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Estimating the Cost of Work Rule Changes in Transit

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Estimating the Cost of Work Rule Changes in Transit

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FOREWORD

In many transit labor negotiations, management and labor want to explore a variety of changes in work rules. A dozen or more changes may be desired in a typical negotiation. To assess the cost implications of these proposals, a complete schedule runcut is needed for each work rule change. Unfortunately, the cost of making these runcuts is expensive when conventional scheduling procedures are used. As a result, work rule changes that may be advantageous to management and labor are not fully considered at many transit systems.

This report is a summary of an effort to develop and test computer modeling techniques for use in labor negotiations. A new computer tool for estimating the costs of work rule changes was subjected to testing and evaluation at the Southern Rapid Transit District (SCRTD) in Los Angeles, California. We believe that the results of the effort at SCRTD will be of interest to many transit systems.

Additional copies of this report are available from the National Technical Information Service (NTIS), Springfield, Virginia, 22161 at cost.

Further information on this UMTA project can be obtained from Brian McCollom, Office of Methods and Support (URT-41),(202) 426-9271.

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ATE Management conducted this study in consortium with GIRO, Inc. of Canada. The project team consisted of Jean-Yves Blais, GIRO; Jim Curry, Mike Harbour, and Ed Kouneski, ATE; and Roger Mitchell, the ATE project manager.

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1.0 INTRODUCTION

During the seventies, federal transit operating funds steadily increased and emphasis was placed more on increasing ridership and expanding service than on controlling the cost of providing service. As more express and commuter-oriented routes were introduced in peak periods, it became more difficult to schedule a full day's work for many drivers. Since most labor contracts included penalties for less than eight hours of scheduled work, penalty payments rose, labor productivity decreased, and paytime per vehicle service hour increased.

Transit systems currently faced with reduced federal operating subsidies are now examing new ways to increase productivity. Particular attention is being given to the cost of work rules in the union contract, which is subject to periodic negotiations between labor and management. Although the impact of factors such as cost-of-living, wages, and fringe benefits can be readily understood, work rule changes are not as easily handled. Because of uncertainty in assessing their impact, work rule changes that may be advantageous to both labor and management are not being considered.

This report examines the feasibility of using computer modeling techniques to accurately and rapidly predict the impact of work rule changes on operating costs. A new tool for estimating the cost of work rule changes -- HASTUS -- was subjected to in-depth testing and evaluation.

The Southern California Rapid Transit District (SCRTD) served as a case study for the application and demonstration of HASTUS. SCRTD received special Section 8 grants from the Planning Research and Evaluation Division of the Urban Mass Transportation Administration (UMTA), U.S. Department of Transportation to accomplish the following objectives:

- install and calibrate a mathematical model for analyzing the cost implications of work rule changes for transit labor negotiations; and
- test and verify that the model predictions are valid and accurate, within acceptable limits.

HASTUS, the mathematical model installed at SCRTD, was developed by Dr. Jean-Marc Rousseau and Jean-Yves Blais at the University of Montreal. It uses linear programming techniques. A more detailed description of the model is given in Chapter 4 and the mathematical formula is presented in Appendix A. In 1981, HASTUS was awarded distinction as "the outstanding operations research application of the year" by the Canadian Operations Research Society.

This report on the evaluation of the HASTUS model is organized as follows:

- Chapter 2 describes the SCRTD organization and service area and presents relevant operating statistics;
- Chapter 3 reviews and evaluates past methods used by SCRTD to estimate the impact of work rule changes;
- Chapter 4 describes the development and the evaluation of the new mathematical model for analyzing labor costs;
- Chapter 5 presents the results of a trial implementation of the mathematical model;
- Chapter 6 discusses the conclusions drawn regarding the effectiveness of the mathematical model; and
- The Appendix contains sections which describe in more detail the mathematical formula and calibration/validation techniques applied in this study.

