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# Effect of speed reductions for train punctuality

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**Abstract:**

The rail way sector has been losing market, required increased subsidies and failed to generate anticipated rate of return. Therefore there has been a strong interest to measure the performance of railway operators in terms of punctuality. It is evident that In Norway punctuality shows considerable variation; most of the line being in non-optimal condition, speed is frequently reduced. Such speed reductions are often highlighted as major causes of delays. This master thesis studied the actual delays occurring on the parts of the line between Oslo and Trondheim which have speed restrictions. In doing actual time, travel times and speed restriction magnitudes data have been collected along the line. Combining both qualitative and quantitative approach to research the master thesis have mapped and analyzed speed restriction zones along the line. Using restriction mapping, statistical tools and curve fittings, the analysis revealed that as long as there is sufficient data, uniformity and regular fluctuation of the time magnitudes data there is an increasing effect caused and trend displayed on the actual time taken in the presence of the speed restrictions. Furthermore the research has looked in to the magnitude based relationship between the lost time due to restrictions and associated deviations in travel time. These resulted in a strong correlation between deviation of travel time and magnitude of lost time due to restrictions.

Keywords:

1. Speed restriction
2. Railway
3. Lost time due to restriction
4. Devaition in travel time



## **Preface**

This report is a result of a Master thesis TBA4910 in Project Management at the Norwegian University of Science and Technology (NTNU) in Department Of Civil and Transport Engineering in the spring of 2012. The report analyzes the effect of speed restrictions on travel time there by its ultimate effect on delays and punctuality.

I would like to thank my supervisor Professor Nils Olsson for his invaluable guidance in choice of the thesis thematic area and in further project work without his input this project would not have come to reality. I would also like to extend my gratitude to Per Magnus Heggland from Jernbaneverket for his data supplements and assistance throughout the project work process. Last but not least I would like to thank my wife, Mahlet, for her love, support and patience during the past two or so years it has taken me to graduate. I would like to thank Tizita and my parents for their unending love and support.



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# Chapter one

## Introduction

### BACKGROUND

The transportation industry is one of the prominent role playing sectors in setting the central hub of nation's economy and supporting economic development by aiding the production and distribution of goods and services (WEF, 2010). From the wide range of means of transportation the railway segment contributes a lot in the field and is one of the major role players in the industry (NHO, 2007). During the past few decades and with today's ever changing business milieu the railway sector had gone through dramatic reorganizations and governance structural reforms (Carney and Mew, 2003; Vatn, 2008). The Governance reforms had led to the adoption of new technologies, and had also redefined relationships and acted as a catalyst for innovation in the way how infrastructure is handled, operated and maintained (Sascha Albersa, 2005 ).

The rail way sector had took the attention of policy makers owing to the fact that it has been losing market, required increased subsidies and failed to generate anticipated rate of return (Nash, 2000). As a result there has been a strong interest to measure the performance of railway operators in terms of punctuality. Punctuality is a critical issue in railways as the provision of reliable arrival time most often out ways the provision of faster journey with less certain arrival times (Harris, 1992).

It is evident that In Norway punctuality shows considerable variation and the official target for several railway lines and train is yet to be met (Olsson et.al 2010). With this context in mind efforts had been employed to provide a holistic explanation regarding factors influencing punctuality (Olsson & Haugland, 2004).

As a component of punctuality analysis comes, the need for finding out the influences of speed reductions. Railways lines have defined maximum speed, which varies along the line. When the line is in non-optimal condition, speed is frequently reduced. Such speed reductions are often highlighted as major causes of delays. The lost time as a result of a

speed reduction is calculated, but the calculation is based on optimal conditions. As a result, it is often claimed that the effect of speed reductions is higher than official calculations show. Thus it is necessary for the railway organizations to develop the way they organize and carry out their punctuality improvement activities.

The master thesis will study the actual delays occurring on the parts of the line which have speed reductions. This information can be summarized in a table or database. The information will be used in the planning and prioritization of maintenance activities. Data on both speed reductions and delays are available. The thesis will include a literature study of punctuality and previous studies.

The actual effect of speed reductions can be analyzed based on punctuality data. One reason we are interested in this analysis is to be able to show the socio economic effect of delays along the line. We can then point to certain parts of the line that need special attention. The resources can be allocated based on this information.

## Overview

As this project is conducted in order to look in to the overall effect of speed restriction on punctuality, due focus has been set in analysing the railway line from Oslo to Trondheim. Punctuality data generated from the Norwegian railway infrastructure administrator Jernbaneverket is used for the analysis and further implications. The analysis also takes in to account the utilization of other company or experience based analysis methods. The scope of the data collected was limited to the extent of available data generated by Jernbaneverket. The generated data were punctuality data including the train number, date of travel, arrival and departure time for individual trains on individual stations.

The data were a mix of both freight trains and normal passenger trains. The intention behind taking in to account various train types is to widen the manifestation of the effect of speed restriction and to trace in detail, its associated effect on various incidents of happenings. Besides it is necessary to analyse statistical data which describes these conditions from observed occurrences. Both ways (from and to) punctuality data will be used to look in to the magnified effect of the restrictions uphill and downhill. The data

collected from punctuality and speed restrictions will be used to further investigate the relationship between the restrictions and their effect on delays.

### Data collection

The data collection includes both primary and secondary data. The data collection horizon is set wide so that it will give the sound base for the demonstration of the effects and relationship between speed restrictions.

**Primary data:** The primary data will be the punctuality data generated by the Norwegian Railway infrastructure administrator Jernbaneverket. The generated data is a recorded time measure for individual trains in the year 2011 -2012 on individual travels. Besides the associated weekly magnitudes of speed restrictions are inferred from the time plan of speed restriction by the infrastructure handler.

**Secondary data:** in virtue of secondary data literature survey on theoretical backgrounds on punctuality, delays and speed restrictions from books, journals, websites and other data collection of written reports of company cases and country specific experiences is conducted. The main data sources included:

- Research journal articles - industry related journals such as Journal of Air Transport Management, Journal of Transportation Planning and Technology and Review of Network Economics,
- Search engines and scientific databases: BIBSYS NTNU electronic library database, Google scholar, Science direct, First Search, Transport and NTIS.
- Websites of companies and governmental institutions – websites of the Ministry of Transport offices of Norway, website of and publications from Jernbaneverket.

### Research questions

The main objective of this study focuses on analysing the effect of speed restriction on delays. In doing so the study tries to address the following research questions:

- What is the relation between speed reductions and delays?
- On what level of detail should such studies be done, such as for each train number, week day, direction, train product, time of the year, etc.

The first research question of the relationship between speed restriction and delays will be addressed by reviewing literatures. Thereby efforts employed to explain the relationship between speed reductions and delays will be reviewed. In addition the associated terms and analysis methods used in this study will be highlighted in the light of literature review. The second research question will discuss about determining the level of detail the study should be set towards to, on the way of figuring out the effects. In doing so the appropriate level of detail in the analysis in the likes of each train number, week day, direction, train product, time of the year, etc. will be determined. In addressing the third research question the study will analyze the available punctuality data and use plots and tables to look in to the effect of the speed restriction and its contribution to specific delays given the magnitude of the reduction.

### **Method of attack**

The method of attack includes both primary and secondary data collection, literature study, data analysis, interpretation and conclusion. As pointed above after data collection; literature studies will aid as a tool in explaining the state of the art in the field under concern. With that, the analysis will utilize various tools to illustrate the associated effects between delays and restrictions. Thereby conclusions will be made based on the output of the interpretations of the analysis. Basically this study holds a strong premises and assumption related to the relationship between delays and speed restriction. Experience and some studies have indicated that there is a hazy correlation between speed restriction magnitude and delays. But it was difficult to illustrate this for a small set of data and low magnitude of speed restrictions. Therefore this study works on the premise of finding the fuzzy boundary above which a pattern of correlation comes in to manifestation. In doing so physical inspection of trends on graphs and correlation analysis will be made on the deviation magnitudes and the lost time due to restriction. Here analysis will be based on day by day analysis , weekly analysis , peak point analysis and average analysis for respective speed restrictions.

### **Limitations**

This thesis thematic area is limited to looking in to the relationships and effect of speed restriction and delays. Furthermore due to lack of weekly speed restriction and associated



data the analysis is done on the line segment of Oslo to Trondheim concentrating on the section of the line Dombas to Trondheim. In addition given the amount of time of six months for the literature reviews, data collection and analysis; the thesis only studies one freight train coming from Oslo to Trondheim. As there are few available researches and publications specifically conducted on this subject matter efforts had been employed to include relevant issues on the shelf.

### **Outline of the report**

The report is presented in such a way that the first chapter discusses the core issues and thematical areas of the thesis. The second chapter reviews and presents literatures coined with the subject matter; which would go in presenting what have been done so far when it comes to effect of speed restrictions on delays and restriction . As well the literature review will discuss key terms and analysis techniques utilized in planning and computing of speed restrictions. The third chapter will present the collected data for analysis and the actual analysis conducted. The analysis is utilizes two method of attacks. The first approach investigates the effect of the speed restriction on delays there by punctuality. The second approach looks in to the relationship between the magnitude of the lost time and the value of the associated deviation in the actual travel times. Finally the last sections will summarize the main findings of the thesis and present the list of main materials and literatures used in the progress of the thesis, in the appendix and bibliography sections.



## Chapter 2

### Literature study

#### The Norwegian railway network

The Norwegian railway network consists of a railway track that extends 4087 km across the country from north to south. This line consists of 2,622 km electrified line, 242 km double track, 60km high speed track, 696 tunnels and 2760 bridges (jernbaneverket). The special feature of the network is its relatively low share of double tracks. The major tracks for long distance, regional and freight trains are single tracks. The figure below shows a diagrammatical display of the Norwegian railway network with the major destinations.

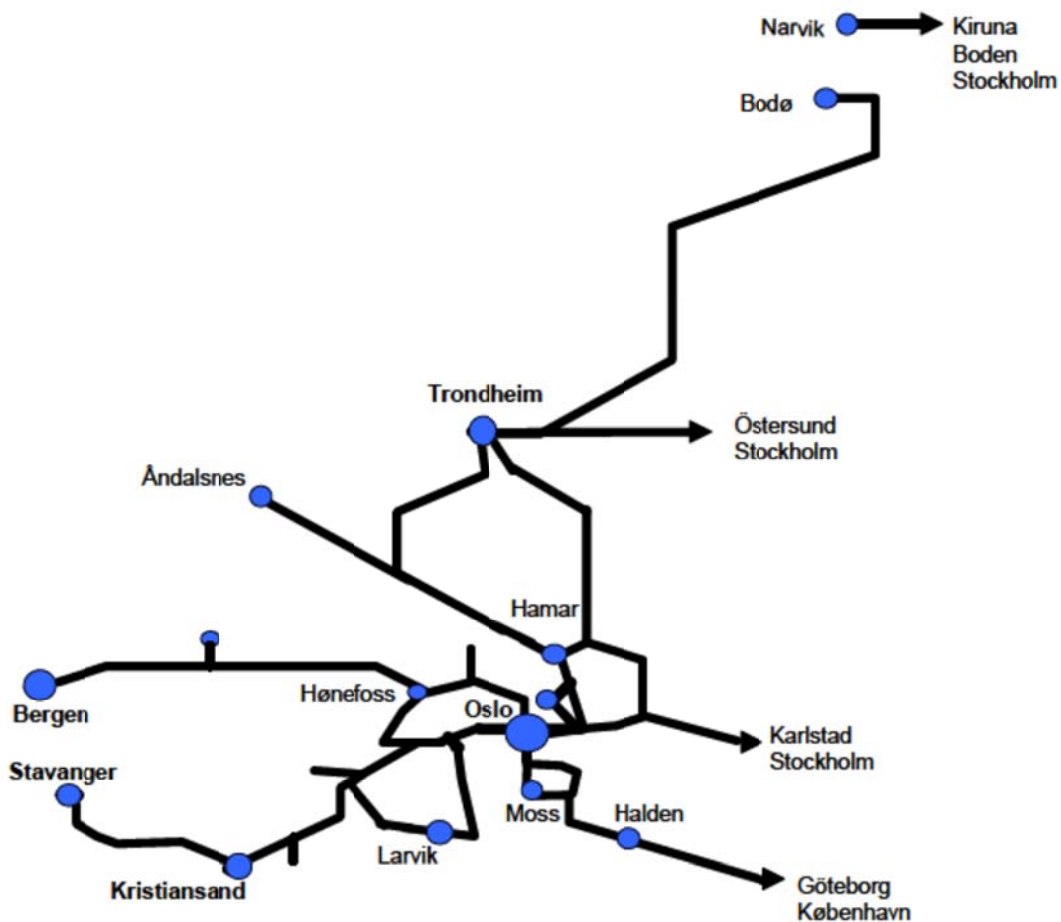
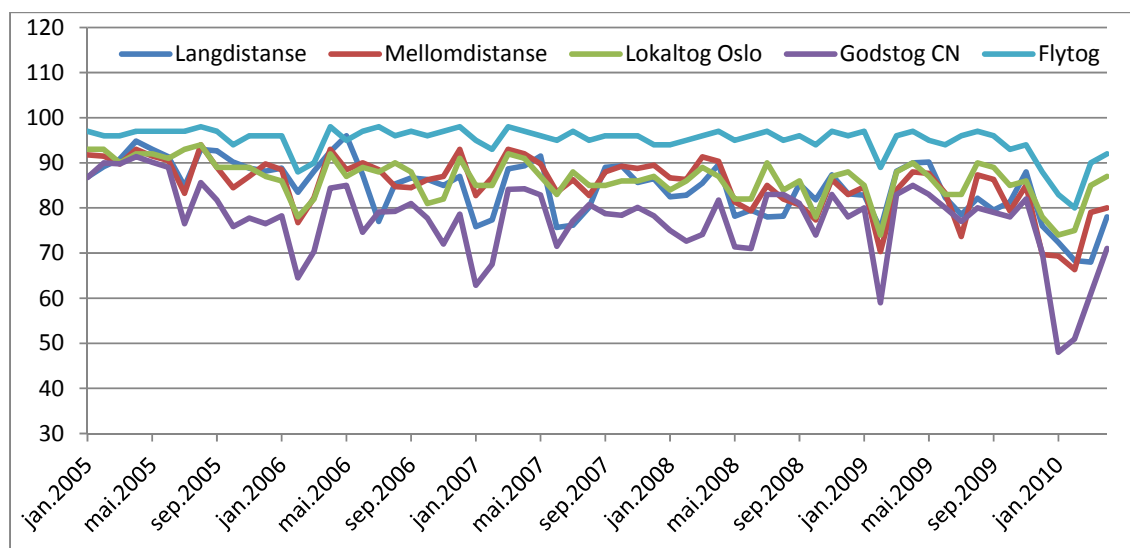


Figure 1 the Norwegian railway network taken from (Sætermo, Olsson, & Veiseth, 2006)

## Punctuality

In the transportation sector service planning goes further beyond determining optimal travel cost and duration. It extends further in to meeting customer requirements and expectations. Studies have shown that these days in the transport sector punctuality takes of critical significance (Hariss, 1992, Bates, 2001). In rail way service in addition to smoothening operations punctuality is contributing a lot towards insuring delivery of quality service. Train stations currently, being crowded with busy multi-platform sets, it is becoming critical to have a clear understanding of the punctuality of individual travels coming in and going out (Carvile, 2003). Punctuality is a critical issue in railways as the provision of reliable arrival time most often out ways the provision of faster journey with less certain arrival times (Harris, 1992).

It have been noticed that in Norway the railway system doesn't only show variation but also there is a declining trend<sup>1</sup> When it comes to punctuality from the year 2005 to 2010 (see figure 2 below ). With this context in mind efforts had been employed to provide a holistic explanation regarding factors influencing punctuality (Olsson & Haugland, 2004).



**Figure 2 Punctuality measured as the percentage of punctuality to the final destination (Olsson et.al 2010).**

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<sup>1</sup> Punctuality measured as the percentage of punctuality to the final destination, month by month from January 2005 to April 2010 for the country as a whole (TIOS Trafikkinformasjon og oppfølgingssystem). Figure 2 is taken from *Driftsstabilitet på Jernbaneverkets nett - årsaksanalyser 2005 – 2010 Punktlighets- og regularitetsutviklingen, gransking av årsaker by: Nils Olsson, Andreas Økland, Mads Veiseth og Øivind Stokland*

Hansen (2001) defines punctuality as a percentage of trains arriving or departing a given location or station across the railway network no later than a specified time in minutes. With similar connotation Rudnicki (1997) also presents punctuality as a state of a measured value that explains a given known vehicle arrives or departs a specific point in a previously set time. In extension Olsson & Haugland (2004) defines Train punctuality as the associated deviation, majorly negative from the defined timetable. For instance in most European railway companies the threshold for delay is equal to or less than 5 minutes; on the other hand trains arriving less than 3 minutes late in Netherlands are considered to be punctual. The limit might also narrow down to 10-15 seconds in case of Japanese train operators. This means that punctuality is often taken as, an event of meeting a set of predefined and anticipated deviations from target value in a schedule. Ultimately failure to meet punctuality or set target will end up in delays in the total train journey. With this context in mind about punctuality, we will further try to look in to how it is measured and what factors affect punctuality or contribute to delays.

Punctuality is a critical issue in railways as the provision of reliable arrival time most often out ways the provision of faster journey with less certain arrival times (Hariss, 1992). Harris (1992) points out three major reasons why punctuality is being taken worse than it actually is as:

- Passengers tend to have selective memory of concentrating more on poor performances on top of good once
- More often passengers take late trains than punctual once
- Train operators tend to avoid early running, as it might balance out late arrivals

Generally for train operators it's of great significance to have a detailed understanding of punctuality as it helps a lot in optimizing their economical resource deployment in line with meeting the requirement and expectation of their customers. Furthermore it enables them to monitor their timetables and travel patterns giving a window of opportunity to analyze and depict more efficient way of running their operations.

## Punctuality and Delays

The two terms are most often mentioned as similar terms but have different meaning although delay could be other version of punctuality. Given a train is not punctual, and had a negative deviation from predefined target time then we call it delayed. Delays are measured in time units whereas punctuality is expressed through percentage of numbers.

Primarily there are two types of delays but different authors use different terminologies and scope of definitions in presenting them. Gylee (1994) uses the term primary and secondary delays to signify delays with their size to impact. The primary once being, the most impacting and the secondary once being shadowed by the influence of the primary once. In conjunction Olsson & Haugland (2004) present the Norwegian version of delay classification as primary and secondary delays. Whereby primary delays are caused by direct influence on the train itself and secondary delays are most often caused by the impact of other delayed trains on the first one. Correspondingly different authors use other terms to explain the above delay types. For instance Gibson et al. (2002) uses exogenous and reactionary. Carey (1999) uses Exogenous versus knock on delays to express similar phenomenon but with further emphasis on the terms.

## Variables affecting punctuality

From above discussions it is evident that having detailed understanding of punctuality has great significance. Hence the next level of understanding will be defining various factors that influence punctuality. There are various factors affecting punctuality. Hariss (1992) has listed five variables that affect punctuality of trains and tried to investigate in to their correlations to punctuality with case studies. The major factors listed were:

- Length of train in carriage: length of a train is assumed to have influence in virtue of time taken to go across up and down hills and accelerate to regain speed in case of speed restrictions.
- Previous number of station stops: this is more related to the lateness caused by loading and unloading as the train stops more frequently.
- Previous distance covered: here it is assumed that with increased distance traveled the probability of encountering defective tracks and wreckage is high.

- Age of the motive power unit: this is a factor more related to aging parameter decreasing reliability of the train engine and power units
- Track occupation: this is more related to secondary type of delays whereby delay or failure of one train propagates in to other train delays on the congested and busier tracks.

While making the regression analysis for these factors to look in to their correlation with punctuality, Harris (1992) found out that only distance covered and train length were statistically significant in determining punctuality.

Correspondingly Olsson & Haugland (2004) had made related investigation on factors affecting punctuality which was a point of inspiration for this thesis research questions. In their research they have used the Norwegian railway network near Oslo and the Nordland to analyze the effect and correlation of certain variables to punctuality. The variables used included:

- Number of passengers and occupancy ratio: it was found out that number of passengers with higher rate of occupancy and punctuality has a negative correlation. With increased number of passengers, it was noticed that the trains tend to be not punctual.
- Infrastructure Capacity utilization : it was noticed that with increased capacity comes increased punctuality
- Cancellation and regularity: this showed that cancellation and punctuality have a positive correlation, cancellation and delay being apparent at the same time.
- Speed restriction: the correlation was found to be weak and sometimes negative opposite to what is expected. This might be counter balanced by the 4% allowance the Norwegian timetable takes in to account. This is the main thematic area of this thesis; hence we will focus more in this area on the chapters to come.
- Railway construction work: as expected during constructions period trains passing by will tend to be less punctual due to jams and stop over's.
- Departure and arrival punctuality. Here the relationship and correlation between departure delays and delays associated with arrival was investigated and it marked strong correlation.

➤ Operational train priority rules

From the above mentioned and discussed factors which affect punctuality we will go in depth to investigate the effect of speed restrictions on punctuality. This is because speed reductions are often highlighted as major causes of delays. The lost time as a result of a speed reduction is calculated, but the calculation is based on optimal conditions. As a result, it is often claimed that the effect of speed reductions is higher than official calculations show. Most often in Norwegian railway network time tabling, the 4% allowances counter balance this phenomenon and it was difficult to purely notice the effects of the restrictions. Besides train time table schedulers have a rule of thumb of adding 1 minute allowance per every 100km the train travels. This might have also led to diminishing the contribution and effect of speed restrictions on total travel time, hence punctuality.

There are various methods of measuring punctuality. For instance Rietveld et al. (2001) mentioned the following lists of measurement methods:

1. the probability that a train arrives x minutes late
2. the probability of an early departure
3. the mean difference between the expected arrival and the scheduled arrival time
4. the mean delay of an arrival given that one arrives late
5. the mean delay of an arrival given that one arrives more than x minutes late
6. the standard deviation of arrival times

Olsson & Haugland (2004) also has cited other methods of measurements including the travel time variability and Norwegian way of measuring punctuality at the destination station.

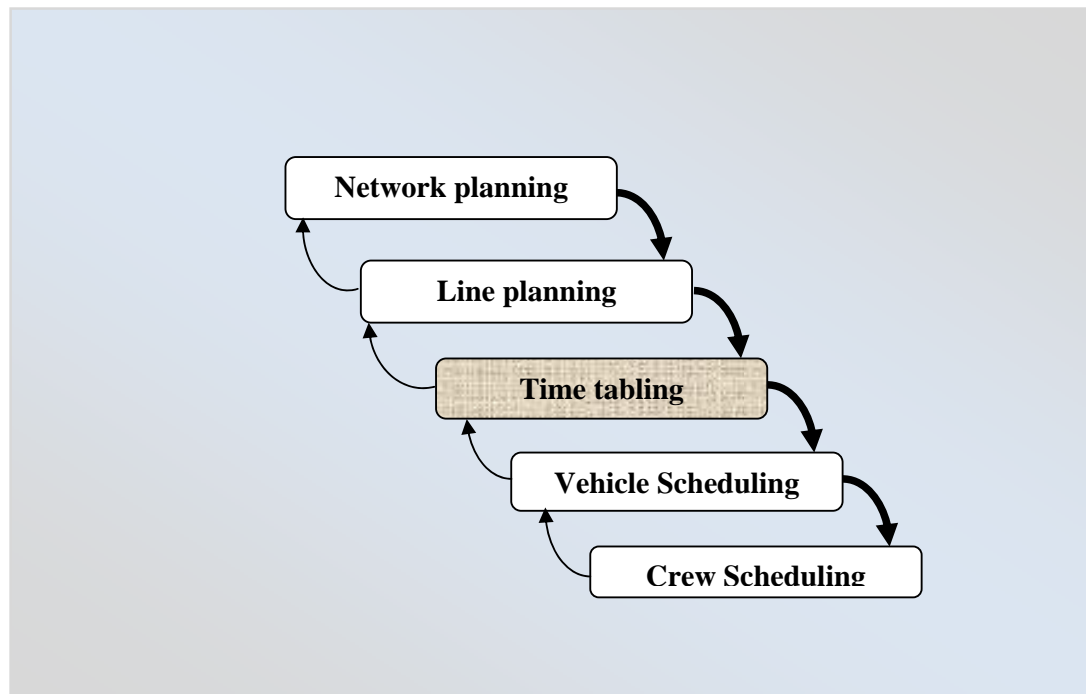
### **Scheduling and running time calculation**

Since scheduling is done in a greater picture for a long span of time and lots of trains' passing by numerous stations; at points the task becomes overwhelmingly difficult to compose. Although scheduling encompasses by far a great deal of tasks the major specific components are determinable. According to Pachl (2002) the main target of scheduling is to determine the travel date, the route along the network, respective arrival and departure times and



maximum speeds for a given train running along the line. Most of these components are determinable and could be monitor by data tracking along the path.

