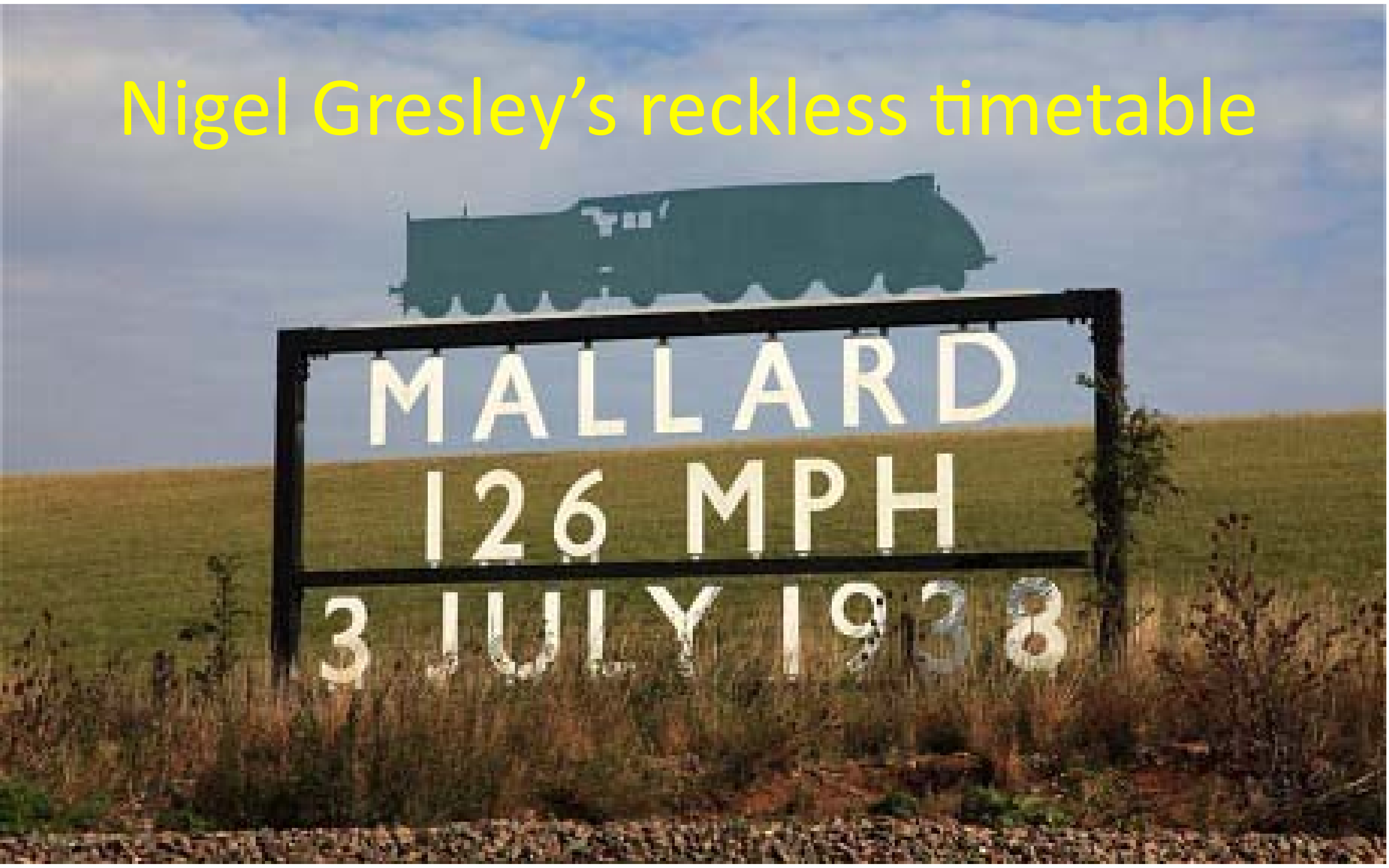
The Times

October 2015

A journal of transport timetable history and analysis

Nigel Gresley's reckless timetable



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SAR Christmas Pleasures
Collecting Timetables with Carl
Matching the coal with the timetable

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Dear Editor

I refer to Albert Isaacs' article in the September Times about various interesting aspects of politics and railways in Victoria in 1884. The overland journey from Melbourne to Adelaide and v.v. of 1884/5 which Albert found and illustrated (Sept. Times, page 5) can almost be placed in the bizarre category. A prospective passenger would not only have had to have a lot of fortitude, but also be particularly averse to sea travel to undertake it. I note that the Sandergrove to Milang branch line in SA opened on 17 December 1884. Presumably this was to facilitate this overland journey, as it was well before the Melbourne-Adelaide Intercolonial line opened on 19 January 1887.

Cheers,
Victor Isaacs

Article Drought

Dear readers. The Times has reached the "End of The Line" when it comes to reader-written and reader-contributed articles. You will notice that, in this issue, I have even had to resort to revamping and jazzing up an old article from 15 years ago. I have a number of scans from old Australian newspapers and journals submitted by readers– but these are hard to craft into articles. I have also a large number of articles on timetable design, history and technology, but these are usually not very "Australian". So—a call to arms please—get your word processors to work ASAP.

A reckless timetable?

JIM WELLS

Two publications have crossed my desk recently. The first was Robin Jones' excellent "Mallard 75 - Celebrating Britain's Greatest Steam Moment".

The background to this is that in the 1930's railways started to get serious about competitive threats from road and air. Premium services were accelerated and air conditioning of carriages was introduced. For example, Victoria got the famed "Spirit of Progress".

They also started to push public relations. Having streamlined named trains was a great help in this regard.

In Britain the front runner was the London and North Eastern Railway (LNER) with streamlined trains running to the North of England and Scotland hauled by the railway's A4 class Pacifics.

One accepts that in introducing trains of this sort a certain amount of test running would be required. If one wants to run trains at 90 mph (about 150 km/h) it's not a bad idea to ensure they run safely at 100 mph (160 km/h). But higher? How much higher?

Test speeds on both the LNER and the competing LMSR got up to about 110 mph in the mid 1930's.

Sir Nigel Gresley, Chief Mechanical Engineer of the LNER, arranged a special brake test trip for Sunday July 3rd, 1938. He was ill that day but it's clear that he sanctioned an all out attempt at high speed. His deputy, Douglas Edge, was on hand.

Coming down from Stoke Tunnel north of Peterborough, Pacific "Mallard" with seven cars ran for five miles above 120 mph (190 km/h) and briefly touched 126 mph

(over 200 km/h).

Was this a reckless, irresponsible decision on Sir Nigel's part? What was known at the time about the tracking qualities not just of the engine but also the rigid wheel base eight wheeled tender not to speak of the 1906 built dynamometer car behind the tender? Would the last carriage of the train have been at most risk of derailment?

The consequences of a derailment would have been severe irrespective of cause which could have been mechanical (eg broken axle, tyre shredding) or track related. Thankfully it was a Sunday so traffic on the adjacent track would have been low. Were down trains stopped for the great speedster to have a clear run?

Let's not reflect on the human tragedy if an accident had occurred but on the consequences not just for the LNER but also railways generally. In those days crashes of aircraft in the development phase were not uncommon but derailments of passenger trains were extremely rare, just as they are now.

The other publication was E S Cox's "Locomotive Panorama". EW S Cox was a well known British locomotive engineer. In 1938, the same year as Mallard's achievement he went to India with a team of British engineers to resolve a long standing problem.

This was that a series of Pacific locomotives of three different sizes were causing track distortions and experiencing derailments. Why did these locos have problems whereas the British ones did not? Poor Indian track was certainly an issue.

The solution arrived at after a lot of testing was to increase "side control" so that there would be more resistance to lateral movement of the leading bogie.

