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# Malmbanan traffic simulations : investments and capacity allocation

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## Abstract

Banverket, Jernbaneverket and MTAB have been studying Malmbanan by traffic simulation. The first project was to dimension the future system. The result was a Base alternative with investments in infrastructure and investments in trains. The simulation showed that the iron ore traffic is robust and the capacity situation for freight and passenger traffic is at least as good as today. The second project was to analyse an Expansion alternative with increased iron ore traffic. The result was a rejection of the Expansion alternative. A general conclusion from theese simulations is a need of improved methods in train dispatching.

## 1 Introduction

Malmbanan (Luleå - Narvik) is 400 km long and has single track. It was originally built for iron ore transports from the mines in Kiruna and Gällivare to the harbours in Luleå and Narvik. Today the traffic consists of iron ore, freight and passenger trains. The freight trains are called ARE, and transport fish products. The traffic operators of Malmbanan are MTAB (iron ore), SJ/NSB Freight (ARE), SJ Passenger traffic and NSB Passenger traffic.

Banverket, Jernbaneverket (Norwegian National Rail Administration) and MTAB have in a common project Stax 30 ton analysed a future dimensioning of the traffic system of Malmbanan.

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The two main questions of the project was:
1. To investigate the possibilities to raise the permitted axle load from 25 ton/axle to 30 ton/axle.
2. To analyse investments in iron ore trains, investments in infrastructure and allocation of track capacity.

The investigation of the first question showed that the raise in maintenance cost due to higher axle load was marginal (+3%). As a result the permitted axle load of Malmbanan will be raised to 30 ton/axle.

The investigation of the second question is the traffic simulation study which is described in this paper.

# 2 The traffic simulation project

## 2.1 Organisation

The traffic simulation of Malmbanan was divided into two projects:
* Dimensioning of infrastructure and traffic
* Allocation of track capacity

<u>Traffic simulation to dimension infrastructure and traffic</u>
The traffic simulations was executed by Banverket region north during the period 9401 - 9610. The result of the project was a Base alternative with investments in new trains for about 1600 million SEK and investments in infrastructure for about 400 million SEK (7,73 SEK = 1 US$). The simulations showed that the capacity situation for the freight and passenger trains is at least as good as today. This simulation study is described comprehensively in this paper.

<u>Traffic simulation to allocate track capacity</u>
The traffic simulations was executed by Banverket Headquarter in cooperation with ÅF Industriteknik AB during the period 9706 - 9709. The purpose was to analyse a new timetable alternative with increased iron ore traffic compared to the Base alternative. The study showed that the timetable was not acceptable in the southern part Gällivare - Luleå. This simulation study is described in a more detailed level in this paper.

## 2.2 Methodology

The method was to use SIMON, the train traffic simulation tool owned by Banverket. The traffic simulations have been performed as an iterative process to specify conditions (input data) and to evaluate the result (output data). The project group has continously been reporting conditions and results to an executive group.

# 3 Dimension infrastructure - traffic

## 3.1 Preconditions and analysis

Preconditions to the analysis was a forecast which stated number of passenger trains and ARE trains, and the weight of the iron ore transports.

The following questions were analysed.

Traffic
* How many locomotives and wagons are needed for iron ore transports?
* Should iron ore trains which are longer than the stations of today be allowed?
* Should ARE trains which are longer than the stations of today be allowed?
* What are the dispatching priorities between the different train products?

Infrastructure
* If long trains are allowed, how many stations have to be long stations?
* Should the long stations have two or three tracks?

The northern circulation (Kiruna - Narvik) and the southern circulation (Gällivare - Luleå) have been modelled as two separate models. The infrastructure and traffic parameters have been analysed in each model separately.

## 3.2 Conclusions Base alternative

The result of the traffic simulation was a Base alternative which included following investments and timetable conditions.

The infrastructure investments was 7 new long stations at the northern circulation (Kiruna - Narvik) and 3 new long stations at the southern circulation (Gällivare - Luleå). Every long station was given two tracks.

In the timetable only iron ore trains are allowed to be long trains. Loaded iron ore trains and ARE trains have been given the highest train priority.

The investments in iron ore trains are at the northern circulation 5 locomotives and 7 sets of wagons and at the southern circulation 2 locomotives and 2 sets of wagons.

| | Iron ore train circulation times |
|---|---|
| Northern circulation | 12 hours (locomotives), 15 hours (wagons) |
| Southern circulation | 16 hours |

The traffic simulations showed that the iron ore trains had no problems with their circulations. The capacity situation of passenger and ARE-trains is as good as the capacity situation in the transport system of today. The number of iron ore trains has been reduced and that gives a reduction in train meetings.