Going in to details scheduling in railway would infer additional tasks of network planning, line planning, timetable generation, vehicle scheduling, crew scheduling, and crew rostering. Although there is no distinct boundary between these interrelated tasks network planning and line planning are more of strategic planning whereas vehicle scheduling and crew scheduling have operational tendency (Liebchen & Möhring, 2007). In between these two tasks lies, the timetable generation, this serves as a bridge between service and operation. This is demonstrated diagrammatically in figure 3 below.



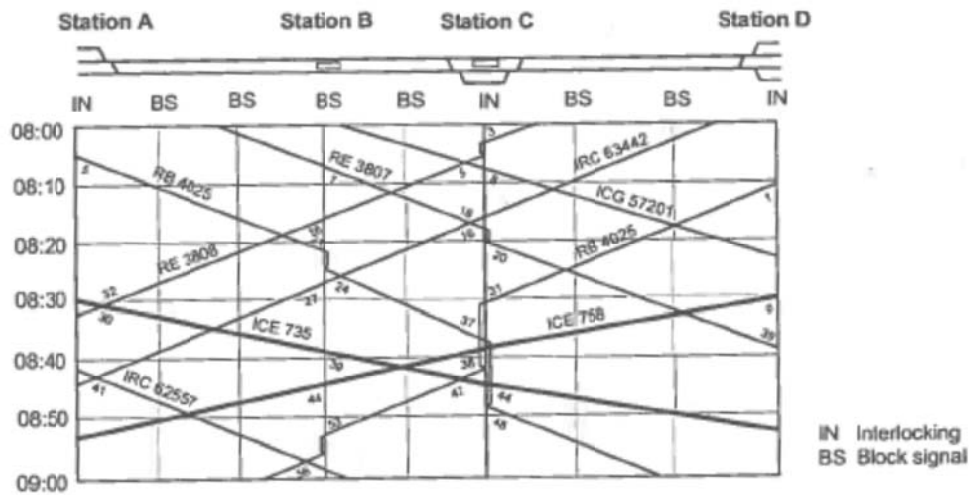
**Figure 3 componential tasks of scheduling and their relationship adapted from PESP model (Liebchen & Möhring, 2007)**

In the coming sections due focus will be given towards scheduling related with timetabling.

### Traffic diagrams

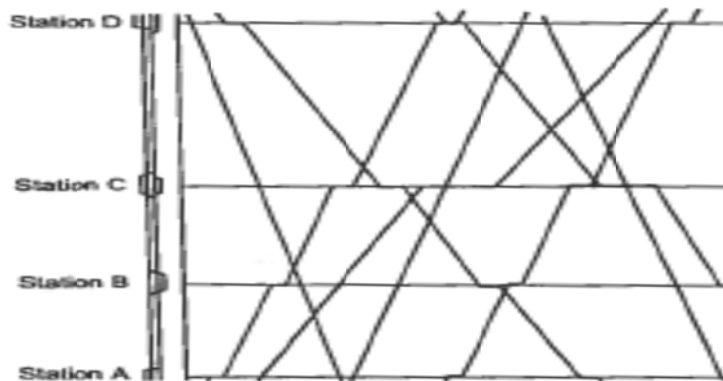
Traffic diagrams or graphical route diagrams are schematical representations and overview of pre-scheduled train traffic at varied intersections. The traffic diagrams have multi-function in laying the basis for planning of railway traffic and serving as an essential document for

monitoring of ongoing operations. The diagrams usually consisted of a vertical axis that describes distance on the line, stations and sidings' and a horizontal axis that describes time in hours along the line. The diagrams also include train paths, which are a time-distance graphs representing train movements, with a train details emblazoned on them (see figure 4).



**Figure 4 Horizontal traffic diagram (taken from Pachl 2002)**

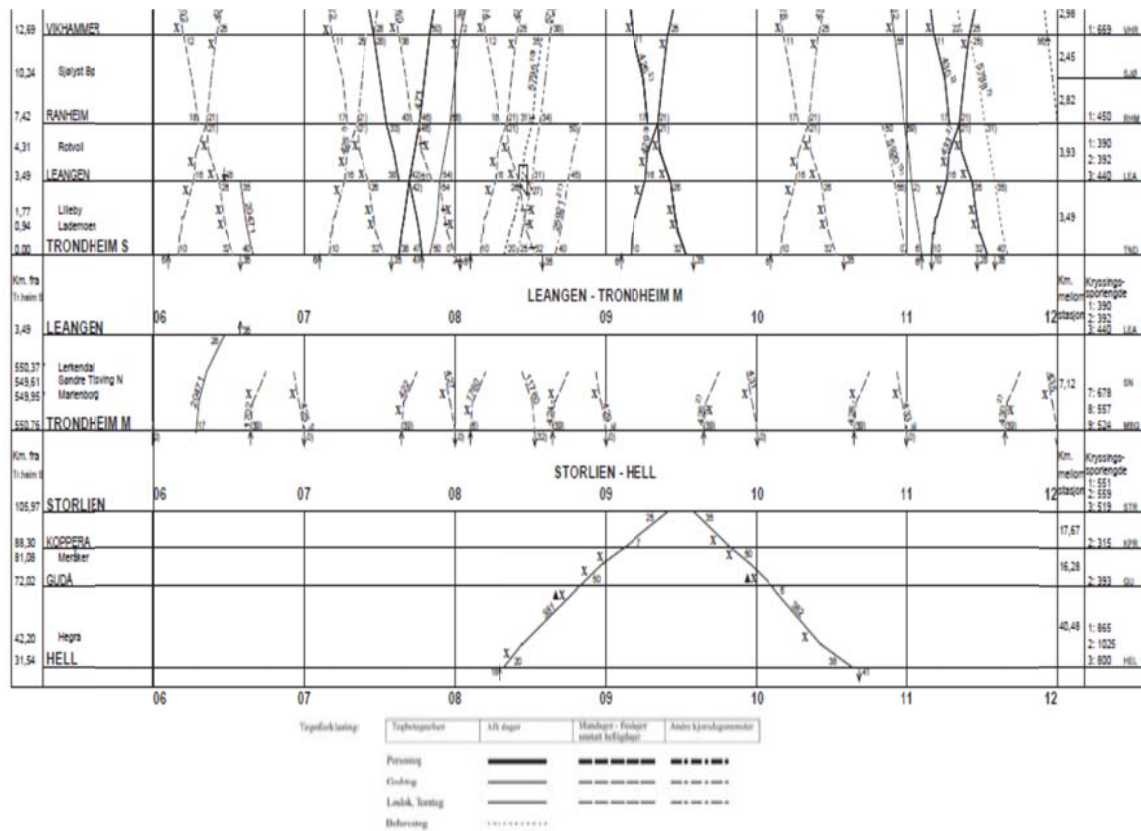
In accordance with the orientation or working tradition of a train operator different railway organizations either use the horizontal or the vertical traffic diagrams (see figure 5).



**Figure 5 Vertical traffic diagram (taken from Pachl 2002)**

In both cases the content of the schematics is the same the only difference lies on the content of the individual axis. In addition these diagrams also include schematics which

describe the traffic inside stations and interlocking given there are different tracks available for respective directions.



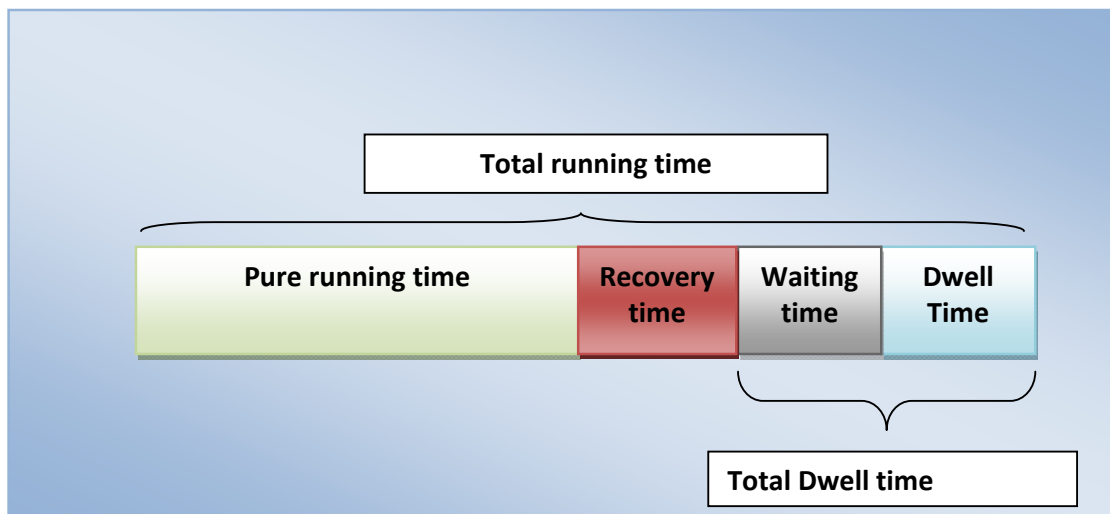
**Figure 6 sectional view of vertical traffic diagram taken from the Norwegian Railway infrastructure administrator Jernbaneverket website**

The figure above displays a snapshot of a vertical traffic diagram from the Norwegian Railway infrastructure administrator Jernbaneverket website. This is sectional part of a Graphical train routes as of 11 December 2011. As can be seen on the diagram the vertical axis describes the station name and distances covered whereas the horizontal axis displays the time frame; for this sectional view only time gap between 06:00 until 12:00 is displayed.

The time-distance graphs representing train route are also displayed all over the schematic with varied line textures and train numbers representing train specific information. From the line textures one can tell the frequency of travel and the basic functionality of the train. Besides the arrow directions on the line indicate the direction of travel and the different stripes and line bending implicitly define track occupancy status on a given station throughout the line of travel. The full traffic diagrams are presented in the Appendix section.

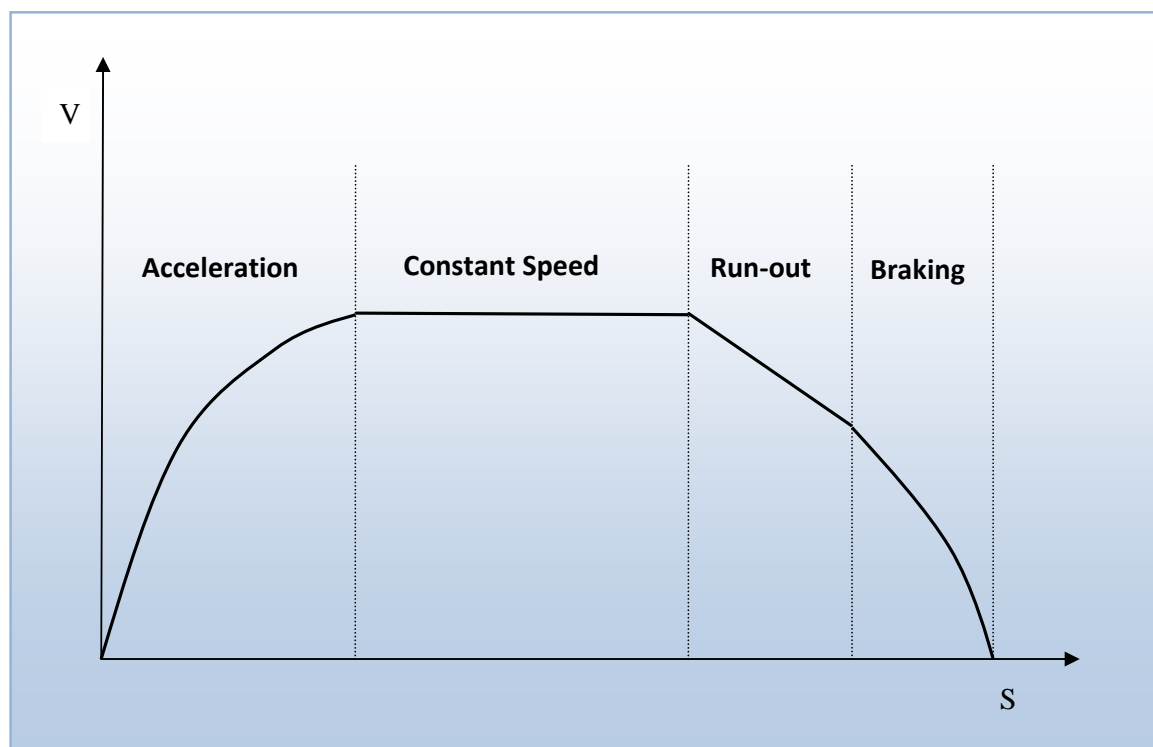
## Recovery time as a component of total running time

Running time of a train is a predefined scheduled time set that defines the total duration of a travel between departure and destination stations. Running time is composed of componential time sets including pure running time between scheduled stops, the dwell time at scheduled stops, recovery time and scheduled waiting times. This is illustrated in figure 7 below.



**Figure 7 Components of total running time**

The pure running time is a mathematically calculated or operationally recorded shortest time that a train takes to cover the distance between departure and destination station. Here it should be noted that the running time is computed without adding time lost due to small delays and malfunctions. It is purely the time taken while the train is under operation and running. The computation of pure running time involves the construction of the speed curve and integration of the curve to determine the running time. Figure 8 illustrates a typical speed curve constructed to visualize and further integrate on the course of computing the running time between two given stops.



**Figure 8 speed curve adapted from Pachl 2002**

The associated elemental movements of the train between these two stop points are composed of acceleration, running at constant speed, run out and braking. There are associate calculations of force, inertia, acceleration and so forth to determine the componential curves in the speed curve. As it is beyond the scope of this study we are not going to deal with them in detail. In general literatures indicate that the construction of the speed curve is a difficult task to develop analytically (Pachl 2002). Therefore one needs to go for a step by step approximation from a series of straight lines.

The dwell time includes the time that is usually elapsed while alighting and boarding passengers on scheduled start and stop stations. Dwell time usually takes in to account those additional minutes consumed in the case of technical checks and schedule margins (Heinz 2003).

To compensate for small delays there will be additional times added on the total running time which is termed as Recovery time. Depending on the train operators geographical location or country of origin there different magnitudes of recovery time additions. Depending on the reason behind the need for the additions and condition specific situations

there are two types of recovery times. Pachl (2002) uses regular and special recovery time terminologies to explain the situations.

Regular recovery time is the time supplement usually added to running time as a percentage of the pure running time. As discussed above this magnitude might vary based on geographical location and country specific situations. In most European railways the magnitude of the regular recovery time lies in between 3% to 7%. The North American railways take an allowance of 6 - 8% (Pachl 2002). Some schedulers often spread the regular recovery time throughout the total line of travel whereas; others supplement it at the end of the last scheduled stop or large intermediate stations.

Special recovery time is another type of recovery time supplement whereby the allowance is targeted at compensating lost time due to construction on the line, maintenance and restrictions related to track malfunctions. Unlike regular recovery time which takes percentage allowances, special recovery time is added as a fixed supplement to the running time.

The fourth component is the scheduled waiting time. This time addition is made so as to align travel time of passengers on change over stations and to make up for scheduled passing or overtaking. Most often the scheduled waiting time is by default included under dwell time as a supplement.

### **Speed restrictions**

Speed restrictions or speed reduction is one of the variables that affect punctuality of trains. In the presence of speed restrictions both freight and passenger trains need to make technical adjustments so as to make it through the speed restriction zones. The railway groups' standard GK/RT0038 (Railway Group Standard, 2000) defines speed restriction as "a set out principles governing the signing and advice of permissible speeds, temporary speed restrictions and emergency speed restrictions on running lines to ensure that train drivers have sufficient information to control their trains safely". Speed restrictions influence the travel time of the trains in virtue of time taken so as to adjust to the limit placed by the restrictions. At times when the train approaches the speed restriction zone the operators need to decelerate to attain the placed speed restriction and have to keep the speed

constant throughout the zone. In addition while exiting from the speed restriction zone the operator again needs to accelerate to regain the optimal permissible speed set. Enticed with this there will be train category and operator experience dependent associated time losses.

Most often the time taken to pass a speed restriction zone is merely a pure physics calculation, which we will see later in the upcoming sections. But there are scenarios of varied intensity which are taken in to account when it comes to the retardation and acceleration of the trains. Despite all this there still prevails a conditional time loss which may vary depending on the context of speed gains across uphill versus downhill, freight train versus passenger train, short train versus long train etc.

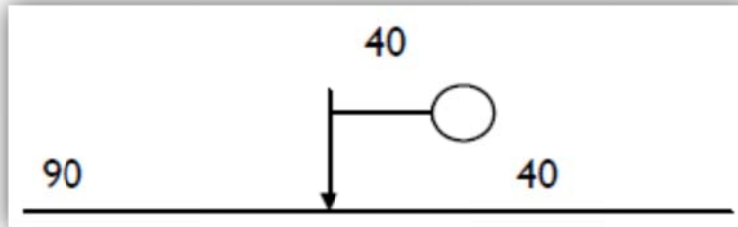
In the railway business there are various types of speed restrictions which might include permissible speed, temporary speed restriction, emergency speed restrictions and weekly operating notice.

### **Permissible speed**

Permissible speed restriction is on schedule basis computed and infrastructure controller approved maximum speed limits over a section of line, for each planned direction of travel and specific to each type of vehicle allowed to use the line. This often takes in to account the physics based calculations so as to come up with the attainable maximum speed enabling train operators to have full operational flexibility and safety clearance to guide their train across the line. The permissible speed is further used to calculate and compose specific deceleration distances. GK/RT0038 defines the deceleration distance as “The minimum distance at which a warning indicator (for a permissible speed) or a warning board (for temporary and emergency speed restrictions) shall be positioned approaching the start of the change in speed to which it applies in order to ensure that all trains have sufficient warning to be able to conform to the reduction in speed”.

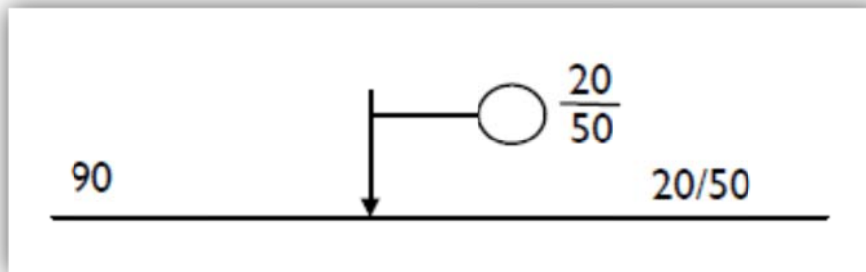
Permissible speed should be backed by continuous route signing that provides a speed indicator at each point where the permissible speed limit varies and the need for warnings arises. Speed limits are usually presented with signings displaying the information with clear and unambiguous clarity to the train drivers. Such signings design is based on the country

specific traffic safety standards; as well as measurement systems such as miles per hour, kilometers per hour, yard per hour etc. As a supplement to this automatic warning systems (AWS) could be put in practice. The figure below shows a typical speed indicator in railways.



**Figure 9 typical speed indicator taken from (Railway Group Standard, 2000)**

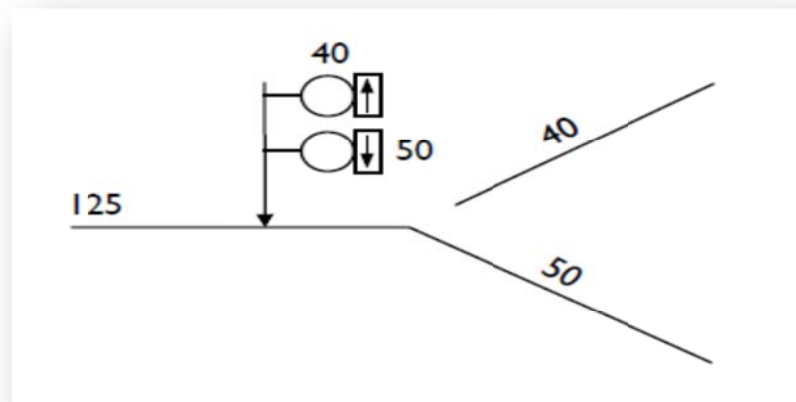
In case of Differential Speed Restriction whereby there is the need for displaying A speed restriction having two values, each of which is applicable to different types of trains one can use a modified version of the above diagram as displayed in the figure below.



**Figure 10 deferential speed indicator taken from (Railway Group Standard, 2000)**

There are also different designs of the signing boards in case of a diverging and cross over junctions on the route of the train. With this set of design one can have displays signaling different permissible speeds commencement for both routes at a diverging junction or crossover. In this case route specific indicators should be placed indicating the commencing reduced permissible speed and direction of divergence pointed by arrows (see the figure below).



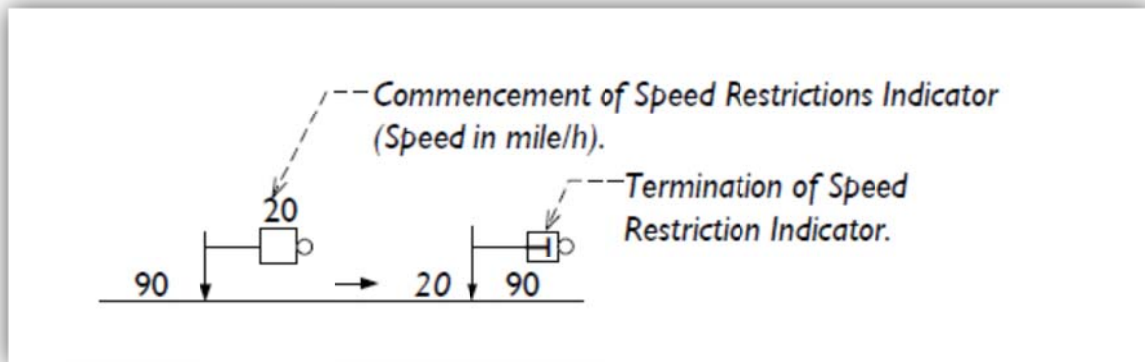


**Figure 11** permissible speed signing in case of diverging or crossover junctions (Railway Group Standard, 2000)

### Temporary speed restrictions

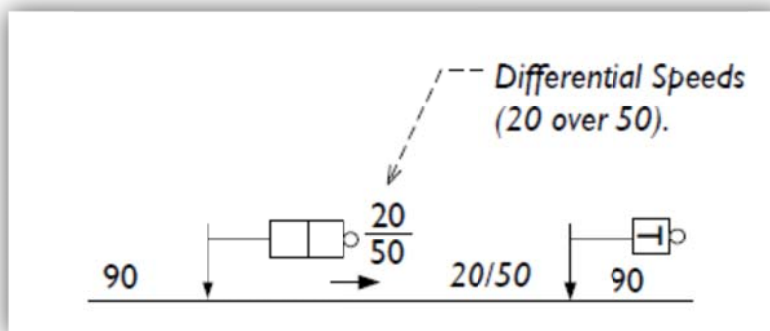
Temporary speed restriction is a time bounded speed limit; usually lasting up to a maximum of six months span, placed so as restrict the train speed to stick to a fixed magnitude less than the permissible speed. Temporary speed restrictions are placed in case of construction work on tracks, maintenance work on the line, weather conditions and so forth. As such types of restrictions have great contribution for occurrence of delays; the speed reduction should be done carefully. While such restrictions are place care should be taken so as to not affect punctuality with propagated delays happening across the line. Here minimum restrictions should be imposed lasting minimum time span possible and allowing the maximum allowable speed, with due course taken in to account the need for safety and operating conditions (H. samuel, 1961).

Temporary speed restrictions planning and design also needs to be backed by a sound and unambiguous information display boards. This provides the train driver the magnitude and location of the speed restriction zone a head of time to keep up with the deceleration and acceleration distances. Otherwise accidents and delays are inevitable. A typical temporary speed restriction display board is shown in the figure below.



**Figure 12** speed indicator in case of speed restrictions taken from (Railway Group Standard, 2000)

The speed indicator should include the sign posts of start of the speed restriction as well should designate the termination spot of the temporary speed restriction with letter “T”. In case of a differential speed the magnitude of the lower speed should be displayed above the higher one as depicted in the figure below.