It's clear that the science of this matter was not all that well understood so one wonders just what Sir Nigel and his team really under-

L.N.E.R. Test Run with Coronation Train, July 3, 1938						
Engine: Streamlined 4-6-2 No. 4468, *Mallard*, Class "A4"						
Driver, J. Duddington, Fireman, T. H. Bray (Doncaster Shed).						
Load, 7 coaches, 236¾ tons tare, 240 tons gross.						
Stations	**Mileposts**	**Times (p.m.)**			**Speeds**	**Cut-off**
		Hr.	min.	sec.	m.p.h.	Per cent.
GRANTHAM	105½	4	24	19	24	40
Milepost	105	4	25	13	32	,,
,,	104	4	26	32	52¼	,,
,,	103	4	27	36½	59¾	30
Great Ponton	102	4	28	35½	63½	,,
Milepost	101½		—		—	40
,,	101	4	29	30	69	,,
Stoke Box (100.1 miles)	—	4	30	16	—	,,
Milepost	100	4	30	20½	74½	,,
,,	99	4	31	05	87½	,,
,,	98	4	31	44½	96½	,,
Corby (97.1 miles)	—	4	32	17	—	,,
Milepost	97	4	32	20¼	104	,,
,,	96	4	32	54½	107	,,
,,	95	4	33	27½	111½	,,
,,	94¼		—		—	45
,,	94	4	33	59½	116	,,
,,	93	4	34	30	119	40
,,	92¾		—		119¼	,,
,,	92½		—		120¾	,,
Little Bytham	92¼	4	34	52½	122¼	,,
Milepost	92	4	35	00	122½	,,
,,	91¾		—		122¼	,,
,,	91½		—		123	,,
,,	91¼		—		124¼	,,
,,	91	4	35	29½	124¼	,,
,,	90¾		—		123½	,,
,,	90½		—		124	,,
,,	90¼		—		125	,,
,,	90	4	35	58½	124¼	,,
,,	89¾		—		123	Steam off
,,	89½		—		116	Brakes
,,	89¼		—		113	,,
,,	89	4	36	29	110	,,
ESSENDINE (88.65 miles)	—	4	36	40	107½	,,
Milepost	88½		—		95	,,

stood about their locomotives and rolling stock when it comes to tracking. One wonders also how the Chief Civil Engineer of the LNER felt.

"Mallard" would not have sustained its performance on the day as it suffered a hot big end.

A word about track. British track tends to be very good and maintenance in the 1930's, although dependent on gangers etc to fix holes in the road and service turnouts etc, would have been of a high order. My first trip on a British train as an adult was on a morning Leeds to Kings Cross "Deltic" hauled express (100 mph) over the same route as "Mallard's" feat. I was astonished at just how steady the ride was; quite different to the Australian norm. London Underground though can be bouncy.

We now know that 500 km/h is technically possible with steel wheel on steel rail but standards of initial build and maintenance have to be of a very high order.

So Sir Nigel got his record and became quite famous in the railway world. What a pity that the second World War intervened to prevent further progress and the wide spread adoption of high speed.

South Australian Railway Pleasures

Victor Isaacs

The former South Australian Railways could always be relied to provide quirky services - with either associated pleasure or exasperation. These examples fall into the first category. They come from a 1909 publication entitled *South Australian Railways: Short Description of Places Worth Visiting: Issue of Excursion Tickets.*

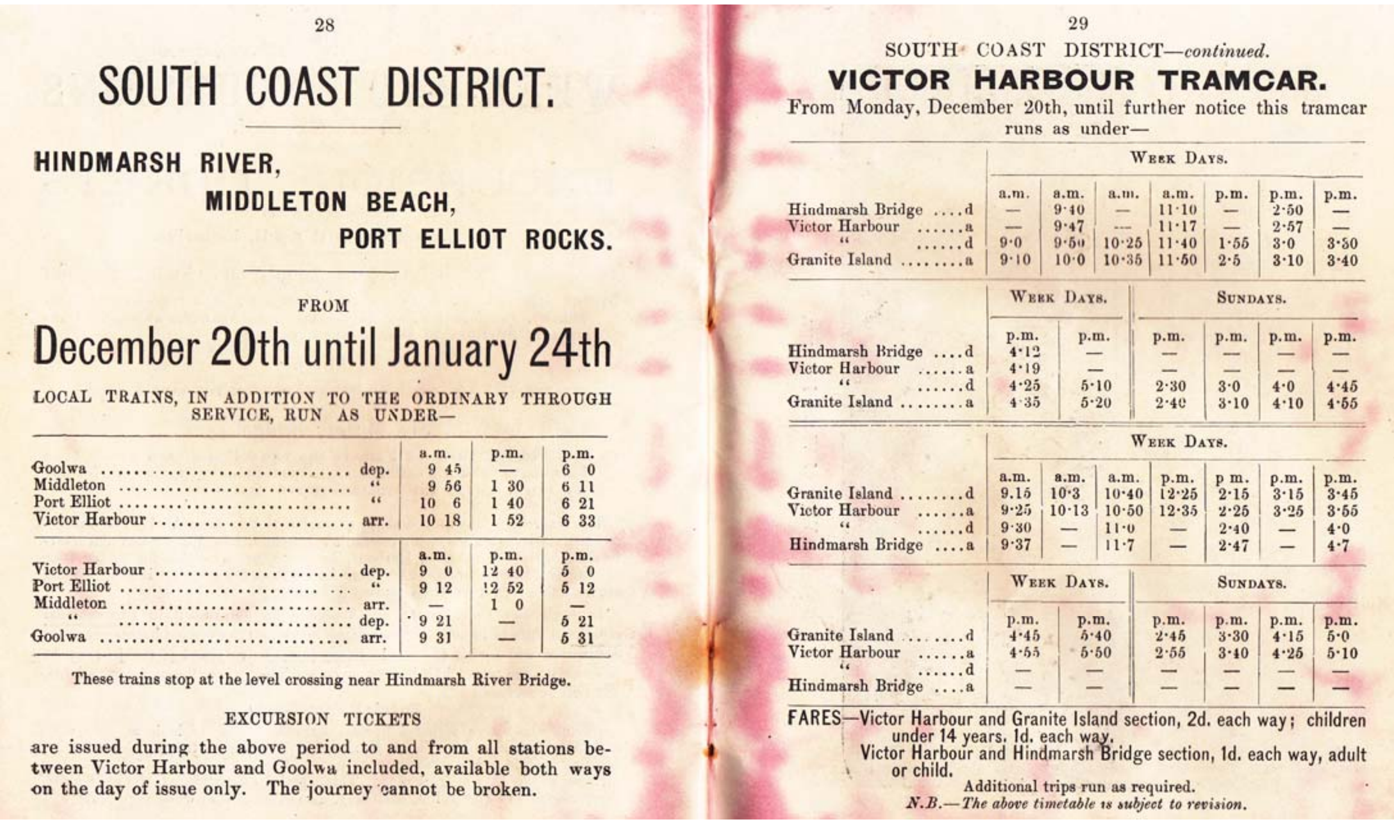
The left hand page shows the local trains, locally called Cockle Trains, which operated in summer along the South Coast between Victor Harbour (then still spelt with a 'u'), Middleton and Goolwa.

The section of line between Goolwa and Port Elliot was opened as a horse line on 18 May 1854, five months before Australia's first railway from Melbourne to Port Melbourne. South Australians will always try to tell you that this line was the first railway in Australia. But the rest of us know that it is not, because upon opening it lacked two of the defining characteristics of a railway - steam/ mechanical propulsion and a regular schedule. And anyway what about the convict-powered "railway" at Port Arthur, Tasmania (1836) and the gravity/counter-balance operated coal "railway" at Newcastle (1831), both of which opened earlier (and which in both cases, the locals claim to be the "first" railway)..

However, it is very nice to see a timetable of the original Cockle Trains, now successfully revived by Steamranger.

The opposite page shows the summer schedule for SAR's horse tramway from Victor Harbour over the causeway to Granite Island. This opened in 1875 and lasted until 1955 when it was deemed too old-fashioned to survive. But the locals knew better and the horse tramway was rebuilt and re-opened by the local Council in 1986. The extension of some tram journeys to Hindmarsh Bridge was, I think, over the tracks of the conventional railway.

The rest of this little 36 page publication was taken up with descriptions of seaside and hill resorts near Adelaide and of excursion ticket arrangements.



