjustment or reconstruction of existing infrastructure, and not a lot of crossings. In such cases a closer evaluated project cost for the reconstruction is estimated, and included in the estimated volumes as a certain number of railway crossings or as a specified lump sum cost.

Concrete tunnels

In each end of rock tunnels there will be a concrete tunnel (portal structure). At this stage of the project the length of portals are not evaluated, and the portals are included in the running meters of rock tunnels.

13.1.2 Evaluation - Fill or Bridges

At this stage of the project it is difficult to conclude on the optimal balance between bridges and fill. A careful evaluation has been carried out. Some places a part of the bridge may be replaced by fill. Other places the use of fill may be replaced by increased bridge lengths or new bridges. In general the use of fill is limited in the crossing of valleys, especially in developed areas, agricultural areas and areas close to rivers exposed to flooding.

In areas subjected to flooding, referred to a 200 year return period, special evaluations should be carried out. The Waterway Authorities will most likely not accept railway founded on fill in these areas, and bridge viaducts should thus be assumed in the cost evaluations.

On route sections where slab track railway is assumed, high fill is avoided due to risk of settlements, and the use of low bridge viaducts is a more likely solution. Due to the specified sections with slab track, some long bridges have been proposed. A slab track solution is shown in Figure 147.

Figure 147. Railway with slab track.

13.2 Gudbrandsdalen

13.2.1 Intercity line from Gardermoen to Tangen

The route alignment follows the proposal for the new intercity line from Gardermoen to Tangen. This section is already planned in detail by Jernbaneverket, and detailed evaluations are not carried out by Rambøll for this route section.

However, two major bridge structures are planned at Minnesund and Tangen, crossing parts of Mjøsa. The planned bridge lengths are respectively 805 meters and 1106 meters.

13.2.2 Alternative D1 from Tangen to Trondheim

Tangen-Lillehammer

The route includes approximately 0.5 km of small railway bridges, and in addition there are some minor road crossings.

There are no bridges on the route which are expected to be particularly challenging.

At profile 168.0 the railway runs along the waterfront of Mjøsa (app. 68 km from Tangen) and approximately 160 m runs on filling in the water. A viaduct replacing the filling may be required, and this point should be evaluated further in the next planning phase.

Lillehammer – Ringebu

The route includes approximately 0.8 km railway bridges in addition to some minor crossings between the rail and roads.

The most challenging bridges are the two crossings of the river Gudbrandsdalslågen, located at Einsby (profile 187.08) and at Bårdseng (profile 196.90), respectively 10 and 20 km north of Lillehammer. The line is situated app. 27 m and 19 m above the river and the bridges are expected to be app. 280 m and 216 m long (see Figure 148 and Figure 149).

At Frya (profile 235,50) 5 km north of Ringebu, a viaduct of 500 m may be required due to space problems concerning the railway running parallel and close to the river Gudbrandsdalslågen and highway E6. This point should be evaluated further in the next planning phase.

Figure 148. Einsby (profile 187.08), 10 km north of Lillehammer.

Figure 149. Bårdseng (profile 196.90) 20 km north of Lillehammer.

Ringebu-Soknedal

The route includes approximately 7.2 km railway bridges in addition to several crossings between the rail and roads.

The most challenging structures are:

- Four crossings of the river Gudbrandsdalslågen with expected bridge lengths from 271m to 766m, where the line is situated from 6m to 25m above ground level. These crossings are located at:
    - Hundorp (profile 239.86) 13 km north of Ringebu, bridge length 285 m (see Figure 150).
    - Tangan (profile 260.54) 34 km north of Ringebu, bridge length 766 m (see Figure 151).
    - Sjoa (profile 265.82) 39 km north of Ringebu, bridge length 271 m (see Figure 152).
    - Dovreskogen (profile 300.62) 74 km north of Ringebu, bridge length 555 m (see Figure 153).
- Crossing of the river Otta at Otta (profile 275.38) 48 km north of Ringebu, bridge length 555 m (see Figure 154). This bridge may includes a 4-track HSR-station, see also 8.6.3.
- At Innset (profile 411.83) 96 km north of Dombås, the line crosses a valley with a river in the bottom, see Figure 155. The expected bridge length is about 520 meters, and the line is situated 74m above the valley at its deepest. A proposal for a railway bridge at this site is shown in Figure 156 and Figure 157. Due to the required distance between the two parallel rock tunnels located very close to both abutments of the bridge, two single track bridges are the most likely option at this site. Composite box girder bridges, based on the same principle as shown in Figure 166, with an approximately height of the steel section of 2.7 m is assumed. The arch in the longest span is most likely to be made of steel since concrete formwork and casting probably will be too cost demanding and time demanding at this site.

At Engan in Drivdalen (profile 373.605) 58 km north of Dombås, the line goes parallel and close to the river Driva, highway E6 and existing railway. Here a viaduct of 700 m may be required, and this is a point to be further evaluated in the next planning phase.

Figure 150. Hundorp (profile 239.86), 13 km north of Ringebu.

Figure 151. Tangan (profile 260.54) 34 km north of Ringebu.

Figure 152. Sjoa (profile 265.83) 39 km north of Ringebu.

Figure 153. Dovreskogen (profile 300.62) 74 km north of Ringebu.

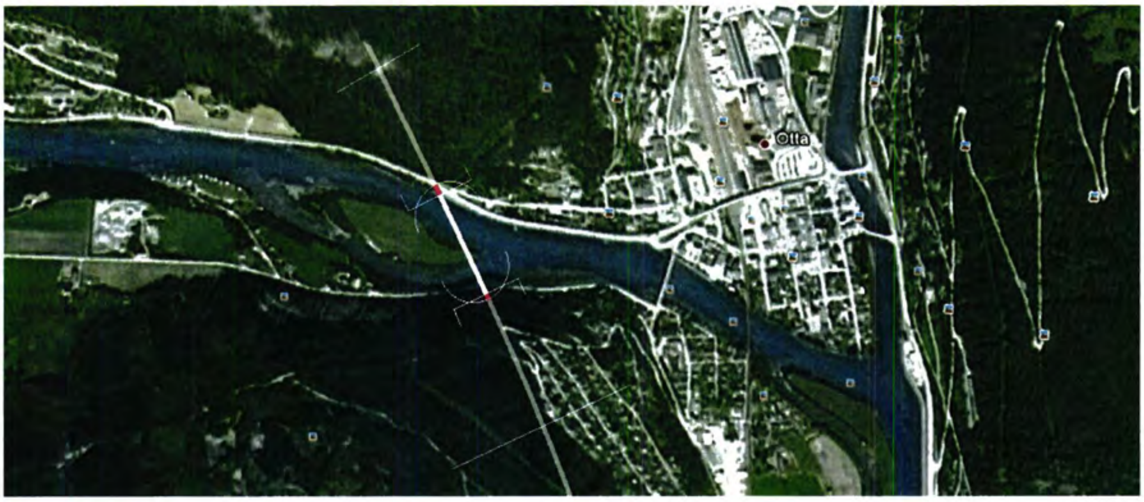


Figure 154. Otta (profile 275.38) 48 km north of Ringebu.

Figure 155. Innset (profile 411.83) 96 km north of Dombås.

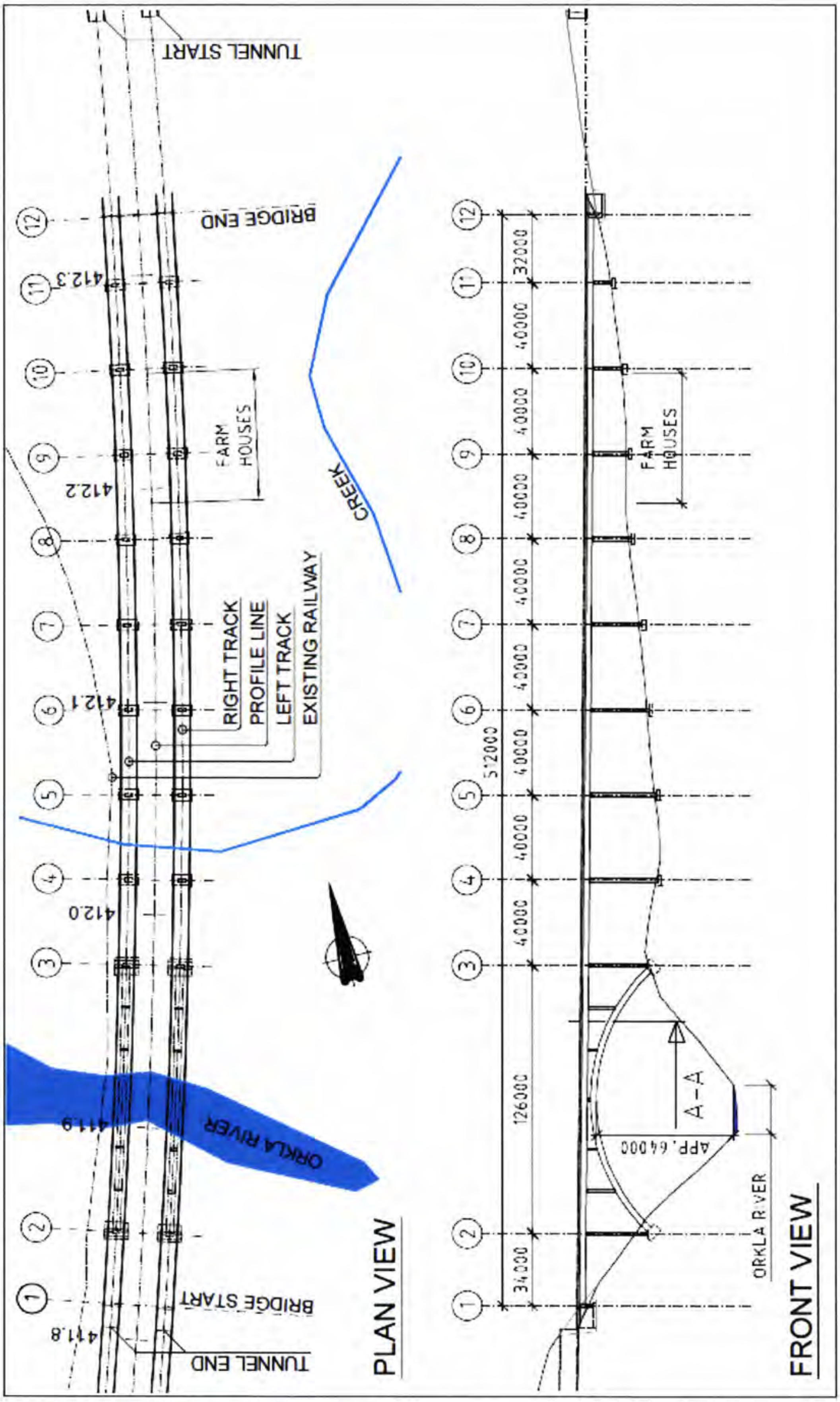


Figure 156. Bridge at Innset, plan and view.

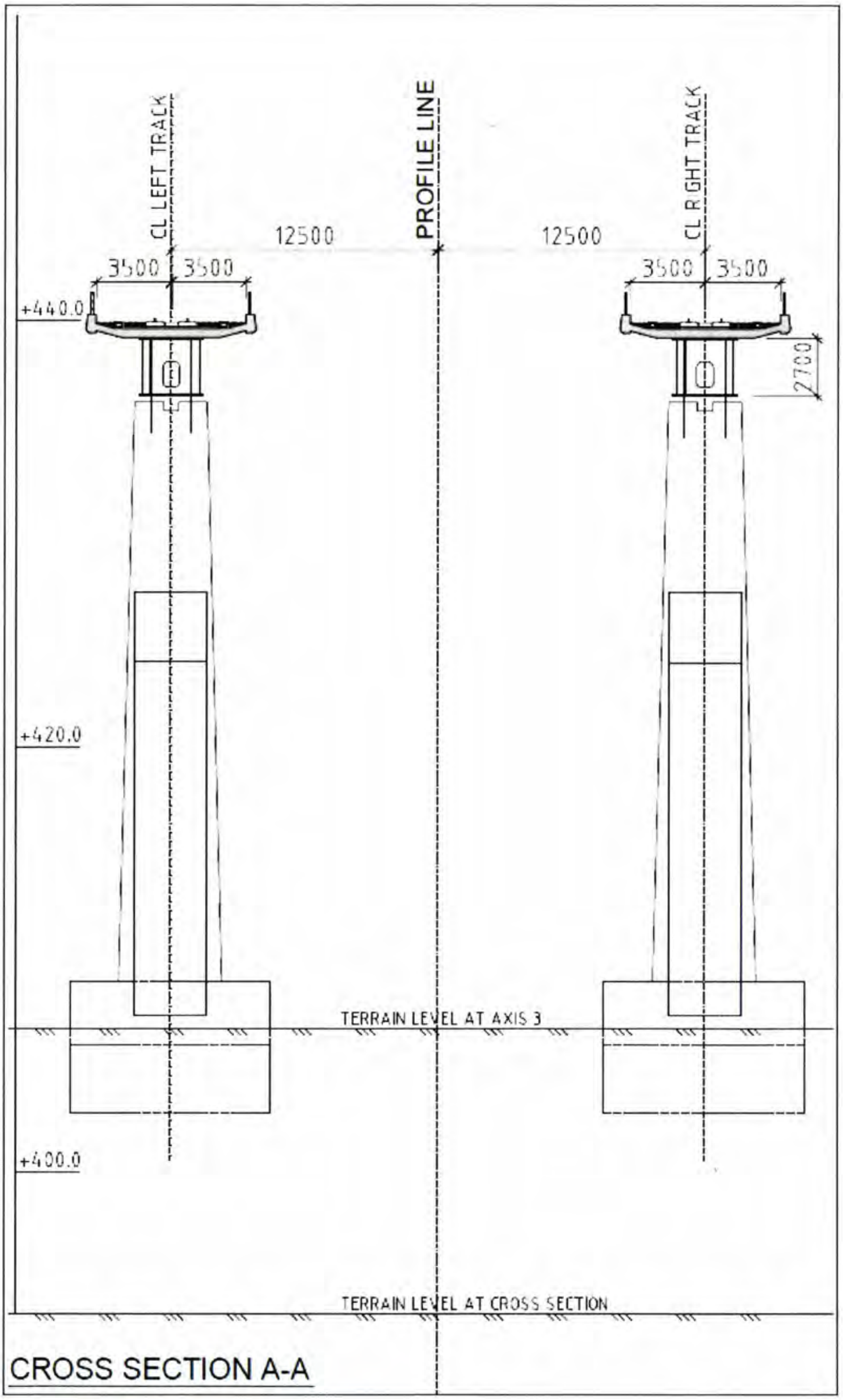


Figure 157. Bridge at Innset, cross section.

Soknedal-Trondheim
The route section includes approximately 8 km railway bridges, nearly all situated along the river Gaula in Gauldalen, close to Lundamo and Ler.

