The Role of Computer-Based Scheduling in Public Transport Reform

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Abstract:

The Public Transport Corporation of Victoria (PTC) last year completed the installation of a computer-based scheduling system (HASTUS) in its Tram and Bus Division.

Since that time, the new victorian Government has embarked on a programme for far-reaching reforms in public transport.

These reforms have placed great pressure on planning and scheduling functions in the PTC. In particular, the PTC is currently engaged in fundamental re-structuring of labour agreements and the widespread re-casting of tram, bus and train service schedules.

This paper discusses the contribution that computer-based scheduling has made, and continues to make, in these areas towards the reform process. Although operational considerations were the primary motivation for the acquisition of computer-based scheduling, the technology has proven itself to be the immense value in planning. Particular attention is given in the paper to the role that computer-based scheduling is playing in planning through the empowerment of non-scheduling staff.

The views expressed in this paper are those of the author and are not necessarily supported by the Public Transport Corporation

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1. INTRODUCTION

Much has been written over the past two decades on the subject of computer scheduling. With time and an accumulation of practical experience, the focus of this literature has gradually moved from theoretical, product-oriented research toward more practical, customer-oriented evaluations and perspectives. Despite this trend, most reporting continues to concentrate on the use of computer scheduling in production rather than in planning.

The recent and, as yet, unreported installation of the HASTUS computer scheduling system at the Public Transport Corporation of Victoria (PTC), and subsequent launching of an extensive programme of public transport reforms by the new Victorian Government, have provided an opportunity to examine computer scheduling "under load" in planning as well as in production

This paper provides a practitioner's view, reporting mainly on work conducted by the author over the past 12 months and on insights into computer scheduling gained while planning and managing the HASTUS project over the previous three years It is intended to shed some light on how computer scheduling can help public transport operators deal with the competitive pressures and turbulence which accompany far-reaching reform.

2. HASTUS AT THE PTC

General Description of HASTUS

HASTUS is a computer-based scheduling system for metropolitan bus and tram systems (Blais et al 1990). The system's developer and supplier is the Canadian firm, GIRO Inc (Montreal).

The primary function of HASTUS is to aid the design of three types of master schedules:

vehicle schedules	defining how vehicles will be used to supply timetabled services;
crew schedules	defining the work to be done by crews to operate the vehicles;
period rosters	defining the sequence of work to be done by crews over successive days and weeks

Thus, HASTUS is used to determine, well in advance, how vehicles and crews set out to provide the timetabled services. It is not used to plan the services shown on the public timetable (although a module, HASTUS-DDS, has recently been developed by Giro Inc for this purpose) or to re-schedule operations in "real time" to deal with eventualities on the day (this is done "manually" at the PTC with the aid of an Automatic Vehicle Monitoring System)

Another function of HASTUS, and of computer scheduling systems in general, which does not appear to be so well recognized, is its use as a planning tool for schedulers and non-schedulers alike. Over the past year, HASTUS has made a major contribution in this capacity at the PTC To a large extent, these experiences have motivated the preparation of this paper

A third function of importance to all operators is the automatic generation of a wide range of reports and other documents for planning and operations purposes

Background to the HASTUS Project

Active involvement in computer scheduling at the PTC began in 1982 with the acquisition of a leading scheduling system by the Tramways Board (later incorporated into the PTC). The system was intended for scheduling buses and trams and their crews, but was never successfully implemented. While it is possible to explain this failure in terms of poor system performance in several areas, it is also true that the problems encountered were never adequately addressed within the PTC. Schedules continued to be produced manually

In 1989, there was renewed interest in computer scheduling Prompted by plans to implement a number of new long-distance cross-town services (Metropolitan Transit Authority, 1988, pp 16-17), it was decided to provide the scheduling function with increased computing support

A project was established to computerize the construction of all tram and bus schedules and the production of associated documentation and data files The project aimed to achieve the following main objectives:

- construction of fully operational schedules at three to four times the manual rate,
- reduction in bus requirements and increase in productivity of tram and bus crews,
- reduction in clerical activities associated with manual scheduling,
- ability to review services more frequently to ensure that they match changing travel demands, and
- ability to rapidly respond to new transport initiatives and handle "what if" analyses associated with award restructuring and planning for new services.