**Figure 13** differential Speed indicator in case of speed restrictions taken from (Railway Group Standard, 2000)

### Other types of speed restrictions

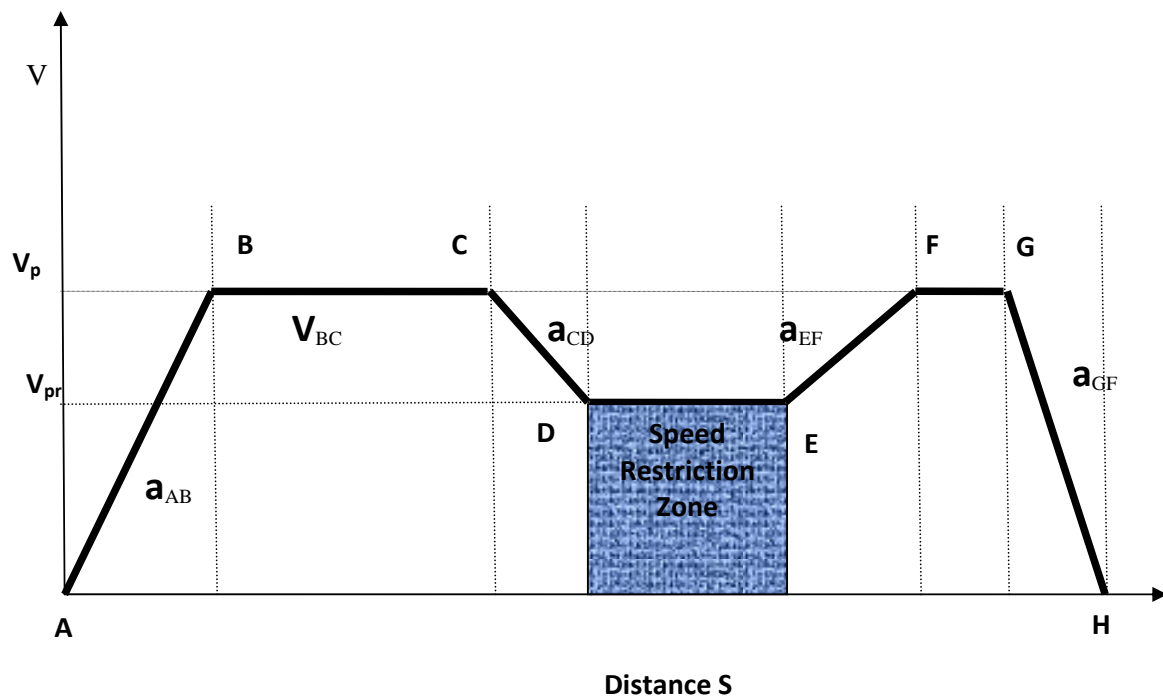
Depending on the internal operating conditions and traffic standards one can find different standards and types of restrictions other than the once discussed above. The majorly noted once include weekly temporary notice and emergency speed restrictions.

Weekly temporary notice is somehow a combination of both permissible speed changes and temporary speed restrictions. The main purpose of these types of weekly official reports is to

provide advice to the train driver about temporary speed restrictions and alteration in permissible speed. The emergency restrictions are similar to the weekly notice but differ in the context of their applicability. These types of restrictions are temporary restrictions; which are more restrictive than they appear on the weekly notice and include those restrictions note displayed on weekly notice. But still these restrictions could be traced from updates and amendments to weekly notices. They appear to be more bounding even when they are not shown.

### Speed Restriction and the associated time calculations

Basically running time calculations will take more than simple physics computations to come up with the determined travel time for a train across the line. The figure below demonstrates a sample train movement between two stops having a speed restriction zone in between them.



**Figure 14 Illustration of Speed restriction zone and the associated velocities and accelerations**

The train first starts from station "A" and accelerates to attain the permissible speed  $V_p$ . Starting from point "B" the train travels with constant speed  $V_p$  until it reaches the speed

restriction zone. At point “C” the deceleration distance starts and the train starts to slow down to reach the speed restriction zone permissible speed  $V_{pr}$ . the Norwegian time table developers take a deceleration rate of  $-0.7m/s^2$  in their computations. The speed restriction zone starts at point “D” and the train travels at constant velocity of  $V_{pr}$  throughout the restriction zone and again starts to accelerate at point “E” to regain its permissible speed  $V_p$  at point “F”. The Norwegian time table developers take an acceleration rate of  $0.5m/s^2$  in their computations. From point “F” onwards it travels at constant speed of  $V_p$  until it reaches point “G” and starts to slow down until it reaches the destination stop at Station “H”.

In case of constant speed zones the train can travel at the permissible speed and the associated time calculation will be as simple as dividing the distance traveled by velocity. See equation 1

$$T = \frac{\text{Distance}}{\text{Average Velocity}} \dots\dots\dots \text{(Equation 1)}$$

$$\text{Average Velocity} = \frac{V+u}{2} \dots\dots\dots \text{(Equation 2)}$$

In the case of speed restrictions where by the condition of differential speeds comes in to play one need to take in to account the change in velocities and the associated acceleration and decelerations. The following formulas become more significant:

$$S = \frac{V^2 - u^2}{2a} \dots\dots\dots \text{(Equation 3)}$$

$$T = \frac{-V_0 \pm \sqrt{V_0^2 + 4as}}{2a} \dots\dots\dots \text{(Equation 4)}$$

We can now use figure 14 to calculate the total time taken between two stop stations “A” and “H” thereby we can develop a common understanding of how timetables in case of speed restriction are developed. First we need to segment the total time taken in to componential times in line with prevailing motion mechanisms. We can develop the time segments as

$$T_{\text{Total}} = T_{\text{AB}} + T_{\text{BC}} + T_{\text{CD}} + T_{\text{DE}} + T_{\text{EF}} + T_{\text{FG}} + T_{\text{GH}} \dots\dots\dots \text{(Equation 5)}$$

The time taken between points “A” and “B” could be computed by using both equation 3 and equation 4. First we need to calculate the distance covered by the train using equation 3 from rest condition  $V_0 = 0 \text{ m/s}$  at point “A” until it reaches the permissible speed  $V_p$  at point “B” assuming a constant acceleration rate of  $0.5 \text{ m/s}^2$ .

$$\rightarrow S_{\text{AB}} = \frac{V_p^2 - u_0^2}{2a} = V_p^2 \text{ m} \dots\dots\dots \text{(Equation 6)}$$

Now substituting equation 6 in to equation 4 we can easily compute  $T_{\text{AB}}$  as

$$\rightarrow T_{\text{AB}} = \frac{-0 \pm \sqrt{0^2 + 4as}}{2a} = \sqrt{2} V_p \text{ sec} \dots\dots\dots \text{(Equation 7)}$$

The time taken between points “B” and “C” could be computed by using equation 1 assuming the train travels at constant speed  $V_p$  and the distance between reaching the permissible speed and point of deceleration C  $S_{\text{BC}}$  is known.

$$\rightarrow T_{\text{BC}} = \frac{2 \cdot S_{\text{BC}}}{V_p} \dots\dots\dots \text{(Equation 8)}$$

The time taken to reduce the permissible speed  $V_p$  at point “C” to the reduced speed  $V_{pr}$  at point D is easily computed in similar way as we did for  $T_{\text{AB}}$  except this time the initial velocity is  $V_p$  and the deceleration rate is  $-0.7 \text{ m/s}^2$ .

$$\rightarrow S_{\text{CD}} = \frac{V_{pr}^2 - V_p^2}{2 \cdot -0.7} \dots\dots\dots \text{(Equation 9)}$$

Substituting equation 9 in to equation 4 we can calculate  $T_{\text{CD}}$  as

$$\rightarrow T_{\text{CD}} = \frac{-V_p \pm \sqrt{V_p^2 + 4 \cdot -0.7 \text{ m/s}^2 S_{\text{CD}}}}{2 \cdot -0.7 \text{ m/s}^2} \dots\dots\dots \text{(Equation 10)}$$

Given we have a constant speed along the speed restriction zone between “D” and “E” and with knowledge about the length of the speed restriction zone we can easily compute the time taken  $T_{DE}$  along the restriction zone as we did for  $T_{BC}$ .

$$\rightarrow T_{DE} = \frac{2 \cdot SED}{v_{pr}} \dots\dots\dots \text{(Equation 11)}$$

For points between “E” and “F” the time taken can be calculated the same way as the time calculation between points “A” and “B” except this time we have an initial speed of  $V_p$ .

$$\rightarrow S_{EF} = \frac{v_p^2 - v_{pr}^2}{2 \cdot 0.5 \text{ m/s}^2} \dots\dots\dots \text{(Equation 12)}$$

Substituting Equation 12 in to Equation 4 we can calculate  $T_{EF}$  as

$$\rightarrow T_{EF} = \frac{-v_{pr} \pm \sqrt{v_{pr}^2 + 4 \cdot 0.5 \text{ m/s}^2 S_{CD}}}{2 \cdot 0.5 \text{ m/s}^2} \dots\dots\dots \text{(Equation 13)}$$

The time taken between “F” and “G”  $T_{FG}$  could be calculated considering a constant speed and knowledge of the distance between attaining the permissible speed again and the start of the braking zone as:

$$\rightarrow T_{FG} = \frac{2 \cdot S_{FG}}{v_p} \dots\dots\dots \text{(Equation 14)}$$

And finally one could compute the time taken to bring the train from the permissible speed at point “G” to stop at station “H” , given a deceleration rate of  $-0.7 \text{ m/s}^2$  as :

$$\rightarrow S_{GH} = \frac{0^2 - v_p^2}{2 \cdot -0.7 \text{ m/s}^2} \dots\dots\dots \text{(Equation 15)}$$

Substituting equation 12 in to equation 4 we can calculate  $T_{GH}$  as

$$\rightarrow T_{GH} = \frac{-v_p \pm \sqrt{v_p^2 + 4 \cdot -0.7 \text{ m/s}^2 S_{GH}}}{2 \cdot -0.7 \text{ m/s}^2} \dots\dots\dots \text{(Equation 16)}$$

Therefore we can calculate the total time taken across the speed restriction zone and the total time along the diagram demonstrated by figure 15 substituting the computed results from equations 7, 8 10, 11, 13, 14 and 16 in to equation 5. In the above computations involving the quadratic equations to calculate time, the negative outcomes should be ignored as it doesn't make sense to have a negative time value.

In case of other railway administrator setting different magnitudes of acceleration and deceleration rates one can easily change the values utilized in the computation above but the basic governing structure of computation remains the same.

One need to bear in mind as mentioned in the speed curve construction the above computations only serve as the basis for the linear approximations on the development of the speed curve. Otherwise every linear trajectory motions displayed are only ideally attainable and depend on the experience of the driver, the type of train, the topographic condition, the age of the engine and so forth.





## **Chapter 3**

### **Data Analysis**

This chapter will present the method of attack and the analysis of this thesis. The chapter is structured in such a way that first it discusses the typical calculations related with speed restrictions. In continuation it discusses the data collected and the associated speed restrictions across the railway line between Trondheim and Oslo. The major analysis part will constitute investigating the effect of speed restriction on delays and punctuality. The analysis will focus on representative train samples on the route including both freight and passenger trains. The analysis will try to fill the research gap on the concept of speed restrictions.

The basic premises behind the analysis is lost time as a result of a speed reduction. The lost time due to the restriction is calculated using the appropriate physics formulas, but the calculation is based on optimal conditions. As a result, it is often claimed that the effect of speed reductions is higher than official calculations show. In this virtue literature studies have shown that the effect of these restrictions seemed to get less significance as they are canceled out due to allowances and long distance of travel. Therefore this analysis attempts to widen the sample size and concentrate on speed restrictions to look in to its associated ultimate effect. Majorly the analysis part will look in to freight train sample and follows the train along the line to compute the deviation in running time with as well without the presence of speed restrictions. Further efforts will be employed to compare the deviations and come up with a reasonable explanation for the noted situations.

In doing so Train number 5733 is selected for further investigation as this train runs between Trondheim and Oslo. Furthermore the delays related to this train and its economical implication has been issue of hot debate in the Norwegian parliament. The analysis will use this train to illustrate the effect of restriction in the respective speed restriction zone and further investigates the associated relative effect of speed restriction magnitudes on the lost times.

## Data collected and restriction magnitudes

As discussed in the literature review section experience of the driver, the type of train, the topographic condition, the age of the engine and so forth influence the time taken to cover the distance between stations on the line. Therefore railway time table developers usually go for adding special recovery time to compensate for time losses due to these factors mentioned.

But the extent to which these recovery additions magnitude should be set without undermining the effect of the speed restrictions remains debatable. In this thesis in line with the Generated time Data by the Norwegian Railway infrastructure administrator Jernbaneverket, we also have acquired data about magnitude of the speed restrictions on weekly basis throughout the railway line from Oslo to Trondheim starting from beginning of 2011 until March 2012. These times are computed in the same way we illustrated in the previous sections; therefore it simplifies the need for computing loss times due to restrictions.

**Table 1 snapshot of the time restriction zones for week 1 2011 on Dovrebanen and Rørosbanen**

STÅENDE SAKTEKJØRINGER I REGION NORD													
I hht T-sirkulære 1/2011 (T.heim) og 1/2011 (Hamar), samt ruteordrer													
	Bane		#	Planlagte			Ikke planlagte		Hastighet Nedsatt til	Årsak	Tiltak	Oppheves dato	kostnad
	Fra km	Til km		Tidstap (sek)	Avtale (min)	#	Tidstap (sek)	(min)					
<b>Dovrebanen</b>			0	0.00	00:00	3	64.00	01:04	(Km/h)				
Fokstua st	361.380	361.580				1	31.0	00:31	60	Feil på spv	bytte spv deler?	jan 2011	
Hjerkinn st	381.910	382.100				1	26.60	00:27	60	Feil på spv	kapping/bytte av deler	jan 2011	
Lundamo st	514.830	515.020				1	6.30	00:06	40	avvikende spv	signalteknisk	2011	0,1 mill
<b>Rørosbanen</b>			0	0.00	00:00	2	12.83	00:13					
Hamar - Løten	141.990	142.730				1	6.73	00:07	80	plo signal	utflytting av innfelt	2011	
Opphus - Koppang	238.200	238.300				1	6.0	00:06	60	setning	innflytting av spor	2011	
<b>Nordlandsbanen</b>			2	136.60	02:17	7	163.11	02:43					

Table 1 above displays a snapshot of the weekly time restriction zone on the north line from Oslo to Trondheim for week 1 of 2011. The report is given in table format columns showing the name of stations, the starting and end point of the restriction zone, the amount of time lost in the zone, the restriction speed magnitude, the reason for restriction and the status.

In addition to this the weekly speed restriction forms collected for the year 2011-2012 also includes the summary of weekly time losses due to the speed restrictions (see Table 2 below). The summary is developed based on values from table shown above. This summary also display the adjacent stations restriction zone lays in between, the planned and not planned magnitude of time lost or delays occurred due to the induction of the speed restriction.

**Table 2 summary of time loss due to speed restriction on the north line for week 1 2011**

<b>Strekning</b>	<b><i>Tidstap for uke 1</i></b>			
	<b>Planlagt</b>	<b>Ikke planlagt</b>	<b>Akseptert tidstap</b>	<b>Totalt</b>
Kongsv - Elverum	00:00	00:15	01:30	00:15
Hamar - Koppang	00:00	00:13	00:30	00:13
Koppang - Røros	00:00	00:00	01:30	00:00
Røros - Støren	00:00	00:00	01:00	00:00
Dombås -Støren	00:00	00:58	01:30	00:58
Støren - Trheim	00:00	00:06	00:30	00:06
Trondheim - Hell	00:22	00:47	00:30	<b>01:09</b>
Hell - Storlien	00:41	00:00	01:00	00:41
Hell - Steinkjer	00:00	00:27	01:00	00:27
Steinkjer - Grong	00:00	00:00	01:00	00:00
Grong - Mosjøen	00:00	00:00	01:30	00:00
Mosj - Mo i Rana	01:54	01:07	01:00	<b>03:01</b>
Mo i Rana - Rognan	00:00	00:11	01:30	00:11
Rognan - Bodø	00:00	00:11	01:00	00:11
Oftbanen	00:00	00:00	01:00	00:00
<b>Hele regionen</b>	<b>02:57</b>	<b>04:15</b>	<b>16:00</b>	<b>07:12</b>

Such similar data for the whole year of 2011 and three months of 2012 have been collected detailing 72 weeks' time loss data due to speed restrictions along the railway line between Oslo and Trondheim.

In addition to the weekly time loss data due to individual restriction points, the time data record for individual trains in the whole line between Oslo and Trondheim has also been collected. These data includes Standard Arrival (STA\_TID), Actual Arrival time (ATA\_TID), Standard Departure time (STD\_TID) and Actual departure time(ATD\_TID) records for individual trains passing individual stations. This way it will be possible to monitor and follow individual trains along the line and look in to the magnitude of change in time where speed restrictions are placed. In line with the time magnitudes the station names and train

numbers were displayed enabling the time calculation between stations a possibility. The Table 3 displays the snapshot format of the sample data collected between consecutive stations between Oslo and Trondheim. This data set is generated by the north line administrative section of Jernbaneverket which tracks real-time data and stores in a database, thus making generation of such data set possible up on request by interested parties.

**Table 3 sample time record for train number 5733 between Alnabur and Bøn stations**

UTG_DT	TOG_NR	STASJO	STA_TID	ATA_TID	STD_TID	ATD_TID
1/3/2011	5733	ALB	03/01/2011 20:31:00	03/01/2011 20:31:00	03/01/2011 20:31:00	03/01/2011 20:31:00
1/3/2011	5733	GRO		03/01/2011 20:36:09	03/01/2011 20:36:00	03/01/2011 20:37:25
1/3/2011	5733	HGA		03/01/2011 20:37:25	03/01/2011 20:38:00	03/01/2011 20:38:21
1/3/2011	5733	HØB		03/01/2011 20:38:21	03/01/2011 20:39:00	03/01/2011 20:40:02
1/3/2011	5733	LØR		03/01/2011 20:40:02	03/01/2011 20:40:00	03/01/2011 20:41:11
1/3/2011	5733	HAB		03/01/2011 20:41:11	03/01/2011 20:42:00	03/01/2011 20:42:38
1/3/2011	5733	FJE		03/01/2011 20:42:38	03/01/2011 20:43:00	03/01/2011 20:44:07
1/3/2011	5733	STN		03/01/2011 20:44:07	03/01/2011 20:44:00	03/01/2011 20:45:00
1/3/2011	5733	SDA		03/01/2011 20:45:34	03/01/2011 20:47:00	03/01/2011 20:46:28
1/3/2011	5733	LLS		03/01/2011 20:47:44	03/01/2011 20:49:00	
1/3/2011	5733	LSD		03/01/2011 20:59:42	03/01/2011 21:00:00	03/01/2011 21:00:51
1/3/2011	5733	FRO		03/01/2011 21:02:06	03/01/2011 21:02:00	03/01/2011 21:02:47
1/3/2011	5733	LBG		03/01/2011 21:03:53	03/01/2011 21:04:00	03/01/2011 21:04:43
1/3/2011	5733	KLØ		03/01/2011 21:06:32	03/01/2011 21:07:00	03/01/2011 21:07:32
1/3/2011	5733	ASE		03/01/2011 21:10:13	03/01/2011 21:10:00	03/01/2011 21:12:48
1/3/2011	5733	LAL		03/01/2011 21:14:08	03/01/2011 21:12:00	03/01/2011 21:15:03
1/3/2011	5733	JEH		03/01/2011 21:17:01	03/01/2011 21:15:00	03/01/2011 21:17:58
1/3/2011	5733	HSR		03/01/2011 21:20:31	03/01/2011 21:19:00	03/01/2011 21:21:17
1/3/2011	5733	SAD		03/01/2011 21:23:00	03/01/2011 21:22:00	03/01/2011 21:23:35
1/3/2011	5733	DAL		03/01/2011 21:25:38	03/01/2011 21:25:00	03/01/2011 21:26:15
1/3/2011	5733	BØN		03/01/2011 21:30:00	03/01/2011 21:29:00	03/01/2011 21:35:12

## The Train selection and the associated data

From number of trains travelling between Trondheim and Oslo Train number 5733 is selected as a focus of investigation for this thesis. Train number 5733 is a freight train passing through the northern railway line it starts from Alnabur station in Oslo and stops at Trondheim Station. This train was selected as a point of focus of the analysis for three reasons:

First this train is a freight train; this enables to widen the parametrical range of investigation of the study. Usually freight trains offer the window of opportunity to consider the effect of speed restrictions in association with the load size on the train while the train passes through the speed restriction zone. This issue takes in to account the extended effect of the restrictions while the trains go along different topographies and landscape levelling. The effect of the restrictions will vary when the train goes uphill and downhill as the ease of respective accelerations and decelerations vary to great extent. It is usually considered passenger trains; given the load size they carry, would take less time to accelerate than freight trains which would carry some load way higher.

Secondly this freight train offers to great extent the opportunity to work on pure running times and their additions, omitting dwell times and their allowances. Freight trains usually have fewer stop stations or nothing at all except the loading and unloading stations or crossovers. This means while analysing the time data one will be working most of the time on pure running times avoiding the need to deal with dwell times and respective allowances which would had been frequent on passenger trains. Passenger train stops almost on every station for alighting and boarding passengers. This will bring in to play the need for computing dwell times and allowances making the analysis of the whole line a complex issue. In such situations it would be difficult to purely work with the effect of restrictions on running times as allowances added to compensate dwell times might have extended effect interfering in to allowances for restriction. Thus freight train is preferred and selected as focal point to benefit from the advantages it offers and the level of analysis needed is eased putting speed restrictions a singled out candidate of investigation.

Finally the freight train 5733 has been known for low punctuality issues. The low punctuality trend associated with this train is known for its direct economic impact. As this train runs majorly along the Trondheim- Oslo line the transported materials have higher economic impact as they will be shipped further with ships to other destinations. Hence delay or time lost by this train would have a chained economical effect to the economy as well to the following shipment and the associated other means of transportation. Few years back this train has even raised a subject of hot debate in the Norwegian parliament owing to the chained economic impact associated with it. Hence working with this train and the effect of

speed restriction would give a clear and in depth understanding of the whole picture of restrictions at its best.

Train number 5733 has been tracked all the way from ALNABRU station in Oslo to Trondheim S in Trondheim. The major stations in between the start and stop stations in sequential pattern included

ALNABUR – GRORUD – HAUGENSTUA – LØRENSKOG – HANABORG – FJELIHAMAR – STRØMMEN – SAGDALEN – LILLESTRØM – LILLESTRØM N - FROGNER – LINDEBERG - KLØFTA – ASPER – LANGELAND – JESSHEIM – HAUERSETER – SAND – DAL – BØN – EIDSVOLL – MINNESUND – MOLYKJA – MORSKOGEN – STRANDLYKJA – ESPA – TANGEN – STEINSRUD – SØRLI – STANGE – OTTESTAD – HAMAR – JESSNES – BRUMUNDDAL – RUDSHØGDA – MOELV – BERGSVIKA – BRØTTUM – BERGSENG – LILLEHAMMER – HOVE – FABERG – ØYER – TRETTEEN – LOSNA – FAVANG – RINGEBU – HUNDORB – FRON – VINSTRA – KVAM – SJOA – OTTA – SEL – BRENNHAUG – DOVRE – DOMBAS – FOKSTUA – HJERKINN – KONGSVOLL DRIVSTUA – OPPDAL – ULSBERG – BERKAK – GARLI – SOKNEDAL – STØREN – HOVIN – LUNDAMO – LER – SØBERG – MELHUS – NYPAN – HEIMDAL – SELBAKK – TRONDHEIM S. The total distance covered along one travel between ALNABUR and Trondheim S being 545.54 Km.

While tracking the train along the way time data of Standard Arrival (STA\_TID), Actual Arrival time (ATA\_TID), Standard Departure time (STD\_TID) and Actual departure time (ATD\_TID) has been taken in to consideration along a time range of 72 weeks. The actual and the standard prefixes designate the real time off happening and ought to be planned schedules respectively. In line with this the speed restriction zones and the respective magnitudes were mapped throughout the line for the whole 72 weeks.

The mapping is done in such a way that the respective speed restriction zones have been identified and the respective restrictions were place in between the adjacent stations to the restriction zone. This will enable us in comparing and analyzing the magnitude and intensity of the restrictions effect on the travel time between these adjacent stations. Thereby we can infer implications and deduce conclusions in line with the computation of the standard time and the actual travel time. With respect to speed restriction data, the obtained data set only covers the line between Dombas and Trondheim S ranging 209.83 kilometers. This is

because of the fact that the generated data set were from the north line administrative section of Jernbaneverket. The time table planners of the northern administrative section are only responsible for administering the line from Trondheim to DOMBAS as far as the route is concerned. Thus the computation and analysis will be conducted for the line mentioned above.

### The time calculations

With the obtained time data for train number 5733 standard and actual times have been computed for consecutive stations depicting the actual and standard travel times between the stations. The formulas used included:

$$\text{Standard time} = \text{STA\_TID at next station} - \text{STD\_TID at next station}$$

$$\text{Actual time} = \text{ATD\_TID at next station} - \text{ATA\_TID at next station}$$

Where:     *STA\_TID* = Standard Arrival time  
              *ATA\_TID* = Actual Arrival time  
              *STD\_TID* = Standard Departure time and  
              *ATD\_TID* Actual departure time

The standard time is the planned time that the train takes to cover the distance between two stations taking into account optimal conditions, permissible speed and respective allowances. Standard time usually remains constant throughout the years unless there is a generic change on the path followed or track set up. Whereas the Actual time is the noted and computed travel time the train actually takes to cover the distance between two adjacent stations from real time data records. Actual time between stations will vary from day to day depending on different factors including the weather condition, the freight load, the driver experience and so forth.