# 4 Allocate track capacity

The task was to analyse a timetable alternative with increased iron ore traffic compared to the Base alternative. The new timetable is called the Expansion alternative.

## 4.1 Preconditions Expansion alternative

### 4.1.1 Infrastructure

The infrastructure in the Expansion alternative is the same as in the Base alternative.

### 4.1.2 Traffic

The difference between the Expansion alternative and the Base alternative is only the iron ore traffic.

<u>Southern circulation</u>
The iron ore traffic has increased from 2 to 3 circulations/day and the circulation time has been reduced from 16 hours to 13,5 hours. By getting a connection between the northern and southern circulation 1 locomotive and 1 set of wagons has been saved.

Other traffic consists of 3 ARE-trains each direction/day, 3 freight trains each direction/day and 3 passenger trains each direction/day.

<u>Northern circulation</u>
The iron ore traffic has increased from 8 to 10 circulations/day. The circulation time for locomotives is still 12 hours and the circulation time for sets of wagons is reduced to 14,5 hours.

Other traffic consists of 3 ARE-trains each direction/day, 2 passenger trains each direction/day and 2 Regional norwegian passenger trains each direction/day.

### 4.1.3 Traffic disturbances

The iron ore circulations of locomotives and wagons are included in the model. In Narvik and Luleå the trains are unloaded and returns with the same locomotive. In Kiruna and Gällivare the locomotive turns and returns with a new loaded set of wagons.

The disturbances which are generated to the system are delays at the first station. The disturbance has a uniform distribution as following.

| Iron ore trains | | Other trains | |
|---|---|---|---|
| Percentage | Intervall | Percentage | Intervall |
| 85% | 0 - 5 minutes | 60% | 0 minutes |
| 5% | 5 - 15 minutes | 25% | 0 - 5 minutes |
| 5% | 15 - 30 minutes | 10% | 5 - 15 minutes |
| 5% | 30 - 60 minutes | 5% | 15 - 45 minutes |

## 4.2 Analysis Expansion alternative

### 4.2.1 The southern circulation Gällivare - Luleå

Two alternatives have been studied. In alternative 1 the iron ore trains have been given the highest priority and in alternative 2 the passenger trains have been given the highest priority.

Alternative 1: High priority iron ore trains

| Priority | Traffic product |
|---|---|
| High | Iron ore |
| Middle | Passenger and ARE-trains |
| Low | Other freight trains |

Alternative 2: High priority passenger trains

| Priority | Traffic product |
|---|---|
| High | Passenger trains |
| Middle | Iron ore and ARE-trains |
| Low | Other freight trains |

The first question to analyse is the circulations of iron ore traffic. In diagram 1 the iron ore arrival times in Luleå for a period of 10 days are shown. The time to unload is the thick line. The iron ore train should arrive before the thick line otherwise the circulation will be disturbed.

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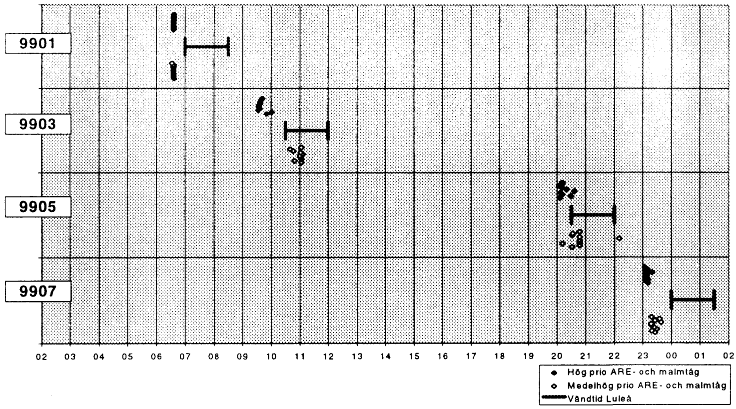


Diagram 1: Iron ore arrival times in Luleå. Alternative 1 High priority iron ore trains (black dots). Alternative 2 High priority passenger trains (white dots).

Diagram 1 shows that the iron ore trains require highest priority otherwise the circulation will be disturbed. In alternative 2 (High priority passenger trains) the iron ore trains which traffic the day (9903, 9905) have disturbed circulations almost all days. Theese trains get delayed because of meetings and overtakings with passenger and ARE-trains. Meetings when a long iron ore train is stopping outside a short station and waits for a short train to arrive has not been allowed. That kind of train dispatching would improve the iron ore traffic in alternative 2. Nevertheless the quality in iron ore traffic is still too low to be acceptable.

