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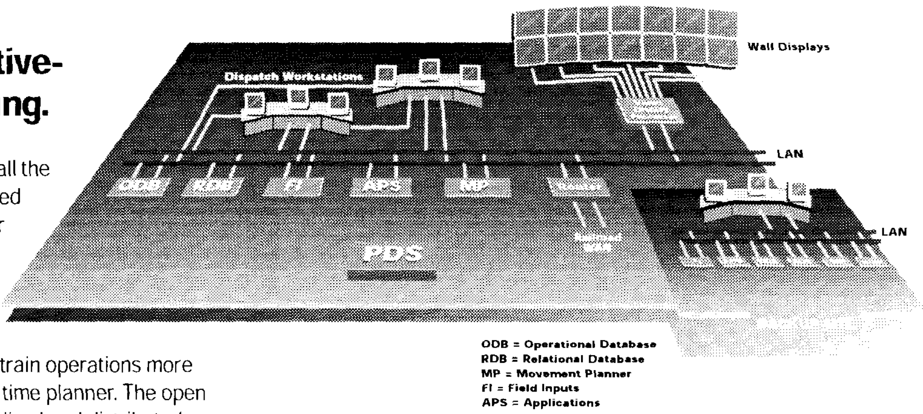

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The Times

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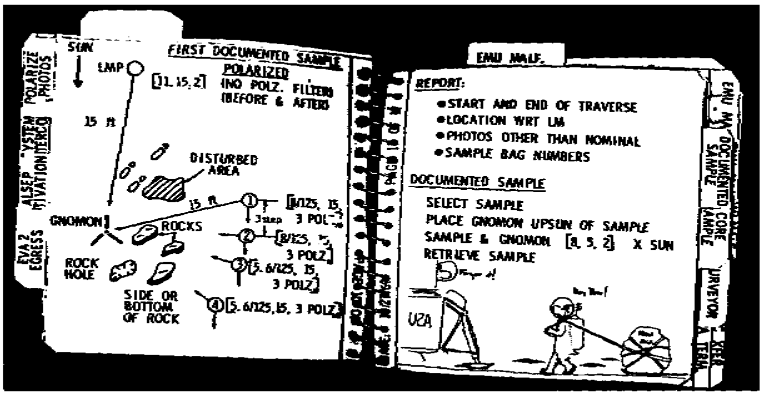
Wanted: Photocopy of the Deepdene- Riversdale and Camberwell Ashburton pages of any Victorian Railways Suburban Working Time Table, between August 1926 and October 1927. Information needed for research for an article on Melbourne's Outer Circle Line. Contact Jack McLean, 60 Kenmare St, Box Hill North 3219 , Vic or Email to jdmclean@telstra.easymail.com.au

Computer-generated train timetables

What do Neil Armstrong, a Hoover salesman and a train controller have in common? They all face problems of activity scheduling— problems that are easy to state, but hard to solve and, as it turns out, hard for computers to solve too. In a world where computers take split-second timetabling control of crashing a spacecraft on Mars, you might expect that they would play a prominent role in keeping trains on time. But train time-tabling is a difficult business and programming a computer to plan a schedule for a busy single line is at least as difficult as programming it to beat Gary Kasparov at chess. **GEOFF LAMBERT** *reports on progress.*

Alan Turing, one of the brilliant mathematicians behind the cracking of the German Enigma code in World War II, was also the inventor of the concept of the programmable computer. Turing expressed the view that any algorithmic task carried out by a human brain could be carried out also by an electronic one. His ideas speeded up the intractable mathematical analyses needed for breaking code. Another such intractable problem is that of scheduling. Whether it is the organisation of astronauts' tasks, the scheduling of travelling salesmen or the drawing up of railway timetables, the solution is both important and incompletely solvable so far. All of these problems have been tackled in intuitive ways by insightful minds, but people will ever be tempted to automate them by mathematical analysis and computation. In the case of the Apollo moon missions, the mission controllers set a schedule for the astronauts (Fig. 1), but were not sure it was the best they could do. The optimum was not obvious. NASA called in mathematicians who were able to say that NASA's schedule could be improved by no more than a few percent.

The travelling salesman problem poses an equivalent question. Given a number of towns and a set of roads that connect them, how should a travelling salesman optimise his travel to visit all with the least possible effort? For a simple case of 3 towns, even the dopiest salesman can work it out. He uses trial and error to list the possible routes and calculates the distance required for each. He quickly discovers there are 3 roads and 2 routes of equal distance. But if he is faced with 6 towns, he finds up to 30 roads—and a number of possible routes and their distances that takes days to enumerate. The only algorithm guaranteed to produce the optimal answer is this exhaustive enumeration of all possible routes.



1 *A "working timetable" for the Apollo 12 moonwalk. Astronaut Pete Conrad carried it on his wrist, but he had to abandon it on the day, when it went horribly wrong. NASA brought in operations research experts to see if the scheduling could be improved. It couldn't.*

However, it has been proved that if the salesman can find an efficient algorithm for his problem, the train controller can use it to solve his problem: they are analogous. Indeed, some algorithms for solving *linear* timetabling problems transform them into equivalent *networking* problems and solve them as they would solve the salesman problem. Most mathematicians believe, although they have not been able to prove it, that there is no simple algorithm for solving scheduling problems. But, the search for one has become the Holy Grail of the science known as complexity theory.

Even the salesman's trial and error (or *heuristic*) method quickly builds difficulties for computers because the possibilities mount so rapidly. Deep Blue, the IBM computer that beat Gary Kasparov can analyse 200 million moves per second. This is too slow to tackle the myriad possibilities of the travelling salesman problem. The problem of devising an optimal train timetable for a single line of railway seems simpler than the travelling salesman problem. After all, a railway is only a one-dimensional thing, and the travelling salesman's trip is two-dimensional. But the one-dimensional problem has extra conditions imposed. There is always more than one train and the trains are allowed to meet one another only at crossing loops. The complexity grows alarmingly with an increase in traffic. On a single line of railway carrying 3 or 4 trains in each direction, where each crossing can occur at any one of 3 adjacent loops, there are 59,000 meet place combinations to consider. If the traffic doubles, this number leaps to 10^{19} (10 million trillion). It would take a Cray supercomputer over 12 days of continuous calculation to evaluate meeting places for an 8-hour shift on a 100-mile railroad with low - to moderate traffic. Computers can't do it, but train controllers do it in real time every day.

Train control seems to be an innate skill, found only in a certain individuals, in much the same way that some are good at chess and some are not. It would be interesting to see if good train controllers are also good chess players. Certainly there *are* good train controllers. In her book "*Folklore of the Australian Railwaymen*", Patsy Adam Smith recounts the story of the impatience of a good train controller with a poor train controller on the QR's South Coast Train Control office. How the former "got the trains moving" once he took over from the latter. Timetable programs attempt to emulate this cleverness.

This distinction between the way a human mind works and the way a computer works is common in artificial intelligence. Chess again provides the best example. It is true that Deep Blue can beat a Grand Master like Gary Kasparov–but it does so by adopting a different strategy from him. By reducing the rules to a set of algorithms and then by sequentially examining and rating all the options, the machine produces "brilliant" play. But Deep Blue is like a mouse exhaustively probing the interior of its maze–and not like the mad scientist crouched above, who sees mouse and maze together and quickly spots the "big picture" answer. If we knew Gary Kasparov's algorithms and programmed ***them*** into a computer, there would be no contest. So it is with train control. When one looks at the gap between what the time-tabling programs can do, and what a train controller can do, one wonders whether automation is justified. Although information scientists say that the travelling salesman and the train dispatching challenges are similar, and have equivalent solution algorithms, this is not so at first glance. The salesman problem remains mentally intractable, but the train dispatching problem is solved hundreds of time per day by busy controllers.

The early days of single-line railways exposed the difficulties of optimising train paths, especially when decisions had to be made on the spot. The infamous 1876 Radstock single-line collision on the Somerset & Dorset Railway was the result of the train controller losing track of 2 of 17 special trains. That failure was essentially one of communications. But even with electronic communication, train dispatching can get into an awful mess. The Union Pacific Railroad became "gridlocked" in the late 1990s, when its takeover of Southern Pacific produced network traffic which was beyond the ability of its controllers to control. The problem took nearly two years to resolve (even using computer-aided dispatching) and became a matter of national political concern.