With this set up in mind on Microsoft Excel sheet the standard and actual travel times have been computed between adjacent stations. In line with this the speed restriction zones were mapped with their respective magnitudes along the line. This resulted in an excel sheet with

respective columns of departure date, the associated times, standard time, actual time and speed restriction magnitudes (*if there happens to be one*).

While doing so 13 speed restriction zones were identified for the line between Dombas and Trondheim S for the 72 weeks range. Each one of this restriction zones have their own adjacent stations identified. The identified 13 restriction zones for Train 5733 along the line during the span mentioned above included:

DOMBAS – FOKSTUA , HJERKINN – KONGSVOL , LUNDAMO – LER , MELHUS – NYPAN ,  
DRIVSTUA – OPPDAL , FAGERHAUG – ULSBERG , GARLI – STØREN , SELSBAKK – TRONDHEIM ,  
HJERKINN – DRIVSTUA , OPPDAL – FAGERHAUG , FOKSTUA – HJERKINN, LER – SØBERG and  
NYPAN – HEIMDAL.

Having this in place the concentration of the thesis is now directed towards analyzing the actual and standard time of the identified 13 restriction zones in line with the restriction magnitude. In doing so, two approaches are utilized to aid the understanding and implications of the computed data set for the given zones.

The first approach is to draw the three time sets; which are the actual time taken, the standard time and the restriction magnitude, along a diagrammatic chart for individual time restriction zones for the 72 weeks' time range. This will enable us to have a close look in to the effect of the speed restriction on punctuality or delays affecting the travel time. This could be inferred from the pattern displayed on the chart by the actual time taken in the presence and absence of the speed restrictions. What usually expected is the actual travel time should go up than normal trends whenever there is an introduction of speed restriction. Here note that the actual travel times will vary along the 72 weeks not only because of speed restrictions but also due to other factors mentioned at the beginning of this section. In addition the speed restrictions are distributed randomly along the 72 weeks. Every day of the 72 weeks will not have a speed restriction in place. Some weeks or days will entertain the restriction where as others will be set to the permissible speed. Besides the restriction magnitudes will vary from time to time depending on the reason behind the need for the speed restriction. Some restrictions associated with reconstruction of the track might last few weeks whereas maintenance activities or temporary accidents might last only few hours.



The second approach is to plot the magnitude of the speed restrictions together with the caused delay or any change in time on the actual travel time compared to the standard time. To do so one can look in to first the deviation between the standard time and the actual time. Thus plotting the magnitude of time lost due to the speed restriction along the x- axis and placing the respective deviation on the y – axis one can investigate in to the effect of the speed restriction magnitude on the deviation. The premise is that with increased time lost due to speed restriction magnitude there will be increased travel time. Thus a strong correlation trend between speed restriction magnitude and delays or lost time is expected. This approach will ultimately enable us to detect if there is a correlation between the speed restriction and the associated lost time.

Therefore the two approaches will enable us to understand and investigate in to first, the effect of speed restriction on actual travel time and secondly if it does have effect, then to what extent restriction magnitude affects travel time and to what level they correlate to each other.

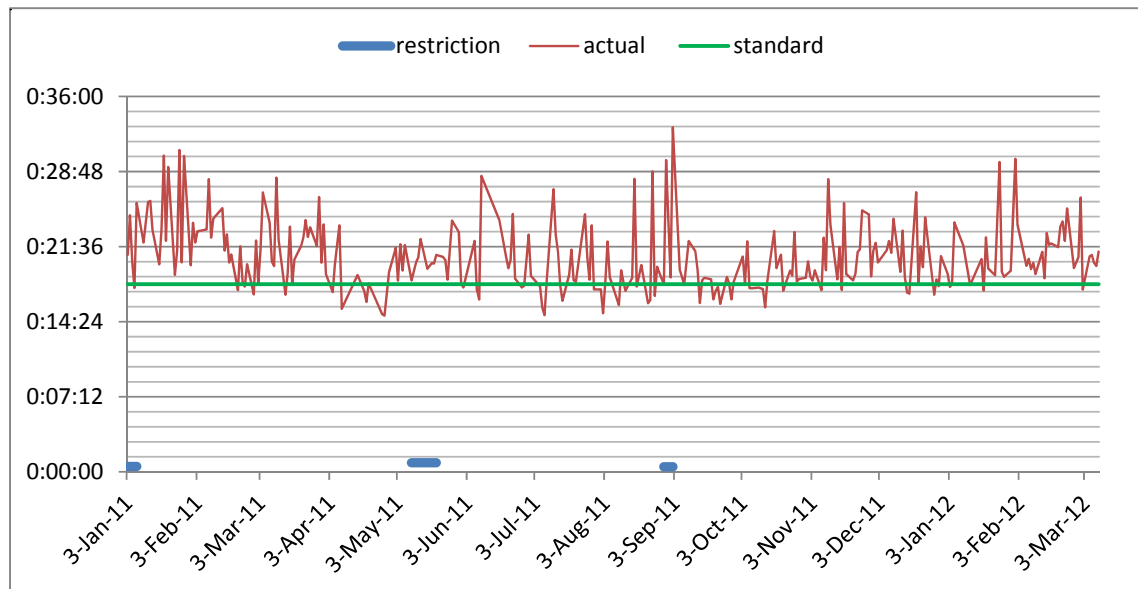
### **The effect of speed restriction on actual travel time**

To understand the effect of the speed restriction on actual travel time we will take the first approach. This approach is designated by plotting the three time sets; which are the actual time taken, the standard time and the restriction magnitude, along a diagrammatic chart for individual time restriction zones for the 72 weeks range. This is conducted in order to see if there is any effect caused or trend displayed in the presence and absence of the restrictions.

With this context in mind a diagrammatical chart has been plotted for individual restriction zones each having the time magnitude on the y-axis and the respective dates of the 72 weeks along the x- axis. The magnitudes on the y-axis will represent the three magnitudes of standard time, actual time and the speed restriction magnitude with a notation of individual series. In the coming sections we will go through the individual speed restriction zone plotted diagrams and investigate in to and discuss the associated trends and patterns displayed. From the inferred implications the first approach will deduce a concrete conclusion on the effect of the speed restrictions on actual travel time on the basis of the patterns displayed.

## DOMBAS - FOKSTUA

The distance between these two stations runs for a length of 18.61 km. while mapping the speed restriction zone it was found out that there are three speed restriction zones between DOMBAS and FOKSTUA. These restrictions have a speed magnitude of 0:00:30, 0:00:31 and 0:00:52 seconds. The restrictions run for 19<sup>th</sup> and 20<sup>th</sup> weeks of 2011, first week of 2011 and week 35 of 2011 respectively. The actual time, standard time and the mapped speed restriction magnitude are plotted; for the time range of 72 weeks starting from first week of 2011, on Microsoft excel as shown in figure 16 below.



**Figure 15 Dombas - Fokstua travel time data and lost time due to speed restriction diagram**

From figure 16 we can see that the actual travel time varies along the line in random pattern fluctuating from higher to lower values regardless of the presence of the speed restriction. At some points it even goes below the standard time. This could be a result of unbalanced special recovery supplements and not custom tailed allowance magnitudes laid over the line resulting in misinterpretation of the standard time. Thus at some point the train might pass by ahead of the scheduled time, but most often it gets delayed more than the 4% allowance added. When it comes to the effect of the speed restriction on travel time there is some sort of paternal uniformity on the second restriction zone and the highest travel time deviations of the whole time range have been noted on the third restriction zone. Thus even though it

is difficult to conclude the restrictions have purely deducible impact we can for sure see there is some sort of effect of the restrictions on the actual travel time.

### HJERKINN - KONGSVOL

The line between Hjerkinn and Kongsvol extends 11.49 kilometer with a standard time of 8 minutes for train number 5733. The line between Hjerkinn and Kongsvol extends 11.49 kilometer with a standard time of 8 minutes for train number 5733. Between these stations there are two speed restriction zones on the first week of 2011 and week 32 of 2011. The respective magnitudes being 0:00:27 and 0:04:09 minutes.

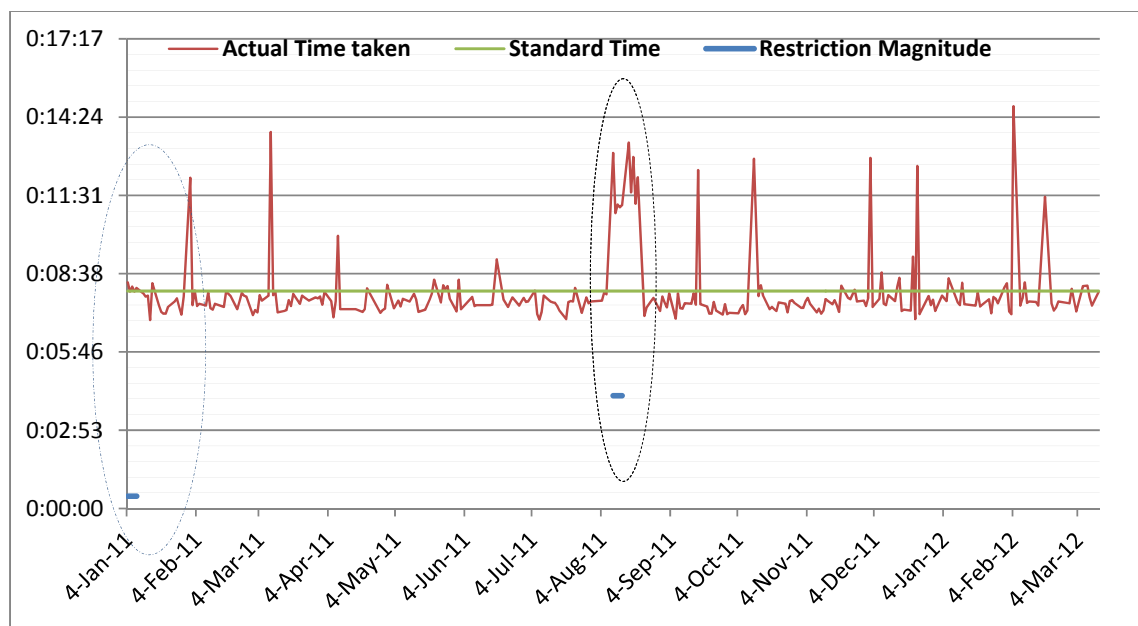


Figure 16 Hjerkinn - Kongsvol travel time data and lost time due to speed restriction diagram

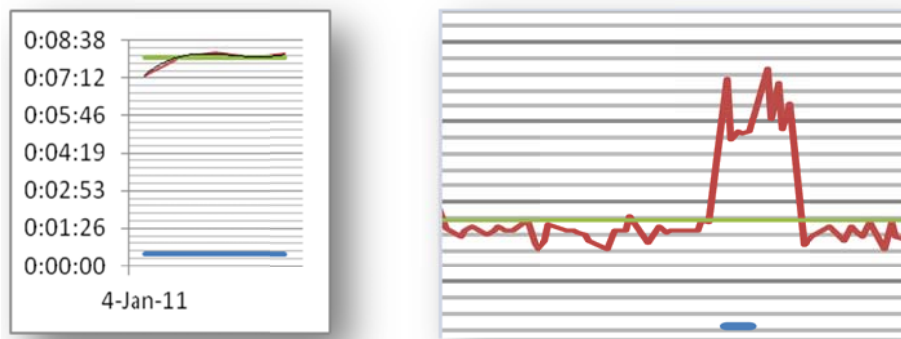
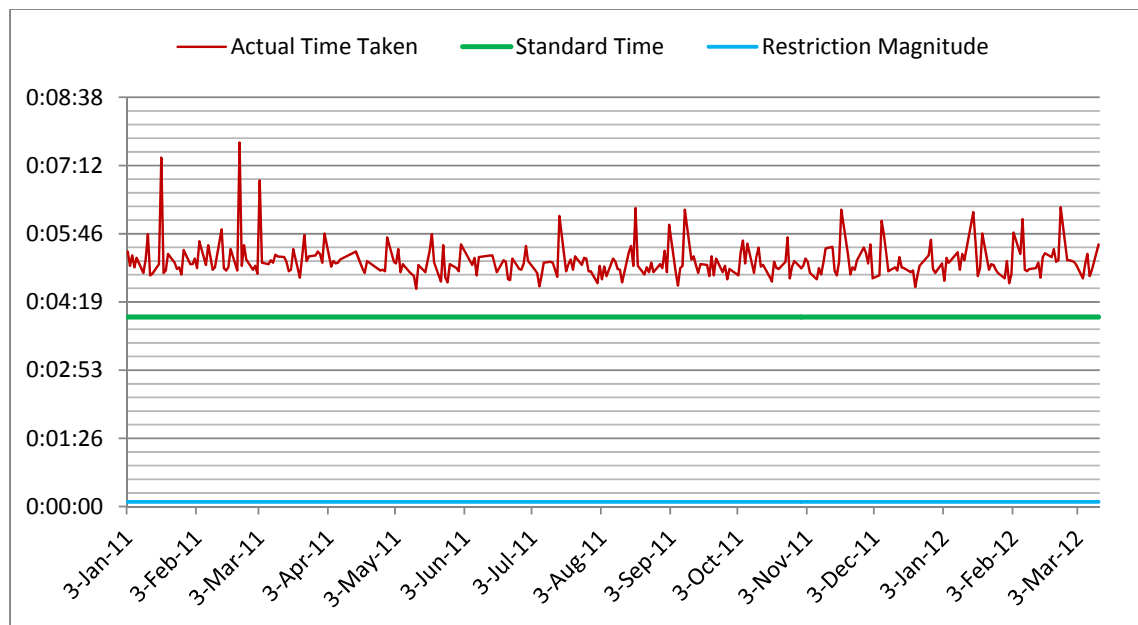


Figure 17 zoomed in view of speed restriction zone Hjerkinn - Kongsvol

looking in to figure 17 we can see that the variability in the actual travel time is patternal with the exception of some pick points. In most of the data ranges the actual travel time lies below the standard time. Looking in to the first zoomed in picture of the speed restriction zone of figure 18 , although the effect of the speed restriction is low the actual travel time is kept above the standard time for the first restriction zone. If we zoom in further to the second restriction zone we can see that the actual travel time goes way above the standard time. In the restriction zone the deviation of the actual travel time from the standard time is two fold larger than the lost time due to the imposed restriction. This might imply the larger the magnitude of the restriction the bigger will be the deviation , but we will investigate the correlation in the second approach.

### LUNDAMO - LER

The track between Lundamo and Ler extends about 5.71 kilometer and usually takes a standard time of 4 minutes for train number 5733. For the range of time considered the speed restriction zone extends through out the whole 72 weeks with a magnitude of 0:00:06.



**Figure 18 Lundamo - Ler travel time data and lost time due to speed restriction diagram**

Looking in to figure 19 above the actual time is distributed and varied in a uniform pattern with centering well above the standard time. But throughout the whole data range the actual travel time is way above the standard time close to tenfold of the lost time due to the speed restriction. The speed restrictions effect is manifested all over the diagram lifting the actual time way above the standard time throughout the diagram. In case of speed restrictions running more than six months it would have been better to incorporate the imposed restriction in to permanent speed limit so that the restriction would be adjusted in to the standard time computation.

### MELHUS - NYPAN

The rail way line between Melhus and Nypan runs for 5.2 kilometer taking a standard time of 4 minutes. The speed restriction mapping shows there is one speed restriction zone between these two stations within the time range of the 14<sup>th</sup> week up to the 20<sup>th</sup> week of 2011. The magnitude of the speed restriction is 0:00:20.

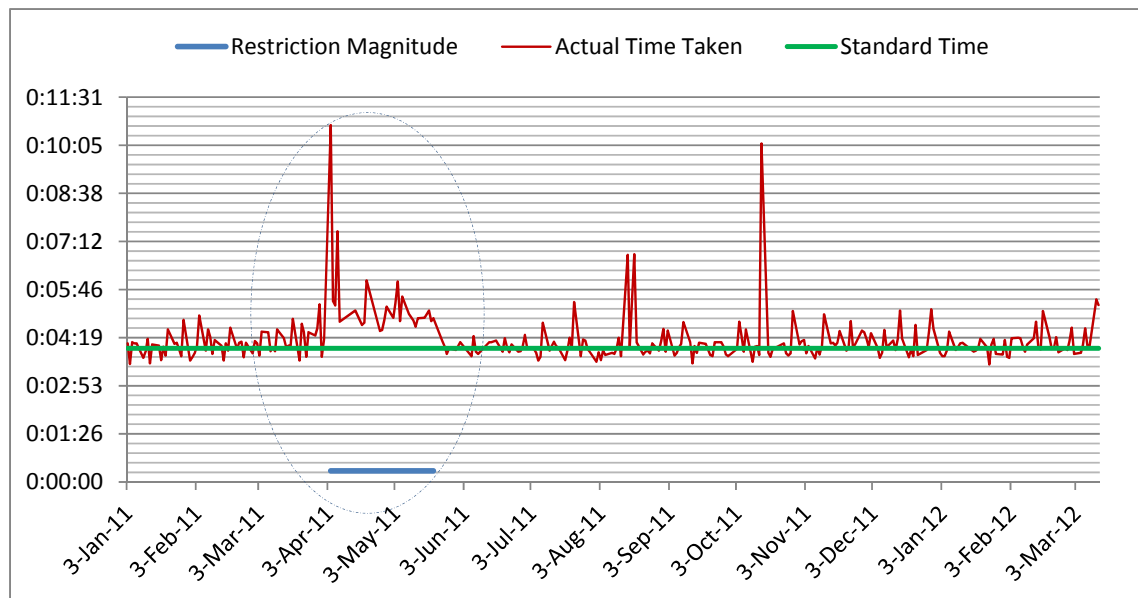
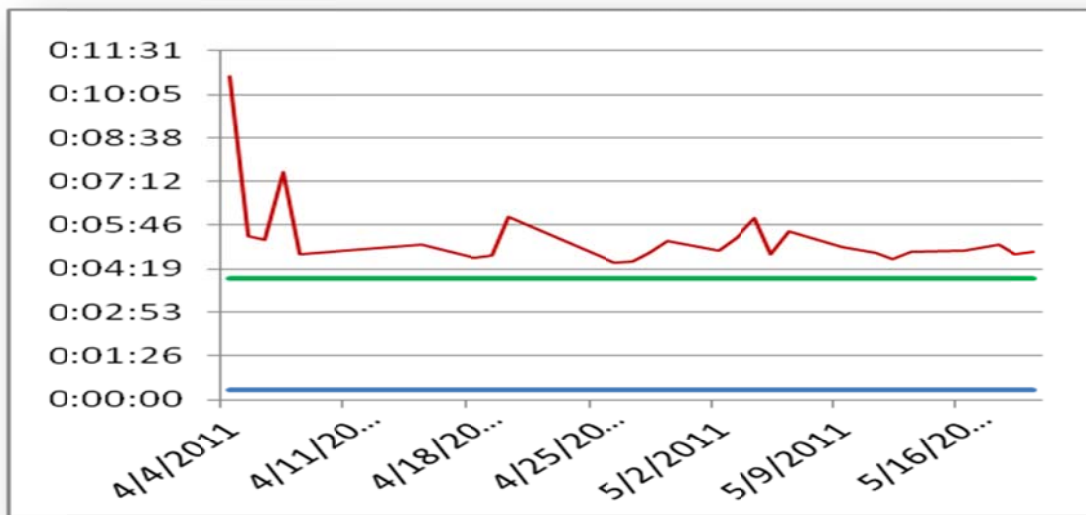


Figure 19 Melhus - Nypan time data and lost time due to speed restriction diagram



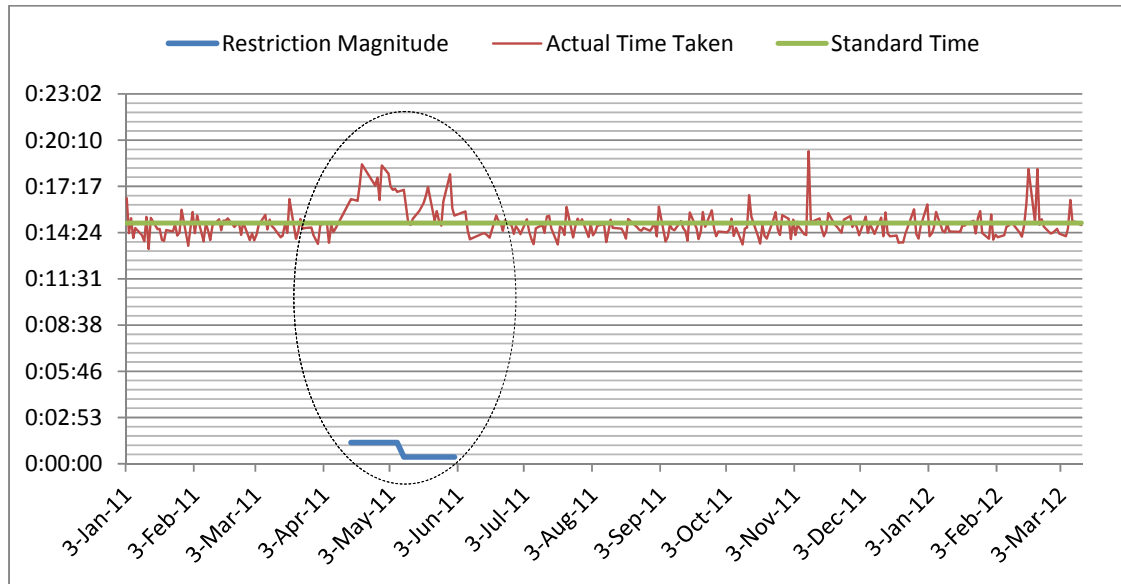
**Figure 20 snapshot of the restriction zone Melhus - Nypan**

From figure 20 we can see that the actual time is well distributed close to the standard time except for the restriction zone and few exceptions. Looking in to the snapshot of the restriction zone on figure 21 it is easily observed that the speed restriction lifted up the actual travel time above the standard time. In the diagram it is noted that the effect of the lost time due to speed restriction lifts the deviation in an increasing pattern to reach the pick and then declines to oscillate at a lowered level. This might be a result of the train drivers getting accustomed and familiarized to the restriction zone.

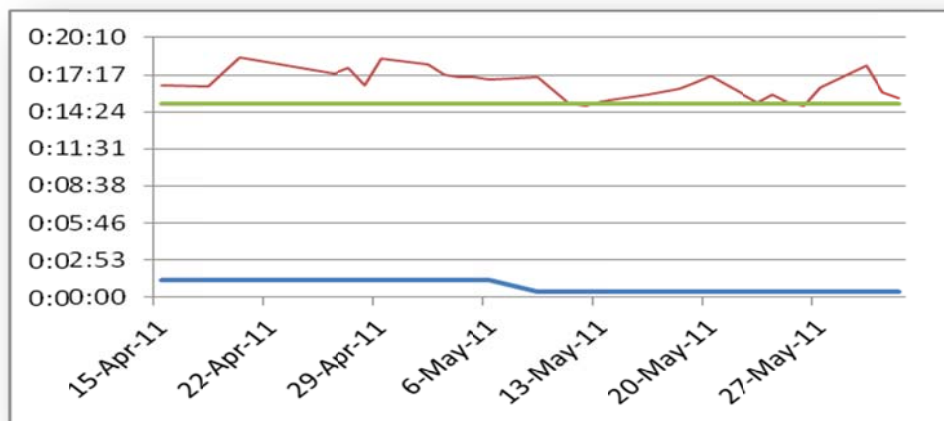
The main cause of time loss in the restriction zones for freight trains is the time lost due to late early breaking while approaching the zone and late acceleration while leaving the restriction zone. So it is no surprise to see the graph to shoot up on the first days of the imposition of the restriction. But once the drivers get used to with the route the lost time dramatically declines and stabilizes to oscillate at some level as seen on figure 21 above. Sometimes there could be a sudden increase in the diagram which could be explained through change of drivers. Therefore the analysis of the time data and lost time due to restrictions clearly illustrate the effect of the restriction on delay or the deviation on the actual time from the standard time of travel.

## DRIVSTUA – OPPDAL

The railway line between Drivstua and Oppdal runs for 22.16 kilometers and takes a standard time of 15 minutes for train number 5733 to cover the gap. The speed restriction mapping shows that there are two speed restriction zones. One running for the duration four weeks between the 15<sup>th</sup> week and 18<sup>th</sup> week of 2011 with a magnitude of 0:01:19. The second one runs in the time range between week 19<sup>th</sup> and 22 week of 2011 with a magnitude of 0:00:25.