The river Gaula is crossed three times in an area of the valley exposed to flooding. Based on information on flooding maps made by the Waterway Authorities (NVE), it is assumed that the vertical alignment, as it is shown on the maps, has to be raised 1-5 meters due to the flooding situation. Further evaluations should be carried out, and NVE must be involved. Most likely, it will not be accepted to have the railway founded on fill in a great part of these areas, and bridge viaducts of about 7-8 km including the two northern bridge crossings of Gaula must be assumed at this stage of the project. Closer evaluations at a later stage may conclude on the more exact zones with bridge viaducts, fill, retaining walls and flooding barriers (see Figure 158).

At the crossing between the railway and the main road E6, the road fill is constructed as a flooding barrier. To let the railway cross over E6 is thus assumed to be the optimal solution at this stage of the project.

Figure 158. Two bridges crossing river Gaula close to Ler. The flooding situation will possibly require bridge viaducts adjacent to the bridges.

The route also includes a new 4-track railway bridge crossing Nidelva in Trondheim (see Figure 159). Estimated bridge length is 220 meters.

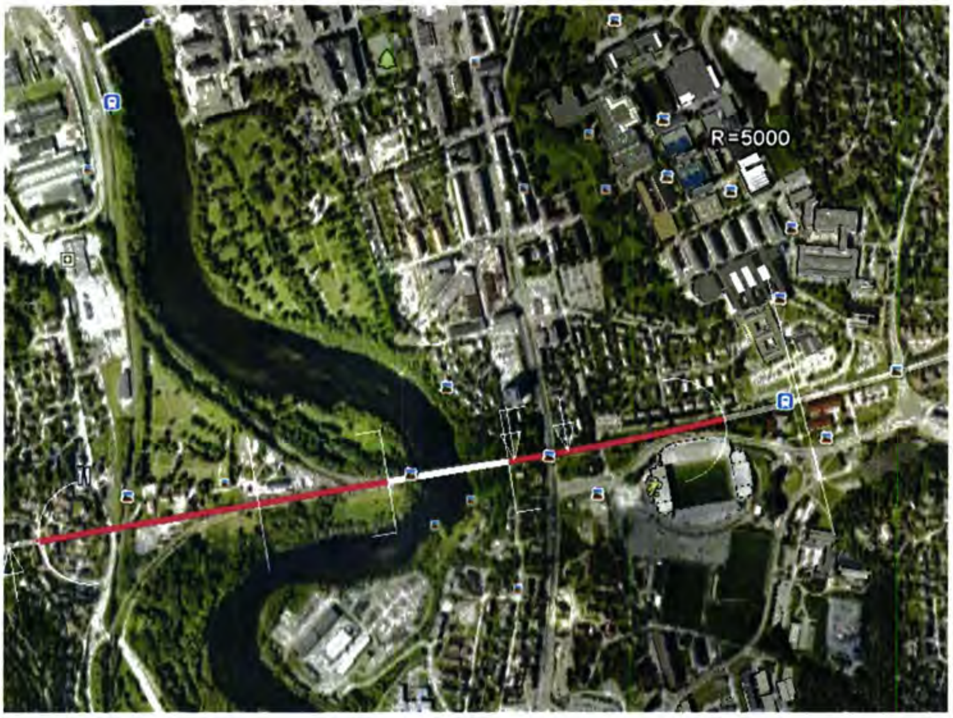


Figure 159. Railway bridge crossing Nidelva close to Lerkendal in Trondheim.

In addition to the railway bridges mentioned, the route section includes one crossing between the new railway and the highway E6, about 8 crossings with two-lane roads and one crossing of the existing railway "Dovrebanen".

13.2.3 Alternative 2* from Trondheim to Værnes

The route includes no major railway bridges, only a small number of bridge crossings in connection with minor roads.

13.3 Rondane

13.3.1 Reference to route sections already described

In the following, only the route sections from Ringebu to Kvikne will be described.

The other route sections for the complete route from Gardermoen to Værnes are described for the route in Gudbrandsdalen or Østerdalen, closer referred to:

- Gardermoen – Ringebu, see 13.2 Gudbrandsdalen
- Kvikne – Soknedal, see 13.4 Østerdalen (Tynset-Soknedal)
- Soknedal – Trondheim, see 13.2 Gudbrandsdalen
- Trondheim – Værnes, see 13.2 Gudbrandsdalen

13.3.2 Alternative D2 from Ringebu to Kvikne

The route includes approximately 5.5 km railway bridges in addition to several crossings between the rail and roads.

The most challenging crossings are:

- The bridge crossing the dam of Vinkelfossen Power Plant at Ringebu (profile 230.22). The line is situated 40m above the water level, crossing approximately 60 m of water. The bridge is expected to be about 400 m long (see Figure 160).
- The bridge at Haldogsenøyi in Folldal (profile 284.64), crossing a valley. The line is situated app. 53m above the bottom of the valley and with an expected length of 650m. The bridge crossing is shown in Figure 161.
- Two bridges at Venbygd and two bridges at Frydalen with expected lengths from 100 to 240 m. All bridges are crossing valleys with small rivers, and the vertical alignment is situated 30 – 45 meters above the bottom of the valleys.

Figure 160. Vinkelfossen upstream the river Våla from Ringebu.

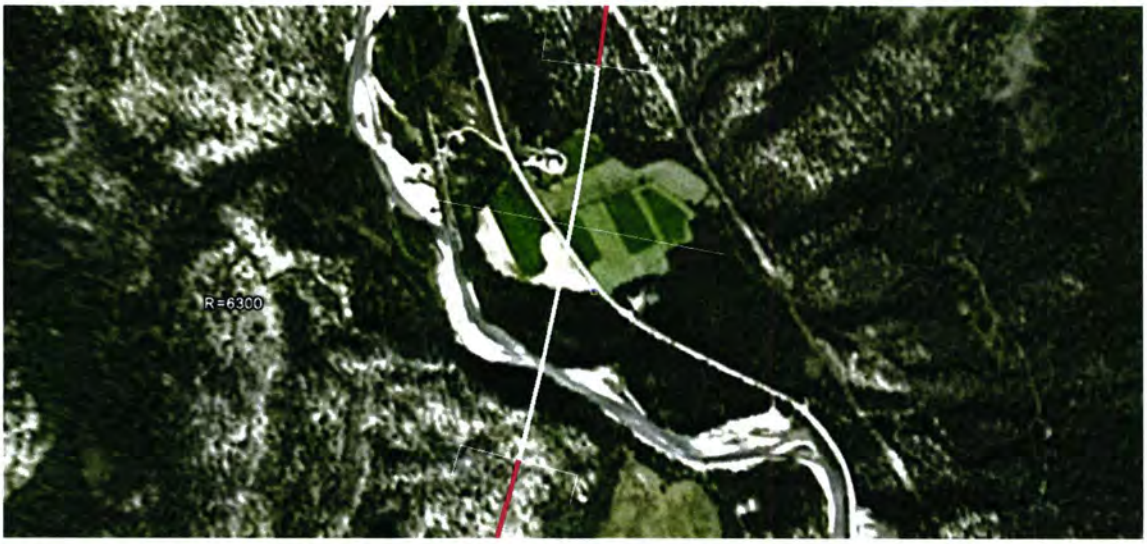


Figure 161. Haldogsenøyi in Folldal (profile 284.64).

13.4 Østerdalen

13.4.1 Introduction and reference to route sections already described

The route via Østerdalen from Gardermoen to Værnes may be subdivided into route sections. Some route sections are similar to route sections described for Gudbrandsdalen:

- Gardermoen-Tangen
- Soknedal-Trondheim
- Trondheim-Værnes

In the following, only route sections not described earlier will be described.

13.4.2 Alternative 2* from Tangen to Tynset

This is an alternative route to the one described in 13.4.3 above. Comments given in that section, related to removal of the existing Rørosbanen and the flooding situation along Glomma, are also valid for alternative 2*.

The route section includes about 4.1 km railway bridges in addition to several crossings between the rail and roads.

The most challenging constructions are:

- The four bridges crossing the river Glomma between Rena and Tynset, including long bridge viaducts in the area exposed to flooding at Tynset.
- A 450 m bridge in very inclined terrain 3 km north of Koppang
- A 500 m bridge situated 5 km north of Rena, partly in the river Glomma and partly along the waterfront of the river.

The route section includes one crossing between the new railway and the highway E6, and about 30 crossings with two-lane roads.

13.4.3 Alternative D1 from Tangen to Tynset

The route includes about 6.5 km railway bridges in addition to several crossings between the rail and roads.

The most challenging constructions are:

- The four bridges crossing the river Glomma between Hanestad (50km south of Tynset) and Tynset (see Figure 162 and Figure 163).
- The very high crossing of the valley at Imsroa (10km south of Koppang). The line is situated 60m above the bottom of the valley, and length of the bridge crossing is expected to be about 735 m. A proposal for a bridge crossing is shown in Figure 164 and Figure 165. Due to the required distance between the two parallel rock tunnels located very close to the eastern abutment, two single track bridges are the most likely solution at this spot. Composite box girder bridges, shown in Figure 166, will be a competitive bridge type both at this crossing and at several other major crossings.
- Three large bridges crossing valleys with tributary rivers to Glomma at Atna, Koppang and Åsta (close to Rena). Bridge lengths are 400- 600 m, and the vertical alignment up to 40 m above the valley.

Figure 162. Bridges crossing river Glomma between Hanestad and Alvdal.

Figure 163. Bridges crossing river Glomma close to Tynset. The flooding situation will possibly require bridge viaducts adjacent to the bridge.

The route section includes one crossing between the new railway and the highway E6, and about 15 crossings with two-lane roads. It is presupposed that the existing Rørosbanen from Hamar to Tynset is removed before the new railway is built, and structures related to conflicts between new and old railway is thus not considered.

Several places along the main river Glomma, flooding of areas in the valley close to the river has to be taken into account in the planning process.

In particular, the area close to Tynset is very exposed to flooding (see Figure 163). A tributary river is running into Glomma at this point, and the landscape is very flat. Based on information on flooding maps made by the Waterway Authorities (NVE), it is assumed that the vertical alignment, as it is shown on the maps, has to be raised 1-5 meters due to the flooding situation.

Further evaluations should be carried out for the Tynset area, and the Waterway Authorities (NVE) must be involved. Most likely, it will not be accepted to have the railway founded on fill in a great part of these areas, and viaducts of about 1,5 – 2,0 km adjacent to the bridge crossing Glomma must therefore be assumed. The need for the long viaducts should be further evaluated in the next planning phase.

The vertical alignment is acceptable for the other bridges crossing Glomma. However, the optimal bridge lengths must be evaluated when flooding maps are available (currently not available).

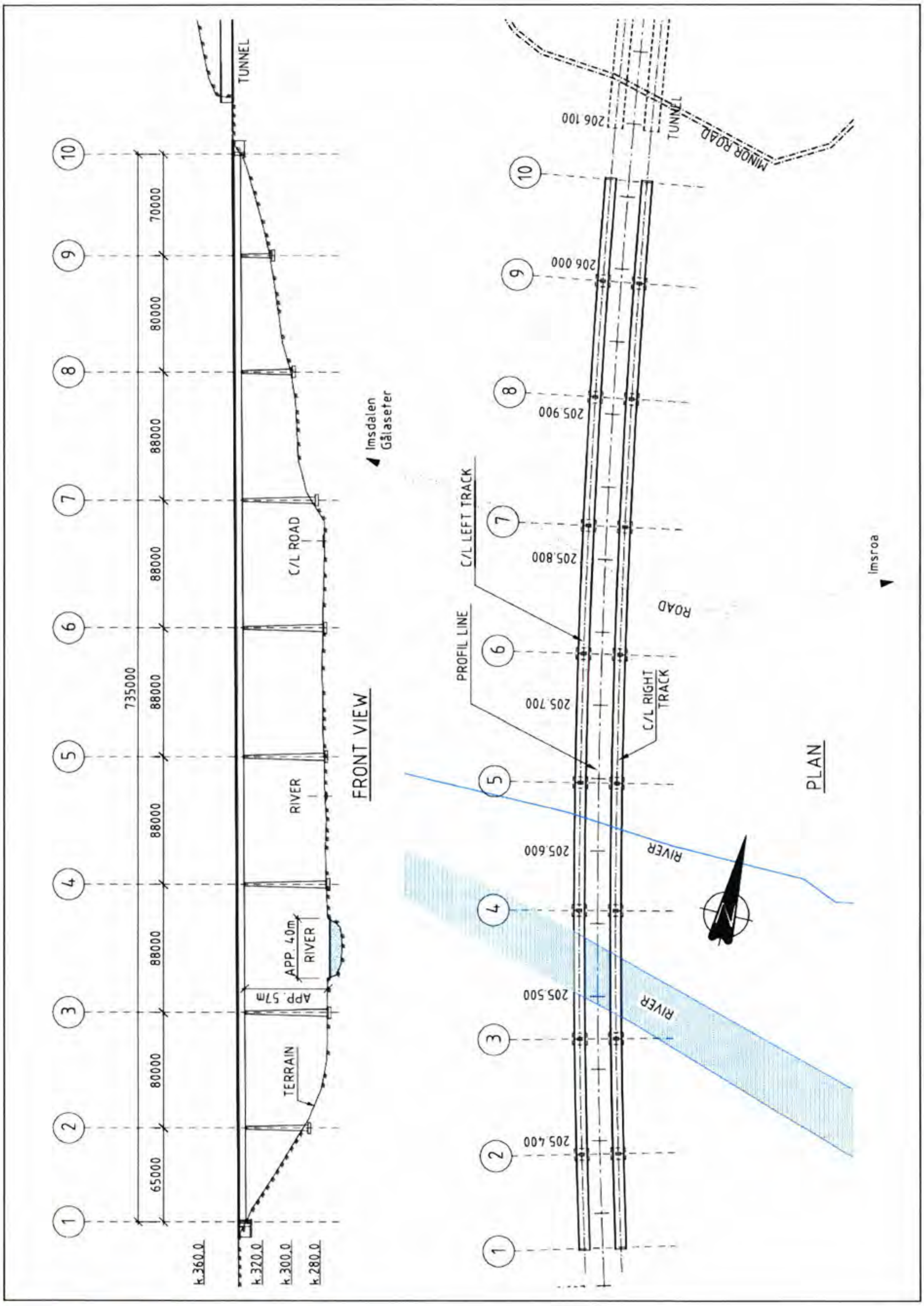


Figure 164. Bridge at Imsroa, plan and front view.