2. *Drawing up a timetable in the traditional way. This man has a exceptional advantage over a computer because he can see a complete picture of all trains over all time and all space– all at once. The computer must examine each separately and serially*

There are a number of areas of railway operations that have received attention from information scientists. One is the so-called *routing problem* which is the railway manifestation of the travelling salesman problem; sending trains economically over a complex network. While this larger task has also been tackled in research over the last 15 years, it lies beyond the scope of the present discussion. Another focus has been *blocking*–the way that mixed-consist trains are made up in "blocks" for dispatch. Operations research people study also the allocation of rolling stock and locomotives and the way that classification yards are managed. Finally, there is the problem of rostering crews to trains; this might also be optimised by the use of computers. While it would be desirable to construct a model of the railway that incorporates all of these components, this has never been done. It is too hard. Our interest here is progress made with line timetabling problems, where the principal distinction is inherent in the name - they plan purely the movements of trains in time.

There are at least three timetabling tasks a computer might tackle. The first is the drawing up of a fixed timetable in advance, thus replacing the usual human planners (Fig. 2). These days, one can buy (expensive) programs for a personal computer that can do exactly that (our cover illustration). The second task is Computer Aided train Dispatch (CAD), a minute-to-minute assistant to the train controller in keeping the trains moving. The third task is in guiding management decisions about rail infrastructure: examining a railway system to determine its carrying capacity or its sensitivity to disruption and delays. Railways might use this approach to determine whether to add another track to a line, or to take one away. Although the correspondence with the above three categories is not exact, computerised timetables have been classified as *optimisation*, *simulation* and *analytical*. The optimisation task is probably the most interesting for timetable students.

Computers can also be used to turn a

table of times into a graphical timetable or into readable typesetting on paper. But these are surely trivial pursuits for a computer. Even I can program mine to do them. It is interesting though, that so many Australian working timetables are "typeset" by spreadsheets like Microsoft's Excel. In my experience it is a program singularly ill-suited to the task.

Attempts to “automate” the scheduling of trains to prevent another Radstock were made 150 years ago. The train graph and a mechanical device for drawing it were developed in France in the 1840’s, as I have previously described (*The Times* Jan. 1996). This method was further “mechanised" in the United States where people built equivalent devices using coloured threads pinned to wall charts. These were *string-line diagrams*.

String devices were in use by railways all over the world by the 1860s, although they were used in only a desultory fashion. The pen and paper versions are still used for planning train schedules and they are still called string line diagrams in the U.S. A string timetable *is* a sort of computer, but an analogue computer rather than a digital computer. It gives a visible representation of the processes that go on in a timetable planner’s mind but it does not supplant that mind. Devices that supplant that mind are what computer-generated timetables are all about but, since we have so little understanding of how the mind’s intuitive processes work, we find it hard to build their computer equivalent.

As early as 1958, O.S.Nock reported that British Railways was using “computers” to draw up timetables, under the guidance of Sam Ell, famous for his system of testing steam locomotives. But Ell’s “computers” were not electronic computing machines, they were simply a set of standardised graphs of tractive effort and train resistance that enabled running times to be extracted from the dynamic characteristics of trains. Many railways used them.

Probably the first serious attempts at mathematical analysis and computer drawing of timetables occurred in about 1960. By 1963, the Railway Magazine reported that the Eastern Region of British Railways was using computer-derived timetables and that the London Midland Region had commissioned the computer department at Leeds University to automate its locomotive rosters.

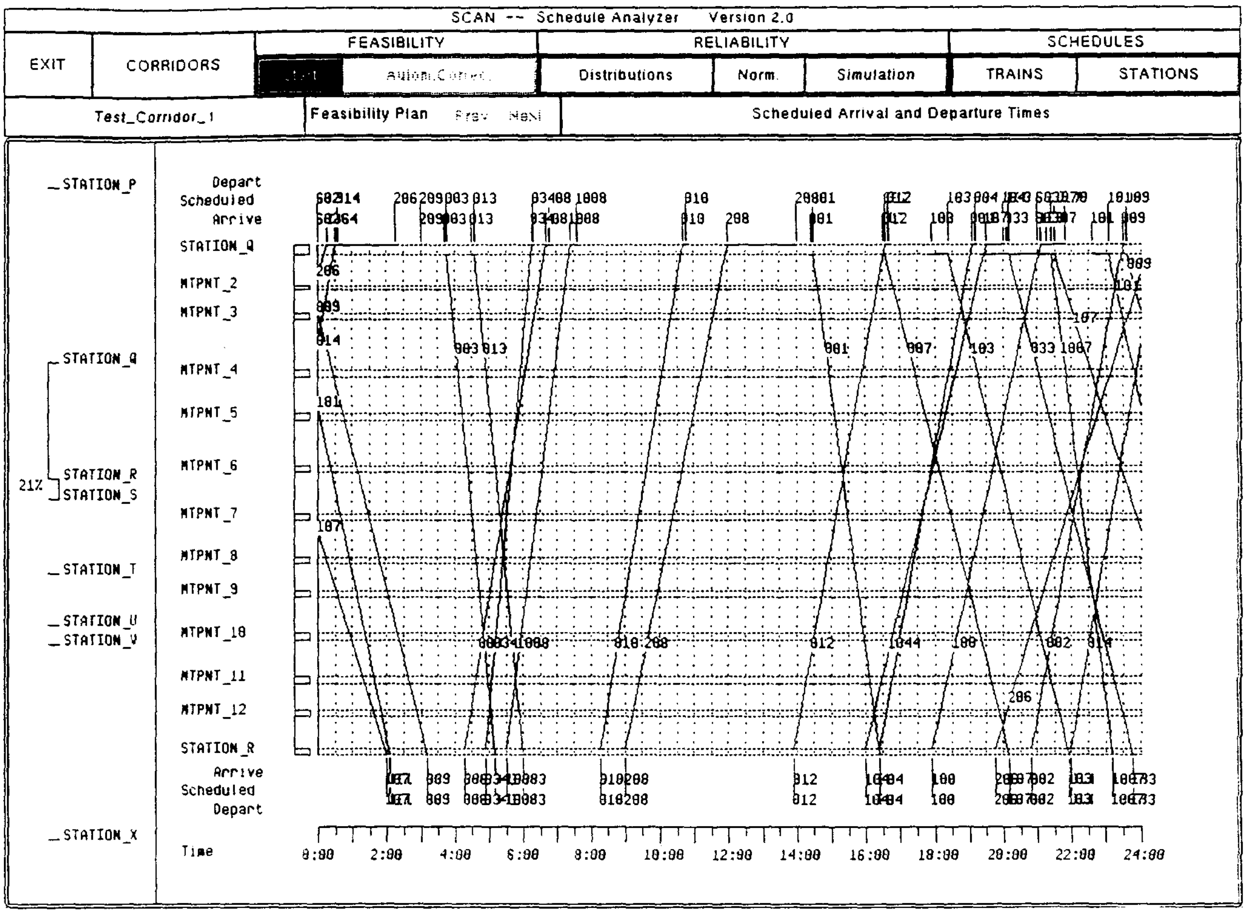
The work proceeded in 2 parallel streams, on the railroads and in universities. Most of published research work comes from the universities. The work of the railways and signal companies was usually hidden in their in-house documents. Railways weren’t the only transport mode attacking mathematical and computerised timetables. By the early 1960’s a lot of work had been done on road traffic flow; the scheduling of air traffic was also coming under computerised control. The author of a recent review of computerised train timetabling works for an airline. All three transport modes, while having obvious differences in their traffic, benefit from the knowledge that if a successful algorithm is found for one, the chance of success for the others is enhanced.

