RUCUS - AN OVERVIEW
IMPLEMENTATION AND OPERATION OF A RUN CUTTING AND SCHEDULING SYSTEM FOR BUSES

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ABSTRACT: *The development history of RUCUS and the significant features and structure of the complete RUCUS system are presented. The value of introducing computerised scheduling and the nature of bus scheduling problems are discussed. Particular attention is focused on the problems of implementation and the need for an implementation program to fully realise the long-term potential of computerised scheduling. The variety of associated advantages are highlighted.*

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INTRODUCTION

There have been many attempts to apply computer techniques to the bus scheduling problem. These attempts have produced several notable successes, but many projects have never been continued beyond the first enthusiastic stages.

Computerised scheduling represents a significant new tool for the operations and planning of bus properties. While the particular computer package used is very important, however, the success or failure of computer scheduling application is far more dependent on the method of implementation. RUCUS is a scheduling system that can be successfully implemented to provide acceptable and efficient bus scheduling operation.

There are several different positions from which computer scheduling can be viewed. The bus operator wants a product which will enable him to more efficiently achieve his objectives. The software developer is interested in providing the best computer software possible to solve the bus scheduling situation. While the operator's main interest is in ensuring efficient day to day operations, the developer is more interested in the problem solving capabilities of his software package.

The third position, and the viewpoint from which this paper is written, is that of the implementation organisation.

The decision to implement a computer scheduling system will be made for many and varied reasons. Once that decision has been made, however, it is generally necessary to call upon an outside service organisation. An advisory organisation is usually needed to provide the necessary expertise

to bridge the gap between computer program and full scale bus operations. The implementation organisation is interested in computer software which can solve the problem, which can be integrated into a total scheduling system and which is responsive to the day to day operations and constraints of the bus operator.

History of RUCUS Development

Over recent years there has been a tremendous revival of interest in the needs of public transport. The United States Urban Mass Transportation Administration initiated a program in the late 1960's aimed at producing a series of new and powerful tools to help the management of public transport and, in particular, bus transport. One of the important elements of this program was RUCUS - a Run Cutting and Scheduling System.

The contract to develop RUCUS was awarded to the MITRE Corporation, a software development organisation, specialising in the development of transportation applications.

Numerous attempts have been made to computerise various portions of the scheduling department activity. The various computer programs have had different degrees of success and, while some have been abandoned, some are in regular use.

Driver allocation has received the most attention since driver's wages constitute a significant portion of the operating budget in this labour-intensive industry. The development of new headway sheets, as well as the structuring of new vehicle schedules, have also received attention from the computer and operation research community.

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Many of the past attempts have been unsuccessful for a variety of reasons:

- Partial computer solutions and implementations are generally unsatisfactory. They are hard to integrate into an existing process and do not provide a solid system basis for expansion or modular development.

- The industry is not computer oriented.

- The analytical personnel attempting computer implementation have not become fully familiar with industry problems.

- Little attention has been given to documentation, training of personnel, and simple user oriented program control.

In developing the RUCUS package, specific efforts were made to avoid past pitfalls. A modular package was designed which covered all phases of the scheduling departments activities and yet was suitable for partial implementation.

Extensive consultation and co-ordination with the transit industry was sought and obtained concurrent with program development. Past efforts were thoroughly reviewed and any appropriate past work was incorporated to the maximum extent. Computerisation of the best available manual techniques was followed wherever possible.

The schedule building portion of RUCUS closely follows well established computer procedures used within the Los Angeles bus operations. (SCRTD, 1960).

The vehicle scheduling portion was developed from a program for the optimal solution to tanker scheduling. (Bellmore et al, 1968; Bellmore et al, 1971). The program uses the Ford-Fulkerson "out-of-kilter" optimisation technique. (Ford and Fulkerson, 1962).

MITRE developed the driver assignment program based on a computer program operated by the Manhattan and Bronx Surface Transit Operating Authority (MBSTOA).

The work of developing RUCUS was carried out in four phases. The first phase entailed a detailed review of existing programs and procedures. In the second phase, program development and component testing were carried out. These phases were finished in late 1971.

The third phase covered operational site testing of the RUCUS package. The site testing was directed towards properties with fleet sizes greater than 200 vehicles.

In order to implement the package under different types of management conditions, several different property types were selected:

- Publicly owned - publicly operated
- Publicly owned - management contractor operated
- Privately owned - privately operated.

