



NSW North Coast Line Capacity - Example Use Case

Modelling the Capacity of the NSW North Coast Line

Introduction

This use case describes an approach to modelling the theoretical capacity of the NSW North Coast line using Traxim.

The NSW North Coast line runs between the suburbs of Newcastle, 200 km north of Sydney, and Brisbane, a bit around 100 km across the NSW / Queensland border. The line is single track for the full distance, with regular loops that are a mix of long loops to accommodate intermodal trains of up to 1500 m, and legacy shorter loops.

The line is used predominantly by intermodal and steel trains, which run the full length of the line, and long-distance passenger trains, of which there are three in each direction per day, running to different locations but travelling most of the line. There is also coal from one mine at the southern end of the line, but this has a limited future and has been ignored. Likewise, there are some shorter distance passenger services at the southern end of the line, but after the coal ceases they will have more than ample capacity and have been ignored for capacity analysis purposes.

There are currently 3 Aurizon, 6 Pacific National, and 4 SCT pairs of intermodal services per week. PN also has 4 northbound intermodals without corresponding southbound services. This gives a total of 30 intermodal services.

The question to be answered is how many more intermodal trains could be operated with no changes to the infrastructure.

This use case paper will first describe the conceptual methodology to be used, then describe the outputs of the modelling, and then finish with the key conclusions.

Methodology

The methodology to analyse the potential capacity will consist of two stages:

- First, the theoretical capacity of the line will be determined using conceptual principles.
- Second, Traxim will be used to validate the theoretical analysis and provide greater richness around the implications of increased utilisation.

Theoretical Capacity

Theoretical capacity can be calculated using the UIC406 methodology as a base.

This methodology essentially sums the section occupancy for all of the trains passing through the most capacity limiting section and represents the capacity utilisation as the number of

minutes of occupation as a percentage of the number of available minutes for the relevant analysis period.

It is important to note though that for a single-track rail line this isn't necessarily straightforward.

Where there is one or more intermediate signals between loops, the section time needs to be based on the time between loops. However, to the extent that those signals allow following moves to simultaneously occupy the loop-to-loop section, utilisation can be higher than the nominal benchmark.

Similarly, where a section between two long loops is split by a short loop that can only accommodate some trains, there are multiple overlapping sections, each with their own utilisations.

These situations can be modelled theoretically, but usually require a bespoke analysis.

It is important to note that it needs to be clear whether the section occupancy includes a transaction time. This includes both the period between when the rear of the train clears the track circuit and when the next train (opposing or following) can pass the signal, and, the difference in section occupancy time between a through train and one that is starting from a stand at the signal, that is, the time lost due to acceleration. Most of the signal clearance time is associated with the communications and safety validation protocols of the signalling system, and these can be significant. If the transaction times have been derived based on observed performance, it is highly desirable to include them. If they are unknown and a nominal time is used, it doesn't especially matter whether its included or not, but the practical utilisation limit should be set having regard to whether it includes transaction time.

The analysis period for this methodology is also important, particularly when traffic levels vary considerably during the day, the week, or over the course of a year.

In this case, there is a distinct preference for trains to depart from Sydney in the late morning and from Brisbane in the early evening. However, as the transit time is in the order of 17 hours, every train will cross every other train at some point, which means there is no particular temporal peaking over a daily period.

The passenger and steel traffic are relatively homogeneous over the course of the week. Intermodal trains can be more sensitive to the weekly cycle, with limited departures on Sunday, and demand typically growing through the week. However, as the task is to determine potential capacity this shouldn't drive the choice of analysis period – a path departing on a Sunday for instance might have less commercial value, but is still a path and is almost certain to be saleable at the right price.

Demand is relatively homogenous across the year, noting that there is likely to be some trains cancelled around major holiday periods, which also tend to get used for maintenance.

For this purpose then, capacity analysis can meaningfully use the full capacity available across a week or year – either will give the same approximate result.

The UIC methodology will only give a quantification of the percentage of capacity used. It doesn't tell us anything about how well the network will perform at that utilisation, or how many additional paths will be available.