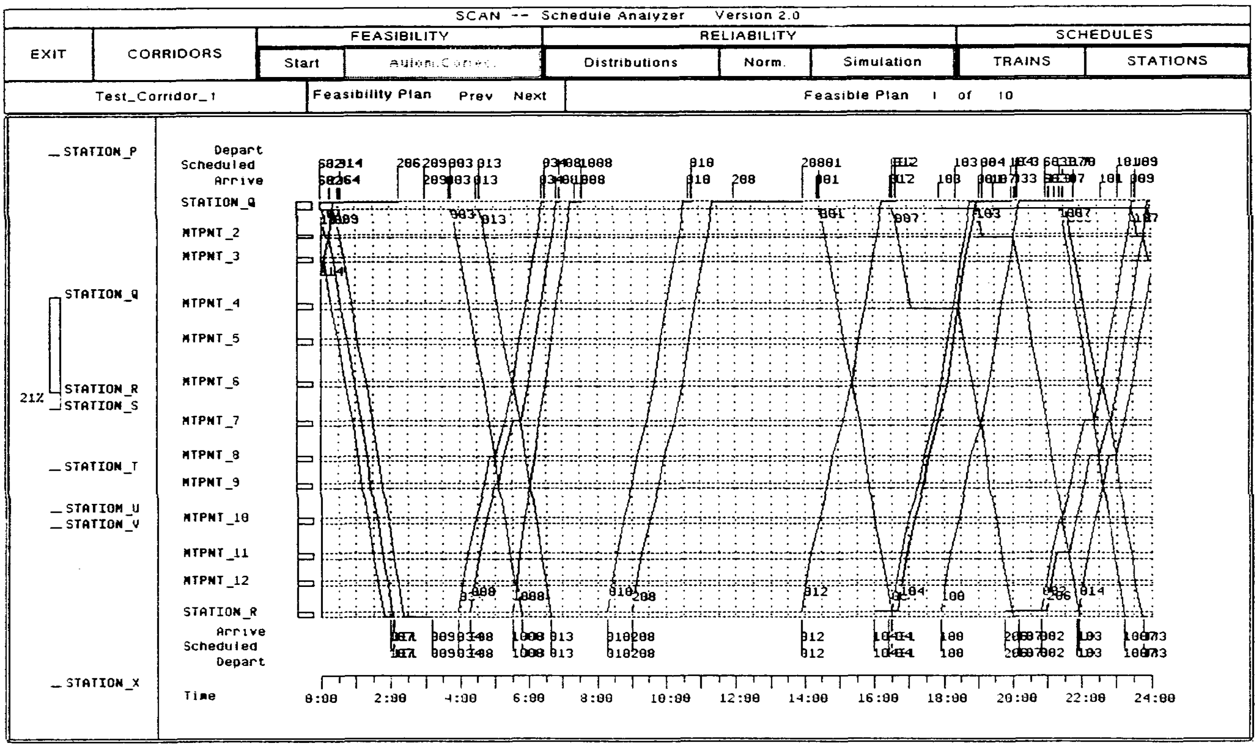
More than 200 research papers on computerised train timetabling have been published in the operational research literature, most in the last 10 years. The research has gone on all over the world, but Sweden, Northern Ireland, the University of Pennsylvania, Canada, Japan, Australia and Turkey have been particularly active. The University of Pennsylvania and Queens University in Ontario have probably been the centre of the field. Little work has come from England or Western Europe. This geographic pattern reflects the priorities of rail operations in these different places. Those with an active program of research are those with extensive networks of single-track railways. Most research is about such lines. It seems that the work is mostly driven by a degree of curiosity on the part of operational research academics, although some has been done as a result of contractual arrangements with railways.

Things move slowly in the transportation publication field. It takes an average of 2 years to get a paper published, 15 months of which is the argy-bargy of peer-review; there must be considerable competition between researchers. But even so, the published papers are frequently flawed by simple errors and inconsistencies that detract from their believability. Probably about half of the research reports are effectively ignored because they appear in obscure places, such as university working documents and the railroads’ own internal technical reports. Some of the key work is contained in Ph.D. dissertations, especially from the University of Pennsylvania, which must be one of the few places on the planet where one can get a Ph.D. in train timetables. Progress made in this field is reviewed from time to time in the operational research literature, most recently in 1998 and the picture I present here draws heavily on these reviews.

All three types of models start with the assumption that railways plan train running by specifying the desired departure and arrival times at terminals. On a string line diagram, this objective plots as a clutch of uninterrupted and unerringly straight travel lines. All trains are non-stop, and they encounter one another in "cornfield meets" between loops. Not even the different speeds on the different sections of line are acknowledged. The modellers even insist that railways also sometimes schedule trains over their lines faster than is physically possible, but this also seems far-fetched.

The models then adjust the lines to vary their slopes and to make the meets occur at the loops. Thus, their *delays* are merely the extra standing time at loops that must be inserted into the running schedule to accommodate crosses and passes. This is a rather naïve assumption about the way a timetable is planned, particularly when a new train is added to an existing timetable. More likely, a railway sets some sort of target departure time (but maybe not even that) and then combs its graphical timetable for a suitable path. These paths will include crossing and passing times as a natural adjunct, rather than a *delay* forced upon the train. The railway may modify existing train paths to more easily accommodate the new train, but it is unlikely to scrap the lot and start again. The railway’s timetable will incorporate the arrival time as an output rather than an input. An illustration of a *desired* timetable and a resultant *optimized* timetable, taken from a recent research paper, is shown in Fig.3. No train planner would take the first "timetable" as a starting point. But, because the train controller's starting point cannot be modelled in an electronic brain, the computer's unworldly





3. *An* ***infeasible schedule*** *(top) transformed into a* ***feasible meet-pass plan*** *(bottom) by the University of Pennsylvania's SCAN I system. Look at all those 3-way collisions in the evening ; is this the way to run a railroad? The line is Burlington Northern's transcontinental line; Station Q is Whitefish,, Station R is Libby. Trains 1007 & 1008 are the Empire Builders*

starting point may be as good as we can get.

For that matter, in America most trains are not scheduled at all. AATTC members are familiar with "time-free timetables", but they have been a revelation to the operations research people who essay a train timetable model. "*What came back to haunt us … was our assumption that railroads desire to operate with schedules*." In reality, many American railroads have no such desire. Devising a tactical timetable planning model for a railroad that dispatches upon tonnage accumulation rather than by timetable slot would be a waste of effort. The railroad might be receptive to a real-time dispatching model, however.

Analytical models

The analytical models attempt to measure the performance of a railway line given its infrastructure, its traffic level and the characteristics of its trains. They don't build a timetable so much as take it apart. They start with a pre-determined timetable and impose on the trains various types of "hindrances", such as meeting other trains and perhaps random delays. Their analyses are usually not value-free in that most incorporate a measure of dispatcher behaviour, in particular how train controllers make decisions on train priority. Such analyses can only begin when they have historical records or make some assumptions about controller policy.

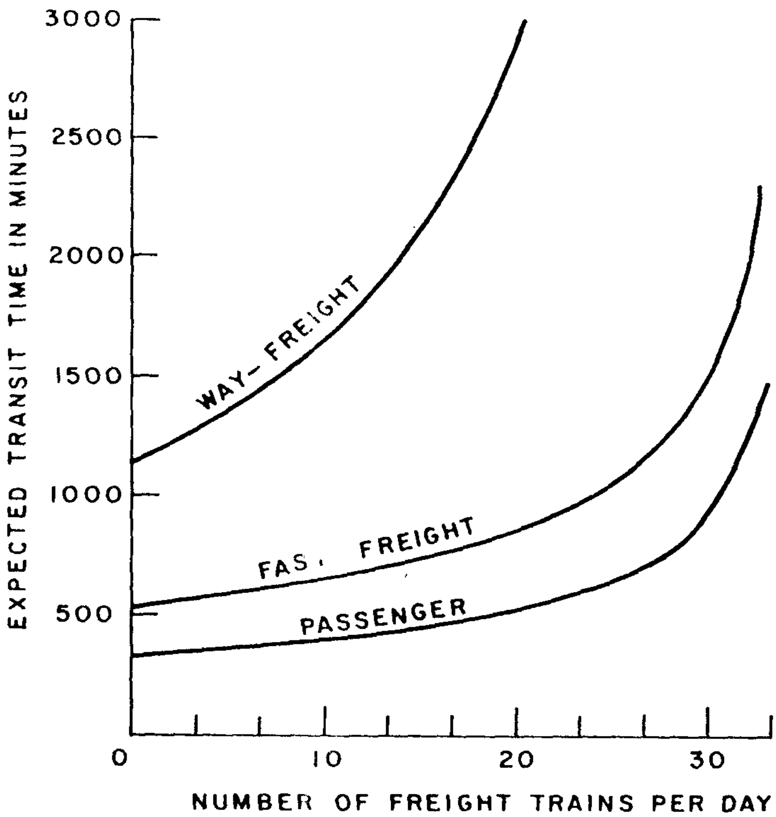
The results are generalised in that they predict what will happen on the average; they do not model what will happen exactly. No string line diagram emerges from them, what emerges is an estimate of total travel times with their reliability or the chance of the timetable being adhered to. One can alter the base assumptions of these analyses (the number or positions of sidings, say) to determine whether altering them would improve timetable performance.