Table 1 lists the properties at which RUCUS was operationally tested, and which modules of the total package were tested in each case.

During the operational testing, extensive feedback between programmers and schedulers allowed for correction of

the weaknesses and difficulties of using RUCUS in the field.

Final site testing was finished early in 1973.

The final phase was a complete review of the RUCUS package, the incorporation of all revisions as suggested from field tests, and the development of suitable user documentation and implementation guides. Once this was completed, RUCUS was officially handed over to the Urban Mass Transit Administration. In July, 1973 RUCUS was released publicly. Throughout the United States seminars and presentations were held to introduce the package to consultants and public transport operators. By 1974 implementation had begun in San Diego (California), Syracuse (New York), Fort Worth (Texas), and Portland (Oregon). In May 1974 the fully documented source code was released.

A major step forward for RUCUS implementation occurred when the U.S. Federal Authorities indicated that RUCUS implementation would be eligible for capital funding. This provided the impetus for many other properties to begin implementation projects.

During 1974 and 1975 Los Angeles, Baltimore, Boston and Minneapolis received federal funding approval for RUCUS implementation.

It was not until March, 1975, however, that the first RUCUS produced schedules were actually put into practice for a total system in Syracuse, New York.

Canadian properties have also shown considerable interest. In October 1974, the Toronto Transit Commission began a demonstration project and, on the basis of the results

are presently proceeding with a full conversion. In March 1976, the Queensway division began working RUCUS produced schedules. These schedules show a fully verified 2 percent saving over the old manual runouts. No timetables have been altered and union representatives were consulted from the very beginning of the demonstration project, ensuring a smooth and acceptable implementation. Following a successful pilot application study for the Ottawa-Careleton system in June 1975, a system wide implementation is presently underway. The cities of Kitchener, Edmonton and Vancouver have also begun implementation studies.

There is presently a tremendous amount of activity using RUCUS. Over the next two years, twenty or more bus properties will be using computerised schedules for normal day to day operations.

BUS SCHEDULING

Nature of the Bus Scheduling Problem

The bus scheduling problem has several features which make it different from the normal class of problems. It is particularly difficult to find satisfactory solutions to such a complex problem.

The fact that bus operations must work, and that bus schedules are the basis on which drivers are paid, places rigid demands upon scheduling. Firstly, it must be accurate. If the schedule is wrong, chaos will ensue on the street. Drivers will react very quickly to errors or impossible schedules.

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The relationship between the scheduling department and the bus drivers is often delicate. The art of good scheduling is to find the compromise between efficient schedules and acceptable schedules.

The schedules and service patterns that are in operation today represent many years of careful manipulation and fine tuning. Historical procedence, and in-built complexity, are often inherent in the schedules. Sometimes there is good reason for these complexities, but some of the reason for their inclusion may have long since disappeared. For example, the structure of many of our bus routes today is based on old tram and cable car routes.

Schedules are often a frustrating mixture of regular and irregular services. A special trip or route deviation may be made by a bus only once in the day or only once in the week. Such schedule irregularities make optimum use of vehicles in providing service to the public, but present significant problems for the computer scheduling programs.

The scheduler is a very skilled, knowledgeable and experienced worker. A good scheduler takes enormous pride in his work and in producing efficient and workable results. They are often limited, however, when asked to look at large scale changes, or the impact of some new set of conditions. Another matter for concern is the longer term prospects of training and developing schedulers with the required experience and skill needed to run todays growing bus fleets.

The work of scheduling can be broken down into several steps:

- Data collection and analysis

- Timetable development
- Vehicle schedule assignment
- Driver run cutting
- Roster assignment.

Data collection is carried out for new schedule development or for schedule review. In most properties this is a continual process. All lines in the system are checked once or twice a year to ensure that the service supplied is balanced with demand and that schedules are worked as planned.

Timetable development is rare for an established system. Development consists of establishing the level of service standards and the type of services to be offered. Timetables represent the compromise between the supply of service and the demand for service. The whole cost and service structure for a bus property is determined by the policies that go into the building of timetables. Once the decision has been made to operate a set of trips past particular points with particular headways, the majority of costs for labour and vehicles are fixed.

Vehicle scheduling is the assigning of a unique bus to every scheduled trip in the system. The timetabling and vehicle scheduling are rarely performed independently and there is frequent feedback between the two processes to ensure efficient timetables.