The first steps in assessing which scheduling system to acquire relied on an earlier review by the author of scheduling systems used internationally and on the results of a "hands-on" trial of several products by the Urban Transport Authority (UTA) in Sydney (now the State Transit Authority of NSW). Both studies concluded that HASTUS was the most promising alternative

The PTC then conducted its own trial on HASTUS in 1989/90 to remove the last vestiges of doubt emerging from the UTA's study concerning the system's ability to handle large crew scheduling problems. The trial, whose aim was to assess the efficiency of HASTUS relative to existing manual methods, involved generating weekday vehicle and crew schedules for North Fitzroy bus depot and comparing results with those produced manually.

The results of the trial were very favourable, yielding a 5% vehicle saving (HASTUS 95 buses cf manual 100 buses) and a 4% saving in bus drivers (HASTUS 147 drivers cf manual 153 drivers). Moreover, the vehicle and crew schedules were judged to be completely roadworthy.

The decision to invest in HASTUS was taken in early 1991. The total project was to cost $1.9 million ($Dec1990) and yield, at least, the following quantifiable savings:

- 3 buses (1%)
- 6 bus drivers (1%)
- 6 tram drivers (0.5%)
- 4 scheduling staff (27%).

The financial indicators ($Dec1990) were

NPV	$2.4 million
IRR	26%
Payback	4.5 years

Implementation

HASTUS was installed at the PTC in four stages between May 1991 and November 1992. The installation plan was designed to permit early application of HASTUS in production as well as to facilitate the effective involvement of PTC staff in the system specification process.

The system was installed on an IBM PC network operating under OS/2 and LAN Server. The network currently consists of a server and 17 workstations located in Head Office, twelve of which are used for production scheduling, four for planning and one for administration. Peripherals include three laser printers, two high-speed dot-matrix printers and several tape devices.

Although the system consists of a number of "off-the-shelf" modules, used around the world by many operators, these needed to be substantially customized to meet local requirements, in particular those associated with Melbourne's tram system and labour agreements.

Commencing from the early stages of the installation, HASTUS has been progressively implemented across PTC bus and tram depots. Presently, all tram schedules and most bus schedules are held in HASTUS and, more significantly, all vehicle and crew scheduling is now performed with HASTUS Against this, however, it should be stated that the period rostering module is not yet in use It is not clear, at this point, what the source of the problem is but we are confident that it will be rectified.

Performance
It is not too early to confidently claim that HASTUS will satisfy the project's objectives. It has become a key tool in the PTC's Passenger Services Division

A measure of success of the system may be gauged from an early application on Doncaster and North Fitzroy bus services in late 1992. Without altering the public timetables, it was found that HASTUS could be used to construct schedules requiring 15 less drivers (4.7%) and 14 fewer buses (6 6%) than the manual schedules which were operating It was also estimated that the time necessary to produce totally new schedules for these depots had been reduced from six months to six weeks.

Finally, with the advent of HASTUS, it has been possible to reduce staffing in the scheduling section from 15 to 10, while simultaneously increasing the scheduling work load dramatically over the past year.

3. AN ERA OF ESCALATING REFORMS

Reforms (or "change projects") have been on the agenda at the PTC for a number of years and there has been some success, as evidenced by a gradual reduction in the workforce from 22,000 in 1989 to 19,000 in 1992 The HASTUS project was undertaken against this agenda of on-going reforms. However, the pace of change has accelerated substantially in recent months.

In October, 1992, a new Government was elected in Victoria A major goal of the incoming Government was public sector reform aimed at reversing the State's increasing debt. In public transport, a major reform theme was "to cut public transport losses by tackling the fundamental inefficiencies in the public transport system" (Liberal National Coalition, 1992 p2).

In January of this year, the Government announced its public transport reform programme which is intended to transform the Victorian public transport system from the "worst in Australia" (Brown, 1993 section 3a) to "a service operating at or near to international best practice" (Brown, 1993 section 5b). The programme aims to reduce the recurrent operating deficit by 50 percent, from \$503 million to \$258 million, over the next 3 years while continuing "to provide an equivalent or better service"(Brown, 1993 section 5b) Central to the programme strategy is a further reduction of 8,500 in the workforce over the same three year period. Already, at the time of preparing this paper, the workforce has fallen by over 3,000.

