Traxim

Parkes – Broken Hill Line Loops - Example Use Case

Modelling the Transit Time Benefit of Loop Enhancement on the Parkes – Broken Hill Line

Introduction

This use case describes the modelling of transit time savings from enhancing loops on the Parkes – Broken Hill line, with Traxim simulations used to validate a theoretical model.

The Parkes – Broken Hill line runs between Parkes in Central West NSW, 450 km west of Sydney by rail, a distance of 775 km westward to Broken Hill, a large mining centre just short of the NSW / SA 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 1800 m, and legacy shorter loops. Signalling is by way of train orders with manually operated turnouts.

The line is used predominantly by intermodal and steel trains, which run the full length of the line. There is some grain on the first 150 km or so of the line, but given its irregular nature, shorter typical train lengths, and ability to operate opportunistically, it is ignored for the purposes of this analysis. There are three minerals trains per week in each direction over 300 km of the western end of the line. Finally, there are two return passenger trains per week.

There are currently 3 Aurizon, 6 Pacific National, and 2 SCT pairs of intermodal services per week. PN also operates 5 steel trains each way per week. This gives a total of 32 intermodal and steel services that operate across the full length of the line.

There are some significant distances between long loops, leading to long crossing dwells. The question to be answered is how much transit time could be saved by motorising the turnouts, and by extending selected short loops. The proposed motorisation of turnouts would be by way of a system known as ICAPS, which has a locomotive mounted unit that allows a turnout to be changed by the train crew when the train is within around 1 – 2 km of the turnout.

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 transit time savings will consist of two stages:

- First, the theoretical crossing delay with current infrastructure, and with the investment options, will be determined using conceptual principles.
- Second, Traxim will be used to validate the theoretical analysis.

Theoretical Transit Time

Theoretical transit time can be calculated using a probabilistic analysis, noting that there are a considerable number of uncertainties that make this a loose approximation.

This approach separately calculates the average dwell per cross, and the probability of incurring a dwell. Average dwell is the product of the two.

The average dwell per cross calculation assumes that two trains will meet randomly at any point within a section. If it is assumed that the train with the lesser required dwell is assumed to take the loop, its delay will on average be 25% of the section time, since on average it would have met the opposing train at the midpoint of the distance between the loop and the midpoint of the section. However, in practice trains have differential priorities applied. The effect of this will be uncertain, but evidence suggests that typically the dwell is closer to 50% of the section time.

Note that the section time needs to be calculated as the time that the rear of the opposing train clears the section.

Importantly, a transaction time also needs to be added. This transaction time needs to include all the sources of delay from when the through train clears the section until the train in the loop can depart, plus the difference between a through train section time and the time taken by a train starting from a stand, that is, the acceleration time.

Also important in this case is that trains taking the loop need to come to a stand to manually change the turnout before entering. To the extent that this occurs prior to the opposing train arriving, it has no delay effect. However, if two trains arrive at the loop simultaneously, both trains are delayed, and the need for the train taking the loop to stop and then pull forward into the loop increases both the probability of this occurring, and the quantum of the delay.

The probability of a train needing to take the loop can be simply calculated as the amount of time that the section is occupied. For the same reasons that average dwell is calculated as 50% of section time, the probability of a train incurring a cross is doubled relative to the logic that on average it is only the occupancy up to the mid-point of the section that triggers a cross.

This approach to predicting transit time doesn't take account of following delays or the effects of congestion. These tend to be very circumstance specific, but can generally be assumed to increase proportionately to section utilisation. In this case, section utilisation is relatively low.

Calculation of Theoretical Transit Time

A theoretical transit time analysis was undertaken for the base case and the full investment case. Individual projects were not analysed separately.

A dynamic train simulation output for a generic intermodal train was first generated using Traxim. Using a single generic simulation for all train occupations is obviously a simplifying assumption.

This was then used to isolate the train pass time for each end of the loops in the scenario. The nominal transaction time was then added and the two directions averaged and multiplied by a nominal simultaneous arrival uplift percentage, and then by the number of trains on the section to get a total weekly occupation time in minutes. This was then divided by 10080 (minutes in the week) to get percentage utilisation.

Table 1 shows these workings for the base case, and Table 2 for the investment case.