Vehicle scheduling techniques vary, some properties have buses working single routes, while others have buses working over the whole system. The ability to optimise vehicle schedules can be directly related to the scheduling methods used at a particular property. For instance, the scheduler may use running times between two points which have built in

time factors to allow for even headways or maintenance of a set number of buses on the route, rather than specifically allowing layover time at the end of a route for these factors. In such cases, optimisation is more difficult.

Once vehicles schedules have been developed, the next phase is the assignment of drivers to each vehicle so that all the union and labour conditions of work are observed. These conditions may be legal requirements or they may be unritten agreements between the union and the scheduling department. Scheduling policies for assigning drivers differ markedly and can directly relate to the optimisation possibilities with computerised scheduling. There is usually feedback between the vehicle and driver assignment phases.

The final phase is the stringing together of daily pieces of work into legal and acceptable rosters of work. A roster may be assigned to each driver for one, two or more weeks. Rosters have built in days off and assignment of special duties. Drivers may operate rotating rosters, or select work on the basis of seniority.

There is an intimate relationship between the number and type of trips scheduled, the number of buses and vehicle hours needed, and the number of drivers and pay hours of work. This relationship is stressed in order to put the possibilities available with computerised scheduling in perspective. If management is not willing to change the timetables when implementing computerised scheduling, the maximum improvements possible are limited. The improvements possibly can only come by reducing the difference between the revenue hours in the timetables and the total of vehicle hours. Likewise the drivers pay hours can never be reduced below the vehicle hours operated. The difference between the revenue, vehicle and pay

hours is rarely more than five to fifteen percent. A reduction of this difference by a few percent is the maximum that could ever be expected given the timetable constraint.

The possibilities for change within bus properties is often limited. Unions are extremely sensitive to any changes, particularly if they are not consulted or do not understand the reason for them. The public will quite often react sharply if changes are made to established travel patterns and levels of service.

The scheduling department is often not structured to be flexible to changes or even capable of any large scale revisions. The daily work load of the department is normally well defined, with a constant series of schedule adjustments, record keeping, pay and driver calculations and public relations work.

Management is often concerned to maintain stable political conditions with the drivers, the public, the press and politicians. The sheer needs of the day to day operation often procludes the consideration of changes by management.

Why Introduce Computerised Scheduling?

Unfortunately, the answer to this question is not simple. The advantages of introduction are numerous and real. The introduction of computerised scheduling, however, is seen by bus operators as having some distinct problems and disadvantages.

Usually, there is disbelief that a computer system will ever be able to handle the complex and varied details of bus operations. This belief is reinforced by past experiences

and failures. Related to this doubt is the belief that even if a computer could produce acceptable results it would not be cost effective. This is based on the belief that computers will not produce any better results, but will increase the scheduling department operating costs.

Frequently, there is marked resistance to new methods, particularly when they represent an unknown expertise, and many advantages which are intangible. Public transport has not been challenged to change for some time, money has always been available to cover operating deficits.

Past implementation efforts by outside organisations have frequently been totally inappropriate. There has been insufficient knowledge of the industry and its particular problems. Wholesale change and insensitivity to the constraints have bred discontent. Implementation has been attempted in short time frames, with little or no involvement of schedule personnel, training for continuation of the system or setting up and documentation of procedures. The long term needs of the bus property have not been fully considered.

However, I believe that most of these doubts are unfounded. The RUCUS program, as has been demonstrated in the U.S., can schedule for the day to day operations. In a recent project demonstrating RUCUS, results were achieved, without changing the timetable or vehicle schedule, which would have saved the Toronto Transit Commission between $50,000 to $90,000 per year for one 200 bus division. These results were completely acceptable to the unions. There was an increase in straight crews, a reduction in short pieces and an overall reduction in manpower. The results did not violate or disturb any of the normal scheduling department procedures. With timetables and vehicle schedules changed

to balance passenger counts and conform to minimum level of service policies, a saving of $300,000 to $450,000 per year could have been achieved. The revised schedules were not fully acceptable at that stage, but the results stimulated the Commission to begin a reappraisal of schedules and policies.

There is a substantial benefit from RUCUS and other scheduling systems in the cost savings. The cost savings will more than justify implementing the system. Schedule department size will not increase and, with a proper and timely implementation program, the RUCUS system and its operating procedures can be operated by the existing staff.