The reform programme contained an extensive set of initiatives encompassing most aspects of the PTC's business. Included amongst these were the following initiatives relating to the provision of metropolitan public transport services:

- contracting of PTC metropolitan bus services to the private sector,
- introduction of an automated fare collection system,
- driver-only operation of trams and suburban trains,
- introduction of all-night bus services on 9 metropolitan routes,
- replacement of several rail services by bus and/or tram services,
- operation of 8 rail and 7 tram routes by buses after 8pm weekdays and, in the case of trams, on the weekends,
- closure of two tram services.

Within 12 weeks of announcing the reform programme, deals had been struck between the Government and the public transport unions on implementing the substance of the programme. Notably the unions accepted the need for dramatic change, including acceptance of the principle of contracting-out, staff reductions, automated ticketing and driver-only operation of trams and trains. In return, the Government made several concessions. In the metropolitan context, these included stepping back from some of the proposed service changes (in particular, modal substitutions) and permitting the PTC (with unlimited union involvement) to bid against private enterprise for the right to operate Government bus routes

4. NEW DEMANDS IN OPERATIONAL PLANNING AND SCHEDULING

Doing more with less

Since the core business of the PTC is concerned with the provision of scheduled public transport services, it is not surprising that many reforms somehow depend upon operational planning and scheduling for their implementation. Thus it is that the last months have witnessed new, increasing demands on the capabilities of computer scheduling in the quest for operational efficiencies inspired by the new reform programme

This section discusses some of the new demands emerging from the implementation of reforms, which computer scheduling has been able to satisfy.

Increased Responsiveness

The overall slowness of manual scheduling has always been an obstacle to change at the PTC. Using manual methods required about 3 months to re-schedule a depot in tram and bus (and about 9 months in rail) Consequently, revisions were avoided and inefficient ad-hoc patching was preferred to substantial overhauls.

Pressure from diminishing operating budgets and new industrial agreements now demands a much greater rate of scheduling output than previously possible. Over the past year, the average age of tram and bus schedules has decreased from around 5 years to 6 months. Indeed, computer scheduling has allowed timetable revisions to become so frequent that there have been problems keeping pace for the production and distribution of up-to-date stopping place timetables (generalized frequency-based timetables are now used instead of the traditional format to deal with this problem).

The rate of scheduling output has also risen in other ways:

- independent schedules are now more commonly produced for shopping days and holidays with special service requirements rather than using incremental adjustments to related schedules;
- drivers and conductors are now being scheduled independently to take advantage of differences in labour agreements and operational requirements (until recently a common conductor-driver schedule was used).

Computer scheduling with HASTUS has increased scheduling responsiveness in several ways. Firstly, the intrinsic speed of computerised algorithms allows many procedures to be carried out much faster than manually. For example, vehicle trips can be linked interactively to form a vehicle schedule in seconds rather than days, and a crew schedule can be batch-produced in several hours rather than several weeks. In turn, this has created opportunities for sensitivity testing and various types of "what if" analysis, which HASTUS has been designed to facilitate. The result is better efficiency in the schedules and in the scheduling.

Secondly, queued batch processing (including overnight operation) and multitasking allows the scheduler to devote his/her time to orchestrating round-the-clock work without engaging in it directly.

Thirdly, computer scheduling lends itself to efficient use of previous scheduling solutions. Each set of schedules is associated with a stored set of files describing routes, running times, trip times, labour agreements, operating constraints and so on. In approaching any new problem, only limited subsets of data will need modification and, indeed, it is usually possible to commence work from an intermediate development stage of an earlier solution.

Fourthly, data processing with HASTUS has greatly accelerated the production of documents and data transfer into other computer systems (eg AVM, payroll, timetable production, etc). Previously, because scheduling was performed manually, all data needed to be keyed into an internally-developed data management system in a separate operation. This was labour-intensive and prone to error owing to the absence of data consistency checks. The production of documents and data files added weeks to the time needed to implement new schedules. With HASTUS, all schedules data is available via a set of interface files, and a much broader range of documents of better quality is produced. Data and reports (including some which were programmed in-house) are available as soon as the associated scheduling is finished. There are also no errors owing to the checks performed by HASTUS during the scheduling process.