Our Fig. 4 shows an analysis of part of the Canadian National network where 2 passenger trains, 3 way-freights and a variable number of priority freights run each day over a 400 mile line with 19 crossing loops. Plotted is the transit time per train for different numbers of priority freights.

Historically, as with other models, the analytical programs started from a simple base and were progressively elaborated until they came to model the operations of a real railway. The first study, by Ove Frank in Sweden, was limited to trains of fixed speed. Frank's trains ran on a fixed interval timetable, over a line with regularly spaced loops, where trains of one direction always had priority and where no train ever overtook another. Frank's aim was to estimate how many single-direction trains could be fitted onto a railway line in a set period. This was a matter of interest to the Swedish military, with whom Frank had some sort of connection. Frank didn't offer an algorithm for *how* to fit these trains in. Analytical models don't do that. Frank's research paper makes no reference to earlier work by others. Probably there wasn't any. Frank's effort was itself a one-off.

A team lead by E. R. Petersen from Queens University in Ontario extended Frank's model by allowing for differing train speeds and for overtakes as well as meets. Later they extended these methods to allow for lines that were partly single and partly double and elaborated it further by devising analyses to avoid *line block.* This is the greatest embarrassment a human or computer train controller can face - a complete clog of the railway when the only way forward is for some trains to go backward. This can arise when the view of operations is *myopic* or too short term. In computer terms, it can be avoided by *deeper* search algorithms at a great cost in computation time. Petersen and team tackle it mathematically by grouping trains notionally into *fleets*, which streamlines the necessary calculations.

The Petersen team also tackled a problem of a different type in the mid-1980s, when they analysed the requirements for a high-speed passenger railway between Toronto and Montreal. A exotic creature in a world where TGVs run on multiple track, the Canadian line was to include 357 km of single track, where trains were to run at 200 km per hour (which is not very fast by world standards). The model assumed that 90% of trains ran to time and 10% were up to 8 minutes late, a few even later. The research sought a likely timetable and its reliability as a function of the number and length of the crossing loops. The researchers concluded that an hourly bi-directional service of 16 trains (plus 2 express freights and 1 work train) could be run over the line each day, providing that 50 km (13%) of the distance consisted of passing sidings. There were to be 4 loops, 9 km long,



***4.** The Petersen analytical timetable model at work on an eastern Canadian line. Here is the effect of saturating the line with more and more freight trains. The transit times of way-freights suffer most as the fast freight trains multiply. Twenty freights plus 2 passenger and 3 way-freights seems to be about the practical capacity of the line* where medium-speed running meets were to occur. To accommodate the express freights, work trains and passenger trains running more than 8 minutes late, there were to be an extra 14 sidings, 1 km long. A major policy change was needed to make the system robust in the face of the >8 minute delays to passenger trains - late-running trains had to take to the short loops to become later and later. Needless to say, this line has not been built. The analysts suggested that their methods applied also to other types of railways, including mine-to-port lines. In 1999, such an analysis appeared from the Australian National Competition Council during a High Court case over Robe River Iron Associates' claim to use Hamersley Iron’s railway instead of building its own. The dual-use proposal required doubling the number of passing loops on the HI line from 10 to 20, to accommodate 1 extra RRIA train per day.

A University of Pennsylvania research team, led by Patrick Harker, broadened the scope of the Petersen models by replacing Petersen's assumptions that train departures were random with models in which trains had definite departure times that were not necessarily equally-spaced. This was closer to the way a real railway is dispatched. Their model also made estimates of the reliability of the calculated delay figures, by using the *variance* of the delay. In statistics, the mean and the variance of a variable are known as the first and second moments, so the Harker team called their method a *two moments estimator.* Later, they extended the model so that trains, although scheduled to depart at specific times, were subject to some uncertainty in the times. They further extended their methods to analyse a partially-double, partially-single-tracked line. This team went on to develop a method of selecting train departure and arrival times to maximise punctuality. This was their *Line Delay Model/Target Time Generator* (LDM/TTG). When used with their own simulation model (*SCAN*, see below) this became a mixed analytical-simulation-optimisation model. The interior workings and philosophy of the Target Time Generator are a trifle obscure, but its chief object was to replace the traditional setting of target departure and arrival times based on priorities with one based on minimising costs.

The Los Angeles area has a complex network of single-track rail lines that service its ports. Many run along or across the public streets of the area and carry an intense service of slow and long freight trains. Such a combination means delays for trains, road traffic and everyday life. The port authorities sponsored research in analytical timetabling methods in an attempt to measure and ease the delays. This research paralleled that which was carried out in Ontario, but was directed at a very different type of railroad, especially since it was a network, rather than one line of railway.

Most of the analytical models envisage that crossings at loops will involve only two trains, but it is well-known that low-priority trains may be "put away" in loops for extended periods of time while a succession of other trains meets or passes them. This reality was modelled, and the resulting delays calculated, by Edwin Kraft from CSX Transportation, who also developed techniques for deciding the locations for extra crossing loops to improve an existing timetable.

Simulation models

Simulation programs set up a model of a railway and then “see what happens”. They weave a string line diagram from the raw materials. They are predictive not prescriptive– they predict the most likely scenarios that could develop on the line, they do not write a *best possible* timetable, although some can be extended to do so.

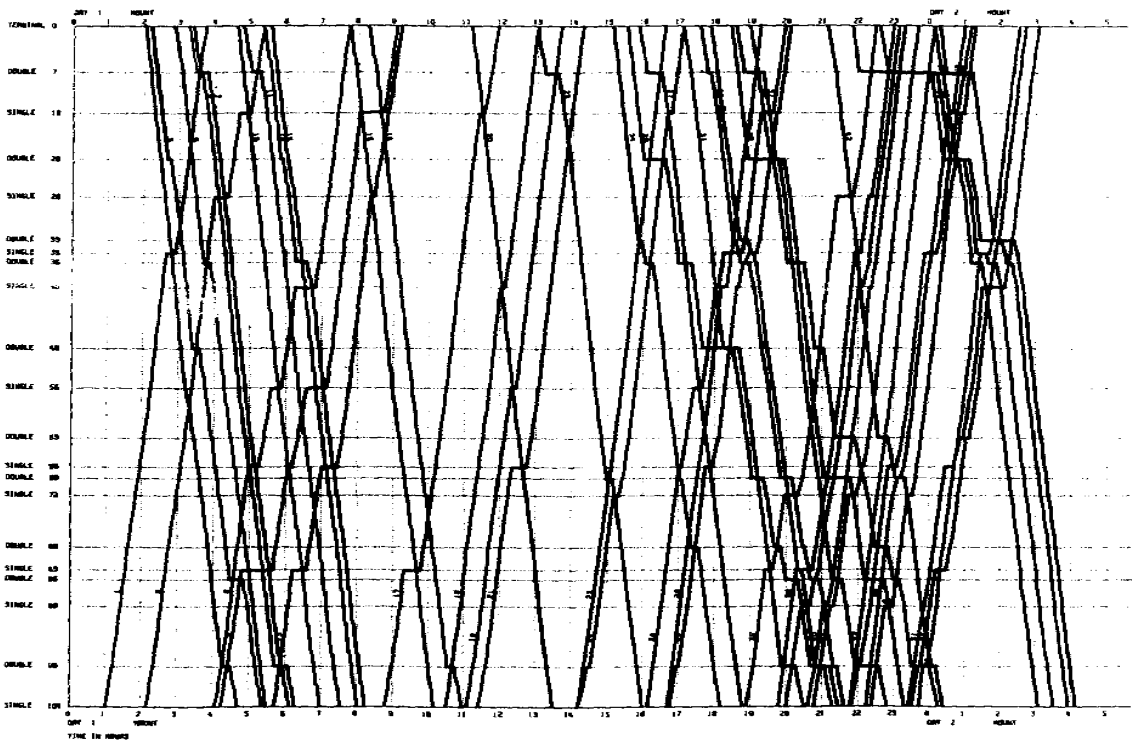
Simulation models have arisen from several different places. The Petersen team from Queens University in Ontario particularly focused upon using simulation models to estimate transit times over a railway and the likely levels of delay in each model. According to them, by the mid 1970s "*detailed simulation models for train congestion are used by most railroads*”. A typical such model was *SIMTRAC* - a model for train dispatching on a single line of railway. By the early 1980s, the Petersen team had developed a Fortran computer program with over 1800 lines of code capable of simulating up to 2000 trains of varying speeds over varying line configurations. 1800 lines of computer code might seem rather a lot, but it is less than one-fifth that required by SIMTRAC. Our Fig. 5 shows a typical string line diagram produced by a Petersen model.