The greatest advantages from implementation, however, are related to benefits that can be obtained outside the pure scheduling operation. Some of these are:

- Reduction in tedious schedule department work, greater exploitation of scheduler skills and reduction in the reliance on any one particular scheduler and his knowledge.

- Greater speed and flexibility in schedule development, updating and distribution.

- Capability to quickly evaluate the impact of work agreement rule changes and to assess the cost implications of new service and policy proposals.

- Availability of a powerful management information data base for application in a variety of related functions such as cost effectiveness analysis of routes, public information and time-

table data, payroll calculations etc.

- Potential for reduction in operating costs through increased efficiency and effectiveness of vehicle and manpower usage.

- Rapid assimilation of new lines or service extensions with existing schedules.

- Production of a basic building block in extending management information and response capabilities.

If public transport is to continue providing a service to the public which is expanding, cost effective, reliable and responsive, these advantages cannot be overlooked.

Computer scheduling will not be implemented overnight. In fact, if it is to be successful, gradual and careful introduction is essential. It may be several years from initial implementation before all phases of a computer system are working with the scheduling department and management to provide the advantages cited above.

While computer scheduling is primarily an operations tool, the planning applications cannot be overlooked. Planning studies and recommendations must be based on solid operational simulation. The majority of present planning tools do not adequately consider the actual costs in vehicles and drivers that would be needed when properly scheduled. The use of RUCUS type systems with an interface to planning input can readily provide this information. Similarly, bus rationalisation, subsidy issues, garage location and consolidation studies are all potential areas where the detailed operational simu-

lation using RUCUS type tools are absolutely necessary.

Scheduling System Criteria

Computer scheduling systems must conform to several basic criteria if they are to be acceptable. Some of the more important criteria are presented below:

- Complete Capabilities Provided

  The system must be set up to provide scheduling assistance for all phases of the scheduling departments work. Not all phases may be used, but the framework and logic must be established for long term development. This ensures compatibility between data and the system function and establishes a system organisation around which future scheduling can be oriented.

- Modular

  It must be possible for new programs to be incorporated into the system. One scheduling function must be able to operate independently of others.

- Data Base Oriented

  All programs must use the same files. This allows different inputs, programs, and even computers to all work within the system. A comprehensive data base will provide the building block for multiple functions, even outside of scheduling.

- Available and Easy to use

  Any system must be fully under the control of the bus property. They must be able to modify and change the system to suit their own needs. Specialists should not be needed to run the programs. The advantages of introducing the system are lost if the schedule department personnel lose control and become dependent on specialists.

- Soundly Based and Workable

  The system must work, it must include as many desirable theoretical features as possible but should be soundly based, considering the best manual methods.

- Capable of being Integrated with Manual Methods

  Any system must allow for manual intervention and review. Unless the flow of computer analysis can be integrated with manual review and analysis, the total system will be a failure. Good computer turn-around is essential in this regard.

How RUCUS satisfies Scheduling System Criteria

Having listed these basic criteria it is appropriate to consider how RUCUS scores.

- Complete Capabilities Provided

  RUCUS presently provides the data management, reporting, timetable building and analysis, vehicle scheduling and driver assignment phases.

It does not provide for roster development.

- Modular

  RUCUS is modular, and each phase can be operated independently. Existing driver assignments, vehicle assignments or timetables can be fed into the package with only a single module used. This type of application has been common for demonstrating the driver assignment module.

- Data Base Oriented

  Four basic file structures provide all RUCUS data. This data is selectively read by each program to obtain the data which is necessary for its operation. In addition, the RUCUS files provide an interface to other systems. The service inventory and maintenance system SIMS, the payroll and management package TRANSMAN and the urban transport planning system UTPS can all communicate to and from RUCUS via its data base system.

- Available and Easy to use

  RUCUS is completely available to anyone from the United States Urban Mass Transportation Administration. The system is fully documented, with special manuals outlining implementation procedures, driver assignment logic and vehicle assignment operations.

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- Soundly Based and Workable

  RUCUS is soundly based but does not include all desirable theoretical features. The driver assignment is excellent, but the vehicle assignment could be improved. The timetable development section probably needs some revision. The timetable development is excellent for analysing existing schedules but does not allow enough feedback with vehicle assignment. Since RUCUS has been released, however, many improvements, additions and new programs have been added which are rapidly overcoming these deficiencies.