**Figure 21** Drivstua- Oppdal time data and lost time due to speed restriction diagram



**Figure 22** snapshot of the speed restriction zone Drivstua- Oppdal

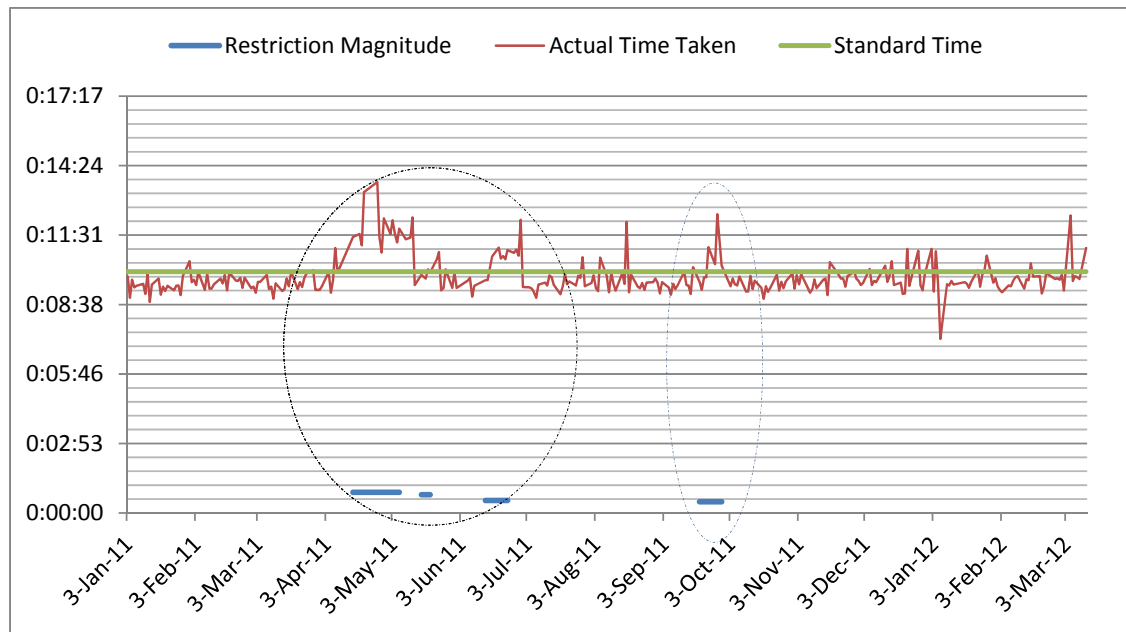
Figure 22 shows the time data and lost time due to speed restriction diagram for the line between Drivstua and Oppdal. From the figure we can see that the actual time lies below the standard time for most of the data ranges displayed and also it is varied uniformly around the standard time. While zooming in to the speed restriction zone as displayed on figure 23 one can see that the Actual travel time curve is lifted further above the standard time. The actual travel time shows a trend of inclining, declining and again inclining and declining.

This is typically associated with a cyclical change in the intensity of the reason behind the speed restriction. For instance, if the weather is behind the imposition of the restriction then cyclical variation in weather could bring the witnessed trend of change in the lost time. This also could be explained through shifting of drivers, the drivers' first hitting the pick and then again lowering the lost time as time goes by supplemented by experience. Therefore from this diagram we can see the actual travel time has been well affected by the imposition of the speed restriction as the diagram entertains huge bump ups in the restriction zone unlike the rest of the data range.

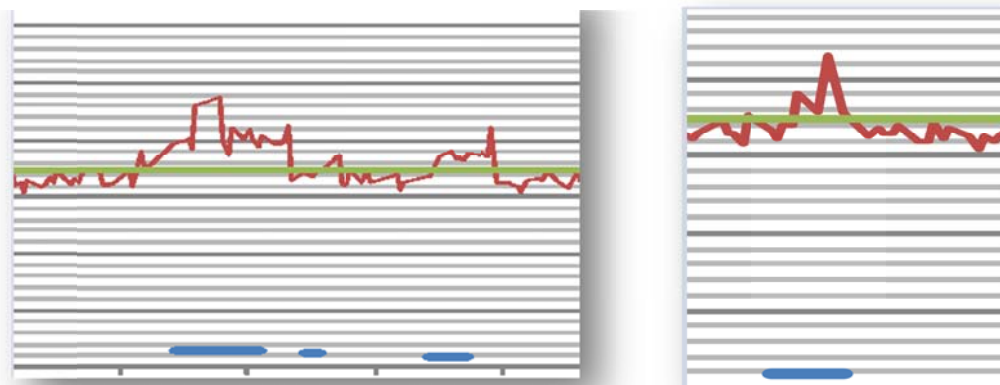
### **FAGERHAUG - ULSBERG**

The line between Fagerhaug and Ulsberg that runs for 13.82 kilometers takes a standard time of 10 minutes for train number 5733 to cross by. This is one of the most congested of the zones mapped over the range of the 72 weeks. There are four speed restriction zones in the data range at between 15<sup>th</sup> and 18<sup>th</sup> week, on the 20<sup>th</sup> week, between 24<sup>th</sup> and 25<sup>th</sup> week and the last one running between week 38 and 39 Of 2011. These zones have a restriction magnitude of 0:00:51, 0:00:45, 0:00:31 and 0:00:28 seconds respectively.





**Figure 23 Fragerhuag - Ulsberg time data and lost time due to speed restriction diagram**



**Figure 24 exploded views of the speed restriction zones Fragerhuag - Ulsberg**

As shown in figure 24 on normal days, most often the actual travel time lies below the standard time. But in the regions where the speed restriction is imposed the actual travel time graph tends to go up leading the deviation to go higher. This affirms the premises of the speed restriction having significant effect on the delays. Furthermore the change in the time lost due to respective speed restrictions magnitude also has its share of enhancing the deviation magnitude by the same or more sums. The progressive tendency of the actual time graph at the beginning to reach a pick at the middle might also be explained through the progressive severity of the restriction's background reason as time goes by. For instance if

the restriction is imposed due to construction work, in the beginning the construction work is not that intensively done and as time goes by the work reaches its major stage creating difficult ease of pass for the drivers. Then when the work comes to a closure little congestion will be imposed on the line and the train can pass through easily with less time lose due to the restriction. Thereby the actual time curve follows the same progressive trend from the beginning to the middle and declines back towards the end.

### GARLI – STØREN

The distance between these two stations extends for a length of 9.29 kilometers having another station called Soknedal between the two. Train number 5733 takes a standard time of 19 minutes to pass through the two stations. The speed restriction is imposed on the 15<sup>th</sup> week of 2011 with a magnitude of 15 minutes. The actual speed restriction zone starts on the way from Garli and Soknedal and ends on the way to Soknedal to Støren. That is why the analysis is being conducted on the margin between Garli and Støren.

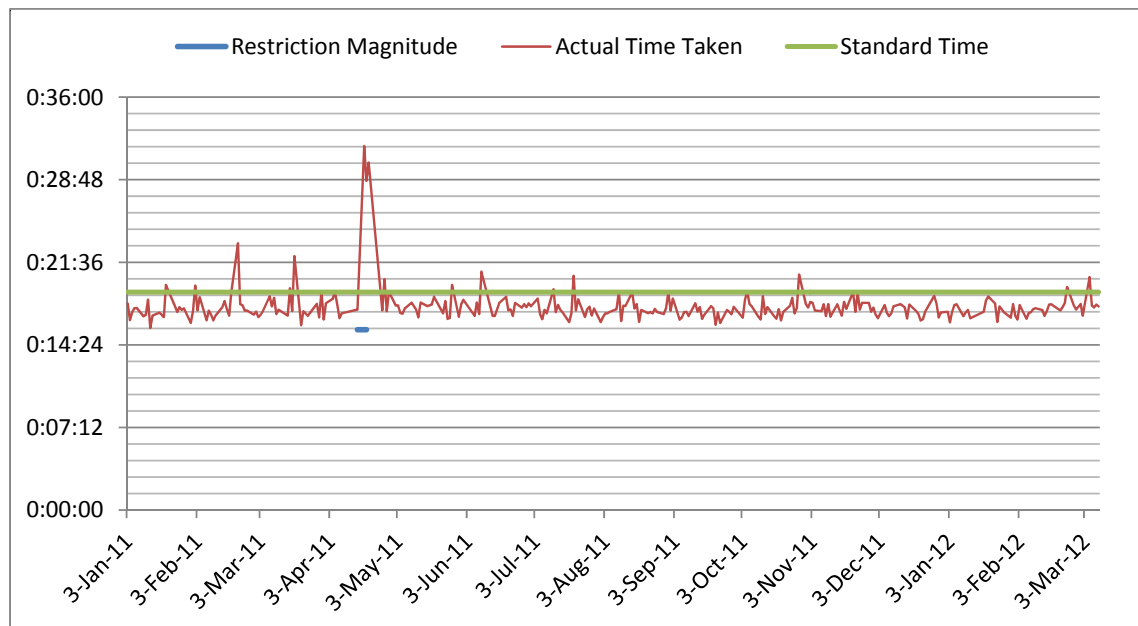
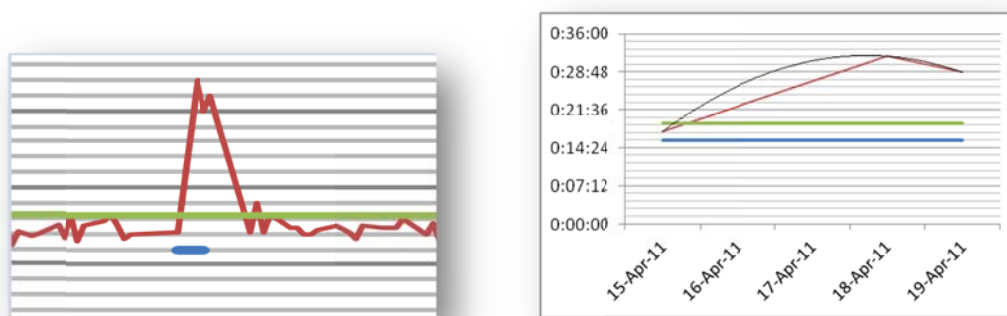


Figure 25 Garli – Støren time data and lost time due to speed restriction diagram



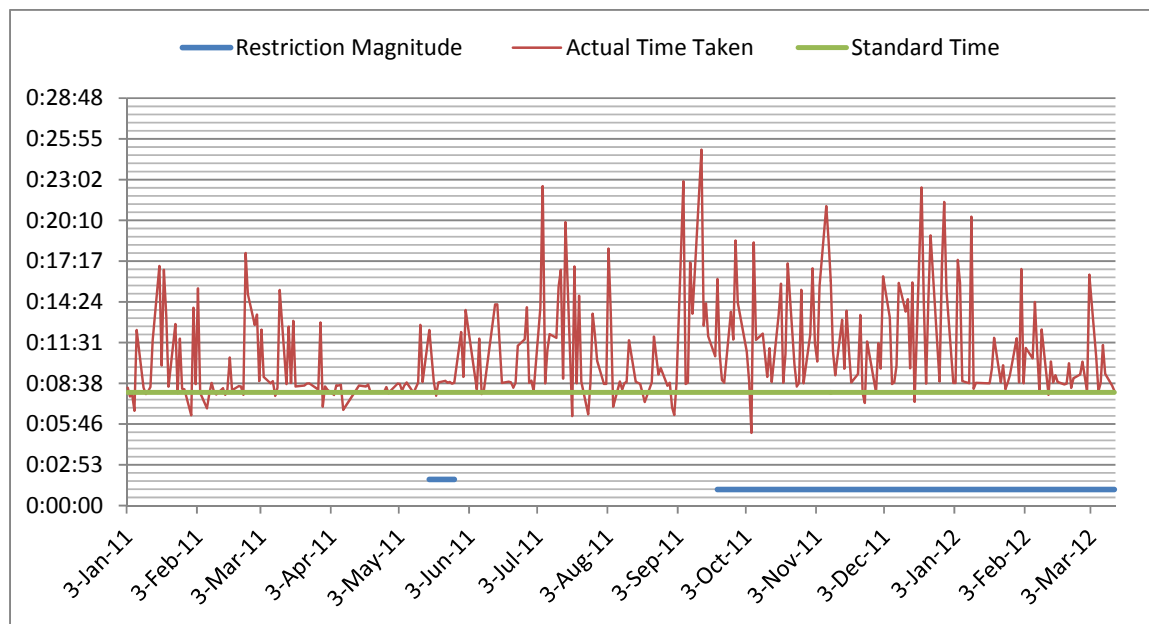
**Figure 26 exploded view of the speed restriction zone Garli – Støren**

Figure 26 shows that the actual travel time is evenly distributed along the whole data range except the speed restriction region. And often the actual time taken lies a little bit below the standard time curve. In the exploded view of the speed restriction zone shown on figure 27 the actual time curve goes up with the imposition of the restriction.

But it is interesting to see the curve even going up after the end of the restrictions imposition. This could be explained through two reasoning's. The first is a straight forward approach that, the planners could have revoked the restriction but still on the ground there were some activities or severe conditions continuing, hindering passing by and making the ease of attaining the permissible speed a difficult task for the train drivers. The second reason could be the placebo effect on the drivers; keeping on to think the speed restriction still exists even after they had been revoked. Still figure 26 affirms our working premises that the restrictions have significant effect on the delays and lost times.

### **SELSBAKK – TRONDHEIM S**

The line from Selsbakk to Trondheim S is the last segment of the line on the way from Oslo to Trondheim extending a length of 6.43. This segment takes 8 minutes of standard time for train number 5733 to pass by until it comes to stop at Trondheim S. this segment has two speed restriction ranges on between 20<sup>th</sup> and 21 week of 2011 and the one that extends from the 38<sup>th</sup> week to 11<sup>th</sup> week of 2012, which is the end of the data range. Each restriction zones have a time loss magnitude of 0:01:51 and 0:01:08.

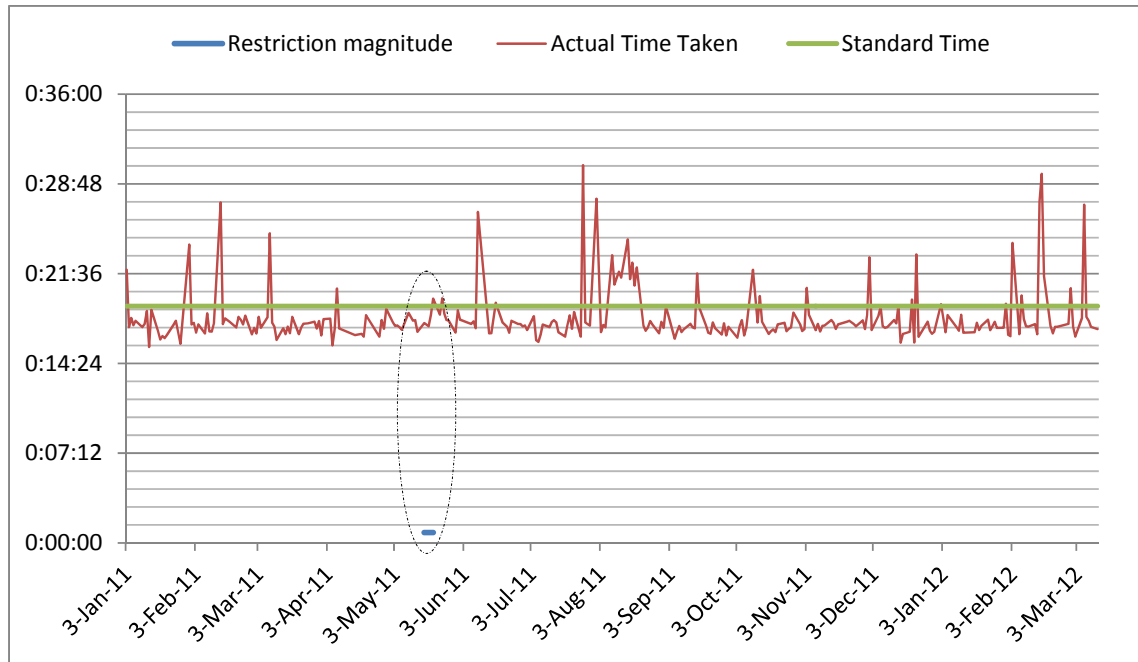


**Figure 27 Selsbakk – Trondheim S time data and lost time due to speed restriction diagram**

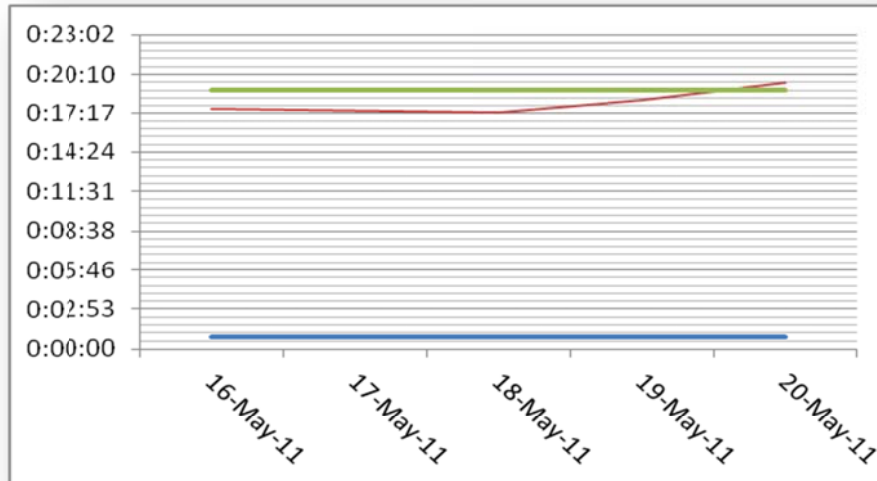
As seen on figure 28 the actual time curve, fluctuates randomly hitting higher points and all of a sudden arbitrarily moving down. Most of the actual travel time's magnitudes are above the standard time. The fluctuation could be due to the intense traffic condition near Trondheim S which could vary on daily or even hourly basis. Therefore from the diagram one can concluded there is no concrete reason to claim the speed restrictions have affected the travel time.

### **HJERNIK – DRIVSTUA**

This section of the line extends for 25.36 kilometers having a station called Kongsvoll in between. Train 5733 takes a standard time of 19 minutes to cross between the two stations. The speed restriction mapping shows that there is one restriction zone on the 20<sup>th</sup> week of 2011 on this segment of the line with a magnitude of 0:00:50. This restriction zone was stretched between Hjernik and Drivstua leaving out kongsvoll in between, because of the fact that the restriction zone lays the whole way across Kongsvoll station. The restriction zone starts on the way between Hjernik to kongsvoll and ends on the way kongsvoll to Drivstua.



**Figure 28 Hjernik – Drivstua data and lost time due to speed restriction diagram**



**Figure 29 Exploded view of the speed restriction zone Hjernik – Drivstua**

As figure 29 shows the actual travel time curve at points stabilizes and have a uniform variation but abruptly there are some bumps noticed making the variability irregular. Referring to both figure 29 and figure 30 although there is a small inclination in travel time

curve, it is difficult to conclude the speed restriction have significant effect on the travel time as compared to other noticeable upward fluctuations across the data range.

### OPPDAL - FAGERHAUG

This segment of the line extends for 12.07 kilometers and it takes 8 minutes of standard time for train number 5733 to cross the section. There is one restriction zone in the data range between 33<sup>rd</sup> and 34<sup>th</sup> week of 2011 with a magnitude of 0:04:44.

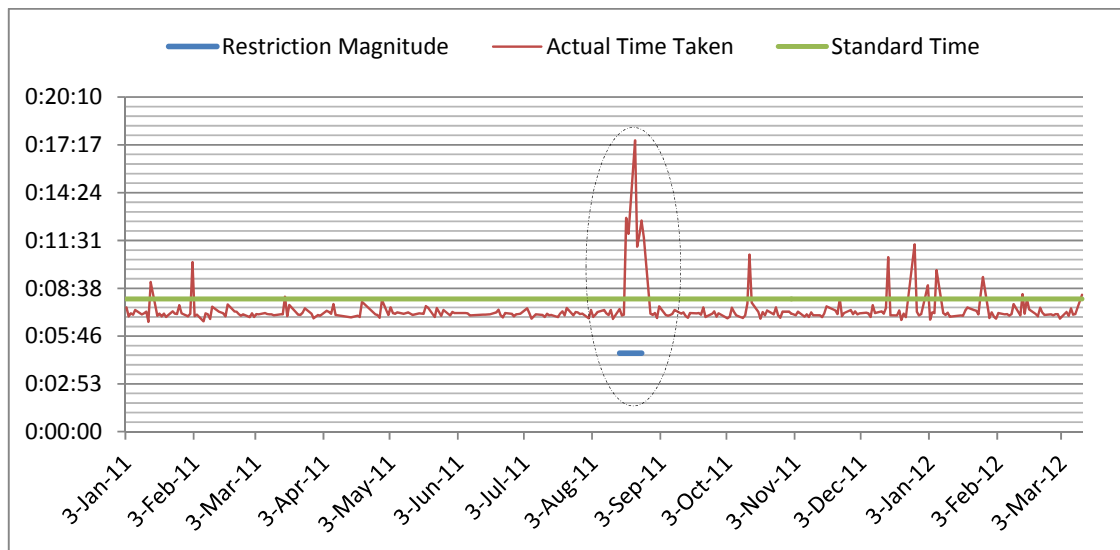


Figure 30 Oppdal – Fagerhaug time data and lost time due to speed restriction diagram

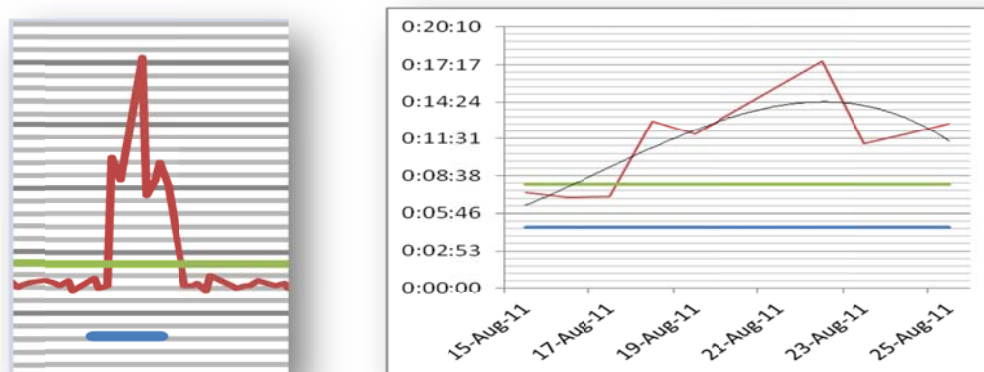
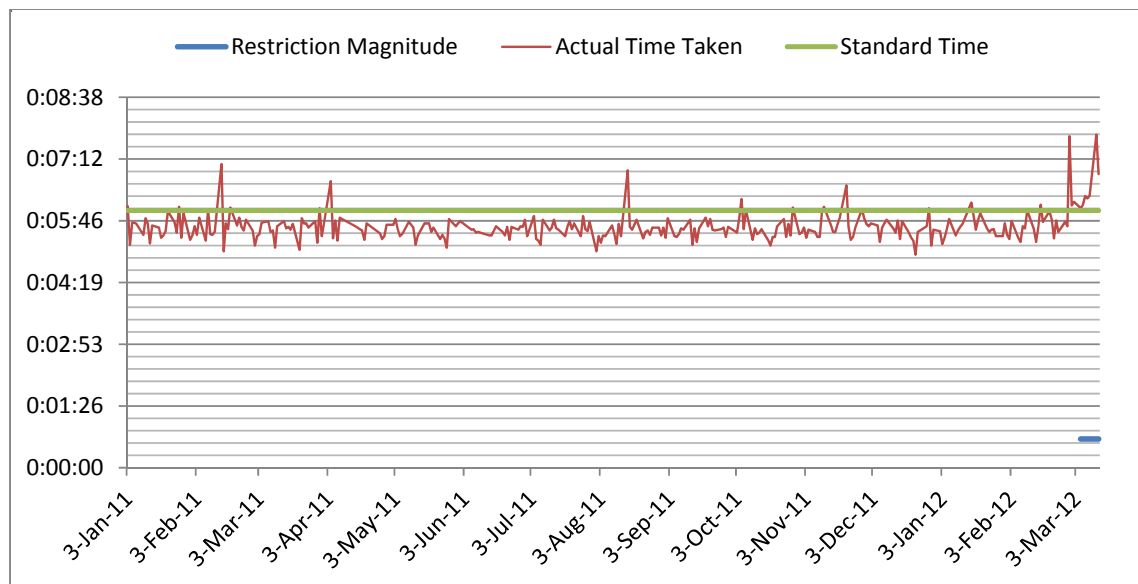


Figure 31 Exploded view of the speed restriction zone

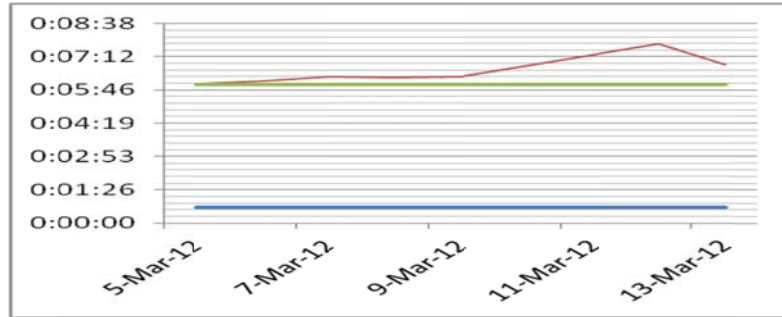
Looking in to figure 31 one can easily see that the actual travel time is regularly distributed and centered below the standard time except few bumps and larger deviation in the speed restriction zone of the data range. Zooming in to the restriction zone in figure 32 it is seen that the Zooming in to the restriction zone in figure 32 it is seen that the imposed restriction first seemed to cause no effect at all but starts to kick of lifting the actual time curve upper as time goes on. But after the imposed restriction was over the actual time curve goes a little bit higher for a while and comes back to the regular variation stream. This only is explained through the mismatch of the planned restriction schedule and what actually happened on the ground. This means that the speed restriction was imposed on the ground later than what was written on the weekly planned speed restriction schedule and also the restriction was revoked later than what was set to be the due date . Still figure 31 as well as figure illustrates the fact that the speed restrictions had a significant effect on the given span.