In diagram 2 the traveltime for passenger train from Luleå to Gällivare is shown.

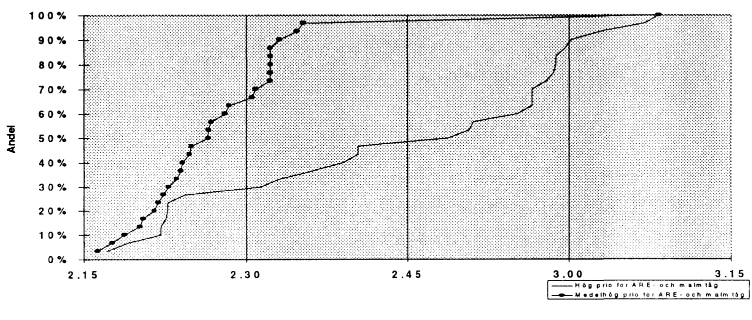


Diagram 2: Traveltime passenger trains from Luleå to Gällivare. Alternative 1 High priority iron ore trains (no dots). Alternative 2 High priority passenger trains (black dots).

When the iron ore trains have been given the highest priority the passenger trains suffer. The passenger trains have to stop more often at meetings. Diagram 2 shows that about 50% of the passenger trains from Luleå to Gällivare loose about 30 minutes compared to alternative 1 (High priority passenger trains).

### 4.2.2 The northern circulation Kiruna - Narvik

One alternative has been studied. The train priorities are as following.

| Priority | Traffic product |
|---|---|
| High | Iron ore loaded |
| Middle high | ARE-trains |
| Middle low | Iron Ore unloaded |
| Low | Passenger trains |

In diagrams 3 and 4 the distribution of delay are shown when the iron ore trains arrive at their end station.

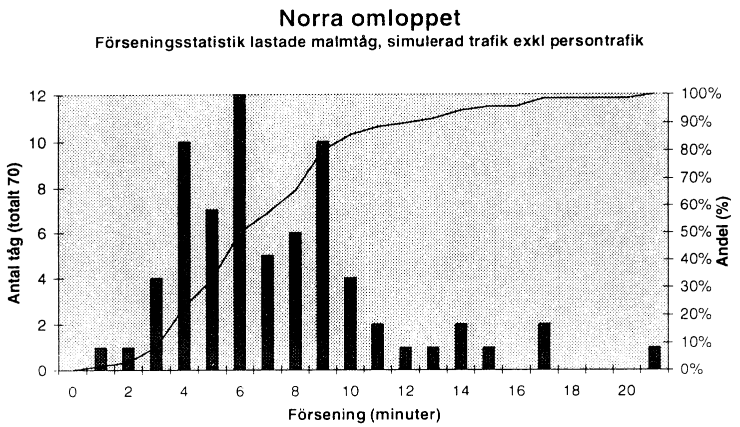


Diagram 3: Distribution of delay loaded iron ore trains when arrival Narvik.

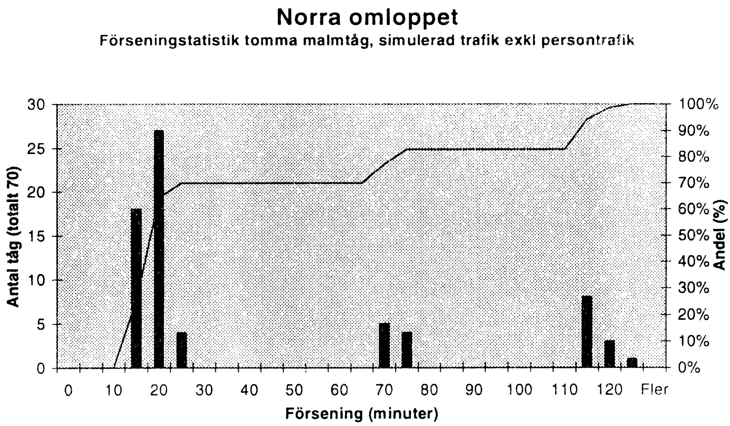


Diagram 4: Distribution of delay unloaded iron ore trains when arrival Kiruna.

The distribution of delay is compared to if the train should have an ideal journey with no meetings or overtakings. All timetable margin has been distributed to the end station. The loaded iron ore trains have 58 minutes margin in Narvik and the unloaded iron ore trains have 125 minutes margin in Kiruna. The traffic simulation shows that the iron ore traffic is acceptable. Some unloaded iron ore trains (1-2 each day) are on the limit to disturbe their circulations.