- Capable of being Integrated with Manual Methods

  Any RUCUS generated result can be readily changed in the data base. Manual input and computer results can be mixed. Manual override controls will stop RUCUS from changing certain solutions and assignments.

RUCUS

This section outlines a conceptual picture of the RUCUS methodology for converting the real world of bus stops, lines and driver movements into a computer format.

The first phase is the RUCUS technique for defining and setting up the data base for a schedule set. The second phase is the RUCUS technique for developing a new schedule set or altering an existing set to conform to new policies and passenger counts. The third phase is the logic for vehicle assignment and, finally, the fourth phase is the various steps

used in the driver assignment module.

Data Definitions

The overwhelming problem in computerised bus scheduling is the enormous amounts of data needed to fully describe the system. The amount of data needed cannot be varied greatly if a complete scheduling system is going to be implemented. The most onerous task is always the conversion of this data to the RUCUS data base.

The data must unambiguously describe the workings of the system. The minimum data needed are a location and time for the start of every trip and an end location and time. If it is important to identify intermediate points, such as branch points, cutback locations and driver relief points, locations and times must also be given for these points. If existing vehicle and driver assignments are to be included, the vehicle garage location, vehicle numbers and driver numbers must also be coded. Additional information which must be included are the length of trip, type of trip (e.g. Saturday, Sunday or Weekday) and the line, route and division codes.

RUCUS has five levels of data hierarchy:

- Division. The service area is divided into broad groups of lines. In general, all lines in one division will be operated out of a single garage.

- Line. A set of trips not all with the same terminii or routes, but with sufficient common overlap that the trips can be considered as a logical data unit.

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- Service Definition. For each line there may be several different types of service. For example the weekday, Saturday, Sunday and school services schedules could all be coded as different services for the same line.

- Direction. For each line and service there exists a one-way schedule representing either an in-bound or out-bound trip.

- Trip. This is the most basic unit of data. A trip consists of a series of times with each time representing the passing of a node point.

The RUCUS data files represent multi-dimensional matrices, the highest level dimension representing the division, the lowest level representing a particular division, line, service and direction. Each row represents a trip and each column represents a unique node point location.

Any trip can be referred to directly by a division, line, service and direction code and the trip sequence number.

Comments and notes can be directly keyed to the division, the line or an actual trip code. All programs can refer to subsets of the data by these codes.

Data files are also built to represent the travel time between all terminals for up to four periods of the day. This is necessary for vehicle assignment.

An identification and comment file is maintained to provide notes, headings and names for all numeric division line, service direction and node codes.

The driver assignment references a file containing the allowed travel times between relief points.

The system contains many programmes to help in the building and maintenance of these files. Several programs produce printed coding sheets especially formatted for direct data input.

One of the major developments since the release of RUCUS has been in the area of improving the data entry capability. One-line editing, floppy disk data communication and generalised conversion programs for data already in coded form are some of these developments.

Schedule Development and Analysis

The objective of schedule building is to schedule trips so that the headway varies with passenger demand throughout the day, subject to policy service levels and the need to be as economical as possible with buses.

All RUCUS schedule building and analysis works with a matrix structure. Each column represents a single point and each row represents a time interval. Thus the day is divided into a definite number of time intervals.

The configuration of a line and feasible routes which can be followed on that line are described. Thus, if a trip is deemed to be necessary at point A then that trip must follow one of the feasible routes to the other end of the line, even though that trip may not be needed at other locations along the route.

For any node in the system, policy headways can be defined for intervals of the day. Similarly, special demands

can be specified, such as ten buses outside a large factory at 4.35 p.m.

The size of the bus, and the allowable loading standards which will apply throughout the day can also be specified. These will only be needed if passenger count information is input. This information can be obtained from an existing schedule or from planning data for a new schedule. RUCUS has one program which will print count recording sheets for direct use in the field when analysing existing schedules.

The final piece of information needed are the running times between all feasible node pairs for each line, and the variation of these running times throughout the day.

These data are analysed to calculate the number of buses required at each node location for each interval. This number may be a function of the policy headway, special demands or passenger count information. Once this table has been produced, the feasible route descriptions allow for calculation of the number of trips following each route on that line. Thus, demand for trips at various nodes is converted to trips which pass each node along routes.