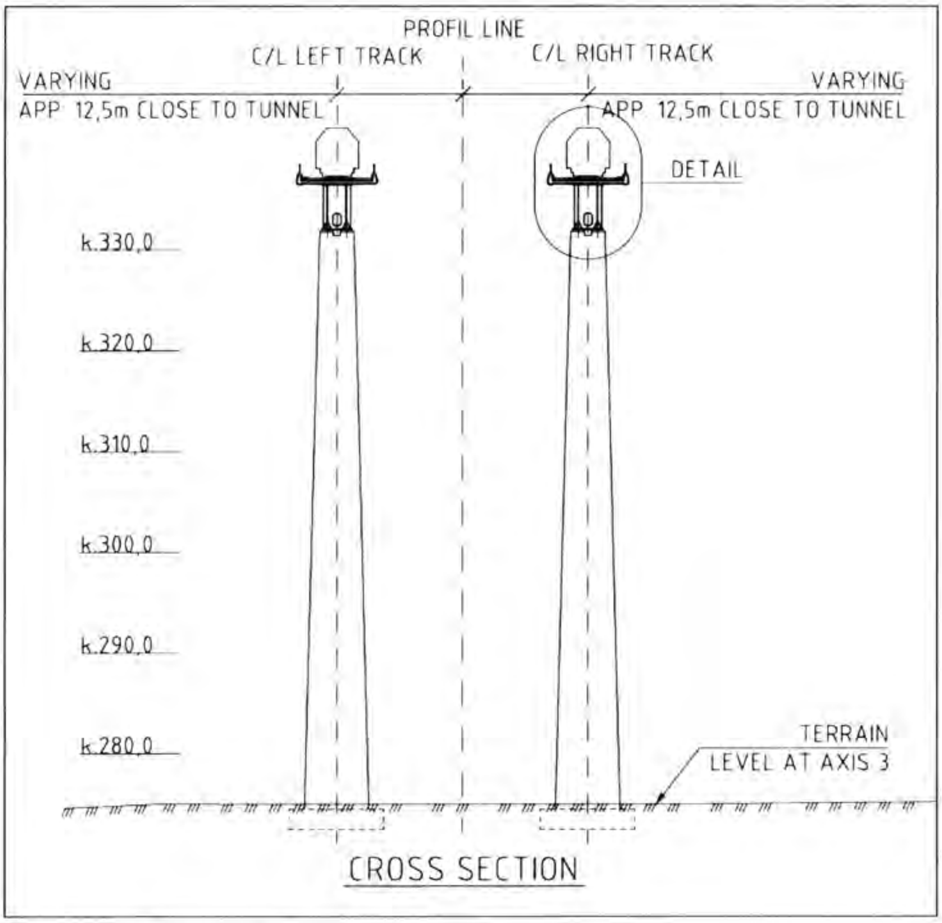


Figure 165. Bridge at Imsroa, cross section.

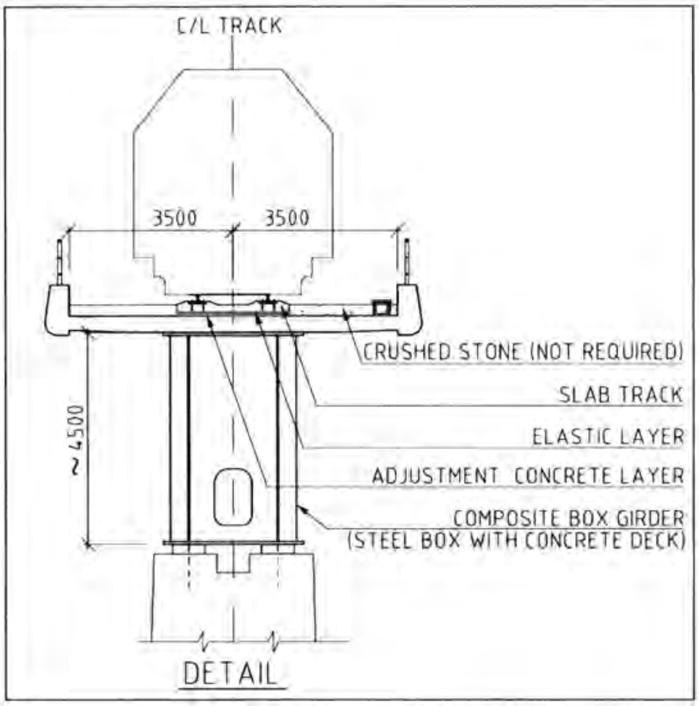


Figure 166. Bridge at Imsroa. Typical cross sections and details.

13.4.4 Alternative D2 from Tynset to Soknedal

The route includes about 2.9 km railway bridges in addition to a small number of crossings between the rail and roads.

The most challenging constructions are:

- The high crossing of the valley with river Sokna at Soknedal. The line is situated 50m above the bottom of the valley, and the bridge length is expected to be about 500m.
- The 40 meters high crossing of the valley with river Tunna about 6 km north of Tynset, bridge length ca 430 meters. Crossing of Rv 3 close to the southern bridge end requires some adjustment of the road and a new bridge.
- The two bridges at Kvikne, crossing small valleys with river, water and the main road Rv3. Total bridge lengths are about 430 m.

The route section includes no highway crossings, but two crossings with two-lane roads.

13.5 Step 2: sections when the IC-line is saturated

13.5.1 Gjøvikbanen - D2 for Gudbrandsdalen and Rondane

This section is planned to be built at a later stage when the intercity-section Gardermoen to Lillehammer has reached its capacity.

The route includes approximately 3.75 km of bridges, the route also crosses several roads which are not included in the number.

There are two bridges of particular interest:

At Gjøvik (profile 129.39) there is a bridge crossing a small valley and it is the planned location of the new Gjøvik Railway Station (see Figure 167). The bridge will be wide with four tracks and two platforms. The bridge is expected to be about 260 meters long, and the line is situated app. 8.5 m above ground level.

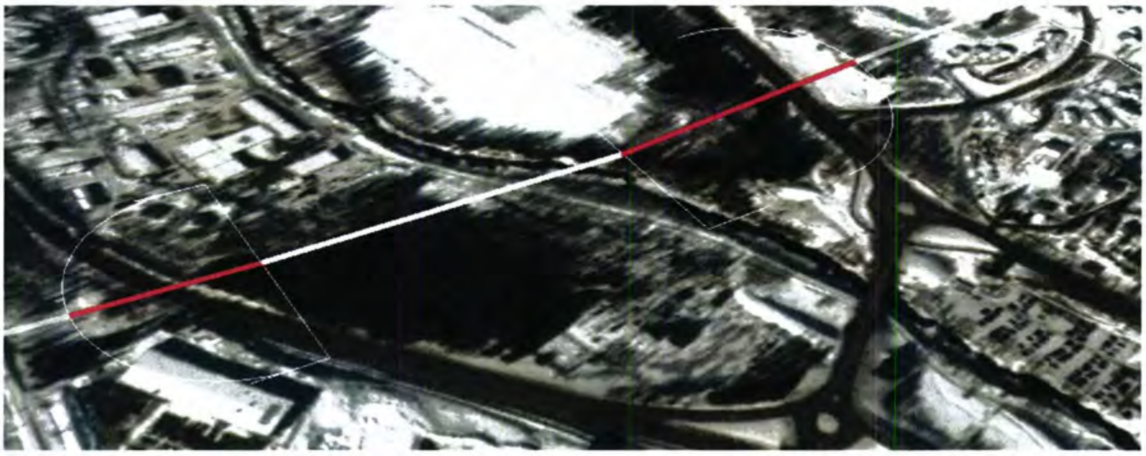


Figure 167. Gjøvik (profile 129.39).

At Lillehammer (profile 171.37) there is a major crossing over the inlet of Mjøsa, also crossing above the existing road E6 (see Figure 168). This bridge is expected to be about 1.0 km long and the line is situated app. 16 m above the water level. This bridge inclueds a new HSR station with four tracks and two platforms.

Figure 168. Lillehammer (profile 171.37).

13.5.2 New D2 section Gardermoen to Tangen for Østerdalen

This section is planned to be built at a later stage when the intercity-section Gardermoen to Tangen has reached its capacity.

The route section includes a total of about 9 railway bridges with a total length of ca 2,1 km. These are mainly crossings of minor valleys with small rivers. All bridges have limited height above the ground level, maximum 15 meters. The longest bridges are situated close to Eidsvoll, Minnesund and Tangen.

In addition to the railway bridges mentioned, the route section includes about 5 crossings with two lane roads and some minor crossings.

14. CONSTRUCTION WORK

14.1 General remarks on the construction process

Figure 169. Construction of the new feeder line to the Brenner base tunnel – "Unterinntalbahn". Big construction sites were needed which had an influence on large areas, shown to the right in the picture.

14.1.1 General

We have studied how we can construct the HSR-lines in each of the four main alternatives (Gudbrandsdalen D1/D2, Rondande D1/D2, Østerdalden 2* and Østerdalen D1/D2), all starting from Tangen and ending at Værnes. Also two sub-sections (Gjøvik and Gardermoen – Tangen) have been studied both starting from Gardermoen.

A potential process plan was produced for all the relevant alignments on the assumption that the whole project would be realised without interruption and in order that the realisation could be evaluated. The process plan identifies the works that might be critical as well as an evaluation of where an earlier start-up should be planned. For this approach, the plans were divided into main aspects.

Tunnelling will be one of the most time-consuming parts. It is assumed that work will proceed 24/7 during 50 weeks per year. Exceptions are made for urban areas. In these areas, progress is calculated based on 5 days at 20 hours, plus half of this amount for every Saturday, but over the same number of weeks per year. All the other sub-sections are calculated using the standard working hours; however all are based on 50 weeks per year.

Construction time for major tunnels was calculated assuming driving from both portal areas at the same time. For tunnels with a theoretical construction time of less than 6 years, the construction time was calculated assuming only one driving direction.

The progress plans were designed assuming that all tunnels and major bridges will be constructed simultaneously. It is also possible to reduce costs by extending the overall construction time in some lots. For detailed information please refer to Attachment 2.

The lots have been defined to comprise construction work of 3000 to 5000 million Norwegian kroner, and include earth movements, road works, bridges and tunnel constructions. Track work, electrification and signaling were not included, as these works are often performed by specialists.

All mass earth movements are calculated based on large trucks with loads of 30 tons or 10 m^3 of solid rock masses. This has to be taken into account in the planning or improving of the road systems used. Building an uninterrupted by-road along the whole line is suggested, except for the case of larger tunnels where a connection to main roads would be necessary.

A number of concrete plants are needed to provide enough concrete for the larger structures. Tunnel portal areas and tunnel-driving direction were evaluated and proposed for major tunnels. The following chapters give more information for each selected route.

14.1.2 Rig and construction areas

The main rig areas have been chosen on the basis of dividing the track into an adequate number of main contractors. The proposed main rig areas are usually situated near to appropriate road systems connected to either tunnel portal area, areas of major tunnels or large bridges. If this is not the case, then such roads have to be constructed. Where access is difficult, such solutions would be combined in order to serve two adjacent lots, so that the roads have to be shared by several main contractors.

The main construction offices for contractors and clients contain service tents, storage spaces, sleeping facilities, cantina and adequate road systems for access. The optimal size is 100 by 100 m for the average main office areas. If TBM technology is selected, it should be at least 40,000 m^2 due to the needs for storage of tubing segments (concrete liners). For larger tunnels, it is advisable to have another 2,500 to 3,000 m^2 rig space at the minor portal areas. This is also valid for minor tunnels and bridges which are not directly connected to the main rig area.

14.1.3 Construction areas with description

All construction sites for work on the critical path have to be planned rigorously. These cases are pointed out in this report.

Rig areas have to be adequate to their purposes. It is obvious that they have to be different in order to respond to their particular purposes. Solutions for mass transports will be proposed in a preliminary way in cases where the project is critical. Consequences for the surrounding area are to be pointed out where necessary.

14.1.4 Mass spillovers and deposit areas

Most of the hard rock along the possible corridors is usable for fill and as concrete aggregate. It is not generally usable for the bearing layer of the tracks or for ballast. We have calculated mass-balance on the basis of not using it for ballast. Spillovers have to be deposited or be taken away on neighboring existing tracks and / or by boat. Finding usable areas for depositing blasted rock will be one of the most challenging tasks. We propose reasonable locations for deposit areas at least every 40 km to keep transport distances short. There should be depositing space for top-soil storage, as well. Topsoil to be reused may not be stored in large stockpiles so as not to destroy its internal structure. We propose storing the topsoil parallel to the main access roads in relatively thin layers.

14.1.5 Mass transports and transport routes

Mass transport increases the general traffic volume. Many of the existing roads are widely used by individual and goods transport. Additionally, they are often neither strong nor wide enough to be used by the proposed trucks. We advise upgrading existing roads instead of repairing them after or during use. Some bridges and underbridges might also require improvements in terms of bearing capacity, adequate headroom or width. Access roads to the track-parallel construction road and to the rig-areas are needed. Persons directly affected by mass transport ought to be contacted and informed in an early phase.

In certain highly-frequented or complicated traffic situations, traffic lights or manually-controlled solutions might be necessary. A traffic plan will have to take this into account. We lwill imit ourselves to some general remarks on all topics connected with planning of structures.

14.1.6 Connection tunnels and reloading stations, emergency tunnels

Connection tunnels every 500 meters allow access to the other tube, in order to avoid the necessity for emergency tunnels, shelters and emergency shafts. The size of the connection tunnels should be chosen so as to be adequate for use by tunnelling trucks (usually 25 m^2 or larger).

Reloading stations might be interesting to consider in order to improve productivity in case of driving restrictions and a lack of resources. This is most relevant for urban areas.

14.2 Construction period

The main impact usually takes place at the rig areas and in the main cuts. Tunnels usually have highest impact within the tube's first 100 meters. An Environmental Monitoring Plan (Miljøopp-følgingsplan - MOP) will have to be established at a later stage, listing all measures to be considered for ecological variables during construction.

14.2.1 Noise

Construction roads, rock cuts, tunnel portal areas and rig areas are associated with high levels of noise during the entire construction period. Tunnelling produces noise from blasting, picking and drilling, and some of these noises can reach up to 100 m in each direction, penetrating into basement rooms or houses with foundations directly on the bedrock. Ventilation noise can also be disturbing. All these noise sources must follow standard national limits on noise level. The topic, Marginal Value is found in T-1442 of the Environmental Protection Department (*Miljøvern-departementets retningslinjer for støy i arealplanlegging*).

Construction measures to reduce noise levels consist of, for example, temporary or permanent noise protection walls or barriers, especially constructed machinery (compressors e.g.), rubber-coated drill pipes.

14.2.2 Transport of blasted rock

Transport of blasted rock has to be performed over construction roads or via designated transport routes. The increase in traffic due to mass transports has to be presented in the ADT (annual daily traffic) for each construction area at a later stage. Transport through cities might be restricted to certain periods. This could be solved by introduction of reloading stations.

14.2.3 Dust

Dust is inevitably associated with road traffic during dry periods if there are no measures implemented to avoid it. Examples of such measures are: chemicals sprayed on the road surface at short intervals or asphalt which is washed regularly. The financial advantages connected to temporary asphalted roads are usually underestimated in comparison to the expensive maintenance of highly used and stressed gravel roads.