Finally, and importantly, several work design factors associated with the use of computer scheduling also account for improvements in responsiveness. With the introduction of HASTUS, it became possible to adopt a more managed approach to schedule production, including the use of critical path methods In essence, there was a shift from a single-person serial process founded on the need to preserve large amounts of detailed information about the problem in one person's head, to a flexible, team-based approach which is supported by HASTUS in various ways:

- HASTUS enables scheduling assistants, who previously undertook mainly clerical tasks, to engage in production scheduling (eg weekends and special events),
- schedules can be quickly constructed by making use of parallel activities (eg at a basic level, people with limited skills can input route and trip data, while at a more advanced level, assistants can schedule weekends while more experienced staff deal with more complex weekday situations)
- information about a problem and its solution can be efficiently passed from one person to another by means of standardized data files, colour graphics and the query facilities offered by HASTUS

In short, computerised scheduling allows scheduling to be treated as a divisible process which can be expedited by the application of more resources, and HASTUS has effectively provided additional resources by permitting the participation of a greater number of staff with different skill levels.

A Tool for Analysis and Planning

Traditionally, management has relied heavily on the scheduling function for analysis of proposals regarding operational feasibility and resource requirements prior to making critical implementation decisions. For example, service planners may wish to know whether a given service can be implemented with the available crews and vehicles, while operations staff may wish to identify the full impact of acceding to some or other union request.

Unfortunately, manual scheduling does not provide a suitable tool for examining such matters. The process is geared towards producing detailed roadworthy schedules based on well-defined specifications for the service and well-understood scheduling constraints There are few shortcuts for rapidly producing broad estimates and the process is not conducive to analysis of the service specifications and constraints themselves In practice, it was often necessary to rely on what amounted to "dart-board guestimates" or to wait several months for a limited analysis of the problem in the form of a detailed schedule.

Another failure of the manual approach is its inability to provide accurate costings or cost-related statistics (eg vehicle-kilometres, vehicle-hours, penalty loadings, etc), so important in achieving the cost reductions required by the reforms In fact, manual scheduling pays no attention to costs directly but instead deals with a few indirect measures, particularly numbers of crews and vehicles, which are more easily calculated Furthermore, there are few measures of efficiency for quantifying the quality of the schedules

To some extent, resource estimation procedures embedded in the PTC's computer-based cost models have for several years provided an alternative tool for analysis. These procedures can be used to estimate the effect of broad service changes on various indicators of vehicle and crew usage For dealing with issues requiring this level of analysis the models have been very useful to PTC planners. In practice, however, two limitations of the procedures concerning the modelling uncertainty associated with the estimates produced (albeit good estimates) and the fact that the approach does not constitute a step in the production scheduling process, probably account for the failure of this approach to be used more widely or help in bridging the gap between planners and schedulers.

As will be seen in the next section, computer scheduling with HASTUS provides a very powerful analysis tool for exploring new initiatives It does this through a combination of features:

- integrated analysis and production environments give analysts ready access to extensive data sets maintained in production,
- flexible and extensive parameterization of scheduling constraints (including work rules, operating requirements and scheduling preferences),
- specific provisions for sensitivity analysis in certain key areas of vehicle scheduling (eg HASTUS has been effectively used to automatically adjust timetabled trips so as to reduce the overall vehicle requirement),
- several automated interactive and batch procedures for carrying out scheduling procedures under parameter control,
- a wide range of available reports containing costings and schedule statistics,
- ASCII interface files for transferring data to external applications, and
- filtering functions for quick flexible assessment of solutions.

Flexibility

Exposure to competition and the standards of international best practice are central to the new reforms. Acceptance of these principles by the public transport unions has eliminated many barriers to change which previously confined the scope of analysis and scheduling activity.

It is now necessary to be able to explore and accommodate vastly different ways of providing services The generalized mathematical formulation of HASTUS is ideal for this. The system is used by more than 70 operators in 16 countries; this necessarily means that the system can be adapted to meet a wide range of situations Indeed, with HASTUS, the user must devote considerable attention to correctly setting parameters so as to avoid outcomes which do not comply with rules and standards in the organization. Thus, computer scheduling is inherently much more flexible (in the short-term sense which is more relevant here) than manual scheduling procedures which have developed over a long period of time around fairly stable conditions and requirements By way of illustration, a significant part of the savings found in the North Fitzroy trial arose from an unexpected interlining by HASTUS of several routes in the city area. This had the effect of eliminating unnecessary service duplication which no-one had previously thought to try

As discussed below, the flexibility afforded by HASTUS has already been used extensively to analyse the restructuring of labour agreements, to evaluate restrictive work practices, to search for worthwhile service and operational changes, and even to carry out a competitor analysis. It must be stated, however, that HASTUS is customized to existing local conditions and, consequently, one often needs to use imagination in stretching concepts to tackle different scenarios. It should also be noted that this has been found to be a very satisfying experience.