The final step is the development of a schedule where each trip is assigned a particular time slot. Because each direction of a line is developed independently a process of adjustment is carried out to ensure that trip ends match. The final schedule is written out to the data base.

If an existing schedule is being examined, however, a matrix of the differences in the requirements as expressed by the new schedule and the supplied service as expressed by the old schedule can be produced. This can become the basis

for updating the old schedule file.

Vehicle Assignment

The basic input to this phase consists of the schedules to be assigned together with the matrix of information for travel times between terminii. The program operates in two steps. The first step consists of the vehicle optimisation when operated from a single garage per line.

The second step consists of the examiantion of this solution so that adjustments can be made to improve the driver assignment and to allow for multiple garages per line.

Four times can be specified to control the examination of vehicle assignments. Minimum and maximum bus times can be nominated. Similarly two times can be specified between which a bus total time cannot occur. For instance, vehicle times between five and six hours may be very hard for efficient driver scheduling and an attempt can be made to eliminate vehicle times of those lengths.

Normally, a line is served by buses out of a single garage, but in the case of multi-garage-lines a special routine is used to optimise the split between the two or more garages.

The objectives of the optimisation algorithm is to minimise a cost function subject to constraints. The constraints that can be imposed are a maximum number of buses and restriction on bus movements between certain pairs of lines and terminii. The cost function is comprised of the following:

- a benefit for each trip which can be varied for each service, line, trip or division;

- a fixed cost for each pullout;
- a fixed cost for defined interline pairs;
- a variable cost for dead time which can be input for various times or internally computed according to a formula controlled by the user;
- a variable cost for time under or over a target layover time with the terminal target specified as a constant or as a percent of the last trip time;
- Absolute maximums and minimums can be specified.

The total daily movement for every bus is reported, together with summary information on total deadtime, layover time, revenue time and pull-out/pull-in time. Though trips cannot be rescheduled automatically, buses are allowed to go backwards in time, thus indicating the desirability for re-scheduling. The normal process would put a high cost penalty on backwards time travel. Then only those reschedulings which were really beneficial would show out.

The RUCUS data base is updated with bus run numbers, next trip and last trip pointers and the amount of time this trip may be moved backwards or forwards without changing the vehicle assignment.

The benefit for operating a trip can be varied to provide additional cost information. At high benefits, all trips will be scheduled, but when the benefit is decreased then some trips will be unscheduled. This indicates those trips which are most "costly" to operate.

Driver Assignments

The input to the program is the set of times at which each bus passes a valid driver relief point and a user coded subroutine which includes all the work rules for controlling assignment. The vehicle data comes from the data base or is input directly, possible from a manual vehicle schedule.

The process is heuristic, following eight levels of possible optimisation. Execution can be stopped at any level. Details of the process are described in two MITRE documents (MITRE, 1974(a); MITRE, 1974(b)).

Since the program was released, however, numerous improvements and changes have been incorporated. Changes have been made to suit the needs of particular properties and to improve the logic, user control, output reports and cost penalties used in processing.

The program can be recycled using a previous run as input. A large range of parameters is available for testing alternative work rules constraints without changes to the user coded subroutine.

The program was developed from an existing driver assignment package, and has been enhanced to improve flow and output. The results to date have been excellent. In all cases manual results can be matched or bettered, and be acceptable to the bus operation.

The prime task with the program is to fine tune the parameters and the work rule subroutine until the right conditions are found for the particular property.

It is anticipated that, with the continuing work on several large implementation projects in the United States, substantial improvements and additions will continue to be made, not just to the driver module, but to the whole system.

DETAILED IMPLEMENTATION APPROACH

The need for a careful and structured implementation has been stressed. The needs and phasing of implementation will depend on the prevailing conditions at the particular bus property. Despite this, however, certain key elements are necessary in any approach.

The objectives for the implementation must be carefully defined beforehand with consultation between management, schedule department, union representatives and the implementation organisation. One intent normally is to provide more cost-effective and time-responsive means for executing the scheduling function. Cost-effectiveness is not construed solely in terms of substantial cost savings, but also in more efficient manpower utilization. The Toronto approach of foregoing large operating cost savings, in order to preserve existing operating practices (at least for the short term future), with accompanying improvements in Scheduling Department work allocations, represents a practical, though less dramatic, strategy. Thus, once a clear but practical set of objectives have been agreed to, the framework has been established for an ordered and structured project. The objectives may be modified and expanded as work proceeds but, without the initial framework, project performance cannot be related to an end product.