Tyre wash facilities might be required particularly in cities, towns and on highly used roads, but also in order to avoid the danger of sliding accidents (slippery roads). Dust in the air might be restricted to the construction areas by using wood fences (barriers), air-spray installations and adequate modern machinery.

14.2.4 Vibrations

There are regulations in Norway limiting vibrations in some particular situations such as quick clay, and hard rock vibrations can be recognized up to several hundred meters away from the origin.

Vibrations and air blasts generated by blast operations can harm constructions in distances of much more than hundred meters depending on ground conditions and the quality of the constructions.

14.2.5 Environmental issues: ground, water, air

Cleaning and treatment plants ought to be established at each major construction area. At central collection points in environmentally preserved cut areas and at – usually the lower – tunnel approach, there has to be sedimentation basins and treatment plants to guarantee that clean water leaves into the environment by controlled pipelines via energy-reducing rock-fills. Both acidic and alkaline water must be controlled and treated.

Usual wastewater from rig areas and sleeping facilities is preferable led into public wastewater systems. When working in cities / towns or recreation areas the air-quality should not be influenced in a negative way.

14.2.6 Groundwater table and settlements

Groundwater table has to be controlled, private wells registered and a conservation of evidence implemented. Changes in the ground water table can be reduced by pre-injection measurements in the tunnels or watering-/ dewatering-facilities. Settlements can thus be avoided.

A registration programme ought to be introduced long before construction phase and updated until the end of the measurements in order to give a good basis for planning work and to avoid unnecessary discussions with aggrieved parties.

14.2.7 Natural scenery

Some of the areas are traditional tourist areas. Construction should if possible not influence the expected experience. In cities and towns a reduced visibility of the construction measurements improves the acceptance among people. A clean and professional appearance of the rig areas is a key-point in this topic.

14.2.8 Interference with existing track

Disturbances by regular train traffic at the construction plans are not considered in the progress-plans. Both from the costs, the time schedule and for the safety it is an inferior solution to work under the influence of regular train traffic. We assume for this paper, that a distance of 100 m from the tracks guarantees a low enough contact to reach an undisturbed working process. Otherwise there will be a situation of exposure (close routing) which for us means that the new track is designed clearly less than 100 meters from the existing track. This is of some importance, if the old track is meant to be kept; it is of high importance, if it is meant to be used during construction.

Using the neighbouring track for transport means that the tracks need to be protected against destruction, that construction personnel and equipment will have limited moving possibilities or that construction needs to be limited in times, in some situations it might be necessary to interrupt the construction process with more than only some hours. This will cause additional costs and health risks and maybe also increase the overall construction time.

The way we calculated the projects in this reports, it is without exception the tunnels which are on the critical path. Tunnelling, however, is not especially affected by exposure, such as the earth-works. In most lots the earth-works might be done with one team parallel with tunnelling (except for the tunnel preparation works). In exposed areas, however, the earth-works might get on the critical path depending on the hindering measurements connected to the exposure.

In accordance with the planning phase we have not divided between different possible hindering amounts but only between exposed areas and not-exposed areas. The results of this will be shown in the chapters of the tracks and their earth-work lots.

An alternative to increased costs and construction time, is to shut down the train-traffic in a period. Closing the existing track because of construction of the HSR will, however, affect the travellers, and is often not a wanted solution.

The Røros line, which is part of the Østerdalen solution might be easier to shut down in some construction periods than the Dovre line in Gudbrandsdalen, which is highly frequented and alternative transport possibilities are difficult to find. For lower frequented sections, buses might be used instead of the regular train traffic. Then it is even more important that the main connection roads are not blocked by construction traffic.

If closing the line is too difficult, a step by step development of the most affected sections might be considered. This is especially interesting in the Gudbrandsdalen and Østerdalen 2* alternatives. In Gudbrandsdalen between Ringebu and Soknedal, this is a particular challenge.

14.3 Route 1 Gudbrandsdalen

14.3.1 General

The Gudbrandsdalen route is divided into 21 lots (main contractors). The process plan shows that the lots vary between minimum 3 years and almost 9 years in construction time depending mainly on how large tunnelling projects they are connected to (see Figure 170 and attachment 2). The process plan clearly shows that major tunnelling projects are invariably on the critical path.

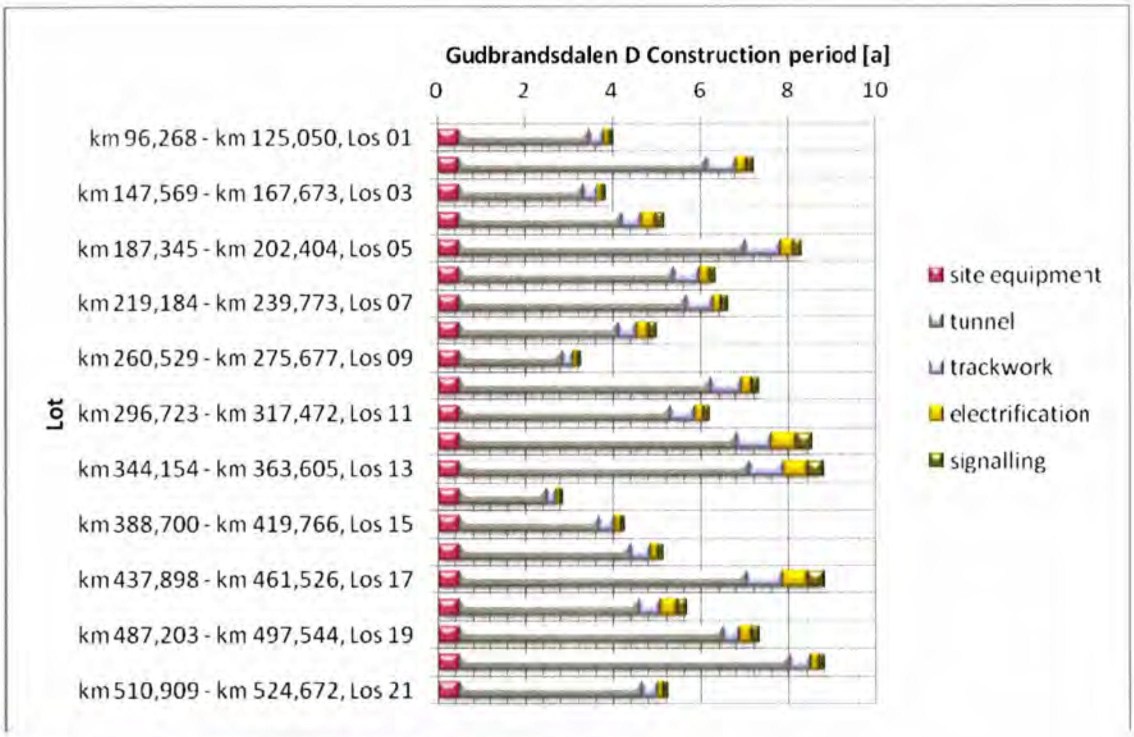


Figure 170. Progress plan Gudbrandsdalen complete line.

The mass balance for Gudbrandsdalen is – as for all the other corridors, too – strongly positive, meaning that we have to calculate with a mass surplus of more than 72 million cubic meters solid rock. This will be similar to a queue of trailer trucks loaded with rock about 100 000 km long, or 40 times Norway from north to south (along roads), or a cube of 416 m in all directions.
The most affected road is the E6 which is connecting some of the major population areas in Norway.

Interference with existing track

Most of the lots are affected by exposure to the existing track. On average, 48 % of the earth-works are close to existing railway lines; in the lots G02, G04, G09 and Ø13 almost 100 % of the construction is affected. The following table gives an overview of the expected situation.

lot	exposure sum in lot (km)	earthwork in lot (km)	exposure percentage in lot
G01	10.897	24.069	45.3 %
G02	4.000	5.464	73.2 %
G03	5.619	10.658	52.7 %
G04	4.893	4.907	99.7 %
G05	0.000	1.126	0.0 %
G06	0.000	3.192	0.0 %
G07	5.631	7.188	78.3 %
G08	0.000	5.048	0.0 %
G09	2.554	3.062	83.4 %
G10	0.013	2.336	0.6 %
G11	3.284	5.796	56.7 %
G12	4.500	8.047	55.9 %
G13	0.000	0.269	0.0 %
G14	7.693	17.278	44.5 %
G15	9.415	22.768	41.4 %
G16	1.863	6.647	28.0 %
Ø13	3.777	3.878	97.4 %
Ø14	5.051	12.873	39.2 %
Ø15	0.877	1.039	84.4 %
Ø16	0.162	1.936	18.1 %
Ø17	3.618	5.179	69.9 %
sum	**73.846**	**152.761**	**48.3 %**

Figure 171. Share of close routing to existing track in D Gudbrandsdalen.

14.3.2 Alternative D1 from Tangen to Lillehammer

This section of the line contains the lots G1 to G4. The process plans for these lots are shown in attachment 2. They vary between almost 4 years and a bit over 7 years in the forecasts. Lot G2 is rather time-consuming containing two major tunnelling projects.

The tunnel between km 125,050 and 133,182 is on the critical path. Its Southern tunnel portal will be situated at a major crossing of three roads (FV 116, Fv 84 and 222) at the North-eastern outskirts of Hamar. Here noise reduction equipment will be necessary. There should be enough space around to incorporate rig facilities. Due to the large amount of excavation masses there should also be found space for a major mass deposit area. It is calculated a demand of 2 million cubic meters solid rock here around. The Northern tunnel portal area lies in a fairly rural surrounding, about 500 m from Fv 67. There are some houses around, so that there is not a huge difference concerning the necessity of noise reduction other than the houses around will be evaluated to be discharged. The road which is necessary for construction will be several hundred meters long. Driving direction makes not a big difference due to an almost un-declined construction. We propose to establish the main rig area at Hamar and to drive the tunnel from South. There is no reason to do other than drill and blast here.

Lot G4 contains a tunnelling project which is even larger. The tunnel between km 176,161 and 186,413 is on the critical path even though it is planned to be excavated from both sides. Its Southern tunnel portal lies in the Southern outskirts of Lillehammer and rather difficult in a minor river valley, connected to a planned bridge construction which ought to be evaluated to be built as an access to the tunnel. Here noise reduction equipment will be necessary. Additionally there is hardly enough space around to incorporate rig facilities. Due to the large amount of excavation masses there should also be found space for a major mass deposit area which will be especially difficult in this area. It is calculated a demand of 2 million cubic meters solid rock here around. The Northern tunnel portal area lies at a steep cut along the Lågen valley right at E6 (Gudbrandsdalvegen) a few kilometres South of Hunderfossen in rural surrounding. Here we propose to establish a major rig area which might be used for the main tunnelling project in the neighbouring lot, too. The river Lågen lies in between, however. This is why we propose to establish the minor bridge construction to the North earlier. Drill and blast will be the most effective driving method.

The main rig areas for the lots might be chosen around km 110.7, 136.3, 157.6 and 177.5, alternatively at the tunnel rig areas attached.

This section is in need of five mass deposits each of which will demand 2 million cubic meters solid rock volume. We propose to establish them at about km 123.0, 140.5, 157.2, 172.8 and 186,4 or somewhere in the vicinity of these because they are connected to major tunnelling projects in mainly populated areas and unnecessarily large transport there ought to be avoided.

14.3.3 Alternative D1 from Lillehammer to Ringebu

This section of the line contains the lots G5 and G6. The process plans for these lots are shown in attachment 2. This section contains three major tunnelling projects which will take between 5 and 6.5 years.

The longest tunnel lies within lot G6 and goes from km 187.345 to 196.862. Lot G6 will have a production time of more than 8 years, which makes it one of the most time consuming lots of all. The start-up for the tunnel named above should be done fairly early. In the Southern portal area there is not too much population. It lies near the proposed main rig area of the major tunnel in the neighbouring Southern lot. However river Lågen lies in between. There are some reasonable access solutions. The one described above is not the only one, though the alternatives might demand a noteworthy road upgrading.

The access to the Northern portal lies near Fv 319 aside of the river Lågen in vicinity of a bridge. The surrounding is not especially difficult accessible, though the ways might be rather long. The tunnel is declining in Southern direction. We advise to drive the tunnel from South, due to the more comfortable access possibilities. Drill and blast will be the most effective driving method. The main rig areas for the lots might be chosen around km 194.9 and 210.8, alternatively at the tunnel rig areas attached.

This section is in need of two mass deposits with demands of 3 (The Southern) and 2 million cubic meters solid rock volume. We propose to establish them at about km 196.9 and 215.2 or somewhere in the vicinity of these to avoid unnecessarily long transport.

The connecting road in this section is E6. It will be rather frequented by the Northern lot because of large masses of blasted rock destined to the Northern deposit area. Alternatively, there is a huge road system to be constructed over the hills or many more minor deposit areas have to be established.

14.3.4 Alternative D1 from Ringebu to Soknedal

This section of the line contains the lots G7 to G16. The process plans for these lots are shown in attachment 2. They vary between almost 3 years and almost 9 years in our forecasts.

Lot G13 is most time-consuming, containing one very large tunnel with more than 18 kilometres length and is thus being on the critical path. The tunnel is situated between km 345.292 and 363.592. Its Southern tunnel portal will be situated near Rv 29 in vicinity to E6 and train station Hjerkinn. There are only very few houses around ("Hjerkinn fjellstue") and space to incorporate rig facilities is easily achievable. Due to the large amount of excavation masses there should also be found space for a major mass deposit area. It is calculated a demand of 3 million cubic meters solid rock here around. The Northern tunnel portal area lies in very rural surrounding, right aside of E6 with only a few houses in longer distance. It might be challenging to achieve the supplies necessary for a major rig. Due to its length we have planned to attack the tunnel from both sides simultaneously.

To reduce construction time it might be chosen an intermediate attack near Kongsvoll train station. This will, however, mean to dig an access shaft from E6 with roughly 1000 meters horizontal and more than 100 m vertical distance.

From the rock conditions and its blast ability there is no reason to do other than drill and blast here. Specialists in central Europe tend to propose TBM drift at projects of similar lengths.

Lot G12 contains a tunnelling project which has equal size as the previously mentioned. The tunnel between km 317.472 and 336.107 is also on the critical path even though it is planned to be excavated from both sides. Geologists have evaluated this tunnel to be slightly easier and faster to be excavated than the one described above. Its Southern tunnel portal lies in the Northeastern outskirts of Dombås, rather difficult in a minor river valley, 300 m from the road E6, connected to a planned bridge construction which ought to be evaluated to be built as an access to the tunnel. Here noise reduction equipment will be necessary.

Due to the large amount of excavation masses, a major mass deposit needs to be constructed. It is calculated a demand of 3 million cubic meters solid rock here around. The Northern tunnel portal area lays in an easily accessible landscape in the vicinity of some tourist facilities. The area is rather wet; adequate access roads and bridges have to be calculated. Due to its length we have planned to attack the tunnel from both sides simultaneously.