2.0 DESCRIPTION OF SCRTD

2.1 System Characteristics

The Southern California Rapid Transit District (SCRTD) serves most of the urbanized part of Los Angeles County, which has approximately seven million residents. Principal employers in the area are aerospace, manufacturing, construction, and service industries. SCRTD has two primary missions: (1) to act as regional bus operator for Los Angeles and surrounding counties within a service area that exceeds 2200 square miles; and (2) to plan, build, and operate a starter line for rapid transit.

In 1982 SCRTD operated 101.5 million vehicle service miles and 7.1 million vehicle service hours. It carried 337.0 million unlinked passengers and scheduled 8.6 million operator pay hours. Total operating costs were approximately $359 million. Passenger fares provided $158.6 million of this sum; the balance was derived from local, state, and federal subsidies. The operating cost per unlinked passenger was $1.06 with passenger revenue providing 47 cents of this cost.

SCRTD employs approximately 8,240 persons, including 4,665 bus drivers, and 1,500 mechanics. The SCRTD bus fleet consists of 2,500 active vehicles, of which more than 2,000 are required during peak periods and approximately 1,150 in non-peak periods. SCRTD buses are dispatched from 13 operating divisions as shown in Exhibit 2-1.

The Metropolitan Planning Organization for SCRTD's service area, which encompasses Los Angeles, Orange, San Bernardino, Riverside, Ventura, and Imperial counties, is the Southern California Association of Governments (SCAG). It is a voluntary association of 130 cities and six county governments. It cooperates with the California Department of Transportation and SCRTD to provide regional transportation planning for approximately 11 million residents of the region.

At SCRTD, three functional departments were involved in aspects of this study: scheduling, transportation, and labor relations.

2.2 SCRTD Operating Conditions

To more fully understand the need for this study, it is appropriate to review the operating conditions of SCRTD, one of the five largest transit systems in the country. Table 2-1, which displays SCRTD operating statistics, shows that the system operates 7.1 million vehicle hours per year but because of the operator contract work rules, this results in a 21 percent increase to 8.6 million payhours. The operator contract specifies work and pay rules for such items as (1) an 8-hour daily pay guarantee; (2) report time to work; (3) overtime premium after eight hours work; (4) overtime premium after 10 hours spread for regular operators; (5) overtime premium after 11 hours spread for extraboard operators; and so forth. These provisions as well as many others have been negotiated by the operators' union over past decades to compensate the operator for the unusual daily work schedule (called a "run") typically found at large transit properties. The unusual work schedules are caused mostly by the peaking of transit demand during rush hours, thereby requiring some runs to be split into two pieces separated by a two to four hour break in the midday. This type of run is called a "split run" as opposed to a "straight run", which consists of a continuous piece of work approximately eight hours long.

Since a split run is much less desirable than a straight run, from the operator's point of view, another work rule in the SCRTD contract specifies that 60 percent of all regular weekday runs must be straight. Furthermore, split runs that extend beyond a 10-hour span, which includes unpaid break time, must be paid overtime at time and one-half. These collaterals significantly add to the total payhours.

A common measure of the cost of work rules is the ratio of scheduled payhours to vehicle hours. The systemwide annualized ratio for the SCRTD is 1.21 to 1, (21%) which is about normal for most large transit authorities. Industrywide, the ratios range from about 1.05 to 1.30. In one sense this ratio is a measure of "contract efficiency." A more efficient contract, with more relaxed work rules, would have a lower ratio. This translates into significatnt dollar savings for the same level of service. A one percent reduction represents a direct annual saving to the SCRTD of approximately $1 million.

TABLE 2-1

SCRTD Operating Statistics

1.	Number of bus divisions	11
2.	Average number of peak hour vehicles	1900
3.	Average number of mid-day (base) vehicles	1200
4.	Number of full-time bus operators	4100
5.	Number of part-time bus operators	330
6.	Annual vehicle hours operated	7.1 million
7.	Annual operator scheduled pay hours	8.6 million
8.	Annual operator scheduled pay dollars	$ 96.0 million
9.	Annual operator pay dollar with fringes	$ 144.0 million

*Figures supplied by SCRTD, based upon October 1982 statistics annualized.