The University of Pennsylvania team studied simulation models extensively, coming up with their own system, *SCAN* (***Sc***hedule ***An***alysis system). The SCAN people were working under a grant from Burlington Northern, their model was tested on BN's Washington-Montana line and BN apparently adopted the system to plan its timetables for these lines.

As with their analytical models, the team started with *infeasible* end-to-end *schedules* and modified them to produce *feasible meet/pass plan diagrams*. The authors stated, "the purpose of SCAN is to *help* in the design of robust (reliable) schedules, not to provide an optimal schedule.” *SCAN* regards as infeasible any plan that makes any train late at its destination by even the tiniest amount. On-time or early arrival of all trains is its target. SCAN can model the unreliability of services produced by unexpected slow running of trains (as opposed to other models where the uncertainty arises from variable departure times). Unsurprisingly, sometimes the program fails to produce a feasible plan and must be run again with different target times. Train controllers are reluctant to throw away a given set of schedules for an optimal set, so this tactic is not popular.

SCAN has other drawbacks. It takes no account of train priorities, it ignores the fact that train timetables are cyclic (e.g. they repeat each day or each week) and it assumes that all trains are mandatory. The SCAN people see their system as handing a weapon to controllers to use in their war with Regional Vice Presidents who prefer slack schedules so that the trains of their region are never seen to run late.

In Australia, the NSWPTC developed a simulation model called TWS (*Train Working Simulator*), but details of what it did are hard to find. The Bureau of Transport Economics looked at TWS and at SIMTRAC when it was evaluating options for upgrading various intercapital rail links in the 1970s. The BTE considered both models inadequate and developed its own model, *Single Track Simulation* (or



***5.** A one-day simulation for a Canadian line, formulated by a team from Queens University at Kingston. This appeared nearly 20 years ago and marked a considerable advance in the scope of simulation programs*

STS) in an attempt to calculate line delays. It preferred a simulation model to do this because it believed that analytical models were too difficult to use to assess the delays inherent in different upgradings. Among other things, the BTE used its model to examine train delays on the Junee-Albury section of the Sydney-Melbourne line. The best the simulation could do was to find quicker paths for pick-up goods. The delays it estimated for all other trains were higher than the train controllers could achieve. This was so, even when the simulation was guided by the apparent train priority ratings made by the controllers. The BTE was still tinkering with this model in the 1990s, as it went through another round of evaluations of rail upgrading.

Optimisation models

Optimisation models try to write the best possible timetable. They "play trains", in a game where they test a number of scenarios to find one that will have the least total transit time, or the smallest delay (or risk of delay) or the biggest profit, or the one that requires fewest locomotives or shortest crew working hours.

In drawing up an *optimisation* timetable, the aims seem fairly clear– one starts with a known track configuration and some specifications about the service one would like to run: number and types of trains and their speed characteristics, approximate (or exact) desired departure and arrival times, perhaps a priority rating system for the trains. The object is to draw up a timetable in which the target criteria are met.

The people who draw up analytical models also have an interest in optimisation models, thus we find that the Universities of Montreal and Pennsylvania are both very active in optimisation modelling. However, it is also being tackled by numerous other teams, including several in Australia.

Optimization models can be subclassified by:

Planning horizon: *strategic*, i.e. drawing up a fixed timetable, *tactical*, i.e. on a short term management basis and *operational* i.e on an instantaneous management level - looking over the controller's shoulder;

Type: *fixed velocity* versus *variable velocity*;

Objective function: To maximise reliability, to adhere to the timetable, to save fuel, to minimise conflict, to minimise overall costs, to mimimise delay and risk of delay;

Model structure: *Linear* or *nonlinear integer* or *mixed-integer* problems;

Solution method: *branch and bound, heuristic decomposition, Lagrangian relaxation, neural network, genetic algorithm, TABU search.*

Is that clear? If these terms appeal to you, then you will probably also like "Max tension problem", "greedy heuristics", "violated clique inequality", "computation explosion", "improved neighbourhood" and "NP-hard"– all terms that pepper the optimisation literature. The appearance of so many abstruse terms in the models is only one symptom of their inherent difficulty. I don't know much about most of these terms and I am also daunted by the mathematical symbolism in

$$\begin{aligned}
\frac{\partial g_i(\mathbf{T},\mathbf{V})}{\partial T_i}
&= \sum_{j:\mathrm{D}_i(j)\geqslant 0} \left\{ \frac{\partial \mathrm{P}(t_i \geqslant \mathrm{D}_i(j))}{\partial T_i} \mathrm{Var}(d_{ij}) \right. \\
&\quad + \left\{ \frac{\partial \mathrm{P}(t_i \geqslant \mathrm{D}_i(j))}{\partial T_i} \right. \\
&\quad \times \sum_{k:\mathrm{D}_i(j)\geqslant \mathrm{D}_i(k)\geqslant 0} [1 - \mathrm{P}(t_i \geqslant \mathrm{D}_i(k))]\mathrm{E}(d_{ik}) \\
&\quad - \mathrm{P}(t_i \geqslant \mathrm{D}_i(j)) \\
&\quad \times \sum_{k:\mathrm{D}_i(j)\geqslant \mathrm{D}_i(k)\geqslant 0} \frac{\partial \mathrm{P}(t_i \geqslant \mathrm{D}_i(j))}{\partial T_i} \mathrm{E}(d_{ik}) \\
&\quad - \frac{\partial \mathrm{P}(t_i \geqslant \mathrm{D}_i(j))}{\partial T_i} \\
&\quad \times \sum_{k:\mathrm{D}_i(k)\geqslant \mathrm{D}_i(j)} \mathrm{P}(t_i \geqslant \mathrm{D}_i(k))\mathrm{E}(d_{ik}) \\
&\quad + [1 - \mathrm{P}(t_i \geqslant \mathrm{D}_i(j))] \\
&\quad \left. \left. \times \sum_{k:\mathrm{D}_i(k)\geqslant \mathrm{D}_i(j)} \frac{\partial \mathrm{P}(t_i \geqslant \mathrm{D}_i(j))}{\partial T_i} \mathrm{E}(d_{ik}) \right\} \mathrm{E}(d_{ij}) \right\}
\end{aligned} \tag{15}$$

6. *The innards of a timetable program. This is a single equation used to calculate elements of a Jacobian matrix and is taken from a "two-moments estimator" paper from the University of Pennsylvania. We could show you an equation from a "Lagrangian relaxation" method- but the effect would be anything but relaxing.*

each (see Fig. 6). We may at least say that *integer methods* essentially assign integer or logical variables (1 or 0) to trains according to whether events (such as a meet) happen or don't happen. *Branch and bound* methods essentially consist of searching a *tree* of possible alternative paths in space and time, but limited by particular constraints. *Variable velocity* models refer to those that employ *pacing*, the deliberate slowing of trains in order to meet destination objectives or to minimise fuel consumption. Some of the *decomposition* methods appear to involve a two stage process where a feasible schedule is first determined (*à la* the simulation models), then it is tinkered with to improve the end result. These don't necessarily produce the best "global" timetable. In fact, no method is guaranteed to produce the best timetable, users have to be satisfied with approximate solutions.

One of the first optimisation timetables came from Israel. This was not surprising–Israel has one of the world's simplest and least busy railway systems, scarcely even earning the description "system". The authors of this study, while they could produce a timetable for their very simple case, admitted that anything bigger would have stumped their model.