There is hardly any possibility to reduce construction time with an intermediate attack. There might be solution from near the E6 around km 331, but this shortens the time only a bit being far from the middle of the tunnel. This would imply digging an access shaft from E6 with more than 100 m vertical distance in a boggy area.

From the rock conditions and its blast ability there is no reason to do other than drill and blast here. Specialists in central Europe tend to propose TBM drift at projects of similar lengths.

The main rig areas in this section and the deposit areas proposed are given in Figure 172.

main contractor	from km to km		proposed main rig area	proposed rock deposit area	station (km)	deposits with capacity (in mio m^3 solid rock)
G7	219.206	239.773	229.5	GD8	226.419	3.0
				GD9	239.755	3.0
G8	239.773	260.529	250.2	GD10	247.229	2.0
				GD11	260.511	2.0
G9	260.529	275.691	268.1	GD12	269.220	2.0
				GD13	273.663	2.0
G10	275.691	296.723	286.2	GD14	283.960	2.0
				GD15	296.710	3.0
G11	296.723	317.484	307.1	GD16	306.237	2.0
				GD17	317.261	3.0
G12	317.484	344.166	330.8	GD18	336.111	3.0
G13	344.166	363.605	353.9	GD19	345.295	3.0
				GD20	363.592	2.0
G14	363.605	388.700	376.2	GD21	365.702	2.0
				GD22	379.966	3.0
G15	388.700	419.766	399.3	GD23	406.258	2.0
G16	419.766	437.898	429.9	GD23	421.316	3.0
				GD24	423.055	2.0
				GD25	428.570	2.0
				ØD9	436.681	2.7

Figure 172. Main rig and deposit areas alternative D1, section Ringebu – Soknedal.

Alternatively, the main rig areas might be chosen at the tunnel rig areas attached.

The connecting road in this section is E6. It will be frequented by all contractors. We propose to introduce construction roads in large areas parallel to the project line, connected to the E6 at main crossings with special traffic features in order to reduce the negative influence of the construction traffic to the public to the possible minimum. Alternatively, many more minor deposit areas have to be established and the truck concept is to be adapted.

14.3.5 Alternative D1 from Soknedal to Trondheim

This section of the line contains the lots G17 to G19 (adequate to Ø13 to Ø15). The process plans for these lots are shown in attachment 2. This section contains three major tunnelling projects which will take between 5.5 and almost 9 years.

The longest tunnel lies within lot G17 (Ø13) and goes from km 442,303 to 461,512. All tunnelling projects in this section have to be attacked from both sides simultaneously. Lot G17 will have a production time of almost 9 years, which makes it one of the three most time consuming lots of the whole project.

Its Southern portal area lies high up over E6 with a narrow access road more than 6 km air-line distance in between some houses. We propose to start this area with developing the track-line from South to give access here. This would also improve the possibility to install an adequate rig area, which is absolutely necessary here. The access to the Northern portal lies at Fv 672 ("Grinnivegen") about 3 km from train station Lundamo. Access might be possible from South, but it is a very minor road along the river which is providing it. Road-upgrading will be inevitable. Place for rigging will be plenty. Drill and blast will be the most effective driving method, although the tunnel has a length which might guarantee a good economy with TBM too.

Our geologists have estimated the tunnel in lot G19 (Ø15) to be especially difficult to build. This is why this relatively short tunnel might be rather time-consuming. It is estimated with 6 years construction time, partly because it lies in urban areas. The Southern portal area lies in the middle of Heimdal, the Northern attack will be at Breidablikkveien not too far from Trondheim's train-station Marienborg/St. Olavs. These portal areas need special attention, something which has to be provided later on.

The main rig areas for the lots might be chosen around km 442.3 (at the Southern rig area of the above described tunnel), at 473.0 (Kvål) and at around 486.5 (Heimdal), Alternatively, at the tunnel rig areas attached.

This section is in need of three mass deposits with demands of two times 1.4 million (the Southern ones) and 2 million cubic meters solid rock volume. We propose to establish them at about km 442.3, 460.3 and 496.5 near the attached tunnel rig areas or somewhere in the vicinity of these to avoid unnecessarily long transport. Especially the mass deposit at km 496.5 area will be very difficult to find. Due to the nearness of the sea, it might be very interesting to check alternative transport and usage possibilities.

The connecting road in the Southern part of this section is E6. This whole section is characterized by high population rates, which make planning quite challenging. This detailed task ought to be done at a later stage.

14.4 Route 2 Rondane

The Rondane route is connected to Gudbrandsdalen at Ringebu and again at Soknedal. It is divided into 7 lots (main contractors). The process plan shows that the lots vary between 3,5 years and almost 14 years in construction time depending mainly on how large tunnelling projects they are connected to (see Figure 173 and attachment 2).

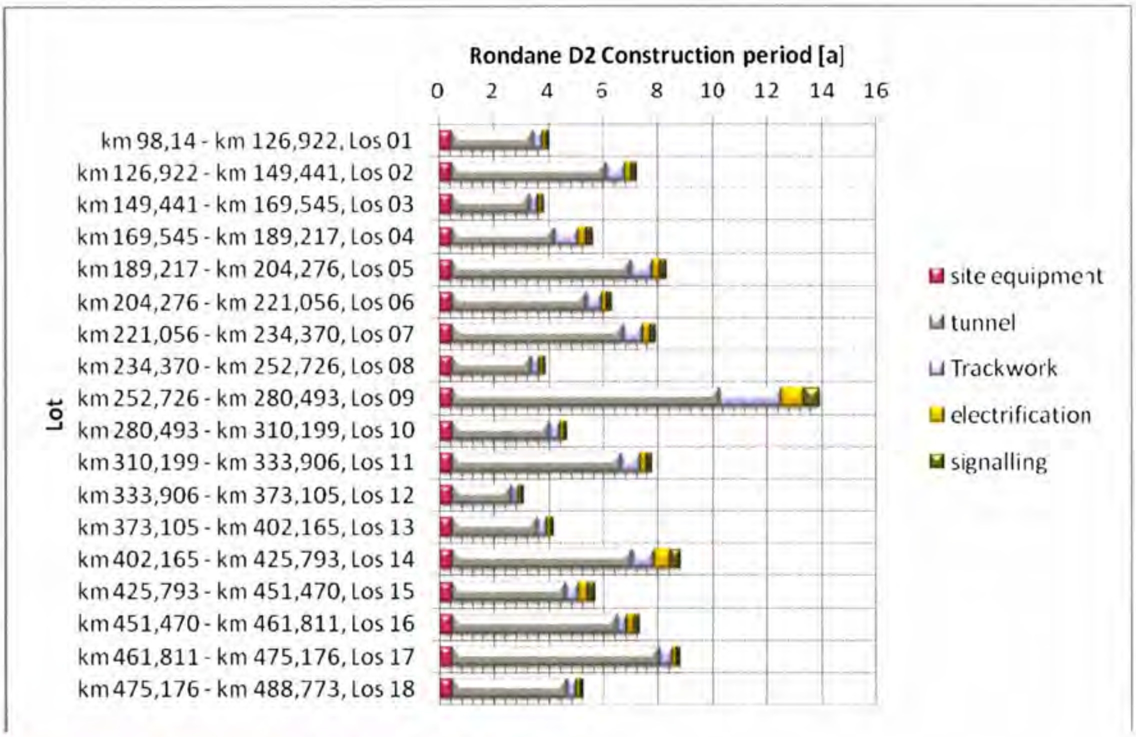


Figure 173. Progress plan Rondane complete line.

The process plan shows that the major tunnelling projects are invariably on the critical path. The mass balance for Rondane is – as all the other corridors, too – radically positive, meaning that we have to calculate with a mass surplus of more than 18,5 million cubic meters solid rock on this part. The total surplus from Tangen to Værnes is 44 mio m^3.

Most affected roads in this quite thinly populated area are Rv 27 and Rv 29 to km 314,0 and Rv 3 from km 340,0. In between there is no noteworthy road, so that there has to be calculated with several 10 kilometres of access-road/construction-road to be established.

Interference with existing track

One of the advantages of the Rondane corridor is that the lots between Ringebu and Soknedal are not affected by exposure to existing track. This reduces the overall-affection to 24 % of the whole distance. The following table gives an overview of the expected situation.

lot	exposure sum in lot (km)	earthwork in lot (km)	exposure percentage in lot
G01	10.897	24.069	45.3 %
G02	4.000	5.464	73.2 %
G03	5.619	10.658	52.7 %
G04	4.893	4.907	99.7 %
G05	0.000	1.126	0.0 %
G06	0.000	3.192	0.0 %
R07	0.000	3.379	0.0 %
R08	0.000	10.215	0.0 %
R09	0.000	0.000	0.0 %
R10	0.000	20.241	0.0 %
R11	0.000	9.305	0.0 %
Ø11 (R)	0.000	30.797	0.0 %
Ø12	0.000	14.622	0.0 %
Ø13	3.777	3.878	97.4 %
Ø14	5.051	12.873	39.2 %
Ø15	0.877	1.039	84.4 %
Ø16	0.162	1.936	18.1 %
Ø17	3.618	5.179	69.9 %
sum	**38.893**	**162.882**	**23.9 %**

Figure 174. Share of close routing to existing track in D Rondane.

14.4.1 Alternative D2 from Ringebu to Kvikne

This section of the line contains the lots R7 to R11. The process plans for these lots are shown in attachment 2. They vary between a bit more than 3 years and almost 14 years in our forecasts.

Lot R9 is most time consuming, containing an almost 28 km long tunnel which is being on the critical path even though it will be driven from two sides. The tunnel is situated between km 252,726 and 280,476. Its Southern tunnel portal will be situated deep in the Norwegian wilderness near Fryfallet, accessible via Fv 386 and Østkjølvegen from Fv 27 at Venabygd and a very minor gravel path up to Fryfallet. The way up from Fv 27, which is more than 16 kilometres, has to be upgraded for usage. There is no lack of space to incorporate rig facilities, fresh water is also there. However, all the other resources which are necessary for tunnelling are missing. Power supply and concrete delivery are factors to think of at this project. Due to the large amount of excavation masses a major rock deposit with space for around 2,5 mio m^3 solid rock has to be developed around this site. The Northern attack for the neighbouring tunnel to the South is only a few meters away.

The Northern tunnel portal area of the large tunnel lies not too far from Fv 3 at the Northern end of Rånåtjønne (Rondeveien, Sollia). There has to be calculated with several hundred meters roadwork and the construction of an access bridge to get into the rig area. It might be challenging to have the necessary supplies for a major rig-area. Due to its length we have planned to attack the tunnel from both sides simultaneously.

To reduce construction time it might be useful to have an intermediate attack. However, we do not see any reasonable possibility to place such an attack in the middle of the mountain ranges near Hornflågån.

From the rock conditions and its blastability there is no reason to do other than drill and blast here. However, from time and financial aspects it might be a very interesting project for TBM operations. It might be very advisable to make a special planning project concerning this possibility.

The main rig areas in this section and the deposit areas proposed are given in Figure 175.

main contractor	from km to km		propose d main rig area	proposed rock deposit area	station (km)	deposits with capacity (in mio m³ solid rock)
				RD1	221.303	2.5
R7	219.206	234.386	230.3	RD2	230.077	3.0
				RD3	248.122	2.0
R8	234.386	252.742	238.5	RD4	252.726	2.5
R9	252.742	280.492	280.5	RD5	280.473	2.5
R10	280.492	310.199	299.4	RD6	308.612	2.0
R11	310.199	333.906	320.0	RD7	333.870	2.0

Figure 175. Main rig and deposit areas alternative D2, section Ringebu – Kvikne.

The connecting roads in this section are the relatively small Rv 27 and Rv 29. An upgrading has to be evaluated together with a traffic concept based on the ADT (annual daily traffic). We propose to introduce construction roads in large areas parallel to the project line despite in areas with long tunnel projects. Alternatively, the truck concept is to be adapted.

14.4.2 Alternative D2 from Kvikne to Soknedal

This section of the line contains the lots Ø11 and Ø12. The process plans for these lots are shown in attachment 2. In the main process plan (see Figure 173 and attachment 2) they are shown as lot 12 and lot 13. This section contains a lot of average tunnelling projects and the lots will take 3,5 and a bit over 4 years, if the tunnel projects are done simultaneously.

The longest tunnel lies within lot Ø12 (lot 13) and reaches from km 375,353 to 379,829 (km 369,356 to 373,832 in the Østerdalen chainage). In the Southern portal area there is hardly any population. It lies – together with its fellow tunnel to the South – about 700 m west of Rv 3 high above it. There is a minor bridge construction connecting these two tunnelling projects. It is advisable to build the bridge first, connected to the establishment of the access road. To access the Northern portal upgrading of ca. 4 km sand- and gravel road is inevitable.

The tunnel is declining to the South. We advise to drive the tunnel from the Southern portal, due to the more comfortable access and rigging possibilities. Drill and blast will be the most effective driving method.

The main rig areas for the lots might be chosen around km 350,0 and 388,3 in vicinity of Berkåk train station, Alternatively, at the tunnel rig areas are attached.

This section is in need of three mass deposits with demands of 1,7, 1,4 and 2,7 million cubic meters solid rock volume (from South). We propose to establish them at about km 356,649, 373,275 and 402,161 or somewhere in the vicinity of these to avoid unnecessarily long transport.

The connecting road in this section is Rv 3. It will be rather frequented by the constructors due to relatively long distances between the rock deposit areas. This should be taken care of concerning public use of this road. Alternatively, we advise to establish construction roads parallel to the project, or to rework the truck concept, possibly also to establish many more minor deposit areas.

For the attaching parts of the route to Trondheim, please refer to the Gudbrandsdalen chapter 14.3.5.

14.5 Route 3 Østerdalen

Our description of the Østerdalen route starts at Tangen and it connects to Rondane (and further North to Gudbrandsdalen) at Kvikne. It is divided into 7 lots (main contractors) independently of which solution to be taken.

The most affected road in this populated area is Rv 3. We propose to establish construction roads parallel to the future track with adequate access roads from Rv 3 in order to guarantee the smoothest possible public traffic.

14.5.1 Alternative 2* from Tangen to Tynset

The process plan shows that the lots vary between 3,5 years and almost 9 years in construction time depending mainly on how large tunnelling projects they are connected to (see Figure 176 and attachment 2). The process plan shows that the major tunnelling projects are invariably on the critical path.