ARTC has historically adopted a ceiling utilisation rate of 65%, though this has been increased to as high as 72.5% for the intensively utilised and highly actively managed Hunter Valley coal network. The ARTC utilisation benchmark includes transaction time in the section utilisation rate. This analysis will use the 65% utilisation limit as the starting point.

The final consideration is the question as to what constitutes an available path. In this case, because we are only interested in the capacity for additional trains of one type, we can just base the path calculation on the section time for an intermodal train.

Calculation of Theoretical Paths

The Traxim “Timetable” output file provides a list of all arrival and departure times at nominated nodes. This can be used to calculate section occupancy.

Noting the comments in the theoretical section in regard to differing loop lengths, it is worth noting that the steel trains are nominally longer than most short loops. Also, passenger services have absolute priority over intermodal (and steel) trains and hence all crosses will be at long loops, other than where two passenger trains cross each other. Hence, for practical purposes, it is the section time between long loops that matters, qualified to the extent that the intermediate loop will give a small uplift in capacity where it allows multiple following trains to be occupying the long loop to long loop section simultaneously.

Using the current (June 2025) master Train Plan as the train input, the most heavily utilised section between long loops is Nambucca Heads - Boambee Beach at 3,776 minutes across the course of the week.

The generic intermodal train has a section time of 36.0 minutes on Nambucca Heads - Boambee Beach section for the average of directions. This has been calculated including a substantial proportion of trains either starting from or ending in a loop, so it includes a reasonable allowance for acceleration / deceleration. However, this time also needs to be adjusted to include signal clearance time.

While not all trains will be starting from a loop, as utilisation increases the probability that they will do so increases. The probability of a train being held at a signal before entering the section is roughly half of the utilisation level. If we assume 65% is the utilisation, we should add, on average, 32.5% of the nominal transaction time. Allowing a generic 90 seconds for signal clearance, this is 29 seconds. This makes the effective section time 36.5 minutes.

Hence, the number of additional paths is simply:

$10,080 \text{ (minutes in a week)} \times 65\% \text{ (adopted maximum capacity utilisation)} = 6,552 \text{ minutes.}$

$6,552 - 3,776 \text{ current occupation minutes} = 2,776 \text{ minutes surplus.}$

$2,776 / 36.5 \text{ minutes nominal intermodal section time} = 76.1 \text{ additional paths across the course of a week, or approximately 38 each way per week.}$

Simulated Capacity

Having reached a conclusion as to the theoretical capacity available, this can now be validated using Traxim.

The value of validating capacity in this way is that Traxim necessarily needs to accommodate the effect of heterogeneity in loop spacing and length, and the disruptive effects of differences in train priority. It will also properly apply transaction time and train acceleration and deceleration.

In this case, the three passenger services per day in each direction get absolute priority over all other trains. Intermodal trains will also get a relative priority over steel trains. For the purposes of modelling, intermodal trains are given a ratio of approximately 3 relative to steel trains. That is, a steel train can be delayed at a cross for 3 minutes to avoid an intermodal train being delayed by one minute. Traxim also permits overtaking of slower trains by faster trains provided they have equal or lower priority.

A good process for determining the limit of capacity is to run Traxim in wrapping mode (ie, it wraps trains back to the start of the week when they reach the end of the week) and incrementally add trains until the overflow of trains at the end of the week exceeds the ability to absorb them at the beginning of the week. In this case there is no viable solution, and hence Traxim will fail to resolve.

It's important to note though that there is a need for a degree of intelligent design in the input train plan. Simply adding trains at random is likely to cause localised congestion that can potentially sterilise available capacity at the capacity limiting section.

The calculation of theoretical paths also tells us nothing about transit time or reliability, which are inherently intertwined with capacity utilisation. Another advantage of simulation with Traxim is that the transit time impact can be quantified.

In regard to reliability, Traxim can be considered to be a good, though not perfectly optimising, timetable generator. To the extent that train control is undertaken manually in real time, it might not be possible to reach the levels of efficiency implicit in a Traxim generated timetable. Traxim also attempts to replicate the average performance of a train. In practice, there will be variation around the mean, and while trains that run slower than predicted will disrupt efficient train control decisions, trains that run faster won't necessarily offset this.

Hence, while Traxim might be able to generate a theoretical train plan for a given task, this may be optimistic in practice.