The normal implementation approach will follow four phases:

- System Study and Planning
- RUCUS Evaluation and Schedule Conversions
- System Development
- Integration Study and Training

System Study and Planning Phase

The objective of this phase is to ensure that the implementation team have a thorough and detailed understanding of the current scheduling practices and are aware of the characteristics of the public transport system which will affect RUCUS. Several tasks will be necessary. The first will be a thorough system review and documentation of all present procedures and logic. The second task is the definition of the bus system in RUCUS/Computer system terms. This task must consider possible trade-offs between different representations. For instance, there is a difference in whether intersections are considered as one or two nodes. Future growth and the need to maintain flexibility are the chief considerations. Two key documents will result from this phase. The Technical Project Report will identify the technical strategy for the project and reflect the results of the two tasks. It will serve as a manual for the project team. The Project Plan will establish in detail the activities to be performed in the implementation.

RUCUS Evaluation and Schedule Conversion

The primary objective of the evaluation phase is to determine the nature and extent of limitations in the RUCUS system as they apply to the bus operators. This phase can be split into several tasks.

The largest task is the data evaluation and conversion. Extensive edit checking and a considerable period of time must be allowed for this task. In order to permit comparison of RUCUS with the current scheduling system, it is usual for a few RUCUS report formats to be changed. This task will also have been defined in the Technical Project Report.

The core task will be the evaluation of each of the RUCUS calculation modules. Development of a close working relationship between computer specialists and scheduling personnel will allow any deficiences or problems to be identified for changes or program additions.

The final task will be the review of all evaluation tasks and the production of a detailed Development Plan which will augment the original Project Plan and lay out the necessary developments to reach an ultimate desirable computer scheduling system.

System Development

The development plan will serve as the basis for all system development work. Changes should not be implemented immediately. The development activities should be structured into packets which can be tackled on a step-by-step basis.

The initial objective may be to fully develop the Driver Assignment Module. Then gradually, once this has been proved in practice and the results accepted, the plan may call for the development of the Vehicle Assignment Module. A long term development may be the generation and review of schedules. Interfaces with maintenance planning or management systems may be included in the development. Complete new modules may

be developed. For instance, the financial analysis of lines using count and fare input data may be contemplated.

Integration Study and Training Phase

The integration study will consider the hardware requirements, the organization structure and the personnel responsibilities necessary for a smooth and controlled operation with the scheduling system. Procedures must be established to ensure data integrity and control. Responsibilities must be defined so that proper and effient use is made of the total system. Training is one of the most significant tasks for any implementation. A close working relationship between bus property staff and the implementation team will ensure "on the job" training. Formal classes will be necessary for both scheduling and computer system support personnel. A Systems Manual would be produced for maintaining the computer system, and a Users Manual produced for schedulers' use.

Appreciation

As with any use of computers, the GIGO principle applies. Careful data preparation is essential. Also, a critical appraisal of results is imperative. No bus property can ever expect to produce all of its schedules and assignments by computer processes. Manual intervention will always be required.

Computer scheduling can, however, eliminate the tedious tasks, leaving the experienced scheduler to handle the difficult assignments and, more importantly, to exercise his mind on innovative solutions to scheduling problems. Of course, RUCUS would be available for him to test his solutions.

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This overview has but scratched the surface of the total breadth of computer scheduling of bus operations. Both the bus property and the competent implementation organisation recognise the complexity of bus systems. Regardless of appearances, however, it is extremely unlikely that there is any bus property in the world for which more than 15 percent of their services are inappropriate for computer scheduling. RUCUS is a proven tool in this regard.

Table 1

RUCUS PILOT APPLICATION SUMMARY

Transit Property	Division	Trips	Vehicles	Drivers	Data Module	Schedule Module	Vehicle Assign-ment	Driver Assign-ment
Akron	All	800	38	56	x		x	x
Baltimore	Eastern	2800	180	300	x	x	x	x
D.C. Transit	Western & South-eastern	3300	360	500	x	x	x	x
San Diego	All	1700	225	400	x		x	x
Vancouver	Oakridge	-	-	525	x			x

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