Negotiation of relaxed work rules, therefore, becomes a significant means of improving a transit authority's productivity. In the past 20 years, there has been only one operator work rule change at the SCRTD. In the 1979 contract a provision for 10 percent part-time operators was negotiated. While only one change was agreed upon, management actually proposed making several work rule changes. Examination of historical documents shows SCRTD management has proposed relaxing several work rules at each contract negotiation for the past 15 years. Likewise the union has proposed tightening of work schedules. Through this process, which is common at most transit authorities, is the problem of estimating the costs of work rule changes.

3.0 EXISTING SCRTD WORKRULE EVALUATION PROCEDURES

3.1 Introduction

This chapter addresses the methods of evaluating changes in work rules that were available at SCRTD prior to the application of the HASTUS model. Each change in a work rule provision during labor negotiations requires the development of a new runcut. It is the task of developing this runcut which makes it difficult to estimate the cost of work rule changes.

Runcutting is the task of creating driver assignments from the vehicle schedule. The vehicle blocks, which show the times vehicles leave an operating division in the morning and later return, can be cut at specified points (relief points) and recombined into daily driver assignments. The schedulemaker-runcutter attempts to do this in a manner which minimizes cost. The goal of this effort is to increase productivity by decreasing the pay-time-to-platform-time ratio (reducing the percentage of pay that is penalty pay), without initiating any work rules.

Developing a runcut at an SCRTD operating division is an extremely complicated process. The large number of ways in which a bus schedule can be combined into driver assignments and the trade-off in costs created by the number of work rules in existence requires that an iterative process of continual refinement be used.

In general the runcutting process proceeds as follows:

- runs are cut using a particular strategy;
- the cost of each assignment is calculated; and
- runs with high penalty or guaranteed pay are examined to determine if better combinations can be created.

The SCRTD work rules which govern the runcutting process are presented in Appendix B. A summary is presented in Table 3-1, Summary of Selected

TABLE 3-1

SUMMARY OF SELECTED SCRTD WORK RULES

Regular Runs	Provision
1. Percent straight runs, weekday.	60% minimum
2. Preparatory time for a pull-out.	10 minutes
3. Storage time. For a pull-in.	5 minutes
4. Travel time.	Between division and relief points
5. Paid break.	Any break less than 30 minutes
6. Guaranteed pay hours - makeup.	Minimum 8 hours
7. Overtime after 8 hours work.	Time and one-half
8. Overtime paid after 10 hours spread.	Time and one-half
9. Definition of regular run: --any combination of work totalling 7 hours which can be made within a spread of 10 hours.	
Extra Board	
1. Same as Regular Runs except as follows.	
2. Overtime paid after 11 hours spread.	Time and one-half
Part Time	
1. Preparatory and storage time.	10, 5 minutes
2. Minimum work hours.	3 hours
3. Maximum work hours.	5 hours
4. Number of part-time limited to 10% after regular runs.	

SCRTD Work Rules. In addition to these work rules the SCRTD Scheduling Department uses another group of policy rules which have much the same effect as work rules; these are specified in Appendix C and summarized in Table 3-2. For a more detailed examination of industry rules and their application in contract negotiations see Appendix D.

3.2 Methods Used To Estimate Labor Costs

Prior to the development of HASTUS, two methods were generally used at SCRTD to estimate costs associated with changes in work rules. One method is that of manual runcutting. The majority of transit systems nationwide prepare runcuts manually. Because of the time needed to prepare a manual runcut systemwide, most large transit agencies select the runs at a large operating division as representing the runcut of the entire agency. Most often the representive division selected is one whose peak-to-base ratio and vehicle characteristics are similar to those for the entire agency. At smaller transit agencies the general practice is to manually cut runs systemwide.

The second method available for estimating the impact of work rule changes involves the use of a software package know as RUCUS. RUCUS is an UMTA developed computer software package for transit scheduling and runcutting. Released in 1974, RUCUS, in a modified form, is used by many U.S. and Canadian transit authorities. The SCRTD uses a highly modified version of RUCUS for runcutting only, that was installed in 1976 by TRW, Deleuw Cather and Canada Systems Group.