Table 1		Section time		Section time incl TT			
	Trains / week	Westbound (secs)	Eastbound (secs)	Westbound (mins)	Eastbound (mins)	Average Section Occupancy (m/week)	Average Section Occupancy (%)
Goobang Junction - Yarrabandi	36	2,733	2,898	61.1	63.9	2,250.67	22.3%
Yarrabandi - Kiacatoo	36	3,029	3,104	66.1	67.3	2,401.44	23.8%
Kiacatoo - Matakana	36	2,824	2,918	62.7	64.2	2,284.00	22.7%
Matakana - Trida	36	3,546	3,636	74.7	76.2	2,716.47	26.9%
Trida - Ivanhoe	36	2,412	2,434	55.8	56.2	2,015.50	20.0%
Ivanhoe - Kaleentha	36	4,786	4,910	95.4	97.4	3,470.19	34.4%
Kaleentha - Kinalung	39	4,811	4,912	95.8	97.5	3,768.40	37.4%
Kinalung - Broken Hill	42	2,881	2,651	63.6	59.8	2,591.36	25.7%

Table 2		Section time		Section time incl TT			
	Trains / week	Westbound (secs)	Eastbound (secs)	Westbound (mins)	Eastbound (mins)	Average Section Occupancy (m/week)	Average Section Occupancy (%)
Goobang Junction - Gunningbland	36	1,349	1,480	31.3	33.5	1,165.35	11.6%
Gunningbland - Yarrabandi	36	1,384	1,418	31.9	32.4	1,157.32	11.5%
Yarrabandi - Condobolin	36	1,663	1,787	36.5	38.6	1,351.78	13.4%
Condobolin - Kiacatoo	36	1,366	1,317	31.6	30.7	1,121.66	11.1%
Kiacatoo - Matakana	36	2,824	2,918	55.9	57.4	2,039.20	20.2%
Matakana - Roto	36	1,894	1,962	40.4	41.5	1,473.53	14.6%
Roto - Trida	36	1,653	1,675	36.3	36.7	1,314.94	13.0%
Trida - Ivanhoe	36	2,412	2,434	49.0	49.4	1,770.70	17.6%
Ivanhoe - Darnick	36	2,303	2,357	47.2	48.1	1,714.86	17.0%
Darnick - Kaleentha	36	2,483	2,552	50.2	51.3	1,827.33	18.1%
Kaleentha - Menindee	36	2,535	2,636	51.0	52.7	1,868.04	18.5%
Menindee - Kinalung	42	2,276	2,276	46.7	46.7	1,962.89	19.5%
Kinalung - Broken Hill	42	2,881	2,651	56.8	53.0	2,305.76	22.9%

Average dwell time per cross was then calculated as the average of the section time in each direction for each side of the loop (using the section time excluding transaction time), divided by two as per the theoretical discussion above, and then transaction time added. For Goobang Junction and Broken Hill, being the end points of the analysis, only the section within the analysis area was used to calculate the average section time.

Opposing direction occupancy was calculated as being 50% of total occupancy. The average number of crosses at each loop for each train is this percentage, expressed as a decimal.

Finally, average crossing delay per train is simply the product of the probable number of crosses and the estimated average dwell per cross.

These calculations are shown in Table 3 for the base case and Table 4 for the investment case.

Table 3	Average dwell time per cross	Opposing direction occupancy	Number of crosses	Average crossing delay per train
Goobang Junction	36.46	11.2%	0.11	4.07
Yarrabandi	37.51	11.5%	0.12	4.33
Kiacatoo	37.74	11.6%	0.12	4.39
Matakana	39.93	12.4%	0.12	4.95
Trida	38.06	11.7%	0.12	4.47
Ivanhoe	43.30	13.6%	0.14	5.89
Kaleentha	53.45	18.0%	0.18	9.60
Kinalung	44.78	15.8%	0.16	7.06
Broken Hill	36.05	12.9%	0.13	4.63

Table 4	Average dwell time per cross	Opposing direction occupancy	Number of crosses	Average crossing delay per train
Goobang Junction	19.79	5.8%	0.06	1.14
Gunningbland	19.73	5.8%	0.06	1.14
Yarrabandi	21.02	6.2%	0.06	1.31
Condobolin	20.78	6.1%	0.06	1.27
Kiacatoo	25.55	7.8%	0.08	2.00
Matakana	27.99	8.7%	0.09	2.44
Roto	22.96	6.9%	0.07	1.59
Trida	25.03	7.7%	0.08	1.92
Ivanhoe	27.81	8.6%	0.09	2.40
Darnick	28.20	8.8%	0.09	2.48
Kaleentha	29.26	9.2%	0.09	2.68
Menindee	28.26	9.5%	0.10	2.68
Kinalung	29.01	10.6%	0.11	3.07
Broken Hill	31.05	11.4%	0.11	3.55

Table 5 summarises the other input assumptions, and the key outputs.

Crosses per train decreases marginally with the investment case, while average delay per cross declines significantly. The average delay per train is forecast to decline by 23 minutes.

Table 5 - Theoretical Analysis Statistics	**Base Case**	**Investment Case**
Transaction time assumption	13	8
Simultaneous arrival uplift assumption	20.0%	10.0%
Trains	37.8	37.8
Crosses per train	1.19	1.13
Average delay per cross	45.83	27.74
Total delay per train	54.38	31.39
Theoretical Savinig - all projects		**22.99**

The largest contributor to the saving is the introduction of ICAPS, which is assumed to reduce the transaction time from a nominal 13 minutes to nominally 8 minutes. The simultaneous arrival uplift is assumed to halve from 20% to 10%. These assumptions are significant contributors to the benefit, but difficult to predict.