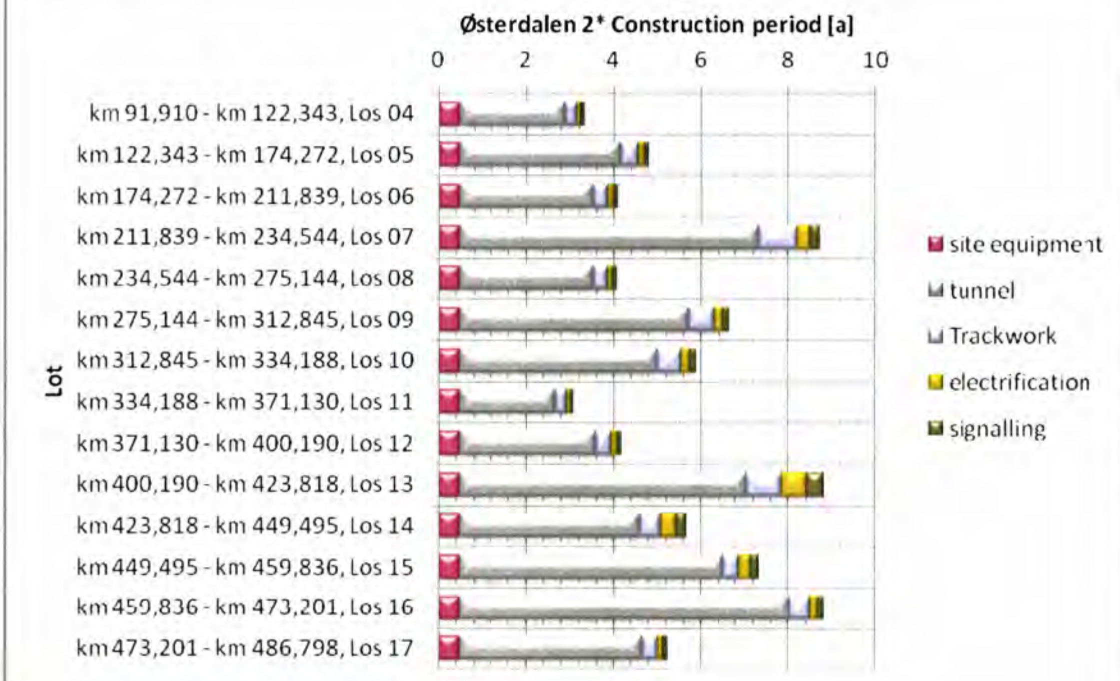


Figure 176. Progress plan Østerdalen 2* complete line.

The mass balance for Østerdalen alternative 2* is – as well as for all the other corridors – radically positive, that means we have to calculate with a mass surplus of more than 10,5 million cubic meters solid rock on this part The total surplus from Tangen to Værnes is 27 mio m^3.

The process plans for these lots are shown in attachment2. Lot ØS7 is most time-consuming, containing one large tunnel and is thus being on the critical path. The tunnel is situated between km 224,056 and 234,500. Its Southern tunnel portal is reachable via Fv 632 and Fv 633 ("Atnaveien") from Koppang train station via a ca. 1000 m long minor gravel road ("Tresdalsveien"). There is only one settlement in the vicinity and space to incorporate rig facilities is easily achievable.

The Northern tunnel portal area lies in rural surrounding, right aside of Fv 633 Atnaveien, which connects both portal areas in a comfortable manner. Some upgrading is though inevitable. Drill and blast will be the adequate way of progress. Due to our geologists there are no major difficulties to be expected. We advise to attack from the Northern portal area due to a slightly easier rigging evaluated. On the other hand, it might be a good solution to drive northbound to avoid major amounts of water to be pumped away from the progressing tunnel portal area as the tunnel is rising to North.

The main rig areas in this section and the deposit areas proposed are given in Figure 177.

main contractor	from km to km		proposed main rig area	proposed rock deposit area	station (km)	deposits with capacity (in mio m³ solid rock)
ØS4	91.910	122.343	107.6	O2D1	115.6	1.2
ØS5	122.343	174.272	146.5	O2D2	168.0	1.2
ØS6	174.272	211.839	192.5	O2D3	200.0	0.7
ØS7	211.839	234.544	221.1	O2D4	218.8	2
ØS8	234.544	275.144	253.8	O2D5	253.2	2
				O2D6	275.1	2
ØS9	275.144	312.845	292.7	O2D7	292.7	1.4

Figure 177. Main rig and deposit areas alternative 2*, section Tangen – Tynset.

Alternatively, the main rig areas might be chosen at the tunnel rig areas attached.

The connecting road in this section is Rv 3. It will be rather frequented by all contractors. We propose to introduce construction roads in large areas parallel to the project line, connected to the Rv 3 at main crossings with special traffic features in order to reduce the negative influence of the construction traffic to the public to the possible minimum. Alternatively, many more minor deposit areas have to be established and the truck concept is to be adapted.

Interference with existing track

Regarding exposure to the existing track, the D1 and 2* are quite different.
In the 2*-alternative, most of the lots are affected by close routing to existing track resulting in 56 % of the earth-works close to existing rail-way lines; in the lots Ø206, Ø207 and Ø209 almost 100 % of the construction is affected. The following table gives an overview of the expected situation.

lot	exposure sum in lot (km)	earthwork in lot (km)	exposure percentage in lot
Ø204	1.700	20.552	8.3 %
Ø205	33.792	46.449	72.8 %
Ø206	27.493	28.340	97.0 %
Ø207	7.918	7.918	100.0 %
Ø208	24.049	31.281	76.9 %
Ø209	26.293	29.193	90.1 %
Ø10	0.000	7.774	0.0 %
Ø11	0.000	28.638	0.0 %
Ø12	0.000	14.622	0.0 %
Ø13	3.777	3.878	97.4 %
Ø14	5.051	12.873	39.2 %
Ø15	0.877	1.039	84.4 %
Ø16	0.162	1.936	18.1 %
Ø17	3.618	5.179	69.9 %
sum	**134.729**	**239.670**	**56.2 %**

Figure 178. Share of close routing to existing track in 2* Østerdalen.

14.5.2 Alternative D1 from Tangen to Tynset

The process plan shows that the lots vary between a bit of 3 years and almost 9 years in construction time depending mainly on how large tunnelling projects they are connected to. The process plans for these lots are shown in Figure 179 and attachment 2. The process plan shows that the major tunnelling projects are invariably on the critical path.

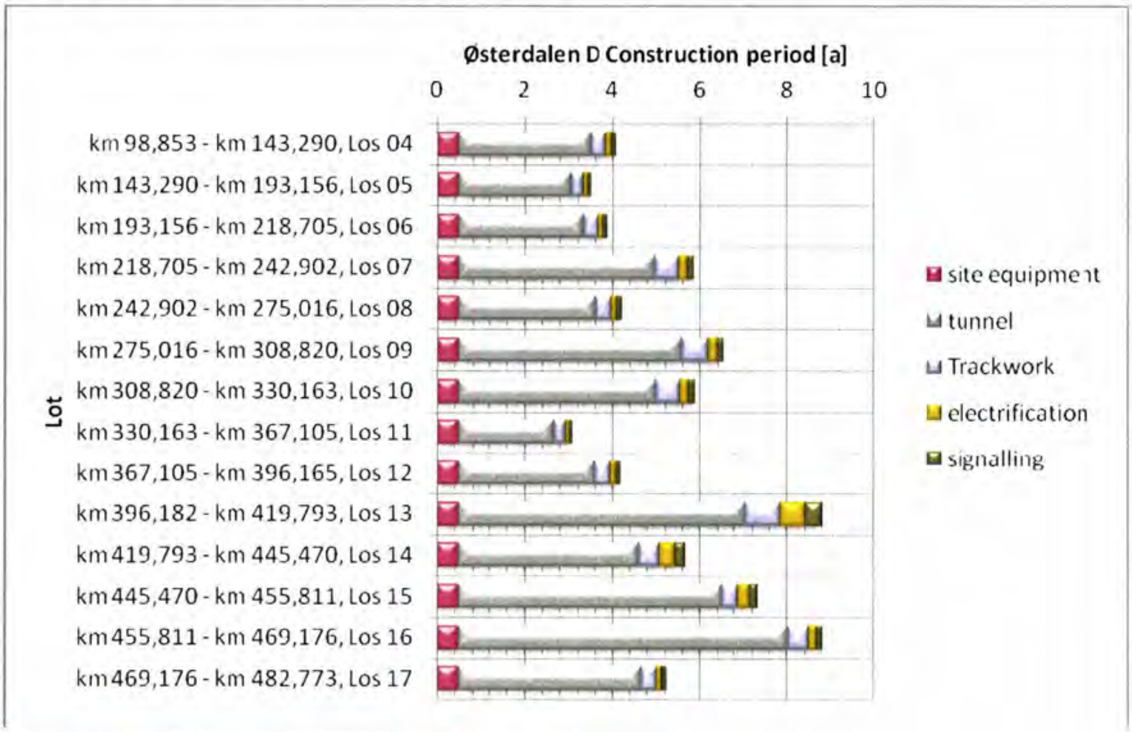


Figure 179. Progress plan Østerdalen D complete line.

The mass balance for Østerdalen alternative D1 is as well as for all the other corridors radically positive, meaning that we have to calculate with a mass surplus of more than 14 million cubic meters solid rock on this part. The total surplus from Tangen to Værnes is 30 mio m3.

Lot Ø9 is most time-consuming, containing one large tunnel and is thus being on the critical path. The tunnel is situated between km 281,728 and 289,051. It is passing Alvdal on the tunnels Western side. Its Southern tunnel portal lies between the river Glomma and Rv 3, a few kilometres South of Alvdal. So it is easily reachable and it seems to have enough space for rigging and the main deposit area necessarily connected to the large tunnel. There are only a few settlements in the vicinity and a minor road dedicated to one of this might be upgraded and used parallel to the main road. The Northern tunnel portal area lies in rural surrounding, accessible via Rv 3 and Fv 681 and a minor road of 600 m length. Some road upgrading seems unavoidable here.

Drill and blast will be the adequate way of progress. Due to our geologists there are no major difficulties to be expected. We advise to attack from the Southern portal area to drive the tunnel rising, avoiding major amounts of water to be pumped away from the progressing tunnel portal area. Rigging seems fairly well possible on both portal areas.

The main rig areas in this section and the deposit areas proposed are given in Figure 180.

main contractor	from km to km		proposed main rig area		proposed rock deposit area	station (km)	deposits with capacity (in mio m³ solid rock)
Ø4	98.853	143.290	123.8		ØD1	114.7	3.0
Ø5	143.290	193.156	166.5		ØD2	197.6	3.8
Ø6	193.156	218.705	209.9		ØD3	223.6	1.8
Ø7	218.705	242.902	236.5		ØD4	236.5	1.9
Ø8	242.902	275.016	253.0		ØD5	265.5	2.0
Ø9	275.016	308.820	288.9		ØD6	281.5	2.0

Figure 180. Main rig and deposit areas alternative D1, section Tangen – Tynset.

Alternatively, the main rig areas might be chosen at the tunnel rig areas attached.

The connecting road in this section is Rv 3. It will be rather frequented by all contractors. We propose to introduce construction roads in large areas parallel to the project line, connected to the Rv 3 at main crossings with special traffic features in order to reduce the negative influence of the construction traffic to the public to the possible minimum. Alternatively, many more minor deposit areas have to be established and the truck concept is to be adapted.

<u>Interference with existing track</u>
The D1-alternative gives possibilities to construct the HSR mostly independently from the existing rail. By using the D1-alternative the percentage of exposure is highly reduced for the whole track, compared to the 2*-alternative; only 17 % is close to existing track. Here it is only Ø09 which is seriously affected – together with the ones in the north (Ø13, Ø15 and Ø17).

14.5.3 Alternative D2 from Tynset to Kvikne

This section of the line contains the lot Ø10. The process plans for this lot is shown in attachment 2. At the main process plan in Figure 179 it is shown as lot 10.

It contains two fairly large tunnelling projects which are calculated to be constructed simultaneously, so that the longer one from km 316,351 to 323,026 (after Østerdalen 2*-chainage km 320,292 to 326,967) is on the critical path defining the construction term to almost 6 years.

The Southern portal area lies a few kilometres North of Tynset on the Western bank of the river Tunna. A bridge construction is planned right at the portal area to pass both Rv 3 and the river. We propose to construct the bridge before start of the tunnelling activities in order to avoid about 7 kilometres up-grading of the local roads. This would also be of advantage for the neighbouring tunnel-project to the South. There are no settlements in the vicinity and Rv 3 will guarantee smooth transport possibilities for rigging. The Northern portal is accessible via an about 4 km long road which needs to be upgraded on its whole length. There are no noteworthy settlements in the surrounding and rigging is possible, but rather challenging here. The tunnel is declining to the South. We advise to drive the tunnel from the Southern portal. Drill and blast will be the most effective driving method.

The main rig areas for the lot might be chosen around km 350.0 and 388.3 in vicinity to Berkåk train station, Alternatively, at the Southern portal are of the above described tunnel (km 316.3), Alternatively, more to the South to give a better connection to Tynset. As noted above, we advise to construct the bridge at the tunnel portal in advance.

This section needs a mass deposit with about 3.2 million cubic meters solid rock volume. We propose to establish it in connection to the above described tunnel attack area at about km 317.0.
The connecting road in this section is Rv 3. It is almost invariably close by. However, it will be rather frequented by the constructors. This should be taken care of concerning public use of this road. Alternatively, we advise to establish construction roads parallel to it, or to review the truck concept. It is also possible to establish some more minor deposit areas.

For the attaching parts of the route to Trondheim, please refer to the Rondane and Gudbrandsdalen chapters 14.4.2 and 14.3.5.

The last few kilometres earthwork will be comprised by the contractor of the lot Ø11, described in chapter 14.4.2 with only minor changes depending on whether the Rondane corridor or the Gudbrandsdalen corridor will be preferred.

lot	exposure sum in lot (km)	earthwork in lot (km)	exposure percentage in lot
Ø04	1.300	36.876	3.5 %
Ø05	0.000	42.452	0.0 %
Ø06	0.000	13.724	0.0 %
Ø07	0.000	8.964	0.0 %
Ø08	4.341	16.235	26.7 %
Ø09	18.561	24.900	74.5 %
Ø10	0.000	7.774	0.0 %
Ø11	0.000	28.638	0.0 %
Ø12	0.000	14.622	0.0 %
Ø13	3.777	3.878	97.4 %
Ø14	5.051	12.873	39.2 %
Ø15	0.877	1.039	84.4 %
Ø16	0.162	1.936	18.1 %
Ø17	3.618	5.179	69.9 %
sum	**37.687**	**219.090**	**17.2 %**

Figure 181. Share of close routing to existing track in D Østerdalen.

14.6 Step 2 – sections when the IC-line is saturated

14.6.1 New D2 section Gardermoen - Tangen for Østerdalen

We have made a concept for the situation when in future the Intercity-section from Gardermoen to Tangen will have no capacity left. This solution describes a second track from Venjar around Tangen to Vallset, connecting to the Østerdalen route.

The process plan shows that the lots take between almost 6 years and a little over 7,5 years in construction time – depending mainly on large tunnelling projects they are connected to (see Figure 182 and attachment 2). The section contains a lot of average tunnelling projects and the tunnel projects are designed to be done simultaneously. The process plan shows that the major tunnelling projects are invariably on the critical path.