3.3 Disadvantages of Existing Methods

Manual

Runcuts which are produced manually have three basic disadvantages. The first is that the manual runcut consumes too much time to be useful for labor contract negotiations. At SCRTD, for example, a complete runcut for 30 bus lines at Division One requires six to eight weeks to complete. Since it is not uncommon for a dozen or more changes to be discussed

TABLE 3-2

SUMMARY OF SELECTED SCRTD SCHEDULING POLICIES

1. Maximum driver vehicle time is 10 hours 25 minutes.

2. Maximum spread time on regular runs is not to exceed 12 hours 50 minutes.

3. Regular runs starting before 5 a.m. must be straight runs.

4. Trippers runs, leftover loosened pieces not operated by part-time drivers are paid at time and one-half.

5. Trippers are guaranteed 2 hours pay.

during contract negotiations, it is clear that manual runcutting is unsatisfactory.

Second, manual runcuts involve human computation which is subject to error. Unless the error is subsequently detected it becomes a part of the contract and may cause hardship on one or the other parties over the term of the contract.

Third, and perhaps most important, manual runcuts produce an answer that is not guaranteed to be optimal or least expensive. When new work rules are added, the schedulemaker may not immediately know how to develop the best strategies for runcutting. Manual runcuts lack the quality of being "optimal." since they are dependent upon the skills of the individual schedulemaker.

RUCUS

During the mid-seventies UMTA sponsored the development of a software package known as RUCUS. It represents a substantial improvement over the manual method of runcutting. RUCUS is based on manual techniques that have been automated. At SCRTD operating divisons where RUCUS has been implemented, it substantially reduced runcutting work efforts during the regular scheduling process. Furthermore RUCUS has been shown to improve operator labor productivity at SCRTD by at least one percent through more efficient runcutting on existing work rules. During SCRTD's 1982 negotiation process, RUCUS was used to estimate the cost impact of several work rule changes. While it reduced the runcutting effort, RUCUS suffered from a few limitations which encumber its use for evaluating work rule changes. For example:

- Changing a work rule often necessitates a change in the runcuttting logic. Changing RUCUS runcutting logic involves reprogramming which can require significant effort by a skilled programmer/analyst familiar with the programs.
- Some work rule changes require several man-months of reprogramming. This investment of effort is not viewed to be productive unless the work rule change was actually adopted. This precludes experimentation with different work rule com

binations. Examples of work rules that would require extensive reprogramming of RUCUS include part-time operators and redefinition of run types such as a three or more piece runs or straights with lunch breaks.

- Because RUCUS runcutting logic needs to be reprogrammed for some work rule changes, the chance for inaccuracies increases.

4.0 DEVELOPMENT OF A NEW MATHEMATICAL MODEL TO ANALYZE LABOR COSTS

4.1 Introduction

To be useful in a labor negotiations context, SCRTD felt that an improved runcutting method should meet four criteria:

- Be able to address all work rules in the labor contract.
- Be able to adjust readily to work rule changes.
- Consistently and accurately predict the cost of work rule changes.
- Be easier to use and faster than other methods.

Researchers have long recognized limitations in RUCUS, and have made efforts to develop a mathematially based runcutting program that would produce accurate and efficient runcuts in all cases. By applying some vehicle data simplifications, researchers at the University of Montreal developed an optimizing runcutting program which employs linear programming mathematics that more closely approximate "optimal"[1] results. This program is called HASTUS. With most work rules specified as simple input parameters, HASTUS quickly produces a divisionwide runcut with cost statistics. The optimizing logic of HASTUS automatically adjusts to each work rule change without reprogramming. Because the input vehicle data has been simplified, however, the final runcut is not suitable for putting "on-the-street".

Prior to the demonstration at SCRTD, HASTUS was implemented at transit authorities in Montreal and Quebec City. It was used to produce hundreds of work rule change runcuts in anticipation of union negotiations.

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[1] "Optimal," referenced throughout this report, is defined as the theoretical level at which the absolute minimum total cost of runs is achieved.