28

SOUTH COAST DISTRICT.

HINDMARSH RIVER,
MIDDLETON BEACH,
PORT ELLIOT ROCKS.

FROM

December 20th until January 24th

LOCAL TRAINS, IN ADDITION TO THE ORDINARY THROUGH SERVICE, RUN AS UNDER—

		a.m.	p.m.	p.m.
Goolwa	dep.	9 45	—	6 0
Middleton	"	9 56	1 30	6 11
Port Elliot	"	10 6	1 40	6 21
Victor Harbour	arr.	10 18	1 52	6 33
		a.m.	p.m.	p.m.
Victor Harbour	dep.	9 0	12 40	5 0
Port Elliot	"	9 12	12 52	5 12
Middleton	arr.	—	1 0	—
"	dep.	9 21	—	5 21
Goolwa	arr.	9 31	—	5 31

These trains stop at the level crossing near Hindmarsh River Bridge.

EXCURSION TICKETS

are issued during the above period to and from all stations between Victor Harbour and Goolwa included, available both ways on the day of issue only. The journey cannot be broken.

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SOUTH COAST DISTRICT—*continued.*

VICTOR HARBOUR TRAMCAR.

From Monday, December 20th, until further notice this tramcar runs as under—

	Week Days.						
	a.m.	a.m.	a.m.	a.m.	p.m.	p.m.	p.m.
Hindmarsh Bridge ....d	—	9·40	—	11·10	—	2·50	—
Victor Harbour ......a	—	9·47	—	11·17	—	2·57	—
" ......d	9·0	9·50	10·25	11·40	1·55	3·0	3·50
Granite Island ....a	9·10	10·0	10·35	11·50	2·5	3·10	3·40

	Week Days.		Sundays.			
	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.
Hindmarsh Bridge ....d	4·12	—	—	—	—	—
Victor Harbour ......a	4·19	—	—	—	—	—
" ......d	4·25	5·10	2·30	3·0	4·0	4·45
Granite Island ....a	4·35	5·20	2·40	3·10	4·10	4·55

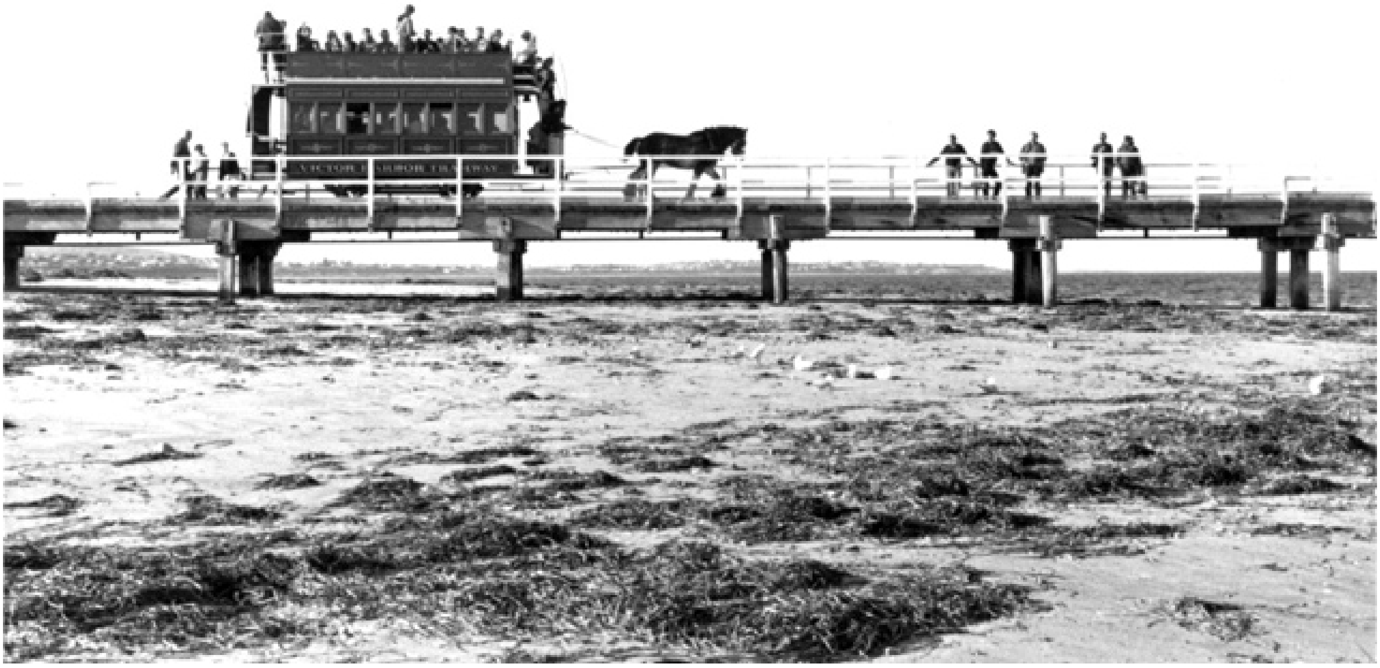
	Week Days.						
	a.m.	a.m.	a.m.	p.m.	p.m.	p.m.	p.m.
Granite Island ....d	9.15	10·3	10·40	12·25	2·15	3·15	3·45
Victor Harbour ......a	9·25	10·13	10·50	12·35	2·25	3·25	3·55
" ......d	9·30	—	11·0	—	2·40	—	4·0
Hindmarsh Bridge ....a	9·37	—	11·7	—	2·47	—	4·7

	Week Days.		Sundays.			
	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.
Granite Island ....d	4·45	5·40	2·45	3·30	4·15	5·0
Victor Harbour ......a	4·55	5·50	2·55	3·40	4·25	5·10
" ......d	—	—	—	—	—	—
Hindmarsh Bridge ....a	—	—	—	—	—	—

FARES—Victor Harbour and Granite Island section, 2d. each way; children under 14 years. 1d. each way.
Victor Harbour and Hindmarsh Bridge section, 1d. each way, adult or child.

Additional trips run as required.

N.B.—The above timetable is subject to revision.



Trams run every day except Christmas Day on an hourly timetable.

Departing Mainland:

- 10.30 am
- 11.30 am
- 12.30 pm
- 1.30 pm
- 2.30 pm
- 3.30 pm

Departing Granite Island

- 11.00 am
- 12.00 pm
- 1.00 pm
- 2.00 pm
- 3.00 pm
- 4.00 pm

The View From Madison; Collecting the Record Of the Nation's Trains

By KENNETH BEST, New York Times September 26, 1999

CARL LOUCKS of Madison has traveled a varied and different career path for someone who graduated from Yale with a degree in civil engineering. He has been a disk jockey, radio advertising executive, consultant and businessman.

But it was on his daily commute into New York City that he would travel down the path to a hobby that combined his fascination with trains and his love of history. Mr. Loucks would read the train schedules he picked up along the way, stick them in his coat pocket and take them home.

Today, Mr. Loucks' collection of railroad timetables numbers about 5,000 and he has another 200,000 available for the 2,000 subscribers to his monthly catalog of timetables that sell from $8 for an April 1981 schedule for the Chicago Union Station line to $125 for a set of timetables for the Chicago & Western Indiana rail line, 26 schedules issued between April 1956 and June,1968.

"Timetable collecting has been around a long time," Mr. Loucks said, sitting behind the desk of his North Haven business, Connecticut Direct Mail, where he keeps a storage room for his train schedules. "It's really a form of history that shows the whole evolution of a form of transportation."

Mr. Loucks favors collecting timetables from the New Haven area, not surprising for someone who has served the past three years as president of the New Haven Colony Historical Society. The more than 400 members of the National Association of Timetable Collectors gather schedules by state, region, railroad or historic period, with many focusing on the turn of the century when train schedules became marketing tools and were enhanced with photographs and maps.

"There are people who collect information about a specific area, as I collect about New Haven," Mr. Loucks said. "In 1938 the New Haven Railroad put out over 12 different public system timetable folders. It's hard to find them all."