### LER – SØBERG

This segment of the line extends for 8.28 kilometers and takes a standard time of six minutes for train 5733. This section contains one speed restriction zone on the 10<sup>th</sup> and 11<sup>th</sup> week of 2012 with an associated time loss of 0:00:40.



**Figure 32 Ler – Sjøberg time data and lost time due to speed restriction diagram**

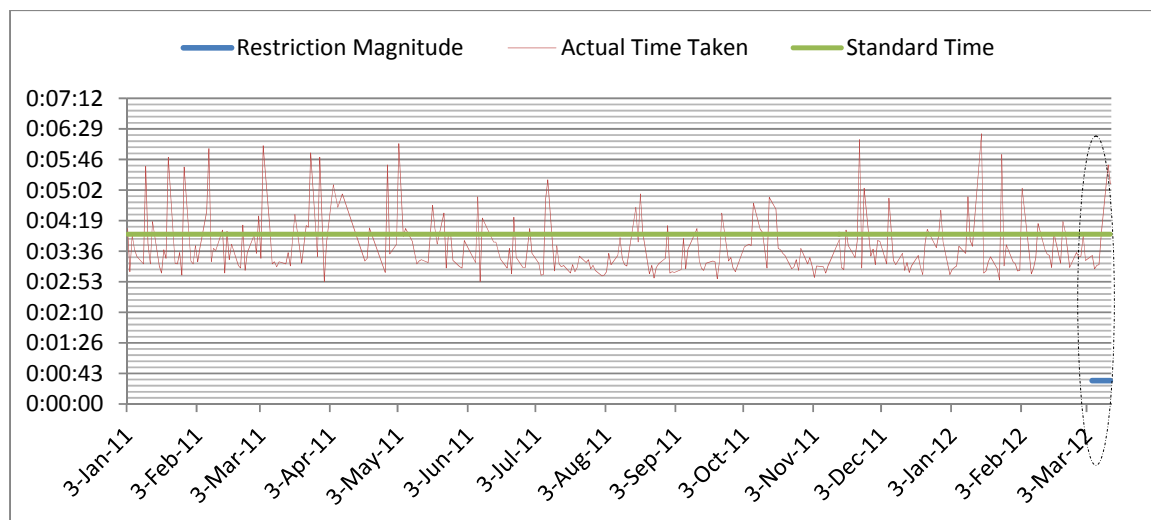


**Figure 33 Detailed view of the speed restriction zone Ler – Sjøberg**

As can be seen on Figure 33 the travel time is uniformly varied centering a little bit below the standard time. If we look further in to the speed restriction zone unlike the patterns throughout the time range the curve tends to go up centering well above the standard time curve. Hence this also confirms our premises on the effect of speed restrictions on actual travel time. Since the collected data range is the end of the limit further conditional implication of the effect could not be noticed.

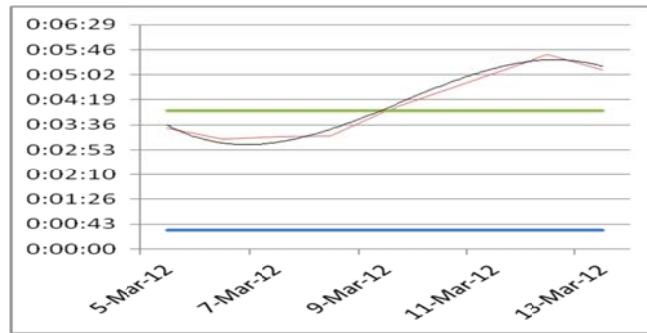
### NYPAN – HEIMDAL

The distance between these two stations runs for a length of 4.3 kilometers and takes a standard time of 4 minute for train 5733 to pass through. This segment of the line contains one speed restriction zone in the data range in the 10<sup>th</sup> and 11<sup>th</sup> week of 2012 with a magnitude of 0:00:33.



**Figure 34 Nypan – Heimdal time data and lost time due to speed restriction diagram**





**Figure 35 Detailed view of the speed restriction zone Nypan – Heimdal**

Figure 34 shows that the actual time taken curve fluctuates above and below the standard time line in a non uniform pattern. But looking further in to the speed restriction zone; even though the travel curve goes high in an increasing fashion, it is difficult to deduce a conclusion that was caused by the introduction of the restriction. As the collected data range ends at this point we are in no position to say if it was affected or not affected by the imposition. Hence we can't use the data analysis between Nypan and Heimdal as a supporting argument for our premises.

In general we can state that most of the analysis done shows that, as long as there is sufficient data, uniformity and regular fluctuation of the time magnitudes on the curves the actual time curve is lifted up above the standard line curve with a significant margin. This in turn a strong finding that supplements our approaches premises. Therefore we can say that there is an increasing effect caused and trend displayed on the actual time taken in the presence of the speed restrictions.

### **The correlation between restriction magnitude and deviation**

From the first approach it was seen that the introduction of speed restriction have significant effect on the actual travel time there by affecting the deviation of the travel time from the planned standard time. But it is not clear how the magnitude of the lost time due to restrictions have affected the deviation itself. Therefore to investigate in to the correlation between the magnitude of the lost time due to restriction and the associated deviation one need to go for the second approach. In the second approach tries to look in to the correlation between the lost time due to the speed restriction and the deviation, with

the premises of the deviation of the going up in line with an increase in the magnitude of the computed lost time in the introduction of the speed restriction.

This premise is built up on the contextual understanding of the train drivers assuming higher restriction magnitudes causing larger delays. To look in to this scenario this section tries to compute the deviation of each recorded actual time from the planned standard time and plots it on a graph against respective lost time magnitudes. Looking at the plots on the graph we will check if there happens to be an increasing, decreasing or random trained in the plot itself. This could be done in two ways; first plotting the actual deviation magnitude against the lost time magnitudes and the second one by plotting the percentage of deviation against the lost time. To do so one need first to compute the deviations and the percentage of deviations. This is computed using the formulas below.

$$\textit{Deviation magnitude} = \textit{Actual travel time} - \textit{Standard time}$$

$$\textit{Percentage of Deviation} = \frac{\textit{Devaitin magnitude}}{\textit{lost time due to restriction}}$$

$$\textit{Lost time percentage} = \frac{\textit{lost time due to restriction}}{\textit{standard time}}$$

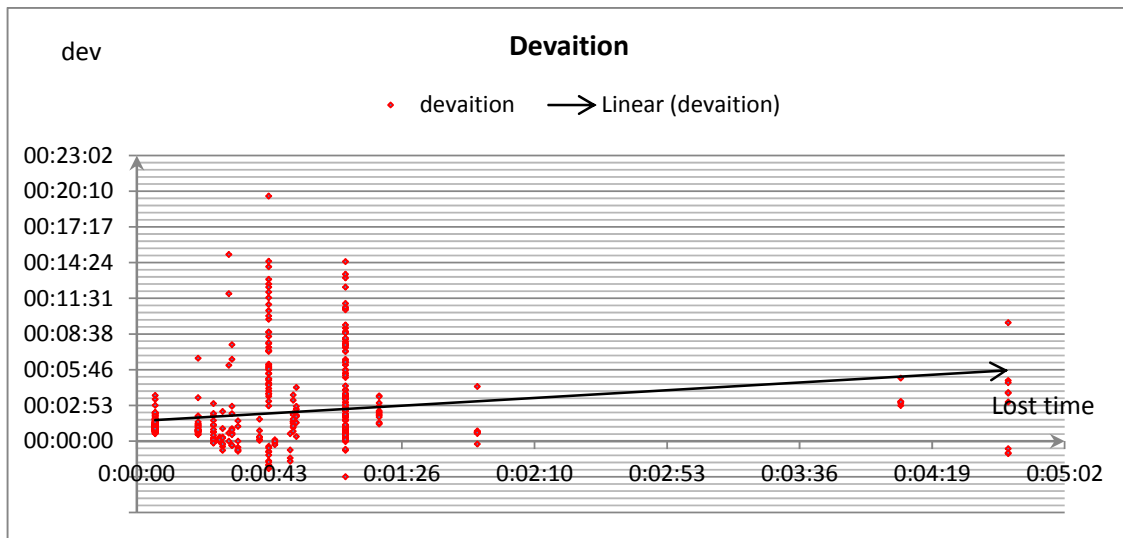
$$\textit{Deviation percentage} = \frac{\textit{Devaition magnitude}}{\textit{Standard time}}$$

Percentage of deviation serves as a key factor to express deviations in terms of their basic cause. Some small lost times could cause larger deviations compared to their own magnitude; may be three times the computed lost time and at same time larger computed lost times due to restriction may cause as half as their magnitude. But for someone who is concentrating barely on caused deviations he/she would infer the larger the lost time the larger would be the deviation. Therefore not to fall in this trap of delusion there needs to be a consideration to take in to account the percentile of the deviation itself.

Plotting the computed deviation magnitude against the lost time will only show how specific magnitude of restrictions have brought lost time and how the trend is displayed if there is one. Whereas plotting the percentage of the deviation against lost time will provide in depth understanding of the criticality as well as the intensity of the speed restriction magnitude itself; thereby also providing an opportunity to investigate in to trends if there happens to be one.

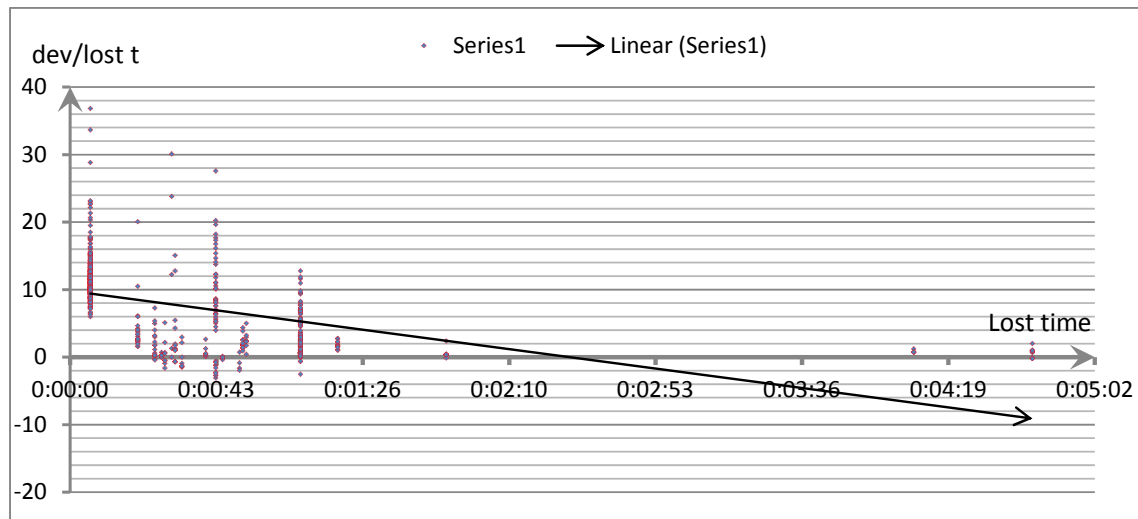
Even though the above notion seems true, there should be a consistency in data type and external factors that will affect the delay of the train in addition to the restrictions. As the set up and the affecting factors on travel time do vary along the line from station to station it calls for the need of normalization. The normalization could be done in two ways either with utilizing factors on the computation or introducing constant denominator that could give a common basis for the computations.

To do so the second way, which is introduction of a consistent denominator is preferred for this condition. Therefore we will compute the both the percentage of the lost time and the deviation percentage. This will enable us to look in to how lost time due to restriction and deviation will vary in line with the standard time. This will be done in such a way that the percentage of the deviation will be computed and rated against respective standard times. Similarly the lost time due to restriction will be rated in percentiles with respect to their standard times. Here the standard time will serve us a basis of consistency for the computation as well it will enable a common ground and base factor to reduce inconsistencies due to variation in stations. Plotting the percentage of lost time due to restriction against the percentile of deviations will give us a primary basis for conclusion when it comes to investigating the relationship between magnitude of lost time due to restriction and the associated deviation in travel time.



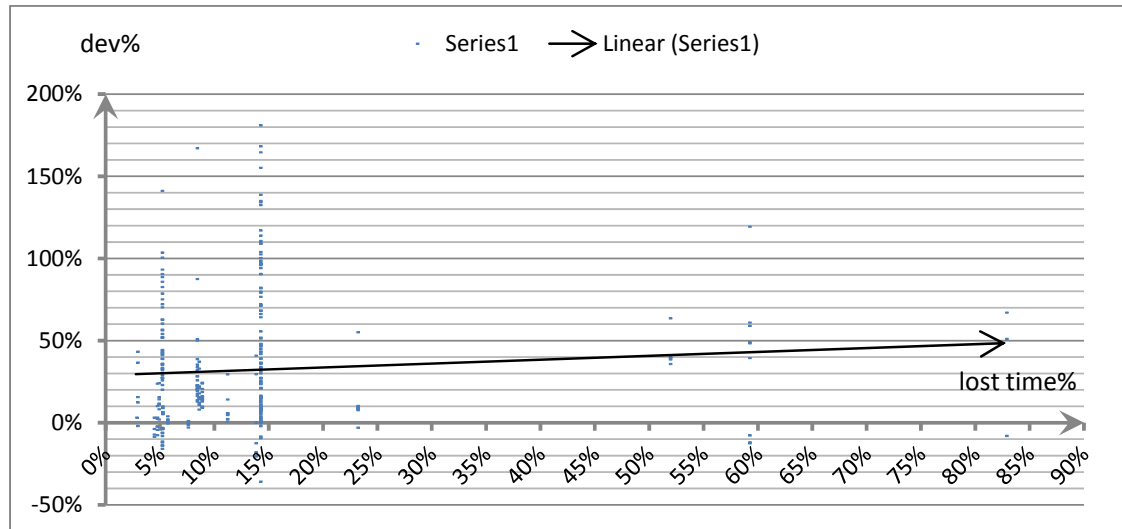
**Figure 36 plot of the deviation magnitude against respective time lost due to deviation with correlation factor of 0.092**

Figure 36 displays the first way of plotting the deviation magnitude against lost time due to imposition of the restriction. The trend shows that starting from a time loss of 0:00:06 until 0:00:43 there is an increasing trend in lost time and then a decreasing and increasing patterns fluctuate randomly until it reaches 0:01:19. After wards the graph shows an increasingly upward curve. This implies with magnitudes larger than 0:01:19 the graph has an increasing trend. Therefore we can state that for this data range collected; for speed restrictions which have a computed time loss of greater than 0:01:19, the larger the magnitude of the speed restriction the higher will be the associated deviation. Fitting the time magnitude points on the scatter diagram with Microsoft excel an increasing linear curve displayed as Linear (devaition) on the legend is obtained. This illustrates as the time lost increases there is an associated increase in the actual travel time taken. Hence somewhat for this data range, time loss due to restriction has positive impact on the associated deviation in the travel time. In addition while doing the correlation analysis for this data set it yielded a week correlation factor of 0.092.



**Figure 37** percentage of deviation against lost time

Figure 37 illustrates a plot of the percentage of deviation drawn against the lost time due to speed restriction. From the pattern displayed we can see that smaller lost times due to restriction tend to have larger effect on travel time, causing by far larger deviations in contrast to their magnitudes. Here further fitting points on the scatter diagram using Microsoft excel we can obtain a down ward pointed decreasing linear curve designated as linear (Series) on the legend. Hence even though small time losses due to restrictions have small magnitude compared to their intensity they have, by far higher percentage of effect. From the diagram we can see that the higher the lost time due to speed restrictions the lower the percentage of the deviations get. Hence smaller speed restrictions, it tend to have higher relative effect on the actual lost time compared to their magnitudes.

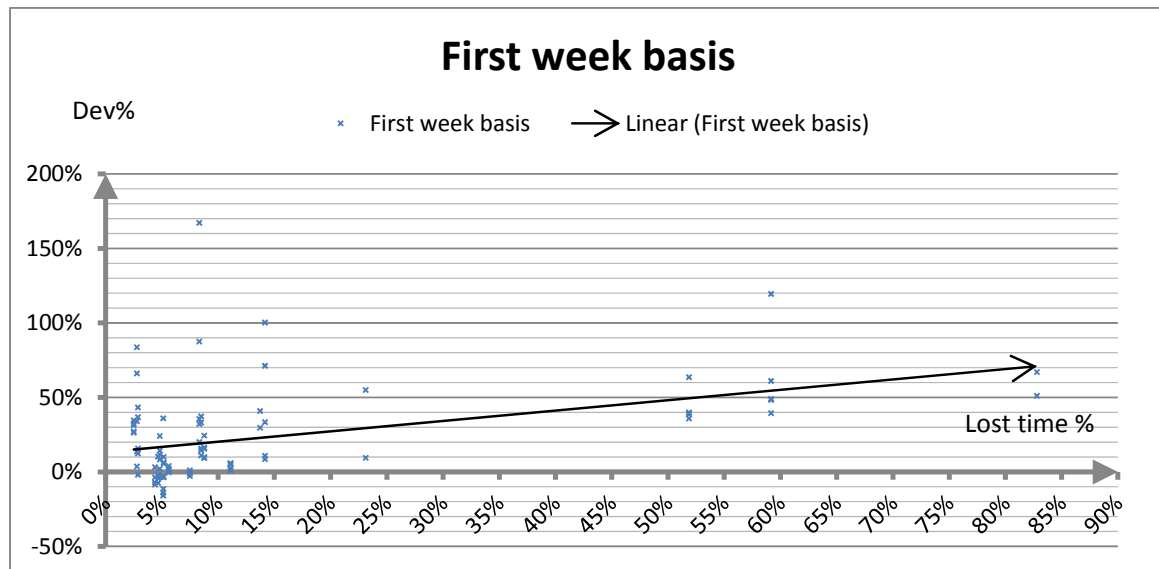


**Figure 38** scatter diagram of percentage of deviation against lost time percentage with a correlation factor of **0.135**

Figure 38 displays a scatter chart of travel time deviation percentage on the Y- axis plotted against lost time due to restriction percentage on the X-axis. From the plots and the percentages of respective magnitudes with respect to standard time percentage is the best way to look in to the correlation between these two factors. Using the standard time as a common of computation will ensure the consistency of the data as well serves a purpose of normalization of the whole data set. Fitting the scatter diagram points in to a curve using the curve fitting option on Microsoft excel the curve noted as Linear (Series 1) is obtained. Although; the slope of the curve is so small, it depicts an increasing trend in the percentage of deviation in line with increasing the lost time due to restrictions. Here in accordance to the primary background premises of the thesis, what has been expected was a perfect linear upward pointed curve especially for lost time magnitudes more than 4% of the standard time. While conducting a correlation analysis for the whole data range including the whole restriction period, it was found out that the percentage of lost time due to speed restriction and the adjacent deviation percentage has a correlation factor of 0.135. Extending and limiting the correlation analysis to peak values only somewhat similar correlation factor of 0.185 was obtained. The small angle of inclination or lower slope of the fitting curve implies there appears to be low correlation between the percentage of deviation and the associated lost time due to restriction. This weakness in the correlation, for the whole data set might be due to in consistency in the setting and nature of the data considered, as the analysis has

been conducted on different stations on different seasons throughout the years. Variation in season of the year will imply varied external effects on the travel time itself. For instance equivalent restriction magnitudes in summer and winter have varied ultimate effect on the actual travel time thereby on the percentage of deviation itself. Furthermore the topographic setup and related conditions on speed restriction zones varies along with the stations hence it makes it difficult to conduct a consistent analysis along the line. Finally the 4% allowances added on the computed standard times had their own effect absorbing the speed restriction effect from manifestation. On figure 38 above, this had been purely the case for data ranges of lost time percentages lower than the 4% allowances absorbing the effect and showing random variation. But for percentage of time lost more than 4% the trend has been somehow an increasing curve.

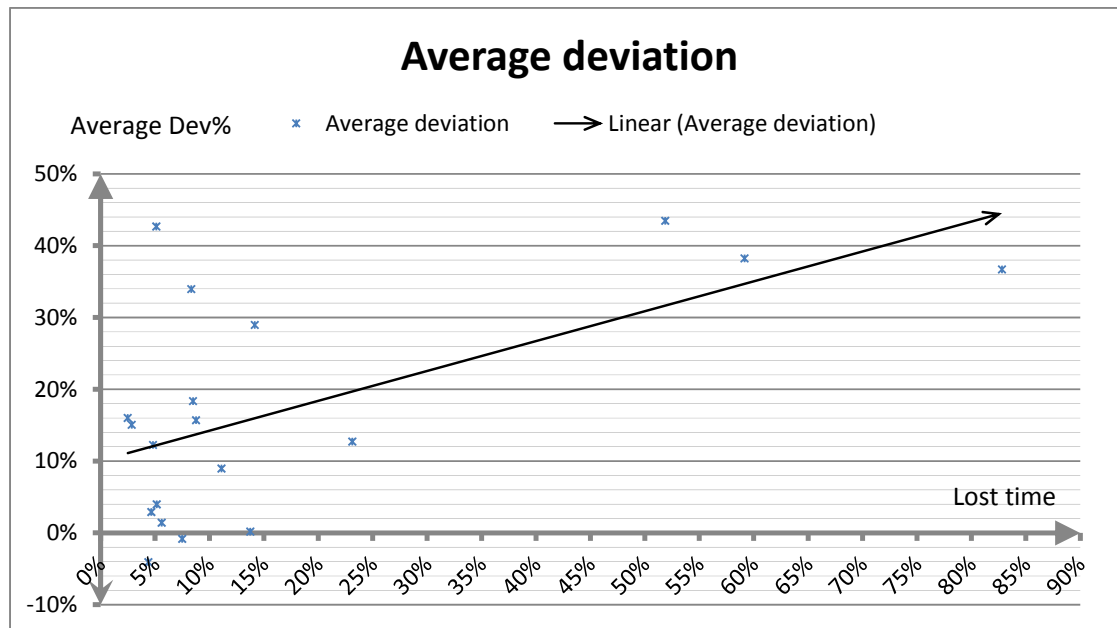
With this weak or no correlation witnessed further efforts have been made to dissect the data in to first week of imposition of the restriction. This is done as there was a tendency or trend of increment in the first weeks of the time diagram graphs of respective zones. While conducting the correlation analysis for this data segment it was found out that the percentage of lost time due to speed restriction and the adjacent deviation percentage has a correlation factor of 0.433. With this finding the percentage of deviation for the first weeks was plotted against the adjacent percentage of time loss due to restriction. Fitting the scatter diagram points in to a curve using the curve fitting option on Microsoft excel the curve noted as Linear (First week basis) is obtained. This shows an increasing curve with increased slope as shown in figure 39 below.



**Figure 39** scatter diagram of percentage of deviation against lost time percentage on first week basis with a correlation factor of 0.433

With this context and new finding in mind further work was done to normalize the data set of deviation percentage and lost time due to restriction percentage. This was done in order to reduce noise of the data and to avoid misinterpretations caused due to arbitrary data with extremely maximum and extremely minimum values. In doing so the average deviation for respective time losses due to restriction percentages was computed. This is done in such a way that the deviation percentages were averaged based on their respective time losses percentages due to the restrictions categories. This means the deviation percentages of individual speed restrictions were averaged. After this, correlation analysis was conducted on Microsoft excel for the average deviation percentages and the respective time losses percentages due to restrictions. This correlation analysis yielded a correlation factor of 0.595. This is a significant number showing a tendency towards a strong correlation. With this finding the average deviation percentage for the data set was plotted against the adjacent percentage of time loss due to restriction on a scatter diagram. Further fitting the scatter diagram points in to a curve using the curve fitting option on Microsoft excel the curve noted as Linear (Average deviation) is obtained. This shows a further increasing curve with added increased slope than the plots so far, as shown in figure 40 below.