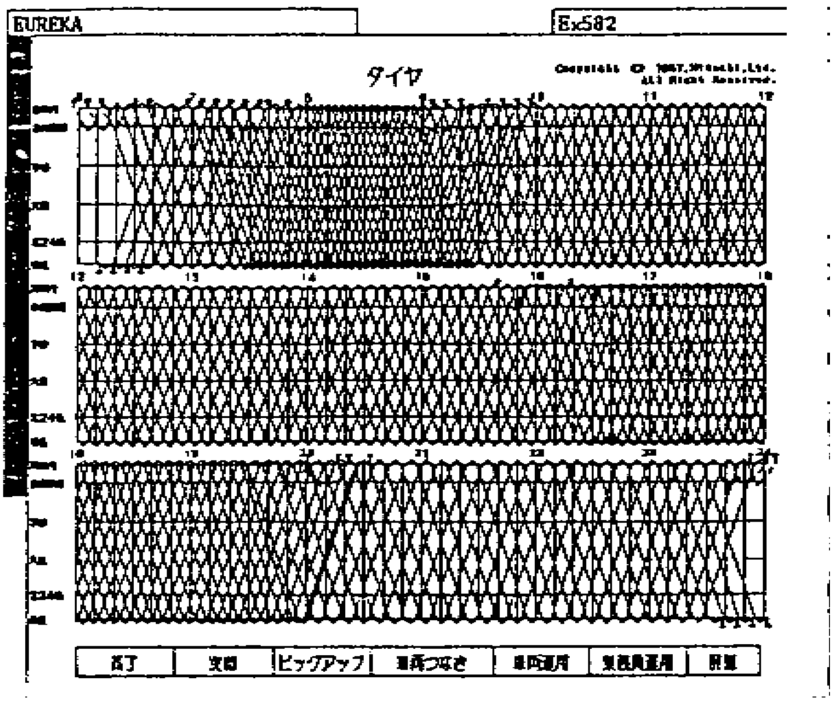
Optimisation models appeared sporadically in the operational research literature from the late 1970s to the early 1990s, but multiplied quickly after that. Once again, the University of Pennsylvania team ventured into this field, in a series of research papers that integrated their SCAN methods into an optimisation scheme. Their aim was to provide a link between tactical timetabling and actual operations by generating target times to be used in dispatching models. In Sweden, a "profit maximising" scheduling model was invented and successfully tested on a realistic example from the Swedish system - a line carrying 18 passenger trains and 8 freight trains over a 17-section single line. In Northern Ireland, researchers at the University of Ulster investigated the writing of optimised timetables for entire double-tracked networks, including complex stations. They demonstrated that the same methods could be applied, in a simplified manner, to dispatch trains on a single-tracked line of railway.

These were fixed-velocity models, but a limited amount of work has been done on the drawing up of timetables for trains that are "paced" too. These again come from the University of Pennsylvania and more recently from the Queensland Institute of Technology. The QIT is one of at least 6 organisations in Australia that have developed simulation/optimisation models. The QIT methods were later extended in a kind of mixed analytical-optimisation model, to produce a method that not only specifies a timetable, but calculates where to build the sidings to minimise train delay.

Japan is a special case. It has the world's busiest and fastest passenger railways which run over long distances. Computerised train timetabling in Japan is oriented towards optimisation of the timetables of these super-railways and commuter lines. Compare the computerised string line diagram–it looks like honeycomb–from Japan's "Eureka" timetable planning computer in Fig. 7 with that in Fig 9. The Japanese work is not only different in aim and scope, it is different in methods as well. There has been very little cross-fertilisation between Japan and the rest of the world in computer aided dispatching. The authors who produced the graph in Fig 7 go to great pains to explain the underlying philosophy of their model. They lay great emphasis on its *user-friendly* approach and the way in which it attempts to emulate the thought processes and paradigms of "scheduling experts". This is an approach that other researchers have indirectly criticised as "paving over cow-tracks". The scheduling experts are pleased, however. They admit they can do no better in ten times the time.

Practical experience

Do railroads use these models extensively in drawing up their timetables or in dispatching trains in real time? Mostly, they do not. If the proof of the



7. Bewildering to the eye. An intense service on a Japanese high-speed line, formulated using an "expert system" approach. In the rush hour between 8 and 9 a.m, 36 trains are sent down the line. The developers at Hitachi tried to mimic the methods of "timetable experts" in formulating their algorithms.

pudding is in the eating, then few railroads are sitting down at the table for dessert. A recent review of the field lamented that very few dispatching models have been implemented and used regularly in railway operations. Quite a few of the programs have been tested on *models* of real railways, including one of interest to our readers, Queensland Rail's North Coast line, but they have rarely been applied to take control of real trains.

In the early 1980s **Norfolk Southern** devised a computer-aided dispatching system and gave it a "dry run" by examining some historical records from its train dispatching office. The company asked its train controllers to "control" these trains. The controllers produced simulated dispatching patterns that were close to those which the real dispatchers had produced some years before. Then the railroad made the dispatchers do it again, but with the computer advising them. On the average this process reduced delays by 34%. On this basis, the railroad installed the system to dispatch trains on its Alabama division, using a minicomputer to control several subdivisions at once. It found similar savings in real life to those it saw in the simulations. However, these are not very busy lines–mostly fewer than 4 trains per day in each direction. The software, which exhaustively analyses all possible meets, cannot handle a really busy line.

An example of such a busy line is that of the **Union Pacific** across Nebraska, where 120 trains, a mile long and 5000 tons in mass, thread the twin tracks each day. Here, at least 50 trains are always on the move on a 300 mile stretch. The Harriman dispatching centre at Omaha controls them all, on a block-long illuminated diagram. The system was designed and installed by Union Switch and Signal, which also built and installed one for CSX Corporation. The dispatchers have a computer which automates meets and passes and clears signals. But they scorn it - it solves some tasks poorly and the they refer to it as "*a trainee dispatcher who isn't going to make it*." This is where the value of computerisation ought to be apparent, but is instead hidden.

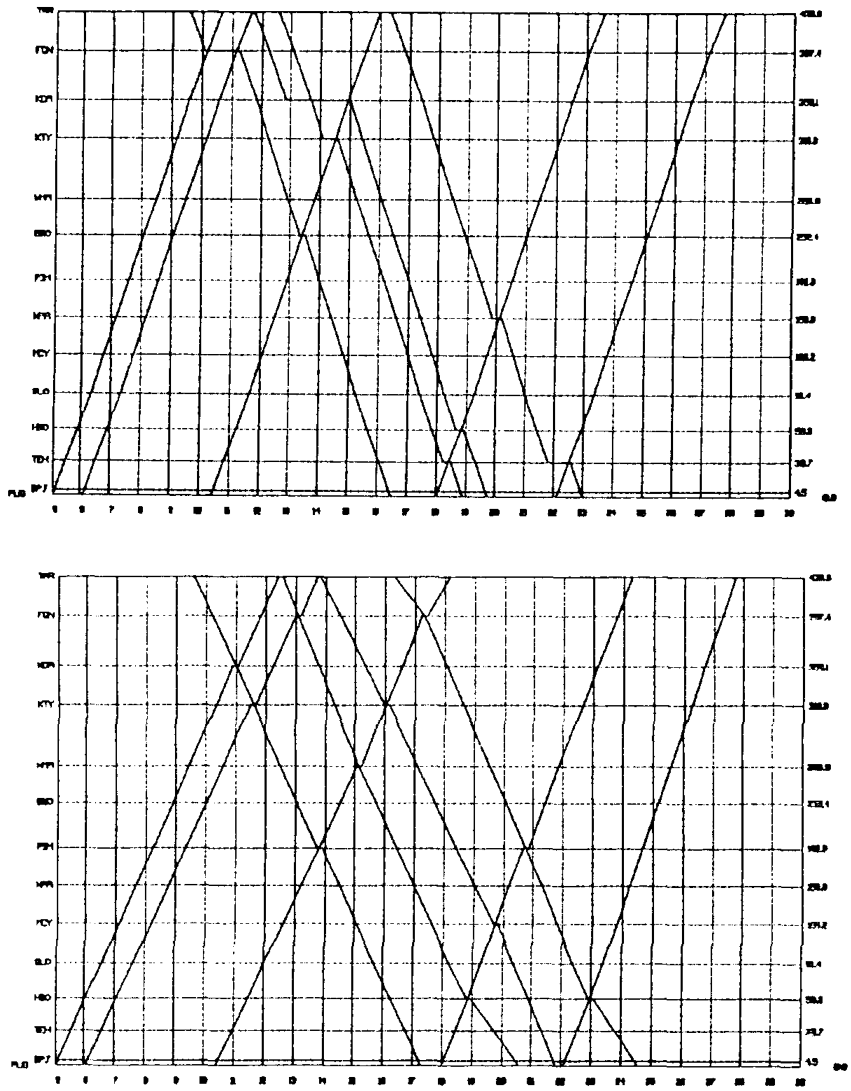
The **Advanced Railroad Electronics System** (***ARES***) is a comprehensive package of computer programs developed by Rockwell International for Burlington Northern. Described as a total train running system, it was part of a general push, sponsored by the American Association of Railroads, for an Advanced Train Control System (ATCS). In ARES, locomotives carry computers which monitor fuel consumption and speed characteristics, calculate position on the track by GPS satellite technology (Navstar) and control acceleration and braking. Central