Empowering Planners

The reform process benefits from the application of a broad range of skills and abilities. These include strategic thinking, creative approaches to problem solving, a willingness to experiment and skills in analysis, business, finance and computing.

HASTUS enables operational and service planners who have such skills to bring them to bear in their work Using HASTUS, planners with a knowledge of operational requirements can develop their ideas more fully and test them more rigorously

HASTUS empowers planners not only by providing an analysis tool for developing quick approximate scheduling solutions but also by eliminating a number of barriers associated with traditional scheduling. Firstly, a planner can become effective with HASTUS after only a short period of training and experience, whereas it takes many years to master the art of manual scheduling. This is because, unlike manual scheduling, computer scheduling is basically iterative in nature, beginning with the creation of an approximate early solution, using various automated procedures and functions, and gradually refining this to a final solution, with progressively greater levels of interactiveness and manual involvement. For the production of roadworthy schedules, all steps are necessary In analysis, however, where comparative evaluation plays an important role, it is usually sufficient to limit work to the earlier more automated procedures which can be quickly learned. Fortunately, the 80/20 rule applies and much can be achieved in such work, particularly if there is a collaboration with the production schedulers

Secondly, the system helps penetrate organizational barriers surrounding the schedulers' work group. The planner can have unrestricted read-access to all the data produced and maintained by the schedulers in the production environment, including schedules and control parameters. This data, to a large extent, encapsulates the schedulers' skill, allowing the planner to apply marginal adjustments here and there to steer the analysis in the desired direction. In effect, the schedulers unwittingly collaborate to a large extent in every analysis In a sense, the system also provides a vehicle for communication with schedulers In using the system to explore alternative scenarios, the planner progresses an idea or proposal from an abstract level to something more tangible which can be laid on the table in discussions. The system provides a way of effectively bridging the gap which once divided scheduling and planning functions

5. CASE STUDIES

The Bus Tender

As mentioned earlier, the deal struck in February this year between the Government, PTC and Tram and Bus Division of the Public Transport Union, enabled the PTC to tender in open competition with the private sector for the operation of the existing Government bus services These services, involving 5 depots, approximately 330 buses and 600 drivers, represent a significant slice of the PTC's business. The agreement required the PTC and the Union to "jointly identify and review all potential workplace reforms and cost savings to enable the PTC to submit a commercially viable tender" (Deed of Agreement). The agreement also emphasized the importance of successfully cutting operating costs by agreeing to assume a commercial level of overheads for the purpose of the tender evaluation.

The tendering process gave the PTC less than four months to prepare its bid for operating the ex-Government services, and since tender specifications outlining the services to be provided were not available until five weeks ahead of tenders closing, timelines for the preparation of the bid were effectively much tighter

HASTUS played two important roles in this work and revealed itself as a potent competitive weapon in the process. Firstly, it was used to guide a working party, consisting of management and Union representatives, towards a new set of work rules for bus drivers with a level of savings that the parties believed would sustain a commercially competitive bid This was a key task given that driver labour costs constitute approximately 50% of operating costs. Secondly, the system was used to schedule the specified services so that accurate final costings could be prepared for the bid.

The following discussion examines the way in which HASTUS was used in this work Unfortunately, for commercial reasons, it is not possible to discuss the results.

Analysis of New Work Rules for Bus Drivers

The analysis of potential work rule changes was carried out in-house using the following methodology HASTUS was used to automatically generate detailed weekday crew schedules under alternative assumed working rules for the current vehicle schedule at a major depot (Doncaster). The costs associated with these individual schedules were next extrapolated across all depots for an entire year so that absolute costs and savings could be estimated These experimental schedules and related costs were then compared with current conditions. Because schedulers can spend considerable time adjusting the automatically produced crew schedules for implementation (eg adding standby shifts and "as instructed" duties, and making the schedules more attractive to the drivers), this step was avoided in the testing by using HASTUS to quantify the adjustment costs in the current schedules for separate consideration In this way, it was possible to carry out the analysis using only automatic scheduling.