**Figure 40** scatter diagram of average deviation percentage against lost time percentage with correlation factor of 0.595

On figure 40 the y axis represents the averaged values of the deviation for individual speed restrictions **whereas** the X-axis displays the percentage of lost time for individual speed restrictions. This graphical illustration on figure 40 and the obtained correlation factor of 0.595 from the correlation analysis shows there is somehow a positive tendency towards correlativeness between the average deviation percentage and the lost time percentage. (See appendix).

Further working correlation analysis was made on the average deviation percentage of the data set for more than 4% of the time lost percentage due to restriction. From the correlation analysis it was found out that the average deviation percentage and percentage of time lost due to restriction are correlated by a factor of 0.603 (see appendix). The increase in the correlation factor after the 4% is as expected the fuzzy boundary of correlations that came in to existence due to 4% time allowances added on the standard time. Therefore omitting the extreme values or normalizing them using averaging statistical tool one can see there is a correlation between deviation magnitude and the associated time loss due to restrictions.



## Conclusion

This conclusion part is structured in such a way that, it presents the conclusions made on the course of addressing the research questions.

### To what level of detail should such studies be done?

For data analysis involving investigation in to speed restriction care should be taken in selecting the appropriate tools of analysis. On the course of conducting this thesis it was found out that restriction zone mapping and statistical analysis play the major role. In addition diagrammatical plotting of data sets on Microsoft excels and inferring implications is of high prominence. Specifically curve fitting and line plots on will take the biggest share of the implication deduction part enabling a clearer understanding of outputs.

The actual Travel time and standard data sets collected also plays of high significance when it comes to the ultimate outputs of the analysis and the thesis itself. The data set should be consistent and accommodating when it comes to different attributes that would affect travel time or else it should be normalized to mitigate interference. Otherwise it is difficult to get grasp of the clear image and effect of speed restrictions, as different factors such as topography, climatic conditions, seasonal variation, travel direction and type of train might affect and sub standardize the analysis.

In this thesis work efforts has been employed to ensure the consistency of the analysis and data sets collected. In this virtue the analysis was done on freight 5733 with lots of punctuality complaints history. This has enabled the manifestation of trends on speed restrictions to greater extent. In addition to keep uniformity of the analysis similar analysis tools has been utilized throughout the work including normalization by averaging and percentiles.

## Relationship between speed reductions and delays

### Trend based relationship

From the analysis of most restriction zones and fitting curves of the travel times in the restriction zone; it was found out that, for most of the restriction zones the travel time tends to go up to reach its pick and declines again to lower magnitude towards the end. This tendency is associated with the time based build up of learning curves of the drivers getting accustomed to the restriction zone after a while. Furthermore progressive severity of the reason behind the imposition of the restriction could also offer an explanation for this phenomenon. In the restriction zone between Lundamo and Ler it have been noted that, the speed restriction has been imposed more than a year and a half. This type of restrictions as they long last rather than imposing them as temporary restrictions they should be incorporated in to the standard time and should be set as a permanent restriction.

Also in some of the analyzed restriction zones cyclical variations has been noted which has been explained by seasonal or cyclical variation on the root cause of the restriction imposition itself and change of drivers bringing in to play different learning curves the drivers. Most often lifting of the standard time and random shootings in travel time were explained through imposing and revoking of restrictions ahead of time, placebo effects in play on drivers and unbalanced special recovery times.

Looking in to the analysis done on the 13 restriction zones it was found out that as long as there is sufficient data, uniformity and regular fluctuation of the time magnitudes on the curves the actual time curve is lifted up above the standard line curve with a significant margin. Visual inspection of the graphs indicated that the impact of speed restriction was greater during the beginning of the period. This supports the premises of this thesis assuming existence of an increasing trend in the relationship between the lost time due to restriction and deviation for some range of data. Therefore there is an increasing effect caused and trend displayed on the actual time taken in the presence of the speed restrictions. This strengthens one of the research premises of speed restrictions having effect on the actual travel time thereby causing delays.

## Magnitude based relationship

While working on the relationship between lost times due to speed restrictions and magnitude of the caused deviation, even if the fitting curves has directed an increasing tendency. First it was found out that there was a weak correlation between the percentage of the lost time and the percentage of the caused deviation for the whole data set. But for some data sets above the 4% allowances there, tends to be a positive correlation. The correlation analysis on first weeks based on the imposition of the speed restriction also showed a greater correlation with a factor of 0.433. These led to conducting an average deviation percentage analysis to normalize the data; in which the correlation analysis yielded a correlation factor of 0.595. This showed somehow there is a positive tendency towards correlativeness between the average deviation percentage and the lost time percentage. In addition correlation analysis made for speed restrictions greater than 4% lost time showed that there is an increased correlation factor of 0.603. This is an indication that the fuzzy boundary of correlations somehow lies on the 4% zone. This fuzzy boundary might come in to existence as a result of the added 4% allowance which is usually added by the railway time planners on the standard time. Therefore it could be concluded that, omitting the extreme values or normalizing them using averaging and percentile statistical tools there is a correlation between deviation magnitude and the associated time loss due to restrictions. Hence this depicts the fact that there needs to be further work to be done with consistent data sets on fixed positions to clearly zoom in to the real effects displayed.

In the relationship analysis it was interesting to note that small time loses associated with lower restrictions tend to cause higher effect of intensity compared to their magnitude. While fitting such curves it was found out there tends to be a decreasing curve illustrating smaller reductions having significant percentile effect than bigger ones.

The lack of the anticipated purely increasing or strongly correlated pattern between percentage of lost time due to restriction and associated deviation magnitudes is an opportunity for further researches in the thematic area. This could be surmounted by studying and analyzing the restriction zones with consistent data, specific seasons and focused areas on the restriction zones. Furthermore expanding the range of the data to include more percentage of lost time magnitudes, differ directions along segments and

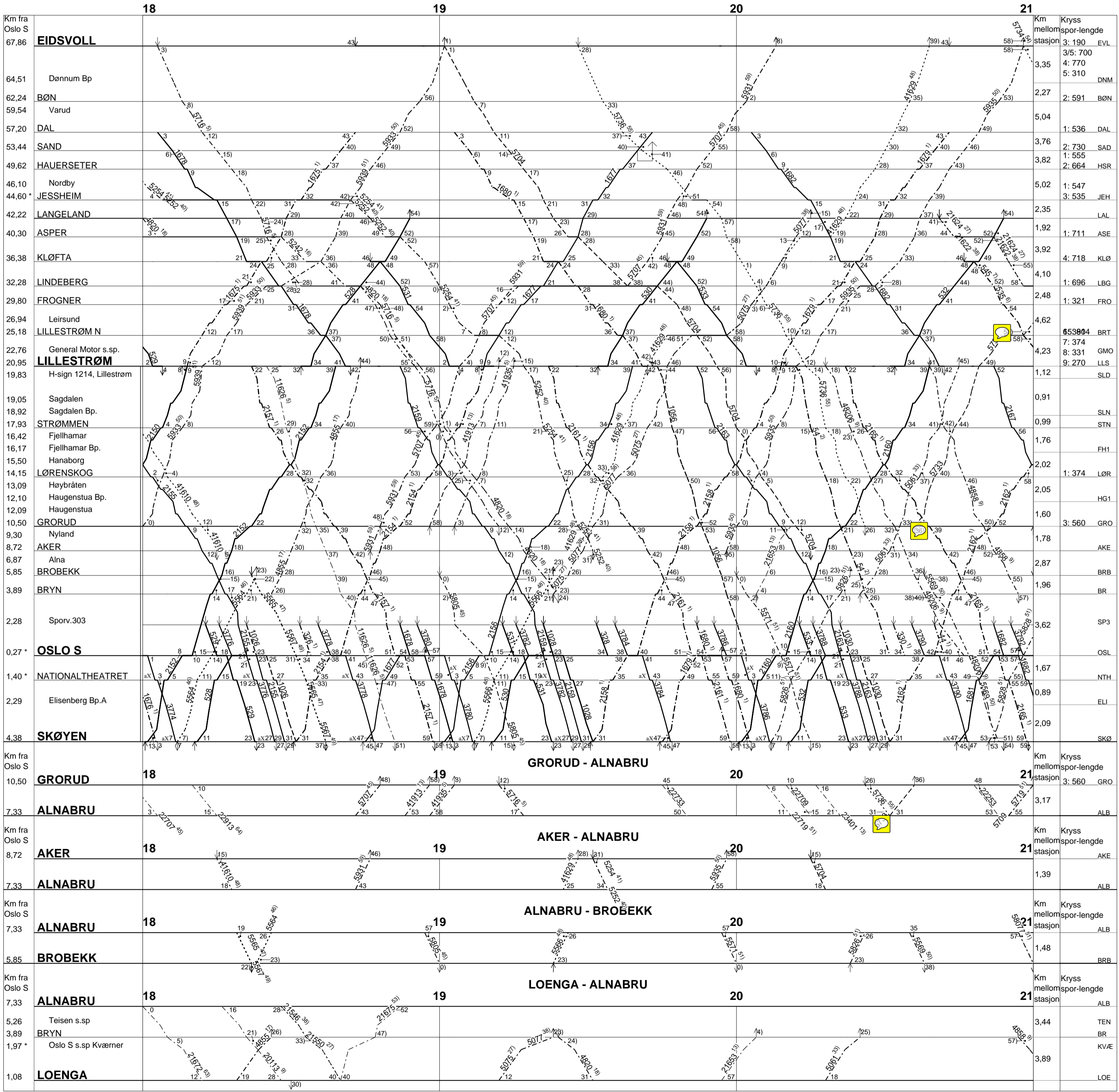
varied types of trains would lead to refined results. In addition causes of different levels of correlations between the lost time and deviation along the route are other thematic areas whereby supplementary researches could be conducted.

## Appendix

<b>Time lost due to restriction %</b>	<b>Average Deviation percentage</b>		
2.50%	16.00%		
2.87%	15.05%		
4.39%	-4.08%		
4.67%	2.90%		
4.81%	12.26%		
5.12%	42.67%		
5.17%	3.97%		
5.63%	1.42%		
7.50%	-0.83%		
8.33%	33.94%		
8.50%	18.35%		
8.78%	15.69%		
11.11%	8.97%		
13.75%	0.18%		
14.17%	28.96%		
23.12%	12.71%		
51.88%	43.46%		
59.17%	38.22%	<b>N= 20</b>	
82.81%	36.70%	<b>Correlation Factor</b>	<b>0.595</b>

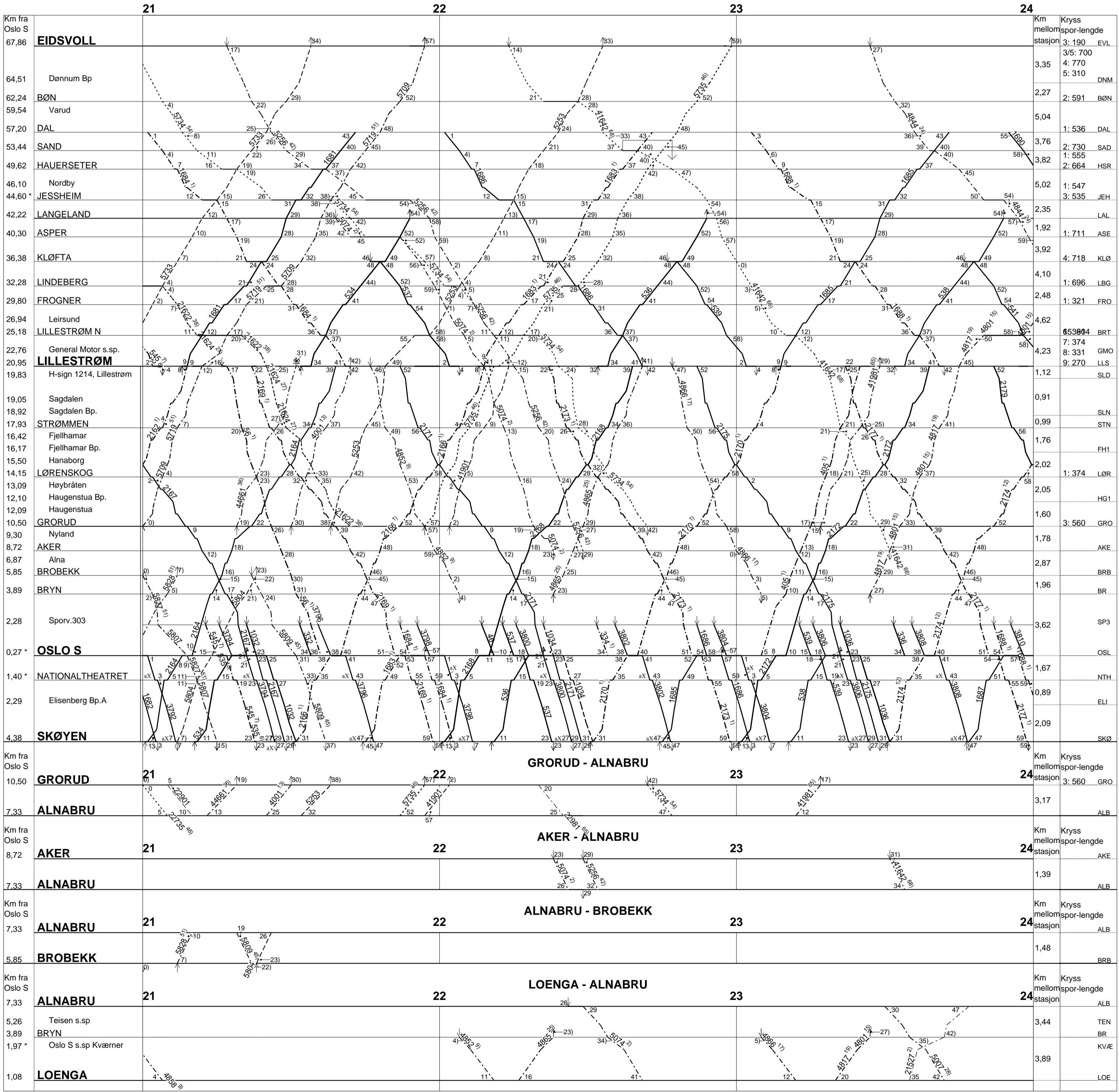
<b>Time lost due to restriction %</b>	<b>Average Deviation percentage</b>		
4.39%	-4.08%		
4.67%	2.90%		
4.81%	12.26%		
5.12%	42.67%		
5.17%	3.97%		
5.63%	1.42%		
7.50%	-0.83%		
8.33%	33.94%		
8.50%	18.35%		
8.78%	15.69%		
11.11%	8.97%		
13.75%	0.18%		
14.17%	28.96%		
23.12%	12.71%		
51.88%	43.46%		
59.17%	38.22%		
82.81%	36.70%	<b>N= 18</b>	
		<b>Correlation Factor</b>	<b>0.6026</b>

BLAD NR. 9	RUTEORD. NR.	GJELDER FRA OG MED:
<b>SKØYEN - OSLO S - EIDSVOLL</b>	<b>161.1</b>	<b>Søndag 11. desember 2011</b>
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Kløfta - Loenga Fredager unntatt dag etter helligdag.	25) 4865 Torsdager. 26) 5003, 21533, 40964 Mandager, torsdager og fredager. 27) 5005, 5075, 21535, 21548, 21550, 21624 Tirsdager og onsdager. Kjøres bare etter særskilt kunnngjøring. 28) 5007, 21062 Tirsdager og onsdager. 29) 5021, 5022, 5032 Tirsdager og torsdager unntatt helligdager. 30) 5031 Tirsdager, torsdager og lørdager unntatt helligdager. 31) 5057, 5058 Onsdager og torsdager unntatt helligdager. 32) 5060 Onsdager, torsdager og fredager unntatt helligdager. 33) 5061 Tirsdager, onsdager og torsdager unntatt dag før helligdag. 34) 5064, 20104 Mandager unntatt helligdager. 35) 5066 Tirsdager - fredager unntatt helligdager. 36) 5071, 5072, 21534, 21538, 21620, 44660, 44661 Mandager - fredager. 37) 5076, 21529 Onsdager og torsdager. 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Kjøres bare etter særskilt kunnngjøring. 50) 5569, 5933, 5935 Mandager - torsdager unntatt helligdager og dag før helligdag.	51) 5571, 5719, 5821, 5826, 5827, 5828, 5937, 5939, 21673, 22719 Helligdag før hverdag. 52) 5706, 5806, 5808, 5814 Tirsdager - fredager unntatt dag etter helligdag. 53) 5718, 5820, 10353, 21675, 45989 Hverdag etter helligdag. 54) 5734 Onsdager, torsdager og fredager unntatt helligdager og dag etter helligdag. Kjøres bare etter særskilt kunnngjøring. 55) 5736 Lørdager unntatt dag etter helligdag. Kjøres bare etter særskilt kunnngjøring. 56) 5738, 21567, 41910 Søndager unntatt dag etter helligdag. 57) 5800, 10351, 45944, 45949, 45962, 45965 Tirsdager - fredager unntatt helligdager og dag etter helligdag. 58) 5802, 5811 Mandager - fredager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 59) 5931, 48215 Fredager. 60) 11654 Dal - Lillestrøm Alle dager. Lillestrøm - Skøyen Helligdager. 61) 12001, 12002 Mandager og torsdager unntatt helligdager. 62) 21552, 41960 Tirsdager, torsdager og lørdager unntatt dag etter helligdag. 63) 21672, 41971 Fredager unntatt helligdager. 64) 22913 Mandager, tirsdager, onsdager, fredager og lørdager unntatt helligdager. 65) 22981, 41981 Mandager - torsdager, lørdager og søndager. 66) 40965 Tirsdager, onsdager og lørdager. 67) 41640, 41641 Fredager unntatt dag etter helligdag. 68) 41642 Torsdager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 69) 41643 Fredager unntatt dag etter helligdag. Kjøres bare etter særskilt kunnngjøring. 70) 41922 Torsdager, fredager og lørdager. 71) 41953 Mandager, onsdager og fredager unntatt helligdager. 72) 41973 Mandager - torsdager og lørdager unntatt helligdager.





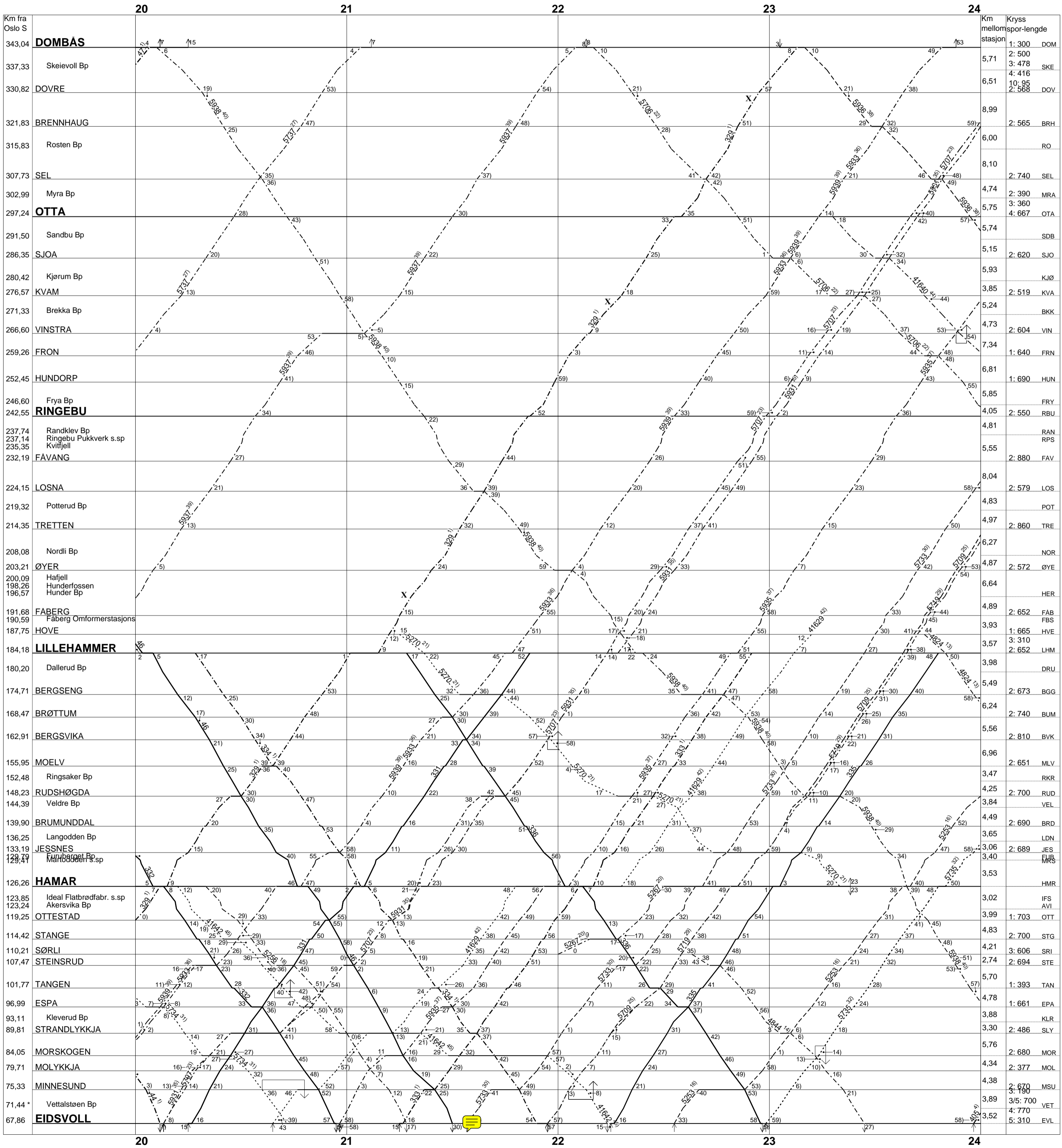
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1) 44, 56, 322, 326, 330, 334, 405, 1671, 1675, 1676, 1679, 1680, 1683, 1684, 1688, 2154, 2157, 2158, 2161, 2162, 2165, 2166, 2169, 2170, 2173, 2177 Søndager - fredager. 2) 54, 4805, 4806, 5073, 5074, 5823, 21526, 21527, 21528, 21563, 21603, 21604, 21626 Lørdager. 3) 306, 310, 314, 318, 505, 507, 1004, 1006, 1008, 1010, 1014, 1018, 1022, 1655, 1656, 1659, 1660, 1663, 1664, 1667, 1668, 1672, 2107, 2108, 2114, 2117, 2118, 2121, 2122, 2125, 2126, 2129, 2130, 2133, 2134, 2137, 2138, 2141, 21565 Mandager - lørdager unntatt helligdager. 4) 406, 2178, 41988 Mandager - lørdager. 5) 502, 4011, 5716, 5737, 11626, 11655, 21655, 22737, 23411, 41935 Lørdager unntatt helligdager. 6) 535 Mandager - torsdager og lørdager. 7) 545 Fredager og søndager. 8) 1038, 5572, 5708, 5730, 5732, 5936, 41906 Tirsdager - lørdager unntatt dag etter helligdag. 9) 1040, 4851, 4852, 4858, 4861, 20113, 21508, 21556, 41633, 41634, 41970, 45964, 48206 Søndager. 10) 1042, 5715, 11523, 11628, 22715 Helligdager. 11) 1653 Skøyen - Lillestrøm Mandager - fredager unntatt helligdager. Lillestrøm - Dal Alle dager. 12) 2174 Skøyen - Strømmen Søndager - fredager. Strømmen - Lillestrøm Mandager - lørdager. 13) 4001, 21653, 23401, 41913 Mandager, tirsdager, onsdager og fredager unntatt helligdager. 14) 4008, 21652 Onsdager - søndager unntatt dag etter helligdag. 15) 4801 Loenga - Frogner Mandager, Frogner - Eidsvoll Tirsdager. 16) 4802, 4824, 4835, 4862, 5241, 5242 Tirsdager. 17) 4811, 4855, 4857, 4866, 5938, 21061, 41637, 41638, 41924 Mandager. 18) 4813, 4820 Onsdager og fredager. 19) 4817 Loenga - Frogner Tirsdager og onsdager. Frogner - Eidsvoll Onsdager og torsdager. 20) 4822, 21537 Onsdager og torsdager. 21) 4836, 41647, 41648 Onsdager. 22) 4840 Fredager. Kjøres bare etter særskilt kunnngjøring. 23) 4843, 41632, 41645 Torsdager unntatt helligdager. 24) 4844 Eidsvoll - Kløfta Torsdager unntatt helligdager. Kløfta - Loenga Fredager unntatt dag etter helligdag.	25) 4865 Torsdager. 26) 5003, 21533, 40964 Mandager, torsdager og fredager. 27) 5005, 5075, 21535, 21548, 21550, 21624 Tirsdager og onsdager. Kjøres bare etter særskilt kunnngjøring. 28) 5007, 21062 Tirsdager og onsdager. 29) 5021, 5022, 5032 Tirsdager og torsdager unntatt helligdager. 30) 5031 Tirsdager, torsdager og lørdager unntatt helligdager. 31) 5057, 5058 Onsdager og torsdager unntatt helligdager. 32) 5060 Onsdager, torsdager og fredager unntatt helligdager. 33) 5061 Tirsdager, onsdager og torsdager unntatt dag før helligdag. 34) 5064, 20104 Mandager unntatt helligdager. 35) 5066 Tirsdager - fredager unntatt helligdager. 36) 5071, 5072, 21534, 21538, 21620, 44660, 44661 Mandager - fredager. 37) 5076, 21529 Onsdager og torsdager. Kjøres bare etter særskilt kunnngjøring. 38) 5077, 21544, 21546, 21622 Mandager, torsdager og søndager. 39) 5078, 21531 Mandager, tirsdager og fredager. 40) 5252 Tirsdager - fredager unntatt helligdager. Kjøres fra og med 29. mai 2012. 41) 5254 Tirsdager - fredager unntatt helligdager. Kjøres til og med 25. mai 2012. 42) 5256, 5816, 41630, 41631, 41676, 41677 Lørdager unntatt dag etter helligdag. 43) 5261, 5262 Mandager og tirsdager unntatt helligdager. 44) 5506 Tirsdager - fredager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 45) 5509, 5707, 5803, 5805, 5809, 22707 Mandager - torsdager unntatt helligdager. 46) 5564, 5735, 22735 Mandager - torsdager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 47) 5565 Mandager - torsdager unntatt helligdager og dag før helligdag. Kjøres bare etter særskilt kunnngjøring. 48) 5566, 41610, 41629 Fredager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 49) 5567 Helligdag før hverdag. Kjøres bare etter særskilt kunnngjøring. 50) 5569, 5933, 5935 Mandager - torsdager unntatt helligdager og dag før helligdag.	51) 5571, 5719, 5821, 5826, 5827, 5828, 5937, 5939, 21673, 22719 Helligdag før hverdag. 52) 5706, 5806, 5808, 5814 Tirsdager - fredager unntatt dag etter helligdag. 53) 5718, 5820, 10353, 21675, 45989 Hverdag etter helligdag. 54) 5734 Onsdager, torsdager og fredager unntatt helligdager og dag etter helligdag. Kjøres bare etter særskilt kunnngjøring. 55) 5736 Lørdager unntatt dag etter helligdag. Kjøres bare etter særskilt kunnngjøring. 56) 5738, 21567, 41910 Søndager unntatt dag etter helligdag. 57) 5800, 10351, 45944, 45949, 45962, 45965 Tirsdager - fredager unntatt helligdager og dag etter helligdag. 58) 5802, 5811 Mandager - fredager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 59) 5931, 48215 Fredager. 60) 11654 Dal - Lillestrøm Alle dager. Lillestrøm - Skøyen Helligdager. 61) 12001, 12002 Mandager og torsdager unntatt helligdager. 62) 21552, 41960 Tirsdager, torsdager og lørdager unntatt dag etter helligdag. 63) 21672, 41971 Fredager unntatt helligdager. 64) 22913 Mandager, tirsdager, onsdager, fredager og lørdager unntatt helligdager. 65) 22981, 41981 Mandager - torsdager, lørdager og søndager. 66) 40965 Tirsdager, onsdager og lørdager. 67) 41640, 41641 Fredager unntatt dag etter helligdag. 68) 41642 Torsdager unntatt helligdager. Kjøres bare etter særskilt kunnngjøring. 69) 41643 Fredager unntatt dag etter helligdag. Kjøres bare etter særskilt kunnngjøring. 70) 41922 Torsdager, fredager og lørdager. 71) 41953 Mandager, onsdager og fredager unntatt helligdager. 72) 41973 Mandager - torsdager og lørdager unntatt helligdager.