The public system schedule is what

Carl Loucks of Madison goes through some of the thousands of railroad schedules he has collected from around the country,

the average traveler sees to learn how often the train runs and the time of arrivals and departures. A more detailed schedule for employees, often more than 100 pages thick, provides a wide range of information on railroad operations. This information includes how fast trains can move between stations, businesses or other landmarks near rail crossings, where tracks must be switched, engine and car restrictions, signal instructions and the names and phone numbers of hospitals, first aid stations and doctors near each station in case employees or passengers are injured.

Bruce Garver, a former Connecticut resident who is professor of history at the University of Nebraska at Omaha, is also an avid timetable collector who finds them valuable as historic documents in a class that he leads on transportation history.

"I give students an employee rule book and a timetable and ask them to write

up what they learn about the life of a railroad employee," said Mr. Garver". Some things strike them such as the list of surgeons. It was an exciting, reasonably well-paid job, but danger The other thing they notice is how rule -driven the operation of the railway was. There was very little discretion left to drivers and dispatchers. I think students need to understand that if they are to understand labor-management relations."

Mr. Garver added that the speed restrictions on curves and crossings within city limits also provides insight into the condition of the infrastructure of the rail lines. "I liken it to a box score for a baseball game," he said. "You can reconstruct a baseball game by looking at the box score. In the same way, you can go into the timetable and reconstruct the operation of a railroad. It's a clearly laid out format."

Alan [“Sky”] Magary of Litchfield, who once edited the newsletter for the National Association of Timetable Collectors, expanded an early interest in timetable collecting through his friendship with Louis W. Goodwin, who lived in nearby Northfield and who was known as the "Dean of Timetable Collectors" until his death in 1994.

"He was really the principal figure in the hobby for three decades," Mr. Magary, a retired airline executive, said. "His collection was simply amazing, really staggering in its completeness and complexity. The important thing about Lou Goodwin is that while he was one of the most advanced collectors, he maintained a long correspondence with many other collectors."

Mr. Magary has an interest in the timetables of railroads that merged before World War I, a time that the publication of timetables changed as a result of the Federal Government takeover of the rail industry due to the war.

"The U.S. Railroad Administration decreed that all railroad timetables should look the same. It ended the ornate timetable designs," he said.

While the information in old timetables is of primary interest to those with an eye to history, there is also relevance for today's transportation issues, Mr. Loucks said, such as the proposed high speed Amtrak service between Boston and Washington.

"People who are coming out against it are saying there will be too many trains in this area," he said. "I can document that in 1935 there were more trains between New Haven and New London pulled by steam engines than there are going to be today pulled by electric trains."

He noted that Amtrak officials had considered a straight line route between Boston and New Haven for the high speed train, instead of the coastal path on existing tracks. The history is already there.

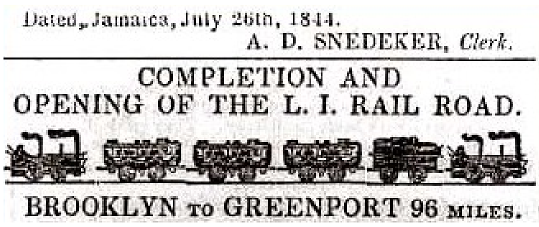
"At one time there was such a railroad running in a straight line -- the New York & New Englander," he said. "It ran from New Haven to Middletown to Willimantic, up to Putnam and to Thompson, before going into Massachusetts."

Amtrak rejected a track that followed the path of Interstate 95 because of a $1.7 billion price tag and environmental concerns, according to David Carol , vice president for high speed rail at Amtrak.

Mr. Loucks carries his love of trains directly to his travel schedule. When he travels with his wife, Barbara, they usually take the train and he said they have covered most American rails over the years and many in Canada.

"It's really the way to the see the country," he said. "This past year Barbara and I flew to Rome and then took the train to Exeter in southwest England. We've been through the Chunnel (the tunnel connecting France and England under the English Channel) twice, going from London to Prague and then to Florence. If you take the train into Germany from the Czech countryside, it's really a very interesting experience to see the small towns that used to have steel mills. After that, every airport looks the same."

Note: this article (or a photocopy of it, first appeared about 15 years ago– as a sideways photocopy but without the photos of the famous timetable collectors mentioned.


Dated, Jamaica, July 26th, 1844.
A. D. SNEDEKER, *Clerk.*

COMPLETION AND
OPENING OF THE L. I. RAIL ROAD.

BROOKLYN TO GREENPORT 96 MILES.

Fitting the coal into the coal train timetable

Abstracted from an upcoming article in RAIRO Operations Research

by **Gaurav Singh , Andreas Ernst, Matthew Baxter & David Sier**

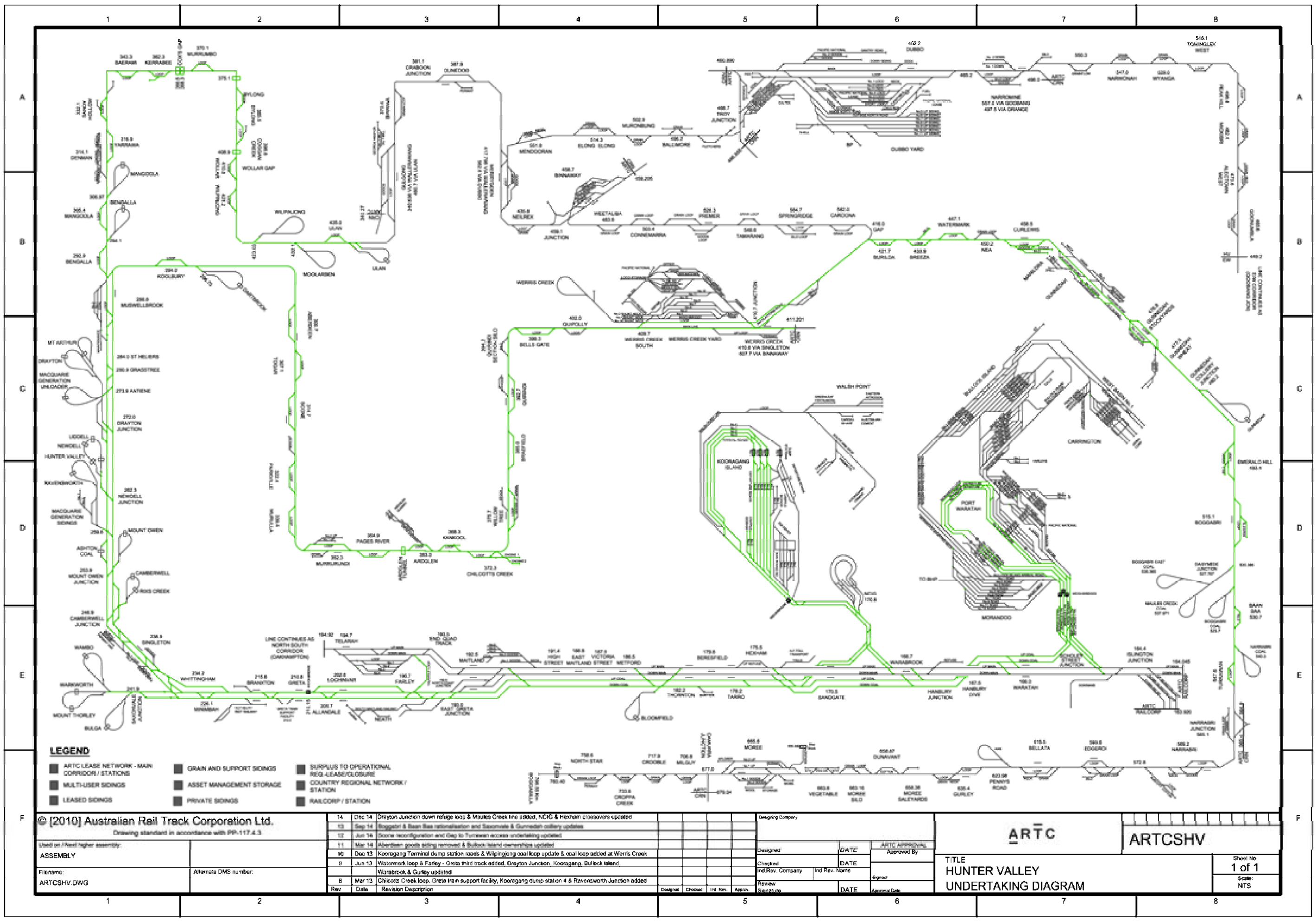
This [edited extract of a] paper describes a method for scheduling trains on the Hunter Valley Coal Chain rail network. Coal for a particular ship is railed from different mines to stockpiles at one of the Port's terminals. The coal producers decide which mines will supply each order in what proportion, so there is no flexibility in the allocation of mines to car goes. We are presented with a list of tonnes of coal which need to be transported from specified load points at mines to specified stockpiles at the port. The operators of the rail network provide a number of paths, with specified arrival and departure times, that can be used for coal movement. The requirement to assign coal trains to these existing paths makes this rail scheduling problem different to most of those discussed in the literature. In this paper we describe the problem in detail, demonstrate that it is very large making it difficult to solve with commercial Mixed Integer Linear Program (***"MILP"***) solvers, and show that our "*Lagrangian heuristic*" [a trial and error ,method– Ed] is able to produce high quality solutions in a reasonable amount of time.