Initially, the work was largely exploratory and aimed at evaluating alternative work rule changes suggested or endorsed by the working party. This was completed by one person in five weeks and involved generating 33 crew schedules for consideration At this stage, the aim was to determine the relative contribution made by individual rule changes and to assess the impact of some likely rule combinations. The rule changes studied included

- reducing sign on and sign off times
- reduced pay-in provisions at meals
- reducing the minimum meal length
- increasing the maximum length of a portion (ie half shift)
- increasing the maximum shift time (ie time worked)
- increasing the maximum spread between sign on and sign off
- eliminating restrictions on the use of broken shifts (percentage and timing)
- allowing meals at shopping centres
- allowing on-vehicle (crib) meals away from depot
- varying levels of part-time.

In the weeks that followed, this analysis effort continued to support the working group as it gradually developed and fine-tuned the package of work rule changes. In this time, an important new rule was explored permitting the limited use of unrostered voluntary overtime The process of developing, analyzing and revising work rules was highly iterative, and HASTUS was typically able to supply an evaluation within 1 or 2 days of rules being modified In the latter stages of the work, confidence in the findings was increased when similar results were found for services from a second bus depot (North Fitzroy).

In all, more than 100 scheduling analyses were performed over the four months In each case, a full crew schedule was produced which enabled shift characteristics to be examined and summarised for the working party This was especially important to the Union representatives who needed to know how the many rule changes, particularly in combination, would translate into practice. Being able to look over the individual duties is an ideal way of communicating this Moreover, the question of "incidence" is important in assessing some new rules (eg what proportion of drivers will need to have meals away from their depot, or need to work broken shifts, etc?) HASTUS provides a filter for quickly discovering how many duties include some specific feature or combination of features (eg short meals, long shift times, etc). Thus, by generating detailed schedules with HASTUS, it was easier to "sell" rule changes which would otherwise have appeared less palatable on the surface.

A second component of the analysis was to establish the PTC's approximate competitive position, re driver costs, relative to the private sector whose drivers are covered by another award. The two groups of drivers have markedly different working conditions and pay systems as shown in Table 1.

Table 1. Significant work rule differences between PTC and Private Sector

Rule	PTC	Private Sector
1. broken shifts permitted?	yes	no
2. second (paid) mealbreak?	no	yes
3. meals away from depot?	no	yes
4. sign on/off	0:15	0:07 - 0:10
5. maximum shift	8:15	13:30
6. maximum spread	12:00	15:00
7. minimum meal	0:40	0:30
8. maximum meal (long straights)	1:00	1:30
9. maximum portion	4:45	5:30

(wage systems are quite different and too complex for presentation here)

The competitor analysis was performed by adjusting HASTUS to comply with work practices found typically in private bus companies and then generating automatic crew schedules to cover the PTC vehicle schedule.

Apart from identifying the relative cost positions, this work was also useful in determining the adequacy of the work rule changes being considered and the need for additional productivity measures or wage system adjustments. Moreover, it was possible to identify work rule changes specifically needed to maintain the average "take-home" pay of full-time drivers.

Above all, the competitor analysis enabled the bid to be structured with a good understanding of the cost relativities. Without HASTUS, the natural unwillingness of the Union to go any further than necessary in its concessions would have almost certainly resulted in inadequate initiatives being agreed.

As it happened, HASTUS was also particularly useful, given the tight timelines, in countering the development of any mistrust between Union and management, and keeping the process focussed on the preparation of the bid As an evaluation tool, HASTUS was accepted by the Union as objective and impartial in a way that estimates derived by other means would not have been The use of HASTUS appeared to promote an openness in the search for cost-saving measures

Scheduling the Services

The second role of HASTUS in the preparation of the tender was for the construction of vehicle and crew schedules for use in calculating the PTC's operating costs. These schedules were based on new service details and the new work rules which were by then agreed.