Simulation Results - Capacity

The iterative process of adding paths to Traxim yielded a total increase of 57 pairs of intermodal paths across the week, or an average of 8.1 per day, before a viable solution wasn't able to be found.

These were spread evenly across the week other than Sunday, which had only around 1/3rd of the additional paths of the other days to help manage the complexity of timetable wrapping.

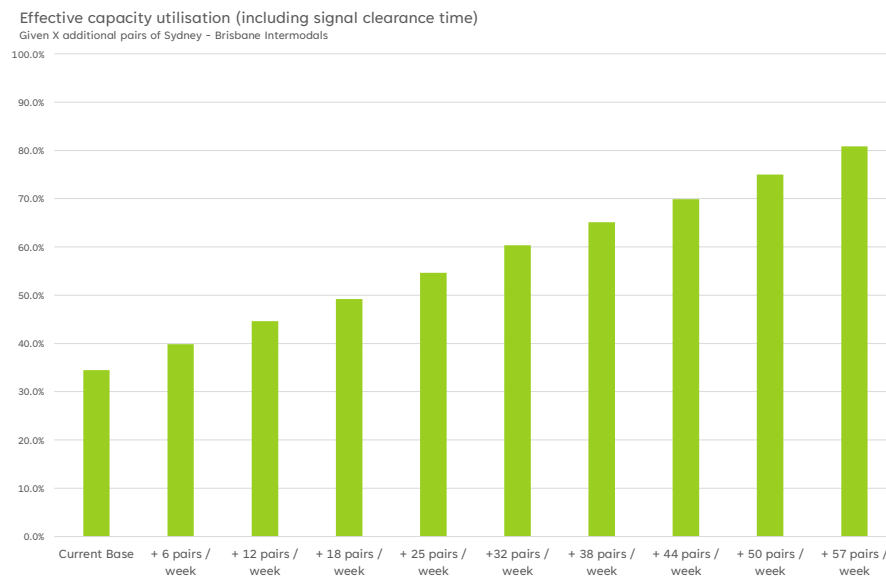
The train plan for this final result is at Appendix 1.

Utilisation is 80.9% including a nominal signal clearance time of 90 seconds. Note though that because there are effectively six intermediate signals, the maximum theoretical capacity utilisation can be more than 100%. The amount of capacity uplift due to intermediate signals is a function of the frequency of following trains. If trains arrived at random this would occur 50%

of the time, but to resolve a timetable at such high utilisation, trains will necessarily tend to be pushed into fleets. Spacing between following trains will be a function of maximum signal spacing and differences in train speed. Given all of these complex interactions it isn't possible to meaningfully hypothesise what the potential uplift is.

It is important to again caveat this result by noting that Traxim may be optimistic, and that the timetable might not be achievable in practice. Offsetting this, it may be possible to add additional paths through more intelligent design, though this seems unlikely and unwise.

Utilisation levels at each scenario simulated are shown in the following chart:



Simulation Results – Transit Time

As previously noted, an inevitable consequence of increased utilisation is increased delay.

The graph below shows the average speed for all trains, and for intermodal trains, as the number of pairs of intermodal trains are incremented.



At an uplift of 38 pairs of intermodal trains, which gives a utilisation rate of 65%, the reduction in average speed equates to an increase in transit time of 2.7 hours. At the maximum uplift of 57 pairs of intermodal trains, which gives 80.9% utilisation, the reduction in speed equates to an increase in transit time of 5.6 hours.

Conclusion

There are currently 30 timetabled intermodal trains per week.

This analysis suggests that with current infrastructure, a 65% utilisation level would be a reasonable target.

This would allow an additional 76 services per week, or 153% growth.

At this level of utilisation, average intermodal transit time would increase from 17.2 hours to 19.9 hours.

A train plan at this recommended utilisation level, simulated jointly with the Hunter Valley coal network operating at 191 mtpa to validate feasibility of the two networks when integrated, is attached at Appendix 2.

Peak achievable utilisation would be around 81%, which would allow an additional 114 services per week. However, attempting to operate at this level of utilisation is likely to result in intolerable unreliability. Average intermodal transit time would also increase to 22.8 hours.