The Port of Newcastle in Australia is the world's largest coal export port, with a throughput in excess of 100 million tonnes per annum. The coal exported at the port is produced in the Hunter Valley region and must be carried by rail from the mines for distances up to 450km. The Hunter Valley Coal Chain Coordinator (HVCCC) is responsible for coordinating the actions of 14 coal producers operating 40 mines, 3 Coal Loading Terminals at the port and 2 different rail operators. The size of the system can be seen in Figure 1 which shows the rail network for the Hunter Valley Coal Chain with four sub-regions, Gunnedah, Ulan, Hunter Valley and Stratford, each containing several mines. The Hunter Valley Coal Chain takes its name from the Hunter Valley sub-region which was the first region developed over the 200 year history of mining in the area.

The train network has a relatively simple tree structure [track map on p 10]. There is a main trunk line with short loops to each of the mines. At the mines, trains are loaded at load points and may then wait for some time until there is an available return path (time slot) on the main line back to the port. While the real situation is slightly more complex, for the purposes of this paper only one train may be on any loop at a time and it can wait at the end of the loop to start its return path for as long as necessary.

The situation is a little more complex for the coal terminals at the ports. When a train arrives at a terminal it waits for access to an inloading receival (or dump) station. However waiting at the terminal is generally considered less desirable than waiting at the mine's load-point loop. As the train moves through the dump station, doors on the bottom of the wagons are opened and the coal falls onto a conveyor belt feeding machines that stack the coal onto the stockpiles in the stockyard.

The stockyard has a number of rows, which are areas where stockpiles can be built. The stacking and reclaiming yard machines travel on (single) tracks between the rows, so only certain machines can serve the stockpiles in a given row. Further, when a machine is



in place and serving a stockpile in a row, it can restrict access to other stockpiles in that row, or adjacent rows. We need to schedule access to the stockpiles in the rows so that delays arising from machine conflicts between the dump stations, stackers and reclaimers are minimised.

As part of this process, trains scheduled to bring coal from the mines have nominated dumpers and stackers at the terminal to move the coal onto the stockpiles. There will be a number of valid dumper-stacker combinations for an arriving train and, where possible, the schedulers will try and assign a preferred dumper-stacker combination for the unloading.

1.3. Using Fixed Train Paths on the Rail Network

The rail network used by the Hunter Valley Coal Chain for coal export is also used for domestic coal deliveries, other freight services, and passenger trains.

The rail operators with responsibility for managing and optimising the overall network provide a number of train paths assigned for export coal movement to the HVCCC. The train paths provide time slots on the network at different times based on train speeds, required train separation distances, and other operational factors.

The paths start or end at a port at a fixed time. A forward path starts at a port at a specified time and provides a slot for a train to travel all the way up the valley. A return path provides a slot for a train to travel all the way down the valley, finishing at a port at a specified time. In this way a path can be used to move a train to/from any mine that is serviced by the path. Each roundtrip “consumes” one forward and return path. Paths going to further mines such as Ulan are less frequent than to closer mines in the Hunter Valley.

The mine load points have more flexible arrival and departure times. The HVCCC schedulers specify: (a) the load point and time at which a train travelling on a particular forward path will exit the path and leave the main network, and (b) the load point and time from which the train will enter a particular return path so as to arrive back at the port at the port arrival time specified for the path.

A train is not on the main rail network while it is loading at a mine or unloading at port, so it will not affect other trains on the network during these operations.

The requirement that we use set paths at set times makes this quite a different problem to most rail scheduling problems in the literature. We are not required to consider any of the track sections between the port and the load points because the set of paths provided to the HVCCC is guaranteed to prevent track conflicts.

If this was the entirety of the problem then we would have a train assignment problem (trains to brands) combined with a path assignment problem. However, we must still consider conflicts at the ports and load points when developing a schedule using the available paths.

Ship arrivals at the terminals provide orders for coal. All the coal for the orders on a given ship must be stockpiled at the terminal before a ship can berth for loading. The coal producers specify which mines will provide the coal components that will be blended to build the coal brands in the stockpiles. Trains must be scheduled to bring the coal from those mines to the terminals where nominated dumpers and stackers are used to move the coal from the trains onto the stockpiles.

The rail schedulers construct daily train schedules to determine which trains are to be sent to the mines, using the available train paths, so that their arrivals at the terminals best meet the planned dumping and stacking operations. The train trips are subject to a number of system constraints such as load point capacity limits, turn-around and refueling delays, and train size limits for individual mines.

In the next few sections we describe the key components of the model, including some definitions, constraints and objectives.

2.1. Roundtrips

The railing model described in this paper uses the idea of a train "roundtrip" as the basis for scheduling the coal deliveries.

A roundtrip is a train journey starting and finishing at a parking area on the rail network. On a roundtrip, a train travels out to a mine on a forward train path, loads with coal at the mine's loading point, may wait for an appropriate return train path, travels back to the terminal on a return train path, and finally goes back to the parking area where crew changes and maintenance may be carried out. Each roundtrip has a value determined by the amount of coal delivered, the idle time spent waiting for access to resources, and the importance of the delivery of different coal types to meet shipping demand.

In what follows, a roundtrip is specified by the following attributes:

ARTC
AUSTRALIAN RAIL TRACK CORPORATION LTD

APPLICATION FOR NEW OR VARIED TRAIN PATH FOR INCLUSION IN WORKING TIMETABLE

Rail Operator name		
Preferred train number (Consistent with Train Numbering Guidelines in TOC Manuals- General Instruction Pages, Section 7)	**Forward trip**	**Return trip**
Type of train path		
Origin - Destination and preferred route		
Main commodity	**Forward trip**	**Return trip**
Days train path to run	**Forward trip**	**Return trip**
Preferred start date		
Period path to apply		

Train Specification Details

	Forward Trip	**Return Trip**
Motive Power		
Proposed Running Schedule		
Trailing Load (tonnes)		
Overall length (incl locos)		
Class & type of rolling stock		

Train Type: Please insert tick [✓] in between brackets. Suggestion - copy and paste the tick from this line.