Giro Inc, played a major support role in this work by adjusting the crew scheduling component of HASTUS and tuning it to the new work rules in time for the preparation of the final schedules. Compared to the standard version of HASTUS used in the analysis, the revised version offered

- better quality solutions in terms of crew numbers, costs and schedule characteristics,
- better utilization of the new rule permitting meals away from depot,
- adjustments for weekend scheduling, and
- better reliability in producing good automatic solutions

The work was carried out by a service planner and three schedulers over a period of four weeks. This paper discusses the more interesting aspects of using HASTUS to plan and schedule the bus services

As it unfolded, the objective was to re-schedule Government bus routes under several assumed peak loading standards An especially interesting aspect of this problem, was the need to re-set services to match substantially reduced fleet numbers (reflecting higher peak loading standards) rather than to work forward from passenger demand, as is usually the case In a manual scheduling environment such a task would have been difficult to carry out accurately and would have resulted in either an unreliable "back of the envelope analysis" (deferring the problem until implementation) or a very lengthy "trial and error" scheduling exercise

With HASTUS, it was possible to approach the problem much more directly. In a first stage, the system was used to adjust service levels to achieve a given percentage reduction in the vehicle requirement, while at the same time attempting to minimize the adverse impacts on customers. The graphics module was particularly useful in doing this. In the graphics environment, one is able to deal very effectively with individual routes or with groups of routes with like characteristics (eg common terminus or route section). Graphics proved useful in a variety of ways:

- by enhancing the visualization of service characteristics, including regularity and co-ordination,
- by enhancing the visualization of schedule inefficiencies encapsulated in the service pattern,
- by providing efficient functions for a wide range of service adjustments to trips, either individually or in groups,
- by providing an interactive "linking" function which was used repeatedly to re-calculate the vehicle requirement as the service was modified,
- by providing on-line statistical updates for the services and the vehicle schedule.

In the second stage, services were examined on a regional basis The objective was to achieve further efficiency savings from marginal changes in the services and vehicle schedule The HASTUS batch module, MINBUS, which is capable of dealing with more complex vehicle scheduling problems involving multiple depots, network effects, different vehicle types and so on, was used for this. MINBUS works by automatically adjusting specific features in the schedule, within limits set by the user and subject to user-defined penalties, to achieve a minimum generalized cost. In this exercise, the system was used to find savings by making small adjustments to trip times and reductions in minimum layovers and deadrunning times (ie time given to run "special" from one terminus or depot to another). This part of HASTUS was also used to allocate routes to depots and, incidentally, to cost the policy decision not to allow depots to share routes.

Tram Scheduling Applications

Over the past two years, since HASTUS became available in production, there have been unprecedented demands in tram scheduling stemming from various initiatives Although there is little more to add to general comments made earlier, the contribution to the reform process is large and deserves mention

Last year, most tram depots were scheduled one or more times to accommodate various interpretations of the 1992 Strategic Tram Review - well known for its planned "cross city linking" of tram routes from different depots (Tram & Bus Strategic Review Committee, 1992) The fact that only few of these schedules were ever implemented, belies the amount of scheduling undertaken.

Earlier this year, all tram depots were re-scheduled to operate at reduced "summer service" frequencies under normal, year-round running times

Currently, an even greater scheduling effort is being undertaken as driver-only operation of trams is being phased in across the system. This year will see every tram depot re-scheduled at least once, some twice and others possibly three times.

This level of output is made possible by the decreased schedule development time (including document production) which HASTUS offers and the opportunity it presents for using less experienced scheduling staff for scheduling rather than support activities.

It is worth relating here some additional observations made by the schedulers concerning the role played by HASTUS in their work. Firstly, there is unanimous agreement that HASTUS has vastly increased the quantity of scheduling able to be performed. It is now expected that the average life of a schedule will be around six months, compared with five years under manual methods.

Secondly, some schedulers maintain that the shortage of time available for scheduling has led to a loss of scheduling efficiency, but they add that this problem will disappear as further experience is gained in the use of HASTUS. The level of efficiency achieved is considered to be acceptable.

Thirdly, there is a strong belief that the schedules benefit immensely from the "what if" testing which is performed at many stages in production. This improves the effectiveness of services offered to the customer and improves the broader efficiency of the schedules (an effect not included in the second point above).

Finally, the contribution from automatic document production cannot be overstated. There is virtually no lead time required for producing a much wider range of better quality documents

HASTUS in Metropolitan Rail

At present, all scheduling in metropolitan rail is done manually Consequently, it takes approximately 9 months to re-schedule the whole rail system with no time or modelling assistance for exploring alternative options

After some planning and research conducted by the author in the late 1980's (McGinley, 1988), it was generally accepted in the PTC that HASTUS might be suitable for crew scheduling and period rostering in rail. The strategy which evolved was to implement HASTUS across tram and bus and, if successful, to consider extending the system to rail. For this reason, certain favourable contract provisions concerning the future expansion of HASTUS into rail were negotiated in the tram and bus project.