Simulating Transit Time

Separately, Traxim was used to simulate the line, with loop enhancements progressively added in the order that they are most likely to be prioritised. All scenarios were run both with and without ICAPS.

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

A shortcoming of using the simulation in this case is that Traxim doesn't have a mechanism to model the need for the train to stop and manually change the turnout at the entry to a loop. It does model and enforce a prohibition on simultaneous entry into the loop. However, it will underestimate both the probability and duration of delay due to simultaneous arrival. Accordingly, it will underestimate the benefit of ICAPS.

For the purposes of the simulation, transaction time was assumed to be 10 minutes without ICAPS and 5 minutes with. The difference of 3 minutes relative to the theoretical modelling is the assumed quantum of train acceleration, which is properly modelled in Traxim.

The train plan used for the simulation is the June 2025 master timetable. Traxim results for the current infrastructure were calibrated against the exit times in the master timetable. Overall, Traxim transit times were slightly longer than the actual timetable.

Transit Time Simulation Results

The following chart shows the cumulative benefit of the potential loop projects. Table 6 shows the results numerically.

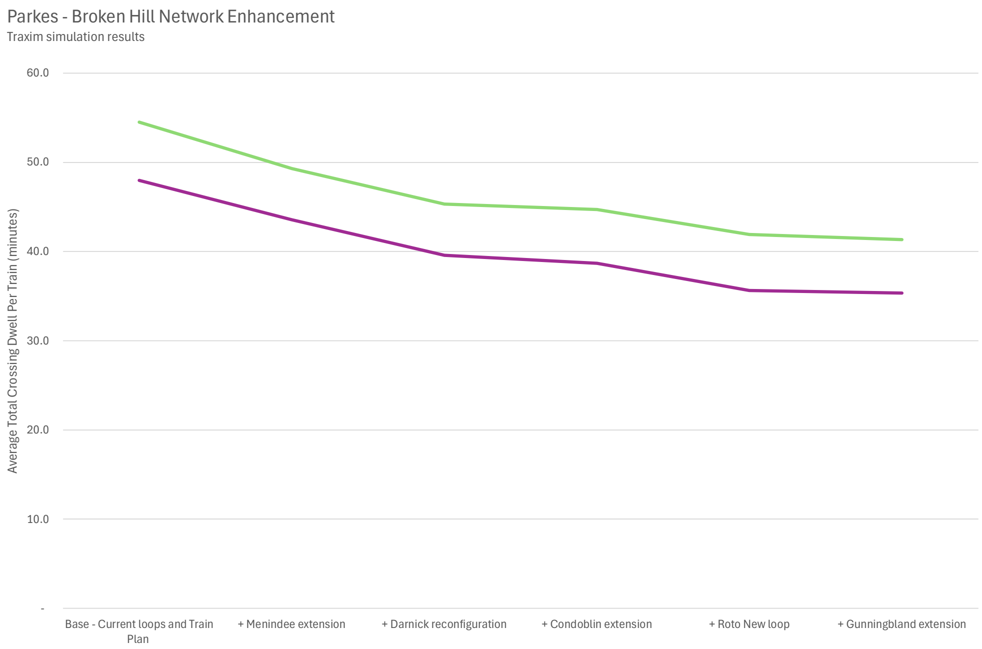

Table 6 - Average Delay Per Train (m)	Base - Current loops and Train Plan	+ Menindee extension	+ Darnick reconfiguration	+ Condoblin extension	+ Roto New loop	+ Gunningbland extension
Without ICAPS	54.5	49.3	45.3	44.7	41.9	41.4
With ICAPS	48.0	43.6	39.6	38.7	35.6	35.3
Reduction relative to current						
Without ICAPS	-	5.2	9.2	9.8	12.6	13.1
With ICAPS	6.5	10.9	14.9	15.8	18.9	19.1

The final result, that is, all potential loop projects plus ICAPS, at 19.1 minutes saving per train, calibrates well with the theoretical analysis which arrived at 23.0 minutes. As previously noted, it is expected that the theoretical savings should be a bit higher due to Traxim not modelling the effect of trains stopping at the entry to the loop.

As a separate cross-check, the average delay per train for the base case and the investment case calculated with Traxim, at 54.5 minutes and 35.3 minutes respectively, correlate well with the equivalent theoretical model results of 54.4 minutes and 32.0 minutes.

Conclusion

Train delays on the Parkes – Broken Hill line have been both theoretically modelled and simulated for a range of investment options.

The two methodologies show a good degree of alignment, with a total saving from all investments in the order of 19 minutes – 22 minutes.

The largest benefit is likely to come from the installation of ICAPS. An extension of Menindee loop, and reconfiguration of Darnick loop to simplify long train crosses, both offer savings in the order of 4 minutes per train. The other projects are more marginal.

Whether any of the projects is commercially or economically justified is a matter for separate analysis.