4.2 Description of Model: HASTUS

HASTUS is a series of programs for producing operator runs, using a mathematical optimizing algorithm (linear programming). With this algorithm, a preprocessing program generates all possible combinations of driver assignments on a given set of vehicle schedules, according to the work rules and the costing procedures. The work rules are specified using easily changed input parameters.

The generation of all possible run combinations that are legal (that is, conform to contract work rules) will produce a temporary dataset of runs many times (at least 30) the size of the final solution. The linear program then processes the whole temporary dataset and solves for the minimum cost solution. Currently there are no computers large or fast enough to economically solve this problem on a medium-sized bus division. Consequently a few limiting factors have been used in HASTUS to decrease the size of the problem. These simplifications are described as follows:

First Simplification: Fixed Interval Reliefs

The major input to any runcutting process, whether manual or automated, is the vehicle schedule, known as a "block." A block contains the schedule of a vehicle for a single day of operation. It identifies the time the vehicle pulls out from the garage, the time it arrives at each timepoint on a route, the direction of travel, and finally the time the vehicle pulls into the garage. A block may be as short as one to two hours for a peak hour bus, or as long as 20 hours for all day operation. In runcutting, long blocks are cut into smaller pieces and combined to make a driver work assignment (run) of approximately eight hours for full-time drivers and four hours for part-time.

For runcutting only a subset of the block information is required. The key elements of data are: the pull-out from garage time, the time each vehicle passes a relief point (called relief time), and the garage pull-in time. When making an operator run, a vehicle can only be cut at a relief point. A typical input block for the a.m. peak may look like this:

- pull-out: 6:15 a.m.
- time at relief points: 7:08, 8:30, 8:45, 9:52
- pull-in: 10:15 a.m.

At SCRTD this is called a "sub". In HASTUS this has been simplified such that a block is composed of reliefs at fixed intervals that approximate the actual relief times.

Initially, the fixed interval at SCRTD Division One was set at 45 minutes. The corresponding HASTUS block would look like this:

- pull-out: 6:00 a.m. (modified to the nearest 45 minute period boundary)
- time at relief points: 6:45, 7:30, 8:15, 9:00
- pull-in: 9:45 a.m.

The result of this simplification is a rough approximation of the actual vehicle profile and reliefs. However it does make the final result unsuitable for putting "on the street".

Second Simplification: No Travel Time Provisions

Most transit authority labor contracts have some provision for paying travel to and from a driver relief. This requires, in both the manual and automated environments, a matrix of travel times to and from each relief and the garage. Each time a run is cut, the travel time is looked up in the relief point travel time matrix and added to the cost of a run.

Calculating the travel time with the number of run combinations generated by HASTUS would be prohibitively expensive, in terms of computer time. Since travel time is usually such a small percentage of the overall costs, it has been eliminated from HASTUS, in the interests of simplification and efficiency. Consequently HASTUS does not account for, nor track, the designation of actual relief point names or numbers.

Because there are no relief points and, therefore, no travel time between relief points, HASTUS cannot restrict the mixing of work pieces between different routes. In other words, HASTUS assumes infinite interlining.

4.3 The Evaluation: Calibration/Validation Procedures and Results

The intent of this study was to test the feasibility of HASTUS as an efficient, easy-to-use means of evaluating the cost of work rule changes. The normal procedure for calibrating an automated runcutting system is to choose a sample division's complete manual runcut currently "on the street" and compare the results to the computer runcut. SCRTD's Division One was selected as being the division most representative of the systemwide operation. It was the origin and destination point for 30 bus lines and 225 buses. Some of the bus lines operate over long distances with part of the route traveling on freeways. Others operate solely on surface streets with frequent stop-and-go service. In addition, Division One was the only SCRTD operating division where the RUCUS package is used to cut runs.

The specific objectives of the calibration/validation process, documented in this chapter, are to determine if HASTUS could:

- o comply with each work rule of the existing SCRTD labor contract to produce labor hour costs which were equal to those produced by RUCUS when given identical input data; and
- o match RUCUS on a repeated basis (consistently) with proposed variations in work rules and combinations of work rules.