Following the installation of HASTUS in tram and bus, the author recently commenced some experimental scheduling work in rail with a view to bringing together knowledge of rail requirements, gained from the earlier research, and more recently acquired skills in HASTUS. The intention was to demonstrate the HASTUS approach and potential to rail management and schedulers. This work received encouraging signals from the rail schedulers and eventually led to the automatic production of crew schedules for one of the rail system's five line groups (Burnley) under a variety of different work practice scenarios

It must be stated that there are many more difficulties in adapting HASTUS to train crew scheduling than there were in adapting it to tram (HASTUS was developed around buses), or to modified labour agreements for tram and bus. There are many reasons for this:

- rail presents a multiple depot problem in which around 600 drivers (the guards are to be phased out) from more than 20 home stations, are scheduled in one problem to work across the whole network,
- there is a need to deal with much greater geographical detail in the scheduling (eg platforms, sidings, the direction in which a train is pointing, etc)
- a broader range of non-driving crew activities must be scheduled including shunting, docking, stabling, preparing, dividing, attaching and so on,
- work restrictions and the demands of operational reliability result in shifts with many more pieces than in tram and bus.

It is not within the scope of this paper to discuss how the work of adapting HASTUS to this task was accomplished except to say that several assumptions and simplifications were necessary. In particular, a major simplification avoided certain limitations in HASTUS on the size of the problem by restricting train drivers to work within the Burnley group of lines. This meant, regrettably, that the solution produced could not be compared directly with an equivalent manual solution or developed for use in production. The schedulers were, however, satisfied that the crew duties produced with HASTUS were realistic and efficient, and that the system, once customized, would be able to accelerate the scheduling process and document production substantially.

The significance of the work in rail with HASTUS in the context of the current reforms is not yet fully evident but is expected to unfold over the coming months. It appears unlikely that HASTUS will be able to assist directly in the current round of reform-driven production scheduling owing to the number of customisation requirements needed for "roadworthiness". However, the system may be able to contribute in the production of subsequent schedules.

Instead, it is likely that HASTUS will make a more immediate contribution in the search for work rule reforms. In the deal struck between the unions, the PTC and the Government in April, it was agreed that the PTC would introduce initiatives to achieve a reduction of 50 drivers in approximately 600. Despite the modelling simplifications in the rail experiment, the rail schedulers consider that HASTUS may already be used for this. This belief developed in a curious way. Since an important aim of the rail experiment was to build confidence in HASTUS by producing realistic crew schedules under current conditions, the schedulers were able to see the gradual evolution of the schedules as work restrictions were successively applied in a series of schedule revisions. In this way, they inadvertently noted the cost/crew increases associated with some specific work practices (eg limited mealroom locations, avoidance of spreads exceeding 8 hours). Consequently, work is now underway to use HASTUS more purposefully to find a means for reducing the driver requirement.

6. CONCLUSIONS

This paper argues the power of computer scheduling and the significant contribution it can make in both planning and production scheduling towards supporting a rapid pace of reform. Recent experiences at the PTC with HASTUS support this contention.

In the final analysis, however, the best scheduling system remains just a tool to be used in pursuing the goals of the organization. The system will analyse better, implement faster and use resources more efficiently, but ultimately its contribution will depend on how the organization chooses to use it

It is now too early to judge the eventual impact of computer scheduling at the PTC On one hand there are risks related to organizational changes which could see planning and scheduling fragmented and diluted to the point where HASTUS is less able play a role; the fate of the bus system will be significant in this. On the other hand, there are opportunities to enhance the contribution of HASTUS including expansion to rail, better integration of planning and scheduling functions, expanding the analysis role of the schedulers and developing related computer-aids for service design and real-time service control.

Notwithstanding these possibilities, the following claims can already be made:

- HASTUS has achieved and exceeded the benefits originally targeted,
- the pervasive use of HASTUS in planning and production scheduling has led to an order of magnitude increase in operating cost savings, and
- HASTUS has become an essential tool in the reform process, both in planning and implementation.

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