[ ]	Grain	[ ]	Trip Trains	[ ]	Passenger
[ ]	Minerals	[ ]	Work Trains	[ ]	Intermodal
[ ]	Coal	[ ]	General Freight		

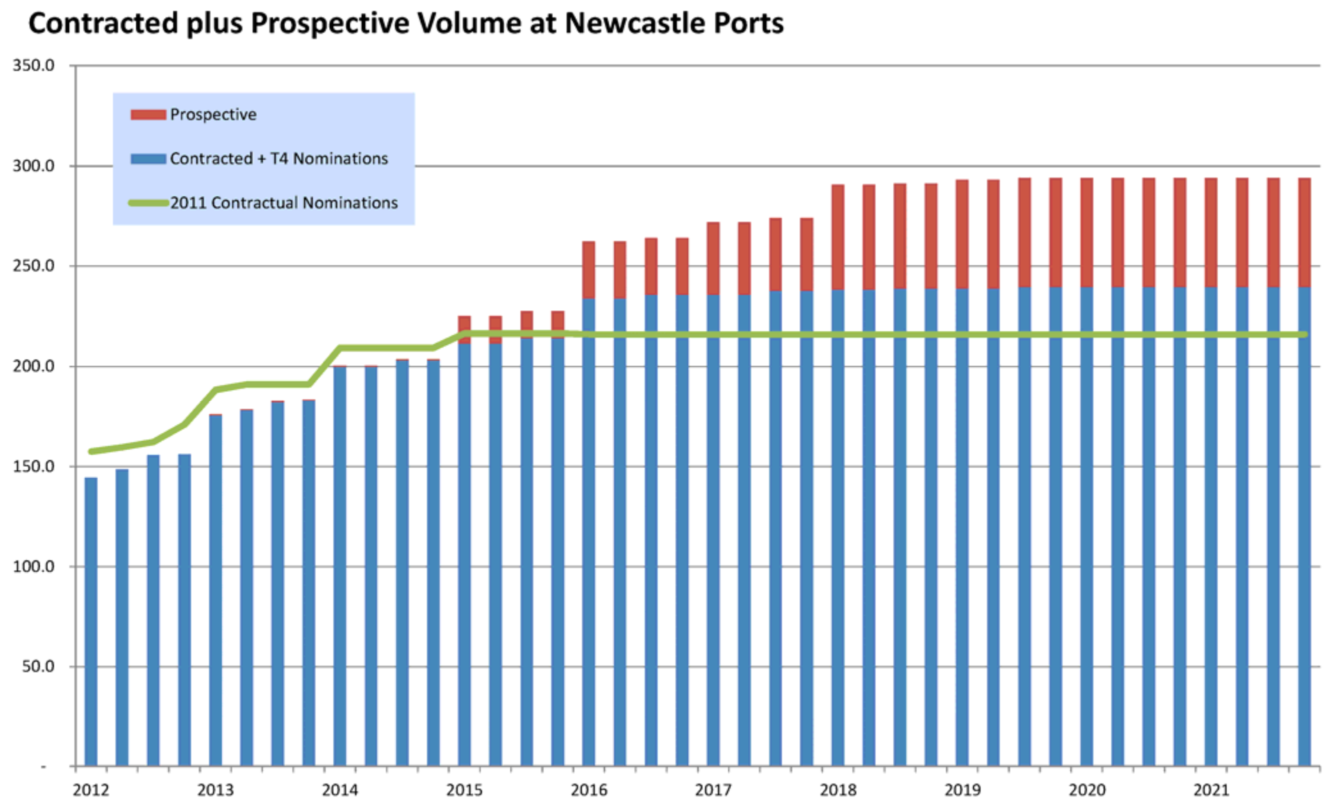
- a component (coal type at a mine) that will be used to build the brand in a stockpile,
- the train used for the journey,
- the forward train path,
- the mine load point,
- the idle time spent waiting at the load point,
- the return path,
- the dump station selected, and
- the stacker used to stack the coal onto the nominated stockpile.

The attributes are subject to a number of hard constraints that must be observed when constructing roundtrips:

(1) Every train is run by its operator and the component specifies which operator's train is to be used for a particular roundtrip.

(2) The component also specifies the mine that is supplying the coal and the stockpile where coal will be stored. This in turn specifies the load point for the roundtrip and restricts the dumpers and stackers that can be assigned to that roundtrip. In particular:

(a) The capacity limit of a load point



specifies a set of possible train sizes. (b) Because not every stacker can access every stockpile, the dumper and stacker combination assigned to a roundtrip must be valid for the stockpile.

(3) Only forward and return paths that match the junction of the load point in the roundtrip can be used.

(4) The start time of the return train path for the roundtrip cannot occur before the train has finished travelling to the mine and loading at the load-point. The time to load a train depends on its size and the capacity of the load-point.is similar to a marshalling yard.

(5) The time between the arrival at the load point and the departure of the train must be within a given time window. This is both a practical restriction on the amount of idle time for a train and a way to limit the problem size. Changing the maximum idle time at the load-point can significantly increase or decrease the number of possible roundtrips.

(6) An appropriate amount of time must be allowed for crew changeover between two subsequent journeys of a train. This is simply modelled using an enforced "idle" time at the end of a roundtrip.

(7) Trains, load-points, dumpers and stackers cannot be used during their pre-planned maintenance periods or any other activities. In general we talk about outages, though some of these might for example be generated implicitly by pre-assigned train trips that the schedulers want to fix as input to the optimisation.

Note that trains are not to sit idle anywhere in their roundtrip except after loading at the load-point. It is theoretically possible for trains to wait in other locations, for example just before the dump stations at the terminals. However there is very little space for trains to wait in these places and idle time in these locations is not allowed at the planning stage, in order to prevent congestion during the implementation of the schedules where some idle time may occur due to delays or other unforeseen circumstances.

We also need to try and best meet the following soft constraints:

(1) Among all the valid dumper-stacker combinations, where possible use the preferred dumper-stacker combination.

(2) Components with an earlier delivery date, based on ships arrival time, have a higher priority or weight.

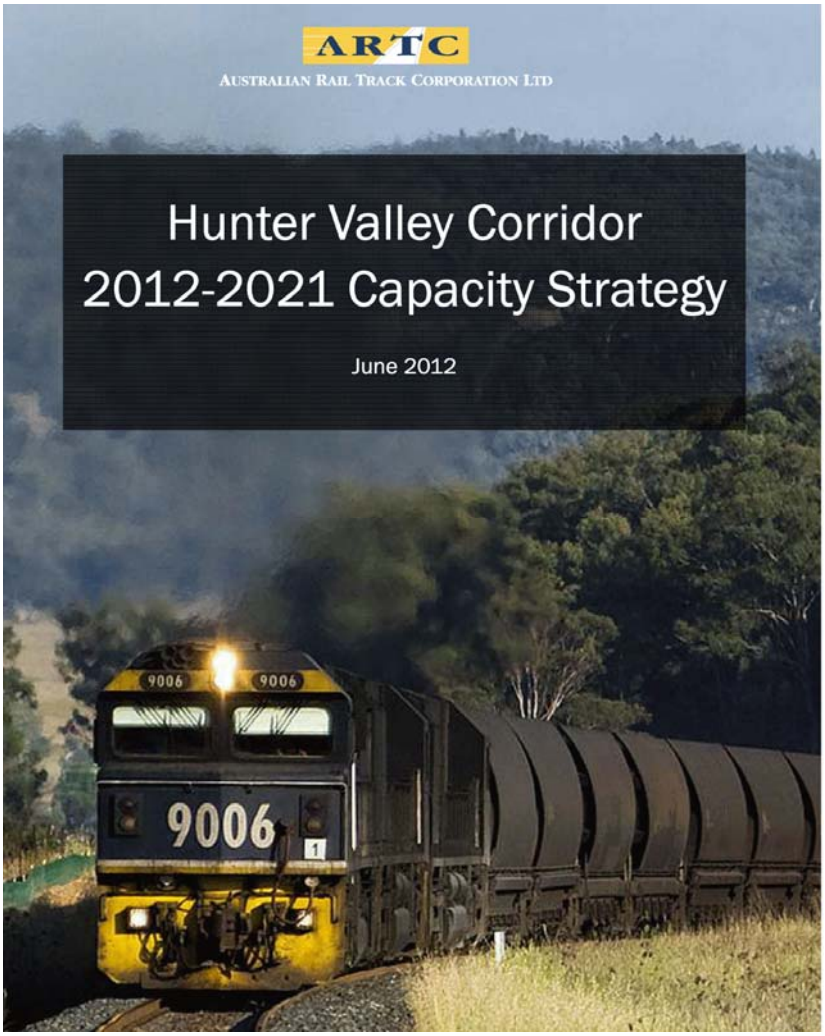
The choices associated with setting up a roundtrip are discrete, except for the idle time spent at the load-points. We discretise this time period into one minute intervals. We also note that unlimited idle time would result in an infinite number of possible roundtrips, so a maximum idle time limit is required. The size (and thus complexity) of the model and the quality of the solutions produced is highly dependent on this choice of maximum idle time. We will defer detailed discussion of this point until the results section.