Calibration is defined as efforts aimed at determining what factors have to be applied to a HASTUS runcut to make it about equal to a RUCUS or manual runcut when given identical inputs. Underlying these efforts is the assumption that both RUCUS and HASTUS must comply with all work rules in the labor contract. As it turned out a strategy evolved with which the use of calibration factors was avoided.

Validation, on the other hand, is defined in terms of consistency of results. The HASTUS model would be validated only after it demonstrated the capacity to consistently and accurately predict the cost of work rule changes. If HASTUS can do this, it would be extremely useful in labor negotiations. Because HASTUS was being evaluated for its ability to predict the cost impact of work rule changes, it was originally thought necessary to compare the HASTUS results to situations before and after a work rule change. Unfortunately, SCRTD had only one work rule change in the past twenty years. In 1979 it instituted a 10 percent part-time driver provision. When it came time to collect the data, however, it was found that:

- The 10 percent part-time was incorporated without re-runcutting the schedules.
- Schedules prior to the change had been archived and were not easily available.

The original calibration procedure called for a comparision of results before and after the 1979 work rule change. Instead, three different calibration approaches were tried, each necessitated by the failure of the previous one to provide consistent, reliable results. Consequently the rationale and success of the third approach can best be viewed by examining the reasons why the first two did not provide good results.

First Calibration Effort: Description and Results

After it was learned that the original before-and-after-1979-contract approach would not work, it was decided to calibrate HASTUS against the SCRTD RUCUS runcutting results. This was a two phased approach:

- Phase 1 -- Base Runcut Comparision. HASTUS would be compared to RUCUS, under the existing work rules (base) and with actual vehicle data.
- Phase 2 -- Work Rule Simulations. HASTUS and RUCUS would be compared on five simulations involving at least one work rule change each. If HASTUS predicted the same percentage payhour change as RUCUS then it would be considered to have been calibrated.

The results of the first calibration were inconsistent and inconclusive. This was due to a number of problems with both the RUCUS runcuts and the HASTUS parameters. The RUCUS runcuts were performed by a person unfamiliar with

RUCUS logic leading to inefficient runcuts, thus making a poor comparison for HASTUS. Subsequent RUCUS runcuts were performed by a person much more experienced in RUCUS logic and programming, resulting in more realistic and consistent results. This situation illustrates one difficulty in using RUCUS for work rule change estimation.

HASTUS had a subtle but important work rule violation which affected the results. Even when a more experienced RUCUS person was used, after correcting the errors in HASTUS and RUCUS, there still remained a significant difference of three to four percent in the total payhours with HASTUS runcuts consistently less. HASTUS produced a runcut which in terms of run types (straights, splits, etc.) was significantly different. For example, RUCUS produced a runcut with 75 percent straight runs and HASTUS on the same division producued the contractual minimum of 60 percent straight runs. Presuming that the cost difference was due to the different run statistics, it was decided to try a new calibration approach that would make HASTUS cut runs similar to RUCUS.

Second Calibration Effort: Description and Results

In order to force a runcut which would look similar to RUCUS, "artifical work rule constraints" were applied to HASTUS using the input paramters. Presumably if the runcut looked similar, then the costs would be similar, and hence proof would exist that HASTUS could cut runs accurately. Furthermore, it would identify the cost impact of the two HASTUS simplifications: fixed interval reliefs and no travel time.

The corrected base runcuts from the First Calibration Technique where examined and seven or eight artifical constraints applied to HASTUS. For example, after RUCUS cut 75 percent straights as opposed to HASTUS's 60 percent, an artificial constraint was added to HASTUS which would guarantee 75 percent straights. The results of this technique were unexpected but explainable.

Applying the artificial constraints to HASTUS set the minimum percentage of straights at 75 percent; however, the actual number of straights was less than

RUCUS because HASTUS cut fewer regular runs and more extraboard runs. Because HASTUS employs global optimizing techniques it seems to always produce the minimum total cost. Each new constraint caused the entire runcut to be re-optimized, often producing radically different solutions. Even though the total payhour cost began to approach RUCUS, it became apparent that it would probably be impossible to make HASTUS cut runs like RUCUS.