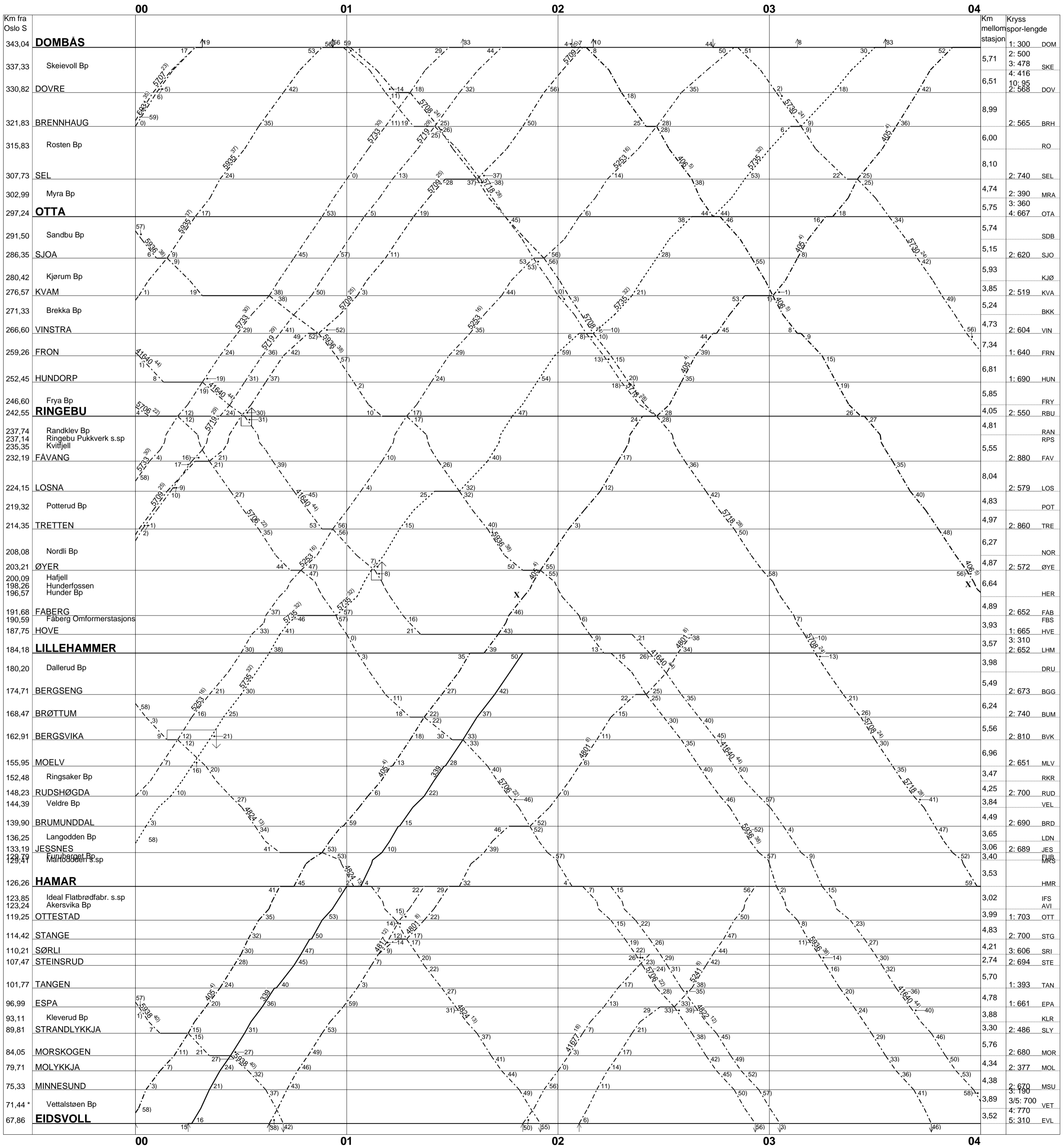
Tegnforklaring:	Togbetegnelse	Alle dager	Mandager - fredager unntatt helligdager	Andre kjøredagsmonster
	Persontog	—————	—————	—————
	Godstog	—————	—————	—————
	Løsløst, Torntog	—————	—————	—————
	Behovstog	—————	—————	—————

▲ - Ubetjent alle dager    △ - Ubetjent helligdager    ▼ - Ubetjent hverdager    ▽ - Ubetjent lørdager    ◇ - Ubetjent lørdager og helligdager    ⊗ - Om betjening, se ruteboken  
 \* - Kjedebrydd

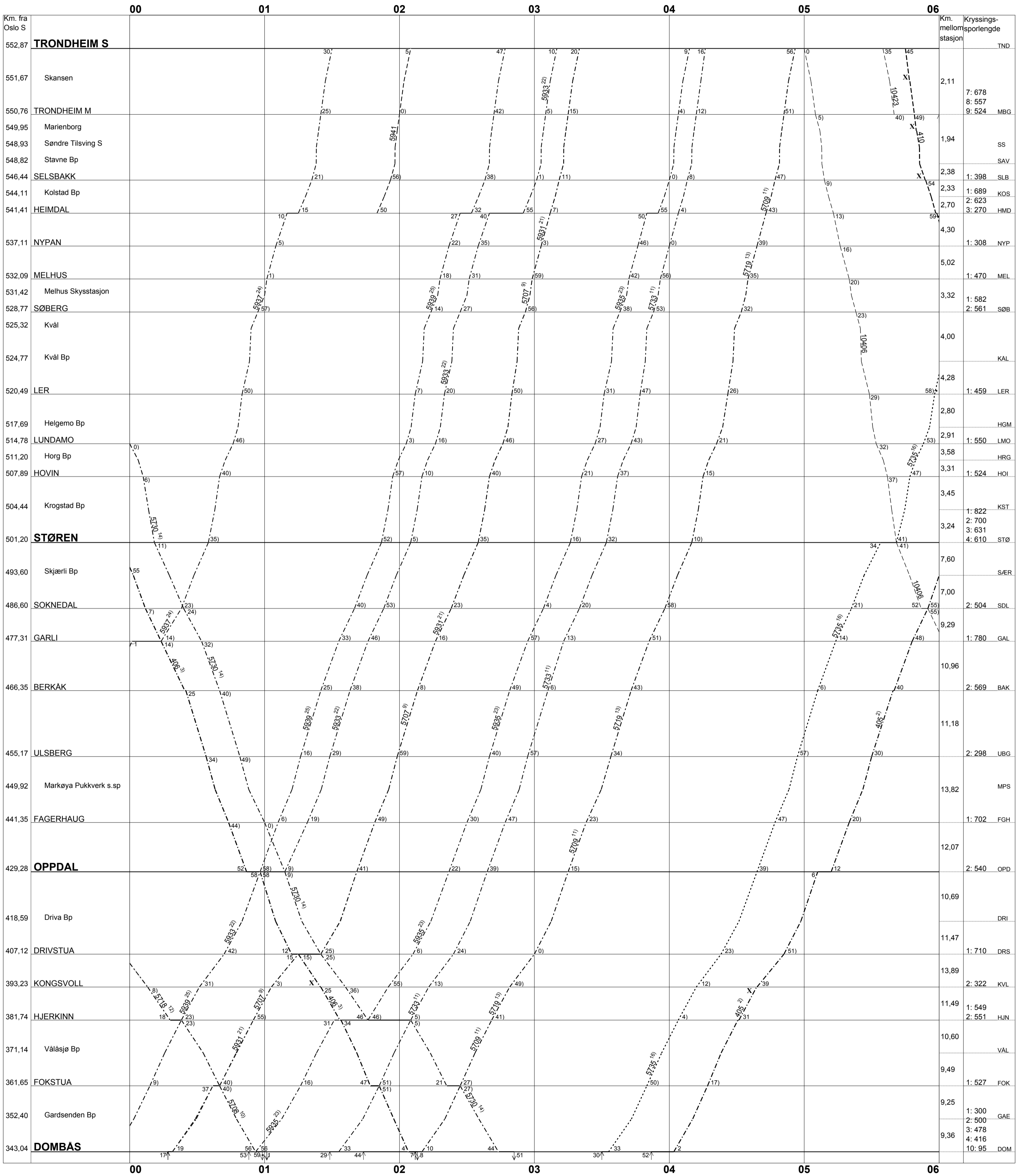
BLAD NR. 10 <b>EIDSVOLL - DOMBÅS</b>	RUTEORD. NR. <b>161.1</b>	GJELDER FRA OG MED: <b>Søndag 11. desember 2011</b>
1) 44, 47, 322, 325, 326, 329, 330, 333, 334 Søndager - fredager. 2) 306, 309, 310, 313, 314, 317, 318 Mandager - lørdager unntatt helligdager. 3) 308 Dombås - Lillehammer Mandager - lørdager unntatt helligdager. Lillehammer - Eidsvoll Alle dager. 4) 405 Eidsvoll - Minnesund Søndager - fredager. Minnesund - Dombås Mandager - lørdager. 5) 406 Mandager - lørdager. 6) 2343 Mandager - fredager unntatt helligdager. Kjøres til og med 25. mai 2012. 7) 2353 Mandager - fredager unntatt helligdager. Kjøres fra og med 29. mai 2012. 8) 4801, 4802, 5241, 5242, 6210, 6212 Tirsdager. 9) 4805, 4806 Lørdager. 10) 4811 Mandager. 11) 4813, 4820 Onsdager og fredager. 12) 4817, 4822 Onsdager og torsdager. 13) 4824 Hove - Brøttum Mandager. Brøttum - Eidsvoll Tirsdager. 14) 4843, 4844, 41645 Torsdager unntatt helligdager. 15) 5252 Tirsdager - fredager unntatt helligdager. Kjøres fra og med 29. mai 2012. 16) 5253 Eidsvoll - Rudshøgda Mandager - fredager unntatt helligdager. Rudshøgda - Dombås Tirsdager - lørdager unntatt dag etter helligdag. 17) 5254 Tirsdager - fredager unntatt helligdager. Kjøres til og med 25. mai 2012.	18) 5256, 41677 Lørdager unntatt dag etter helligdag. 19) 5261, 5262, 20347, 20348 Mandager og tirsdager unntatt helligdager. 20) 5267, 5268 Tirsdager unntatt helligdager. 21) 5269, 5270 Tirsdager unntatt helligdager. Kjøres bare etter særskilt kunngjøring. 22) 5706 Dombås - Ringebu Mandager - torsdager unntatt helligdager. Ringebu - Eidsvoll Tirsdager - fredager unntatt dag etter helligdag. 23) 5707 Eidsvoll - Dovre Mandager - torsdager unntatt helligdager. Dovre - Dombås Tirsdager - fredager unntatt dag etter helligdag. 24) 5708, 5730, 5732 Tirsdager - lørdager unntatt dag etter helligdag. 25) 5709 Eidsvoll - Tretten Mandager - fredager unntatt helligdager. Tretten - Dombås Tirsdager - lørdager unntatt dag etter helligdag. 26) 5715 Helligdager. 27) 5716, 5737 Lørdager unntatt helligdager. 28) 5718, 10353 Hverdag etter helligdag. 29) 5719 Eidsvoll - Tretten Helligdag for hverdag. Tretten - Dombås Hverdag etter helligdag. 30) 5733 Eidsvoll - Fåvang Mandager - fredager unntatt helligdager. Fåvang - Dombås Tirsdager - lørdager unntatt dag etter helligdag. 31) 5734 Onsdager, torsdager og fredager unntatt helligdager og dag etter helligdag. Kjøres bare etter særskilt kunngjøring.	32) 5735 Eidsvoll - Brumunddal Mandager - torsdager unntatt helligdager. Brumunddal - Dombås Tirsdager - fredager unntatt dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 33) 5736, 41630 Lørdager unntatt dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 34) 5738 Søndager unntatt dag etter helligdag. 35) 5931 Eidsvoll - Brennhaug Fredager. Brennhaug - Dombås Lørdager. 36) 5933 Mandager - torsdager unntatt helligdager og dag før helligdag. 37) 5935 Eidsvoll - Kvam Mandager - torsdager unntatt helligdager og dag før helligdag. Kvam - Dombås Tirsdager - fredager unntatt helligdager og dag etter helligdag. 38) 5936 Dombås - Sjøa Mandager - fredager unntatt helligdager. Sjøa - Eidsvoll Tirsdager - lørdager unntatt dag etter helligdag. 39) 5937, 5939 Helligdag for hverdag. 40) 5938 Dombås - Espå Søndager. Espå - Eidsvoll Mandager. 41) 10351 Tirsdager - fredager unntatt helligdager og dag etter helligdag. 42) 41629 Fredager unntatt helligdager. Kjøres bare etter særskilt kunngjøring. 43) 41633, 41634 Søndager. 44) 41640 Otta - Fron Torsdager unntatt helligdager. Fron - Eidsvoll Fredager unntatt dag etter helligdag. 45) 41642 Torsdager unntatt helligdager. Kjøres bare etter særskilt kunngjøring. 46) 41647, 41648 Onsdager.



BLAD NR. 10 <b>EIDSVOLL - DOMBÅS</b>	RUTEORD. NR. <b>161.1</b>	GJELDER FRA OG MED: <b>Søndag 11. desember 2011</b>
1) 44, 47, 322, 325, 326, 329, 330, 333, 334 Søndager - fredager. 2) 306, 309, 310, 313, 314, 317, 318 Mandager - lørdager unntatt helligdager. 3) 308 Dombås - Lillehammer Mandager - lørdager unntatt helligdager. Lillehammer - Eidsvoll Alle dager. 4) 405 Eidsvoll - Minnesund Søndager - fredager. Minnesund - Dombås Mandager - lørdager. 5) 406 Mandager - lørdager. 6) 2343 Mandager - fredager unntatt helligdager. Kjøres til og med 25. mai 2012. 7) 2353 Mandager - fredager unntatt helligdager. Kjøres fra og med 29. mai 2012. 8) 4801, 4802, 5241, 5242, 6210, 6212 Tirsdager. 9) 4805, 4806 Lørdager. 10) 4811 Mandager. 11) 4813, 4820 Onsdager og fredager. 12) 4817, 4822 Onsdager og torsdager. 13) 4824 Hove - Brøttum Mandager. Brøttum - Eidsvoll Tirsdager. 14) 4843, 4844, 41645 Torsdager unntatt helligdager. 15) 5252 Tirsdager - fredager unntatt helligdager. Kjøres fra og med 29. mai 2012. 16) 5253 Eidsvoll - Rudshøgda Mandager - fredager unntatt helligdager. Rudshøgda - Dombås Tirsdager - lørdager unntatt dag etter helligdag. 17) 5254 Tirsdager - fredager unntatt helligdager. Kjøres til og med 25. mai 2012.	18) 5256, 41677 Lørdager unntatt dag etter helligdag. 19) 5261, 5262, 20347, 20348 Mandager og tirsdager unntatt helligdager. 20) 5267, 5268 Tirsdager unntatt helligdager. 21) 5269, 5270 Tirsdager unntatt helligdager. Kjøres bare etter særskilt kunngjøring. 22) 5706 Dombås - Ringebu Mandager - torsdager unntatt helligdager. Ringebu - Eidsvoll Tirsdager - fredager unntatt dag etter helligdag. 23) 5707 Eidsvoll - Dovre Mandager - torsdager unntatt helligdager. Dovre - Dombås Tirsdager - fredager unntatt dag etter helligdag. 24) 5708, 5730, 5732 Tirsdager - lørdager unntatt dag etter helligdag. 25) 5709 Eidsvoll - Tretten Mandager - fredager unntatt helligdager. Tretten - Dombås Tirsdager - lørdager unntatt dag etter helligdag. 26) 5715 Helligdager. 27) 5716, 5737 Lørdager unntatt helligdager. 28) 5718, 10353 Hverdag etter helligdag. 29) 5719 Eidsvoll - Tretten Helligdag for hverdag. Tretten - Dombås Hverdag etter helligdag. 30) 5733 Eidsvoll - Fåvang Mandager - fredager unntatt helligdager. Fåvang - Dombås Tirsdager - lørdager unntatt dag etter helligdag. 31) 5734 Onsdager, torsdager og fredager unntatt helligdager og dag etter helligdag. Kjøres bare etter særskilt kunngjøring.	32) 5735 Eidsvoll - Brumunddal Mandager - torsdager unntatt helligdager. Brumunddal - Dombås Tirsdager - fredager unntatt dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 33) 5736, 41630 Lørdager unntatt dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 34) 5738 Søndager unntatt dag etter helligdag. 35) 5931 Eidsvoll - Brennhaug Fredager. Brennhaug - Dombås Lørdager. 36) 5933 Mandager - torsdager unntatt helligdager og dag før helligdag. 37) 5935 Eidsvoll - Kvam Mandager - torsdager unntatt helligdager og dag før helligdag. Kvam - Dombås Tirsdager - fredager unntatt helligdager og dag etter helligdag. 38) 5936 Dombås - Sjøa Mandager - fredager unntatt helligdager. Sjøa - Eidsvoll Tirsdager - lørdager unntatt dag etter helligdag. 39) 5937, 5939 Helligdag for hverdag. 40) 5938 Dombås - Espa Søndager. Espa - Eidsvoll Mandager. 41) 10351 Tirsdager - fredager unntatt helligdager og dag etter helligdag. 42) 41629 Fredager unntatt helligdager. Kjøres bare etter særskilt kunngjøring. 43) 41633, 41634 Søndager. 44) 41640 Otta - Fron Torsdager unntatt helligdager. Fron - Eidsvoll Fredager unntatt dag etter helligdag. 45) 41642 Torsdager unntatt helligdager. Kjøres bare etter særskilt kunngjøring. 46) 41647, 41648 Onsdager.



BLAD NR. 11 <b>TRONDHEIM S - DOMBÅS</b>	RUTEORD. NR. <b>161.1</b>	GJELDER FRA OG MED: <b>Søndag 11. desember 2011</b>
1) 44, 47, 446, 450, 454, 10446, 10450, 10454 Søndager - fredager. 2) 405 Mandager - lørdager. 3) 406 Trondheim S - Soknedal søndager - fredager, Soknedal - Dombås mandager - lørdager. 4) 413, 5716, 5737, 25701 Lørdager unntatt helligdager. 5) 414, 5715 Helligdager. 6) 417, 10382 Lørdager og helligdager. 7) 418 Helligdag før hverdag. 8) 5706 Mandager - torsdager unntatt helligdager. 9) 5707 Tirsdager - fredager unntatt dag etter helligdag. 10) 5708 Trondheim S - Kongsvoll mandager - fredager unntatt helligdager, Kongsvoll - Dombås tirsdager - lørdager unntatt dag etter helligdag.	11) 5709, 5732, 5733 Tirsdager - lørdager unntatt dag etter helligdag. 12) 5718 Trondheim S - Kongsvoll helligdag før hverdag, Kongsvoll - Dombås hverdag etter helligdag. 13) 5719 Hverdag etter helligdag. 14) 5730 Trondheim S - Lundamo mandager - fredager unntatt helligdager, Lundamo - Dombås tirsdager - lørdager unntatt dag etter helligdag. 15) 5734 Onsdager, torsdager og fredager unntatt helligdager og dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 16) 5735 Tirsdager - fredager unntatt dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 17) 5736 Lørdager unntatt dag etter helligdag. Kjøres bare etter særskilt kunngjøring. 18) 5738 Søndager unntatt dag etter helligdag.	19) 5917, 5938 Søndager. 20) 5920 Tirsdager. 21) 5931 Lørdager. 22) 5933 Dombås - Fokstua mandager - torsdager unntatt helligdager og dag før helligdag, Fokstua - Trondheim S tirsdager - fredager unntatt helligdager og dag etter helligdag. 23) 5935 Tirsdager - fredager unntatt helligdager og dag etter helligdag. 24) 5937 Dombås - Garli helligdag før hverdag, Garli - Trondheim S hverdag etter helligdag. 25) 5939 Dombås - Fokstua helligdag før hverdag, Fokstua - Trondheim S hverdag etter helligdag. 26) 12344, 12347 Onsdager.



Tegnforklaring:

Togbetegnelse	Alle dager	Mandager - fredager unntatt helligdager	Andre kjoredagsmonster
Persontog	—————	—————	—————
Godstog	—————	—————	—————
Loslok, Tomtog	—————	—————	—————
Behovstog	—————	—————	—————

▲ - Ubetjent alle dager    △ - Ubetjent helligdager    ▼ - Ubetjent hverdager    ▽ - Ubetjent lørdager unntatt helligdager    ◇ - Ubetjent lørdager og helligdager    ⊗ - Om betjening, se ruteboken  
\* - Kjedebrydd

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