We model the scheduling problem by generating the set of all possible roundtrips and then searching for a subset which maximises the value of the schedule with no resource conflicts.

2.2. Resources

There are a number of resources that are "consumed" by a roundtrip. The selection of an optimal set of roundtrips is largely constrained by the availability of these resources. The roundtrip attributes and associated resources considered here are:

TRAIN NO		115	117	611	119	121	503	125	127	129	131
LENGTH (Metres)		0	0	1250	0	0	0	1543	0	0	0
DAYS		MON	MON	MON	MON	MON	MON	MON	MON	MON	MON
SCHEDULE		1CE	1CE	1CE	1CE	1CE	1CE	1CE	1CE	1CE	1CE
STATUS		C	C	M	C	C	C	C	C	C	C
OPERATOR		AVC	AVC	PNC	AVC	AVC	AVC	AVC	AVC	AVC	AVC
COMMODITY		NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH	NHVCPTH
Port Waratah Yard Depart	dep			01:25							
Kooragang Departure	dep	01:10	01:20		01:30	01:40	01:50	02:00	02:10	02:20	02:30
Sandgate	dep	01:36	01:46	01:51	01:56	02:06	02:16	02:26	02:36	02:46	02:56
Thornton	arr										
	dep	01:51	02:01	02:06	02:11	02:21	02:31	02:41	02:51	03:01	03:11
Maitland	arr										
	dep	02:01	02:11	02:16	02:21	02:31	02:41	02:51	03:01	03:11	03:21
Branxton	arr										
	dep	02:21	02:31		02:41	02:51	03:01	03:11	03:21	03:31	03:41
Minimbah	arr										
	dep	02:29	02:39		02:49	02:59	03:09	03:19	03:29	03:39	03:49
Whittingham	arr										
	dep	02:37	02:47		02:57	03:07	03:17	03:27	03:37	03:47	03:57
Mt Thorley	arr										
	dep										
Singleton	arr										
	dep	02:42	02:52		03:02	03:12	03:22	03:32	03:42	03:52	04:02
Camberwell Junction	arr										
	dep	02:50	03:00		03:10	03:20	03:30	03:40	03:50	04:00	04:10
Mt Owen	arr										
	dep	02:56	03:06		03:16	03:26	03:36	03:46	03:56	04:06	04:16
Ravensworth Junction	arr										
	dep	03:00	03:10		03:20	03:30	03:40	03:50	04:00	04:10	04:20
Drayton Junction	arr										
	dep	03:10	03:20		03:30	03:40	03:50	04:00	04:10	04:20	04:30
Antiene	arr										
	dep	03:13	03:23		03:33	03:43	03:53	04:03	04:13	04:23	04:33
Grasstree (MK53)	arr										
	dep	03:23	03:33		03:43	03:53	04:03	04:13	04:23	04:33	04:43
Muswellbrook	arr	03:33	03:43					04:23	04:33	04:43	
	dep	------	------		03:52	04:03	04:12	------	------	------	04:52
BRANCH SCHEDULE					1CE	1CE					1CE
Bengalla	arr				04:00	04:11					
	dep				04:05	04:22					04:59
Bengalla Junction	arr										
	dep				04:12	04:29					05:05
Mangoola	arr										
	dep				04:20	04:37					05:13
Mangoola Mine Junction	arr					04:40					
	dep				04:22	------					05:15
Yarrawa	arr				04:35						
	dep				04:47						05:27
Sandy Hollow	arr										05:42
	dep				05:02						06:01
Baerami	arr				05:21						06:21
	dep				05:41						06:41
Kerrabee	arr				05:59						06:59
	dep				06:09						07:10
Murrumbo	arr				06:27						07:28
	dep				06:49						07:38
Bylong	arr				07:05						
	dep				07:18						07:53
Coggan Creek	arr										08:08
	dep				07:33						08:18
Wollar Crossing Loop	arr										
	dep				07:50						08:36
Wilpinjong	arr										
	dep				08:02						08:48
Wilpinjong Junction	dep				08:03						08:49
Moolarben Junction	dep				08:18						09:04
Ulan	arr										
	dep				08:22						09:08
Ulan Colliery	dep				08:30						09:16
Gulgong	arr										
	dep										
FORMS OR DESTINATION		TERM	TERM	STC	TERM	TERM	BJE	TERM	TERM	TERM	TERM



(1) The forward and return paths. Each path can only be assigned to at most one roundtrip.

(2) Dumpers, stackers and load points can service at most one train at a time.

(3) At most one train for a particular stockpile can be unloaded at a given time.

Since most of these resource constraints, with the exception of the path assignment, apply over the whole time horizon we need to create a set of discrete constraints. This is done by considering for each roundtrip the fixed interval over which it is using a resource and then determining the maximum clique sets of this interval graph. For each such clique a constraint is created that at most one of the corresponding roundtrips can be selected. The case where the resource is unavailable due to existing activities or maintenances is already dealt with by not generating conflicting roundtrips.

2.3. Tonnages

Each component represents a demand for a certain number of tonnes to be shipped from a particular mine to a defined stockpile at the terminal. This demand may require multiple train trips to be satisfied and can be completed by one or more combinations of the trains. For example, a component with total tonnage as 10, 000 tonnes can be scheduled by two 5, 000 tonne trains or one 7, 000 and one 3, 000 tonne train. In general the tonnages provided as input to the model are chosen so that the they can be satisfied exactly with an integer number of trainloads. However the model allows some of the tonnages to not be satisfied and simply maximises the amount of coal scheduled for delivery to the port.

3. The rail scheduling model

[Thence follows Sections 4 and 5-many pages of complex maths and linear programming exposition—Ed.]

6. Conclusion

In this paper we have described a real world rail scheduling problem that has some interesting characteristics due to the need to fit train trips into given time slots or paths on the main line. These problems can be formulated as very large integer linear programs that are too large to be amenable to solution using commercial solvers such as Gurobi or Cplex. However using the Lagrangian heuristic described in this paper it is possible to get good schedules and also useful relaxed bounds in an acceptable amount of computing time.

Future research will look at improving the software. This will include additional detail encountered in practice such as dealing with maintenance and more complicated constraints on train occupancy of the mines' load-point loops. In addition it is also of interest to consider whether multi-core computers can be used to solve these kinds of problems more efficiently in parallel. For example, running different versions of the *"greedy heuristic"* software in parallel.

Hunter Valley Coal Chain

From Wikipedia

The **Hunter Valley Coal Chain** (**HVCC**) is the chain of coal delivery from (mainly open-cut) coal mines in the Hunter Region to the Port of Newcastle and domestic coal-fired power stations in the Hunter Valley. The HVCC essentially follows the path of the Hunter River travelling south-east from the mining areas in the Hunter Valley to Newcastle. The HVCC mainly deals in the sea-borne export coal trade, especially to Asia (Japan and Korea in particular).

The port of Newcastle is the world's largest coal export port. Rising demand for coal, particularly in the Asian region has resulted in a strong increase in the volume of coal exported through the port. In 2013 port throughput was 150.5 million tonnes, up from 68 million tonnes in 2000.

Coal generally goes through the following stages between mine and port:

- The producer makes arrangements to sell coal to a buyer on certain terms. The coal is mined (most of the coal mines in the Hunter Valley are open cut mines, also known as open pit mines), processed, blended and stored either at a railway siding located at the mine or at a coal loading facility (used by several mines).
- The coal is then transported to the Port of Newcastle, almost exclusively by rail. Some coal is transported to the port by road, but this generally requires permission from the local council (due to the effect on roadways and other infrastructure) and is also usually more costly per tonne than rail transport.
- The coal is offloaded at the port onto stockpiles in the Port Waratah Coal Services and Newcastle Coal Infrastructure Group facilities.
- Once the vessel arrives at the port, the coal is loaded onto the vessel.