8. An ARES control panel for the 9th District of Burlington Northern's Dakota Division, the iron ore lines of the Lake Superior region. ARES, the Advanced Railroad Electronics System, used GPS technology to keep track of trains and an optimisation model to despatch them. It was the world's first optimised dispatching system but BN abandoned it in 1992.

control offices have computers too, that monitor the state of the track and receive reports from the trains. They can optimise dispatching patterns continuously, organise network routing and schedule line meets and passes as needed. Rockwell calls this the Tactical Traffic Planner (TTP) and it communicates with the operators through string line diagrams (among other things). At a higher scheduling level, the operations plan (timetable) is planned *off-line* using these same concepts–the Strategic Traffic Planner (STP)-which becomes the blueprint which guides the TTP. The whole system is driven by the goals of cost minimisation and profit maximisation. The designers admit that real-time cost-control seems an arcane motive for timetabling, but insist that it is a valid description of the motivating force behind a good human train controller. A notable feature is the importance attached to *pacing* the trains This has the dual aim of saving fuel and of holding back trains from their destination should there not be the ability or need to accept them there - some trains have a *cost penalty* for early running! Billed as a “dramatic advance” by its proponents, ARES has not caught on. It found a home, of sorts, on the iron ore lines in the Mesabi Range. This section of line is mostly self-contained, with dedicated locomotives and rolling stock, and low-density traffic that stays within its borders. BN spent some years evaluating the system and, although it contemplated extending it to high-density sections of its track, it decided to scrap the system in 1992.

In 1999, a consortium of General Electric and Harris Technology announced a successor to ARES, using Orbcomm satellites in place of the military’s Navstar system. An excerpt from GE-Harris’ description of the system appears on our cover.

The Australian experience with computerised timetabling has been surprisingly extensive. As already mentioned, the NSWPTC had developed a simulation method (TWS) by the early 1970s. The Bureau of Transport Economics evolved TWS into its own system a couple of years later. This work was carried out in conjunction with the IBM Systems Development Institute in Canberra. This was the Single Track Simulator, or *STS* and was applied as part of a project to investigate main line rail upgrading. The University of Adelaide also did research and ultimately developed an optimisation model, the Dynamic Rescheduling System (*DRS*) in the late 1980s. As an illustration, the University applied it to improving the timetable of the eastern end of the Trans Australia line, claiming to show time savings over the “traditional” timetable (Fig. 9). Australian National itself began to develop a local optimisation model, but there is no information about what happened to it. In 1981, Westrail adapted the STS simulation model as the base for its own attempt to build an optimisation model. Westrail eventually came to regard STS as too limited for the task and by 1985 had developed its own model, the Single Line Train Scheduler (*SLTS*). SLTS was apparently applied to write Westrail's working timetables from the mid 1980's. An example of a computer print-out of a timetable for the Collie line is shown in Fig. 10. SLTS could also draw string line diagrams. At the same time, the Mathematics Department at the University of Western Australia (apparently independently) was working on the problem and applied it to simulate the Mt Newman iron ore line. Finally, there is the excellent work done by Andrew Higgins at the Queensland Institute of Technology. Like the Pennsylvania academics, Higgins has obtained his doctorate in train timetabling and has



***9.** The University of Adelaide’s Dynamic Rescheduling System reschedules the Tarcoola - Port Augusta line. The upper graph is described as a “traditional timetable” and appears to be from a late 1980s ANR working timetable. The four east-bound trains spend a total of 5¾ hours waiting to cross the west-bound trains. After a DRS rescheduling, the total waiting time has been reduced to 1¼ hours, roughly evenly shared between east and west. The Indian Pacific appears in this graph, can you spot it?*

worked on analytical and optimisation models for both single lines of railways and for networks such as the Brisbane suburban area. His optimisation model for single lines is probably the best yet developed in terms of speed and efficiency. It has been applied to Queensland Rail's North Coast line with good results. So far, Higgins has not yielded to the universal temptation to give his model a name and an acronym!

A bibliography of over 270 references on computers and railway timetabling

COLLIE	ARR										
	DEP		06 24	07 00				09 54	10 12		12 00
WORSLEY	ARR		06 59	07 35				10 29	10 47		12 35
	DEP		06 59	07 35		09 01		10 29	10 47		12 35
BEELA	ARR		07 24	07 59		09 25		10 53	11 12		12 59
	DEP		07 24	07 59		09 25		10 53	11 12		12 59
BRUNSWCK JTN	ARR		07 44	08 19		09 45		11 13	11 32		13 19
			X 81	X 81							
	DEP		07 44	08 19	08 33		09 20		11 32		13 19
BRUNSWCK NTH	ARR		07 50	08 25	08 36		09 23		11 38		13 25
	DEP		07 50	08 25	08 36		09 23		11 38		13 25
BENGER	ARR		07 57	08 33	08 45		09 32		11 45		13 33
									X 9		X 63
	DEP		07 57	08 33	08 45		09 32		12 01		13 37
HARVEY	ARR		08 09	08 45	08 59		09 46		12 13		13 49
	DEP		08 09	08 45	08 59		09 46		12 13		13 49
WARRAWARUP	ARR		08 13	08 49	09 04		09 51		12 17		13 53
									X 21		
	DEP		08 13	08 49	09 04		09 51		12 20		13 53
YARLOOP	ARR		08 27	09 03	09 19		10 06		12 34		14 07
											X 15
	DEP		08 27	09 03			10 06		12 34		14 22
WAROONA	ARR		08 43	09 21			10 20		12 50		14 40
									X 63		
	DEP		09 43	09 21			10 20		12 59		14 40
COOLUP	ARR		09 00	09 39			10 32		13 16		14 58
											X 65
	DEP		09 00	09 39			10 32		13 16		15 18
PINJARRA STN	ARR		09 09	09 50			10 12		13 25		15 29
	DEP	05 27	09 09	09 50					13 25	11 08	15 29

__10.__ A computer printout from Westrail's Single Line Train Scheduler for Collie coal trains. Ten Up trains are shown, with crossings of 6 Down trains. Number 9, the Australind is shown crossing an Up Coal train at Benger. Westrail started generating its working timetables this way in the 1990s

UP

COLLIE-BRUNSWICK JUNCTION-BUNBURY (including Brunswick diversion)