In diagram 5 and 6 the distribution of delay are shown when the ARE-trains arrive at their end station.

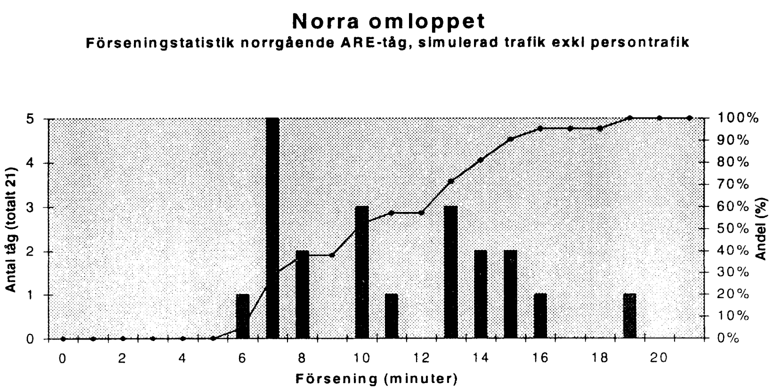


Diagram 5: Distribution of delay northwards ARE-trains when arrival Narvik.

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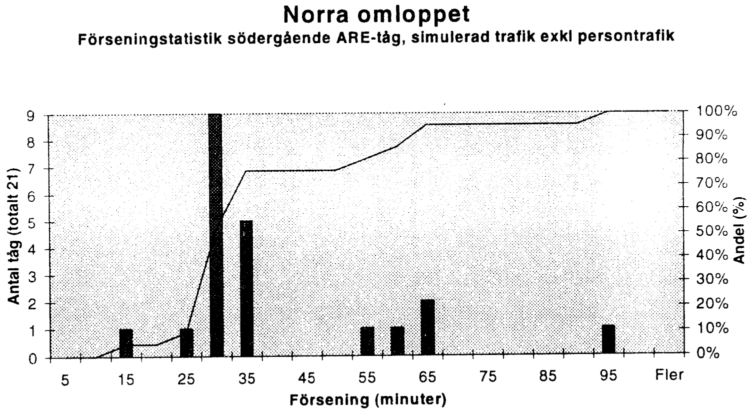


Diagram 6: Distribution of delay southwards ARE-trains when arrival Kiruna.

The distribution of delay is compared to if the train should have an ideal journey with no meetings or overtakings. Diagram 7 and 8 show that the trains which are delayed are southwards ARE-trains. There is a capacity conflict between southward ARE-trains and loaded iron ore trains.

## 4.3 Conclusion Expansion alternative

Southern circulation

The analysis shows that the iron ore traffic requires to have highest priority otherwise the iron ore circulations will be disturbed. As a consequence 50% of the passenger trains will increase their travel time with almost half an hour compared to alternative 1 (High priority passenger trains). That is not acceptable according to Banverket. The Expansion alternative is rejected.

Northern circulation

The analysis shows that there is a capacity conflict between iron ore trains and ARE-trains. To decide if the timetable is acceptable we need better knowledge about how ARE-trains value capacity for example the value of timeperiods of arrival/departure, transport time and quality. If we get this economic value of ARE-trains that can be compared to the economic value of iron ore transports and also to investments in infrastructure.

## 5 Needs of future research

The traffic simulations are in some aspects rough. One example is the dispatching logic which is not so clever. When a train during a simulation calls the dispatcher the priority of the train is compared with next meeting train and next overtaking train. Thus there are possibilities to improve the dispatching logic. Banverket has in this field a cooperation with Dalarna University and Uppsala University [1]. They study mathematical algorithms for and the human behaviour in (Man Machine Interface) train dispatching. There are also discussions using the traffic simulation of Malmbanan as a case study in their research.

The purpose of this research is to get more knowledge in following questions:

* What are the limits of a dispatcher in the process of today? What kind of IT support needs a dispatcher?

* What mathematical dispatching algorithms exist today and what are their limitations? How can theese models be used in train dispatching and timetable planning?

* What possibilities does the future signal system (radio contact control center - locomotive) give to improve train dispatching?

Banverket is satisfied with the research activities in this area performed by Högskolan Dalarna and Uppsala University so far. In Sweden improved train dispatching has high potential to improve the efficiency of the traffic system. Future research acitivities in this area has high priority.

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**References**

[1] Hellström P., Frej I., Gideon A., Sandblad B., Algorithms and Control Systems for Computer-aided Train Dispatching, Proceedings of WCRR '97, Florence, November 16-19, 1997.