The vessel then transports the coal to its destination determined by the buyer.

The railway corridor used is part of the Main North railway line. The Hunter Valley infrastructure is owned by the State Government owned RailCorp and managed by the Federal Government owned Australian Rail Track Corporation under a 60-year lease until 2064. In November 1994, it was announced that the line would be opened up to other operators. Prior to this, only FreightCorp and its predecessors operated trains. The other infrastructure associated with coal transport, such as load points, is privately owned, usually by a mine or a coal loader.

West of Maitland the line is formed of two tracks, with three in places, with the lines being shared with passenger trains operated by NSW TrainLink. East of Maitland the line is formed of four tracks with the southern pair exclusively for the use of coal trains with an underpass at Hanbury west of Waratah allowing trains to reach Port Waratah without having to interface with the northern pair of tracks. In 2006 the Sandgate Flyover was opened to similarly allow trains to access Kooragang Island As at December 2012 there were 50 to 60 coal trains per day up to 1.5 kilometres in length.

To alleviate congestion which frequently sees loaded trains queuing, in November 2013 construction commenced on five relief roads at Hexham that will be located between the two running lines, with the westbound line relocated further south. This will allow coal trains to be pass one another and reach the ports in a more logical order. [This was completed recently– Ed].

Aurizon and Pacific National both provide locomotives and freight wagons to operate coal trains. Freightliner Australia provide crews to operate Xstrata owned rolling stock, with Pacific National doing likewise for Whitehaven Coaland Southern Shorthaul Railroad for Centennial Coal.

Port Waratah Coal Services Limited (PWCS) operates the main coal export facilities in Newcastle. The coal export facilities consist of two coal loading terminals, located on either side of the South Channel of the Hunter River. These are known as the Kooragang Coal Terminal, on Kooragang Island and the Carrington Coal Terminal in the suburb of Carrington. Each of those terminals comprises equipment for the delivery and storage of coal to the terminal and for the loading of coal onto vessels. PWCS leases the land on which the port is situated from the Government of New South Wales under an agreement which states that the port is maintained as a 'common user facility'.

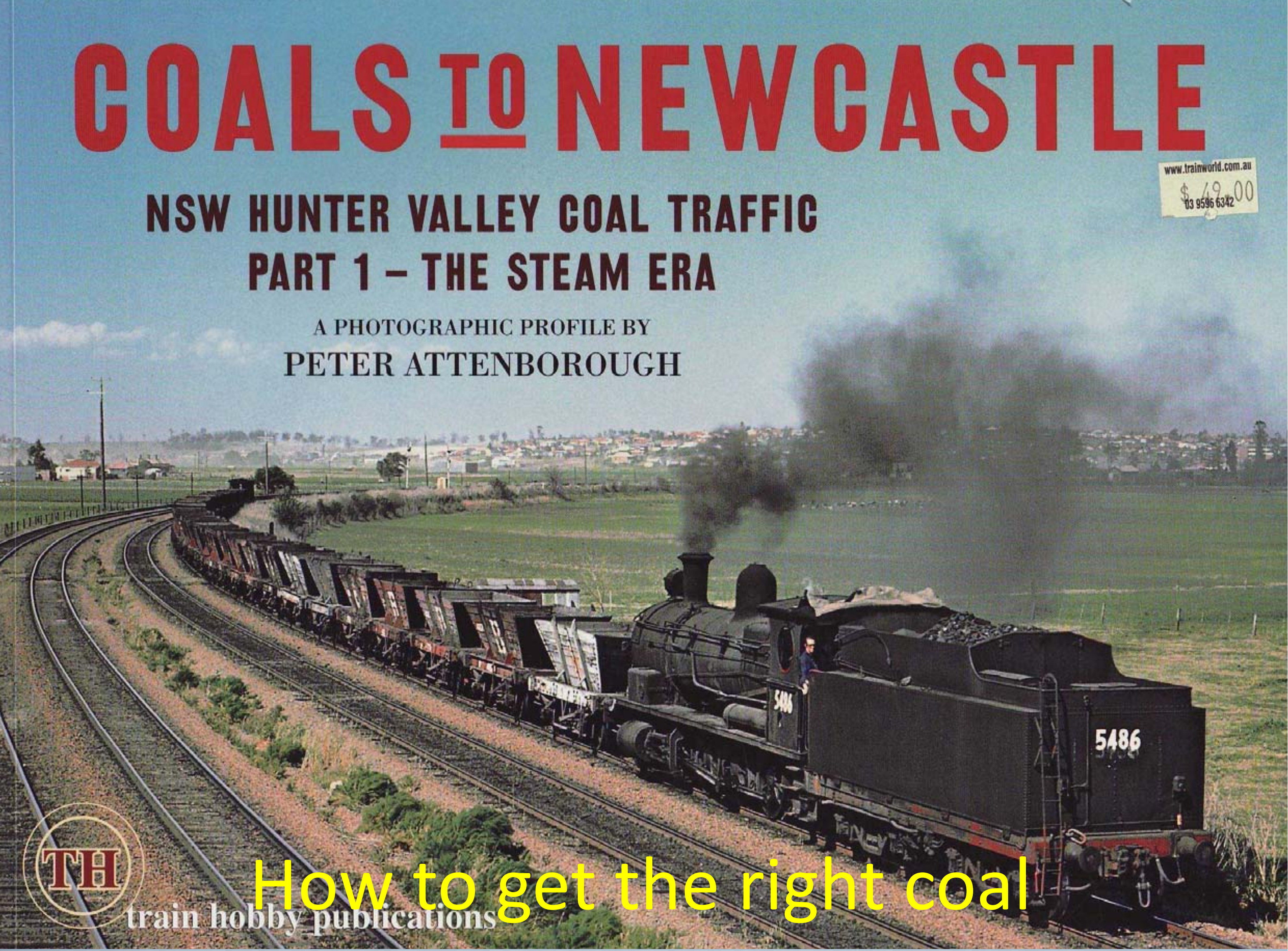
The coal export facilities operated by PWCS have a total capacity of 133 million tonnes per annum (Mtpa):

- Carrington coal terminal has a shiploading capacity of 25 Mtpa. It has berth space for two vessels and shiploading facilities that operate at 2,500 tonnes per hour (tph). Carrington Coal Terminal is able to accept coal deliveries by either road or rail.
- Kooragang coal terminal has a shiploading capacity of 108 Mtpa. It has berth space for four vessels and shiploading facilities which can operate at 10,500 tph. Kooragang Coal Terminal is able to accept coal deliveries by rail only.Kooragang coal terminal has been undergoing expansion due demand since inception. Further expansion is currently underway to take total PWCS capacity to nominally 145 Mtpa by the end of 2012.

The distribution of loading between Carrington and Kooragang Coal terminals is dependent on a number of factors:

- 'Capesize' class vessels usually berth at Kooragang Coal Terminal due to their larger size. However, they are also able to load at the Carrington Coal Terminal. 'Handysize' class vessels are loaded at Carrington Coal Terminal also due to their size. 'Panamax' class vessels may be loaded at either Kooragang Coal Terminal or Carrington Coal Terminal.
- Coal which is to be delivered by road may only be delivered to Carrington Coal Terminal, and therefore any vessels which are to be loaded with road coal must be loaded at Carrington Coal Terminal.
- If the vessel to be loaded is 'geared', that is, it has equipment on deck, then the vessel will usually be scheduled to berth at Carrington Coal Terminal, as the shiploaders at Carrington Coal Terminal are smaller and are therefore more easily able to move in and about equipment on the deck of a vessel.

Remaining vessels are then scheduled to ensure an even queue of vessels is maintained between the Kooragang Coal Terminal and Carrington Coal Terminal. If the queue for one of the terminals is substantially longer than for the other terminal, the schedule may be amended to ensure that the queues are kept reasonably even.



How to get the right coal into the right train timetable