Figure 182. Progress plan Gardermoen – Tangen D2 complete line.

The most affected road in this populated area is E6 together with several country roads (Fv 177, Fv 228, Fv 229 and Fv 231). They are usually developed roads of good quality, but highly frequented by local and long-distant traffic. We propose to establish construction roads parallel to the future track and evaluate solutions to guarantee the smoothest possible public traffic on these roads.

The mass balance for this line is clearly positive, meaning that we have to calculate with a mass surplus of about 3,7 million cubic meters solid rock.

The longest tunnel lies within lot GT1. It reaches from km 68,812 to 77,217. Its Southern portal area is positioned north of the town of Eidsvoll on the Western side of Fv 177. There are a few settlements around which have to be taken care of. A bridge construction project is connecting this tunnel to its neighbouring tunnel project to the South. The road connection seems to be good enough to build those tunnels without having the bridge in advance. There ought to be enough space for rigging around and it should not be too difficult to get the other facilities here, because this is a rural, but well developed part of the country.

The Northern portal area is located in forested area not far from Minnesund. We estimate the access possibilities to be rather difficult. This is why we propose to construct the tunnel northbound and to develop the Northern tunnel portal after the road-works are completed coming from North. Drill and blast will be the most effective driving method.

The main rig areas for the lots might be chosen at the above described tunnel rig area (km 68.8) and at km 97.8 in vicinity of Tangen. A more central position for the main rig area in lot 2 might be preferable, but the track is rather rural, so that we should not propose such a solution.

This section is in need of three mass deposits with demands of 1.5, 1.5 and 0.7 million cubic meters solid rock volume (from South). We propose to establish them at km 68.8 (connected to the portal area described above), at km 97.7 and at km 104.6 or somewhere in the vicinity to avoid unnecessarily long transport.

There are several minor and other highly frequented roads in this section. They will be rather frequented by the constructors too, due to relatively long distances between the rock deposit areas. This should be taken care of concerning public use of this road. We think it might be useful to develop construction roads along the line. They might later be used as maintenance roads. Alternatively, we advise to establish construction roads parallel to the project, or to review the truck concept. It is also possible to establish many more minor deposit areas.

14.6.2 Gjøvikbanen - D2 for Gudbrandsdalen and Rondane

The Gjøvik route connects to Gudbrandsdalen in Lillehammer. It is divided into 5 lots (main contractors). The process plan shows that the lots vary between almost 3 years and a little over 7 years in construction time depending mainly on how large tunnelling projects they are connected to (see Figure 183 and attachment 2).

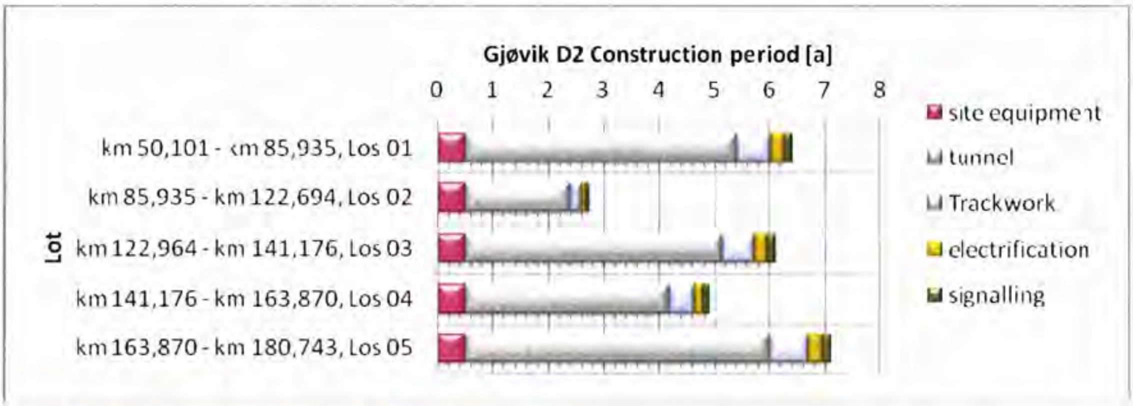


Figure 183. Progress plan Gjøvik D2 complete line.

The most affected roads in this populated area are Fv 120 in the South and Rv 4 in the Northern part. We propose to establish construction roads parallel to the future track connecting these and evaluate solutions to guarantee the smoothest possible public traffic on these highly used roads.

The process plan shows that the major tunnelling projects are invariably on the critical path. The mass balance for Gjøvik line is clearly positive, meaning that we have to calculate with a mass surplus of about 12 million cubic meters solid rock.

Lot GJ5 is most time consuming, containing two large tunnels. The larger of them is being on the critical path. The tunnel is situated between km 172,426 and 180,729 in the northernmost part of the route passing Lillehammer. Its Southern tunnel portal is located within Lillehammer near Mesnabru only a view hundred meters west from the central station. The area is a residential neighbourhood, so it is difficult and challenging to establish and drive a rig area here. Additionally, there is a major shopping mall only a few hundred meters away.

The Northern tunnel portal area lies between E 6 (Fv 312) and river Lågen in rural surrounding. There might be some improvements connected to setting the tunnel attack a few meters back in Southern direction, both guaranteeing the usability of the road and improving the rig situation here. It seems to have enough space for a major rig area on the Eastern side of the road and the terrain is probable not too steep there. Additionally, there might be space for a major rock deposit area around here. Under such circumstances the attack is definitely easier Southbound even though the tunnel has to be driven falling then.

Drill and blast will be the adequate way of progress. Due to our geologists there are no major difficulties to be expected.

The main rig areas in this section and the deposit areas proposed are given in Figure 184.

main contracto r	from km to km		proposed main rig area		proposed rock deposit area	station (km)	deposits with capacity (in mio m³ solid rock)
GJ1	50,101	85,936	67,4		GJD 1	67,4	2,0
					GJD 2	91,7	2,0
GJ2	85,936	122,710	103,2		GJD 3	122,7	2,0
GJ3	122,710	141,192	133,7		GJD 4	141,2	2,0
GJ4	141,192	163,870	150,4		GJD 5	150,1	2,0
					GJD 6	164,2	2,0
GJ5	163,870	180,743	164,3		GJD 7	180,7	1,4

Figure 184. Main rig and deposit areas alternative D2-step 2, section Gjøvikbanen Gardermoen – Lillehammer.

Alternatively, the main rig areas might be chosen at the tunnel rig areas attached.

The connecting roads are mainly Fv 120 in the South and Rv 4 in the Northern part. We propose to establish construction roads parallel to the future track connecting these and evaluate solutions to guarantee the smoothest possible public traffic on these highly used roads. Alternatively, many more minor deposit areas ought to be established and the truck concept is to be adapted.

14.6.3 Alternative 2* from Trondheim to Værnes

This section of the line contains the lots G20 and G21 (adequate to Ø16 to Ø17). The process plans for these lots are shown in attachment 2. The section from Trondheim to Værnes is included in the main routes as shown in Figure 170, Figure 173, Figure 176 and Figure 179. This section contains four tunnelling projects and the lots are calculated to take between 5.5 and almost 9 years. Both of them are very tunnel-dominated.

The longest and most challenging tunnel lies within lot G20 (Ø16) and goes from km 497,692 to 503,492. Our geologists have estimated this tunnel to be especially difficult to build. This is why this relatively short tunnel might be rather time-consuming. It is estimated with 7.5 years construction time, partly because it lies in the centre of Trondheim city. The Southern (Western) portal area lies in the middle of Trondheim near the train station Lerkendal, the Northern attack will be in Ranheim, which is also urban, but providing much better space for rigging than the Southern portal area. Without going more into detail at this stage, it is clearly less challenging to construct the main rig area here, even though attacking here means to drive the tunnel falling, which means more complexity regarding water at the tunnel portal area. Both portal areas need special attention, something which has to be provided in details at a later stage.

The main rig areas for the lots might be chosen around km 504.0 (in Ranheim in between the two tunnelling projects) and at around 519.0 (Hommelvik), attached to the tunnel rig areas. This section is in need of two mass deposits with demands of 2.2 million (the Southern ones) and 2 million cubic meters solid rock volume. We propose to establish them at about km 512.3, 1.5 km to the South near Fv 873 and at km 516.8 right on top of the tunnel. As these lots are close to the sea, it might be very interesting to check alternative transport and usage possibilities.

This section is characterized by rather busy road systems and high population rates, making planning quite challenging. These demanding duties ought to be done in details at a later stage.

14.7 Alternative Østerdalen with freight traffic via Røros

In this alternative, freight trains use the HSR-line from Eidsvoll to Tynset where they go over to the existing Røros line. Therefore the existing Røros line has to be upgraded from Tynset via Røros to Støren where it is connected with the existing Dovre-line. It is connected to the HSR-line about 14 km north at Lundamo.

The line will be electrified on the whole line. There will be no difficulties with access to the line, as there is an existing railway line. Electrification works can be done from the existing railway line. There should not be difficulties due to railway traffic as the utilisation of the line is rather low.

As the utilisation of the line rises highly compared to today, new crossing sections as well as upgrading existing crossing stations are needed on this single-track line. It is assumed, that those works can be done from the existing line and without high impact on the traffic. Furthermore, no major difficulties to access the construction sites are expected as the existing lines follows most of the time the Fv 30.

15. STATISTICS

15.1 Alignment

Alternative D1/D2 is designed with a maximum speed of 330 km/h. D1 includes freight traffic, whereas D2 is designed for passenger trains only. In Østerdalen, in addition to the D scenario, an alternative with a maximum speed of 250 km/h was worked out. It is called 2* and is designed up to Tynset. North of Tynset the Østerdalen high-speed line is designed with 330 km/h (D2 until Lundamo, D1 from Lundamo to Trondheim) as freight traffic in this scenario is planned to use the existing Røros line up from Tynset.

Corridor	Length [km]	Length of new track [km]	Length / share of tunnels [km] [%]	Length / share of open track [km] [%]	Length / share of bridges [km] [%]
MAIN ROUTES – STEP 1					
Gardermoen - Trondheim					
Gudbrandsdalen Alternative D1	447,2 km	389,9 km	256,9 km 57,4 %	180,0 km 40,3 %	10,3 km 2,3 %
Rondane Alternative D1/D2	411,5 km	354,1 km	213,0 km 51,8 %	189,8 km 46,1 %	8,7 km 2,1 %
Østerdalen Alternative D1/D2	405,5 km	356,7 km	145,7 km 35,9 %	248,9 km 61,4 %	10,9 km 2,7 %
Østerdalen Alternative 2*, D1/D2	409,4 km	357,0 km	134,7 km 32,9 %	266,7 km 65,1 %	8,0 km 2,0 %
Trondheim - Værnes					
Værnes Alternative 2*	29,2 km	27,4 km	20,9 km 71,6 %	8,1 km 27,7 %	0,2 km 0,7 %
ADDITIONAL ROUTES – STEP 2					
Gjøvikbanen Alternative D2	130,6 km	130,6 km	64,3 km 49,2 %	62,8 km 48,1 %	3,5 km 2,7 %
Gardermoen – Venjar - Vallset Alternative D2	59,9 km	48,0 km	23,5 km 39,2 %	34,7 km 57,9 %	1,7 km 2,9 %

Figure 185. Statistics of the routes in the northern corridor in the different scenarios.

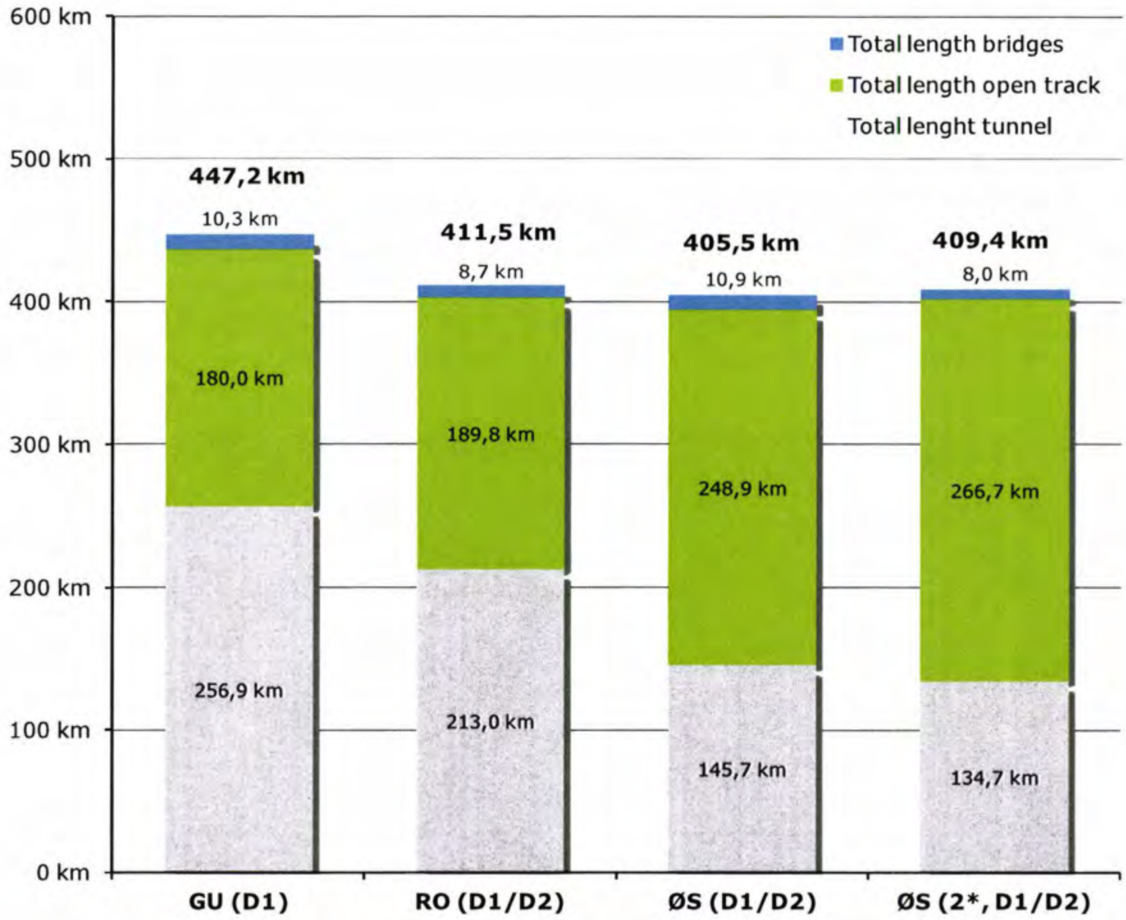


Figure 186. Diagram, showing total length of open track, tunnel and bridges for all main routes to the prioritized alignments from Gardermoen to Trondheim.