Furthermore, the application of artificial work rule constraints complicated the simulation process. For instance, this question was raised: If SCRTD wanted to evaluate the effect of a 10 percent reduction in the minimum percentage straights, would the contractual 60 percent be reduced to 50 percent or would the artificial constraint of 75 percent be reduced to 65 percent? The application of artificial work rule constraints did not answer this calibration question and seemed to make the simulations more complicated. Consequently the Second Calibration Technique was abandoned but the effort was not without worth. Progress was made in understanding the workings of HASTUS, RUCUS, and the complex SCRTD work rules, as demonstrated in the next section. For a more detailed discussion of the First and Second Calibration Effort see Appendix E.

Third Calibration Technique: Description and Results

Objectives

The most perplexing problem faced in the third calibration exercise involved comparing HASTUS with RUCUS runcut results. Even though HASTUS produced actual straights, splits, extraboard combinations, and biddable trippers, they were not directly comparable to RUCUS runs because they were based on the two HASTUS simplifications: fixed interval reliefs and no travel time. Consequently, it was impossible to determine whether the differences between RUCUS and HASTUS on the base runcut were due to (1) logic deficiencies in RUCUS; (2) the HASTUS simplifications; or (3) a combination of both. If this problem were solved and quantified, then HASTUS could be calibrated by comparing it to RUCUS simulations and applying an adjustment factor.

The solution to this complex problem was to have RUCUS cut with exactly the same data simplifications as HASTUS. By comparing RUCUS with real data and RUCUS with simplified data, the effect of fixed intervals and no travel time could be determined.

Methodology

To perform the third calibration it was decided to perform a series of RUCUS runcuts that would progressively change the input data to look more like HASTUS until the data was exactly the same. The progression illustrates the quantitative effect of the data simplifications, as follows:

(1) RUCUS runcut with actual subs and full travel-time file equivalent to "on-the-street."

(2) RUCUS runcut with actual subs and full travel-time file, but no penalty for interlining. (Interline penalities reduce the number of runs which have pieces from more than one route.)

(3) RUCUS runcut with actual subs and a zero travel-time file.

(4) RUCUS runcut with HASTUS subs and a zero travel-time file.

(5) HASTUS runcut with HASTUS subs and no ("zero") travel-time file.

The input data for the last RUCUS runcut (4) and the HASTUS runcut (5) are identical. Comparing the results of RUCUS "on-the-street" runcut (1) with the HASTUS equivalent RUCUS runcut (4) would show the effect of the two HASTUS simplifications: fixed interval reliefs and no travel-time. Comparing RUCUS (4) with HASTUS (5) would show the effect of any logic differences.

After performing the progression, two test comparison of RUCUS and HASTUS were made. In the first comparison work rule changes simulations were made where the RUCUS "on-the-street" non-simplified data runcuts were used.

If the results of these simulations showed a consistent change in the total payhours then HASTUS could be considered at least as accurate as RUCUS. It was decided to use three RUCUS work rule change simulations, that had been recently performed on the test SCRTD operating division as part of SCRTD's on-going labor contract negotiations. These particular RUCUS runcuts simulations were considered of the highest quality because they were performed by SCRTD's most experienced RUCUS Systems Analyst who was responsible for the original RUCUS runcutting installation.

In the second comparison it was decided to perform work rule change simulations using RUCUS but with the HASTUS equivalent input data (i.e.) HASTUS subs and zero travel time file. As in the first comparison the same three work rule simulations were used.

The three work rule changes selected are described as follows:

(1) "7 within 8". The current definition of a regular run is any work that can be combined to make seven hours of work within a spread of 10 hours must be made into a regular run. All other pieces can be put on the extraboard, where some pay provisions are less restrictive. The work rule change involved modifying this provision such that any seven hours of work within an 8-hour spread must be made a regular run.