TABLE 91			192 Gds. Tu. W.	60 Block Coal M. Tu. W. Th. F.	172 Gds. Tu. W. Th. F.	172 Gds. M.	62 Block Coal M. Tu. W. Th. F.	174 Gds. M. Tu. W. Th. F.		64 Block Coal M. Tu. W. Th. F.		186 Gds. M. Tu. W. Th. F.	188 Gds. (C)			66 Block Coal M. Tu. W. Th.	66 Block Coal Su.		
COLLIE .... dep.	....	....	00 20	01 05	05 30	06 40	09 05	11 00	....	13 30	....	18 20	20 30	....	....	21 30	22 25	....	....
Worsley .... arr.	....	....	00 55	01 40	06 05	07 15	09 40	11 35	....	14 05 —67	....	18 55	21 05	....	....	22 05 —63	23 00	....	....
Do. .... dep.	....	....	01 05	02 05	06 15	07 45	09 50	11 45	....	14 20	....	19 05	21 15	....	....	22 30	23 25	....	....
Beela .... arr.	....	....	01 30	02 30 —173	06 40 —65	08 10	10 15	12 05	....	14 45 —61	....	19 30	21 40	....	....	22 55	23 50	....	....
Do. .... dep.	....	....	01 40	02 50	07 10	08 20	10 25	12 15	....	—183 15 30	....	19 40	22 00	....	....	23 15	M. 00 01	....	....
Benger .... arr.	....	....	....	03 15	....	....	10 55	....	....	16 00	....	....	....	....	....	23 50	00 25	....	....
Do. .... dep.	....	....	....	03 30	....	....	11 05	....	....	16 35	....	....	....	....	....	M.toF. 00 15	00 45	....	....
BRUNSWICK JCTN .... arr.	....	....	02 00	....	....	....	....	....	....	....	....	....	22 20	....	....	....	....	....	....
Do. .... dep.	....	....	02 30	To Kwinana Tables 81 and 87	07 30	08 40	To Soundcem Tables 81 and 87	12 40 —14	....	To Robb Jetty Tables 81 and 87	....	20 00	....	....	....	To Kwinana Tables 81 and 87	....	....	....
PICTON JCTN .... arr.	....	....	....		....	09 10			....		....	....	....	....	....		....	....	....
Do. .... dep.	....	....	02 55		08 00	09 20		13 05	....		....	20 25	....	....	....		....	....	....
Bunbury P/H .... arr.	....	....	....		....	....		13 20	....		....	....	....	....	....		....	....	....
Picton (CSBP) .... arr.	....	....	....		....	....		....	....		....	....	....	....	....		....	....	....
Do. .... dep.	....	....	....		....	....		....	....		....	....	....	....	....		....	....	....
BUNBURY .... arr.	....	....	03 05	....	08 10	09 35	....	....	....	....	....	20 40	....	....	....	....	....	....	....

47

For particulars of S.W.R. Main Line Trains—see Table 80.
No. 62 Conveys Coal for Soundcem.
No. 64 Conveys Coal for Robb Jetty Powerhouse.
No. 66 } No. 60 } Conveys Coal for Kwinana Powerhouse.

__11.__ Traditional WAGR working timetable for the Collie line. This is the timetable of June 22, 1981, well before WAGR started doing its timetables by computer, but the train working pattern is similar to the computer-generated version.

LETTERS

The hub of the matter

From Ian Manning

In February Chris Brownbill showed us that 24 of 76 weekly QANTAS flights between Australia and New Zealand connected Sydney and Auckland, and that 50 of the 76 had Sydney as their Australian terminal. In April Tony Bailey showed us that this is not the whole story; several other airlines also ply the Sydney-Auckland route. However, what about QF's most obvious competitor, Air New Zealand? Frequencies for this carrier may be gleaned from Ansett timetables, and a different pattern emerges. Currently, NZ has 114 Australia-NZ flights a week, a neat 50% more than QF, though maybe the planes are smaller. More interesting is the pattern: 47 per cent of NZ's flights use Sydney (QF 66%), 29% use Brisbane (QF 14%) and 24% use Melbourne (QF 25%). At the NZ end, however, the two carriers provide similar services, with around 55% of flights using Auckland and the rest distributed more or less equally between Wellington and Christchurch. One may suspect that NZ has higher market share for traffic involving Melbourne or Brisbane, but that market shares are more equal in the NZ cities.

QF's preference for Sydney as a hub is presumably based on two factors (a) as Australia's largest city Sydney originates more traffic than any other and (b) the airline is based there. However, one may query the adequacy of Sydney airport for the heavy traffic thrust upon it.

First, is Australia really suited to American or European concepts of hubbing? Maybe it is, to the extent that in each mainland state the capital forms a natural hub for intrastate services (with the interesting consequence that there are no air services west from Mt Isa, and whoever wants to get to the Northern Territory quickly from there is better off catching the bus). However, the million-plus state capitals form a curving line, most efficiently connected pair by pair; like New Zealand's three main cities they do not lend themselves to the hub concept.

Second, what about the airport itself? Land-side it is the best in Australia, and will be even better when it gets its rail service, but air-side? It has curfews and a shortage of landing slots. Worse, the citizens of Sydney and QF refuse to support the building of the second airport which Sydney so obviously needs if it is to retain its dominance as the air gateway to Australia.

On top of this, despite recent improvements (dedicated buses on the tarmac, escalators to get in and out of the buildings) Sydney is not well designed for international transfer. For my money, the best in Australia is Darwin, followed by Melbourne. Melbourne is not as convenient as Darwin, since, though domestic and international are in the same building, one has to change level to get from the one to the other. Cairns has separate buildings but the terminals are a short trolley-push apart on a covered footpath, and in Adelaide one can also make the transfer on foot, but this time in the open. (I do not know what plans are afoot for the new terminal there.) Brisbane comes next, with a fairly short bus ride. The bus rides in Perth and Sydney are about equally long, with the Perth bus operating from outside the terminals and the Sydney one from within. One is more likely to have to stand on the Sydney bus.

Given the shape of Australia, I would argue that its true international hub, for traffic bound northwest, is Singapore, Kuala Lumpur or Bangkok, and indeed those cities compete for this function. Relatively little time is lost if northbound traffic (essentially Japan) is routed through Brisbane, while trans-Pacific traffic is likely to evolve in terms of city pairs, with Los Angeles becoming Australia's cross-Pacific hub. These trends can only be strengthened by the continuing refusal of Sydney to build itself a second airport, and present an opportunity for other carriers to provide better service than QF to Australian ports other than Sydney.

From the editor

This issue of The Times is the first to be produced with desk-top publishing, as opposed to a word processor. Perhaps you won't notice a difference, but if you spot errors, bad layout or other infelicities, the editor would like to hear about it.

Recently, I completed an update, and transfer to electronic media, of a comprehensive index to The Times. The index is in the form of a searchable spreadsheet (Excel), but can also be presented as a database like Access, or even a bibliographic database such as in Endnote form. Copies are available at no charge; send an e-mail request to the editor.

Over the next few months we will be continuing our publication of historical timetable checklists of railway timetables. The next to appear will be Tasmania and Western Australia, the latter being a nearly complete listing. Also coming will be a list by Scott Given from our counterpart NAOTC in the U.S. showing the publication details of every known current employee time table (ETTs) for all North American railroads. These lists, like the Times index, are available as spreadsheets or databases from the editor.

Readers may be interested that several issues of the British railway historical magazine *Backtrack* have dealt with the science of timetabling and the influence of timetables on railway operations generally.

New York Times (tables)

No matter how much we try to defend it on the basis of historical relevance, transport studies or people-moving logistics, the hobby of collecting timetables is surely peculiar. Rated somewhere between barbed-wire collectors[1] and philumenists[2], T/T fanatics are properly regarded as slightly (slightly?) odd. Surprising, then, is the very sympathetic treatment given by the New York Times in one of its recent Sunday feature articles

Subject of the article is Carl Loucks, well known to many, not only as a collector, but also as a purveyor of timetables and other railroad paper.

It would be interesting to know whether articles such as these increase tolerance of the hobby and, more important to the editor, whether they increase circulation of The Times.

1 Yes, there are people who are hooked on barbed wire, and they have a magazine too- http://www.barbwiremuseum.com/BarbedWireCollectorMagazine.htm).

2. Surely you don't need to ask!

THE NEW YORK TIMES, SUNDAY, SEPTEMBER 26, 1999

The View From/Madison

Collecting the Record Of the Nation's Trains

By KENNETH BEST

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 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 dangerous. 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 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." ■

Photographs by Thomas McDonald for The New York Times

Carl Loucks of Madison goes through some of the thousands of railroad schedules he has collected from around the country, including the ones shown on this page.

Graphic Insight

GEOFF LAMBERT

This month, we take a long-term view on passenger train travel- 1825 to 1995, and look at the annual number of rail passenger journeys in Britain, NSW, Victoria and the U.S.A. NSW and Victoria include urban journeys. Space prevents us from adding the thousand words to these pictures, but features worth noting are the abrupt drop in apparent passenger numbers in Britain due to the partition of Ireland (1921), the dramatic drop-off in the U.S. A. when Amtrak commenced (1970) and the similarity of the ups and downs of passenger traffic in NSW and Victoria. The effects of Word War II can be seen in all four graphs. Passenger travel peaked about 30 years later in Australia than it did elsewhere.