Section	Length [km]	Length/ share of tunnels [km] [%]	Length/ share of open track [km] [%]	Length/ share of bridges [km] [%]	Max. Gradient [‰]
GUDBRANDSDALEN CORRIDOR					
Tangen – Lillehammer	87,6 km	45,6 km	41,9 km	0,1 km	≤ 12,5 ‰
Alternative D1		52,0 %	47,9 %	0,1 %	
Lillehammer – Ringebu	32,9 km	27,1 km	5,1 km	0,7 km	≤ 12,5 ‰
Alternative D1		82,3 %	15,7 %	2,0 %	
Ringebu – Soknedal	221,3 km	134,6 km	80,5 km	6,2 km	≤ 12,5 ‰
Alternative D1		60,8 %	36,4 %	2,8 %	
Soknedal - Trondheim	56,8 km	39,8 km	15,5 km	1,4 km	≤ 12,5 ‰
Alternative D1		70,3 %	27,2 %	2,5 %	
RONDANE CORRIDOR					
Tangen – Lillehammer	87,6 km	45,6 km	41,9 km	0,1 km	≤ 12,5 ‰
Alternative D1		52,0 %	47,9 %	0,1 %	
Lillehammer – Ringebu	32,9 km	27,1 km	5,1 km	0,7 km	≤ 12,5 ‰
Alternative D1		82,3 %	15,7 %	2,0 %	
Ringebu – Soknedal	185,5 km	90,6 km	90,3 km	4,6 km	≤ 35 ‰
Alternative D2		48,8 %	48,7 %	2,5 %	
Soknedal - Trondheim	56,8 km	39,9 km	15,5 km	1,4 km	≤ 12,5 ‰
Alternative D1		70,3 %	27,2 %	2,5 %	
ØSTERDALEN CORRIDOR					
Tangen – Koppang	117,7 km	23,6 km	90,8 km	3,3 km	≤ 12,5 ‰
Alternative D1		20,0 %	77,2 %	2,8 %	
Tangen – Koppang	121,6 km	23,4 km	96,9 km	1,3 km	≤ 12,5 ‰
Alternative 2*		19,2 %	79,7 %	1,1 %	
Koppang – Tynset	90,3 km	38,1 km	50,2 km	2,0 km	≤ 12,5 ‰
Alternative D1		42,2 %	55,7%	2,1 %	
Koppang – Tynset	90,2 km	27,3 km	61,9 km	1,0 km	≤ 12,5 ‰
Alternative 2*		30,3 %	68,7 %	1,0 %	
Tynset – Soknedal	92,1 km	34,4 km	55,4 km	2,3 km	≤ 35 ‰
Alternative D2		37,4 %	60,1 %	2,5 %	
Soknedal - Trondheim	56,8 km	39,9 km	15,5 km	1,4 km	≤ 12,5 ‰
Alternative D1		70,3 %	27,2 %	2,5 %	
ADDITIONAL SECTIONS					
Gardermoen – Tangen	48,7 km	9,7 km	37,1 km	1,9 km	≤ 12,5 ‰
Existing/under construct.		20,0 %	76,1 %	3,9 %	
Gardermoen - Venjar-Vallset	59,9 km	23,5 km	34,7 km	1,7 km	≤ 35 ‰
Alternative D2		39,2 %	57,9 %	2,9 %	
Gardermoen - Gjøvik – Lillehammer	130,6 km	64,3 km	62,8 km	3,5 km	≤ 35 ‰
Alternative D2		49,2 %	48,1 %	2,7 %	
Trondheim - Værnes	29,2 km	20,9 km	8,1 km	0,2 km	≤ 12,5 ‰
Alternative 2*		71,6 %	27,7 %	0,7 %	

Figure 187. Statistics of the sections of the main and additional routes in the northern corridor.

15.2 Cost-estimate/ volumes

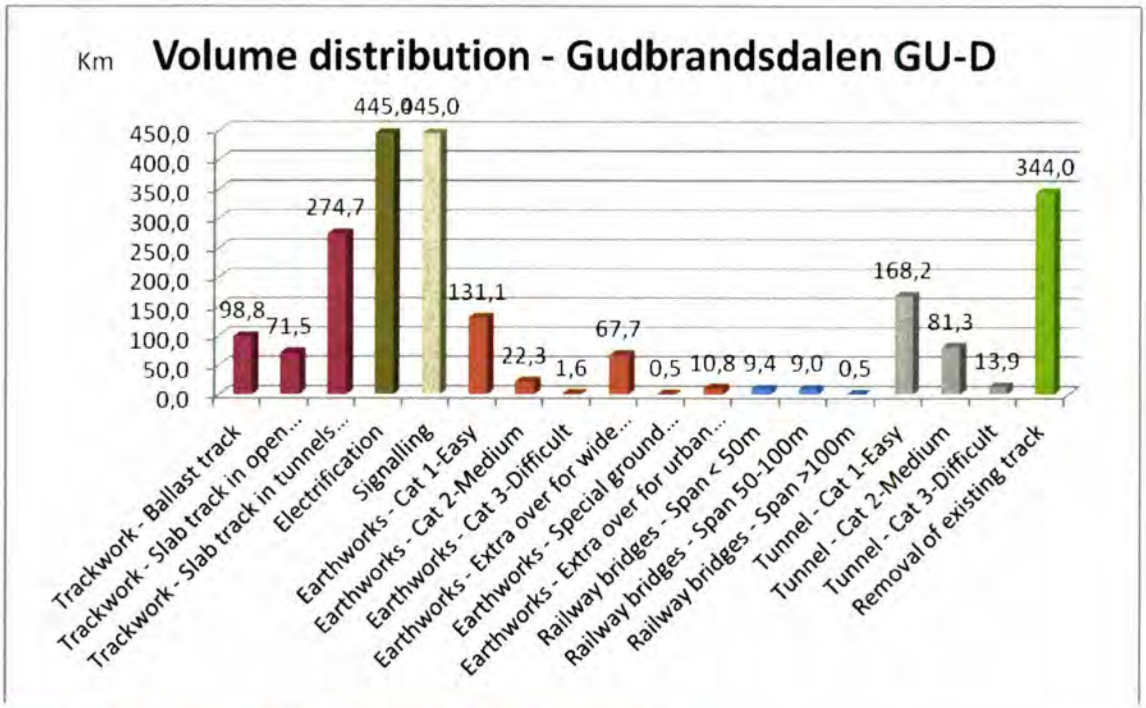


Figure 188. Volume distribution scenario D Gudbrandsdalen.

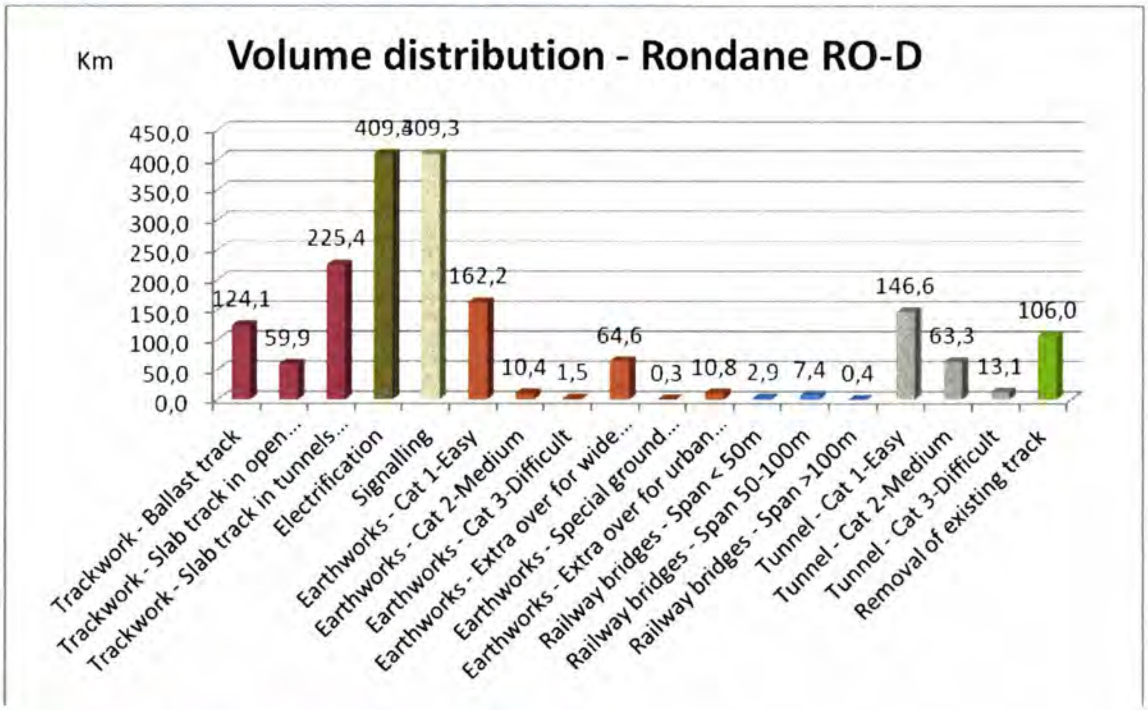


Figure 189. Volume distribution scenario D Rondane.

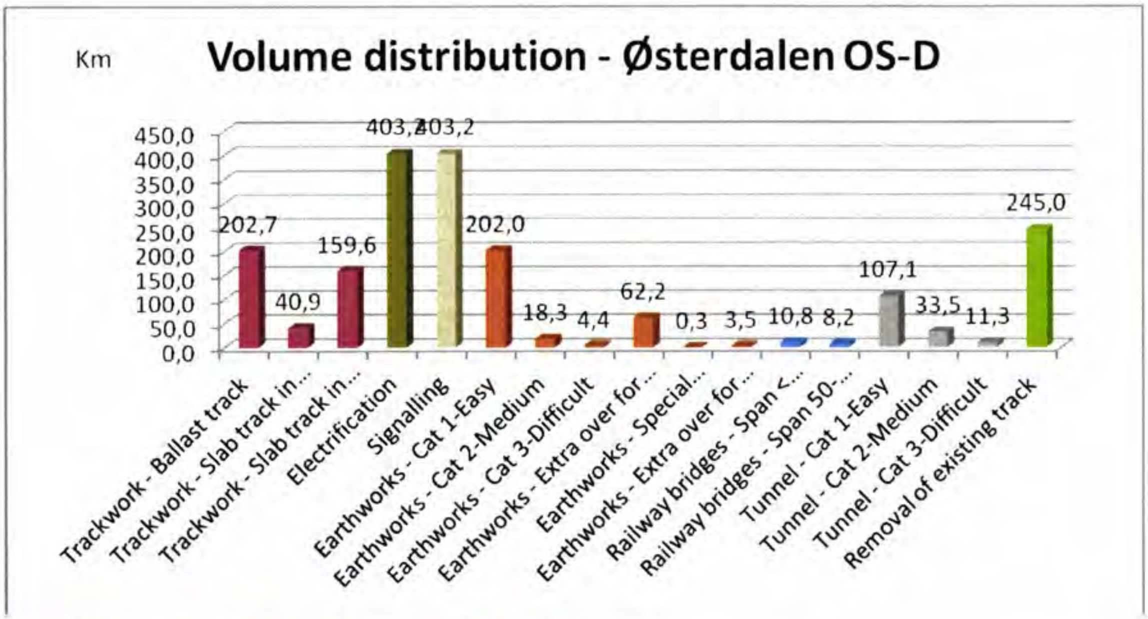


Figure 190. Volume distribution scenario D Østerdalen.

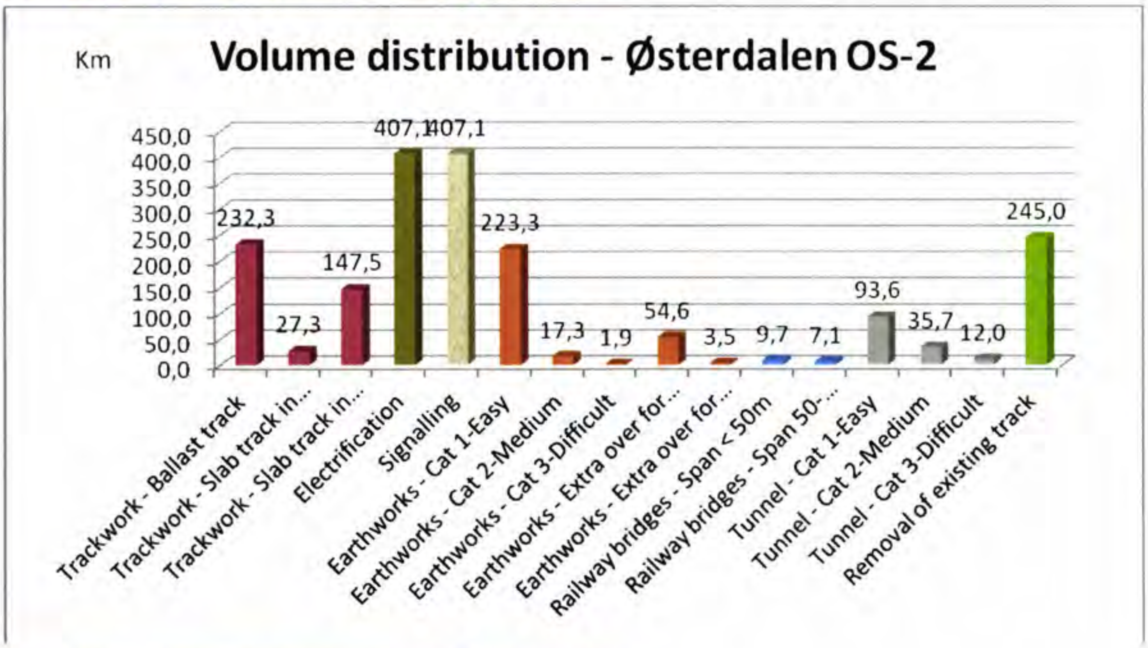


Figure 191. Volume distribution scenario 2* Østerdalen.

16. REFERENCES

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Map base: FKB-product Geovekst.

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Miljøverndepartementets: retningslinje for støy i arealplanlegging, T-1442.

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Norges geologiske undersøkelse, NGU: Quaternary maps giving top layer deposits.

Norges geologiske undersøkelse, NGU: Quick clay risk map and danger maps showing known quick clay zones that should be given special attention.

Norges geologiske undersøkelse, NGU: "skrednett" showing registered sliding activity.

Norges geologiske undersøkelse, NGU/Statens strålevern: Maps showing Alun shist.

Prosam rapport 153 (2007): "Bruk av ATP-modellen til vurdering av busstrase og holdeplassmønster".

Rambøll (2011): møtereferat " Oppsummering idedugnad i Trondheim 6. juni 2011".

Topographical maps.

17. ATTACHMENTS

ATTACHMENT 1: ALIGNMENTS, DRAWINGS 1:50.000

ATTACHMENT 2: CONSTRUCTION WORK, PROGRESS PLANS PER LOT