(2) "8 within 12". The current contract specifies that extraboard combinations are guaranteed eight hours pay within a spread of 11 hours after which the run is paid at time and a half. The work rule change was to make this a guarantee of eight hours pay within a spread of 12 hours after which overtime is paid.

(3) Combination: "7 within 8, 8 within 11, 8 within 12". This would be a combination of three work rule changes, combining the previous two simulations of "7 within 8" and "8 within 12" along with a third. The third change involved changing the guarantee pay of a regular run from eight hours within a spread of 10 hours, to eight hours within a spread of 11 hours after which overtime would be paid.

These work rules are fundamental to SCRTD runcut productivity and are representative of the type of change SCRTD would anticipate in future labor contracts.

Another major aspect of the contract negotiations was a management desire to increase the eligible part-time from 10% to over 20%. Since RUCUS does not cut part-time drivers, the only method to simulate this work rule change was by rough manual estimation or HASTUS. A series of HASTUS runcuts were made on a range of part-time percentages for reference purposes.

Finally the new SCRTD contract resulted in a compromise work rule change calling for the definition of a regular run to be seven hours work within a spread of nine hours instead of 10 hours. While not part of the calibration effort, a HASTUS simulation on "7 within 9" was run for reference purposes.

Results

Following are the results of the third and final calibration/validation technique presented for the following activities:

1. Base (Existing) Work Rules -- A progression of RUCUS runcuts on existing work rules from actual "street-ready" data through to HASTUS equivalent data.

2. Work Rule Simulations -- Three work rule changes on RUCUS, HASTUS, and RUCUS with HASTUS equivalent data.

3. Part-time Simulations -- HASTUS simulations on various percentages of part-time driver provisions.

4. 1982 Contract Simulation -- HASTUS simulation of the estimated savings from the recently negotiated SCRTD labor contract.

Detailed supportive evidence for the third calibration technique results are along with tables illustrating the findings are presented in Appendix F. Runcut and payhour statistics for each of the runcuts produced are presented in Appendix G. A summary of the results follows.

Task 1: Base (Existing) Work Rules

The purpose of this task was to evaluate the effect of the HASTUS vehicle data simplification by comparing RUCUS runcuts with real relief points and full travel time penalty to RUCUS and HASTUS runcuts with fixed interval reliefs and no travel time penality. The results quantify the effect of data simplification and the logic differences between RUCUS and HASTUS.

To summarize the conclusions of this task, it was found that:

- The effects of no interline penalty and no travel time were negligible, less than 0.3% of the direct payhours.

- The effect of using 65-minute fixed interval subs (vehicle data) is more complex but was found to be approximately one percent less expensive. The results of comparing the RUCUS runcut using HASTUS-equivalent subs with the RUCUS base runcut using real data (suitable for putting "on-the-street") are that total direct payhours are reduced by 1.3 percent while total burdened payhours increase by 0.4 percent. (Generally, there is no relationship between changes in direct and burdened payhours; if the runs are shorter, overtime costs go down, but manpower requirements go up, increasing the burdened cost.) The RUCUS runcut using HASTUS-equivalent subs represents a refinement over the parameters of the previous RUCUS run. Further refinement to maximize the effect of fixed interval subs might produce somewhat lower total burdened payhours, however, the lower cost might increase the direct cost. Since one purpose of this task was to develop a factor for using fixed interval subs, an estimate could be made by multiplying the percent differences of direct and burdened payhours. This estimate is about - 1%.

- A significant objective of this task was the calibration of the HASTUS runcutting model. When calibrating models in other disciplines, the predictions of the model are compared to real world observations and the difference K is used to adjust the model predictions to real world observations. The difference K is generally caused by data simplifications in the model in order to make it easier to run. In subsequent operations of the model using different parameters, the predictions of the model are adjusted by the calibration factor difference K. On the calibration of the HASTUS-MACRO model on the base runcut using exsisting work rules, a difference K of -3.5% was found compared to the RUCUS base runcut. Following the general practice with model calibrations, the difference K of -3.5% could always be applied to subsequent HASTUS tests. However this approach did not adequately compensate for the differences between model predictions and real world observations.

In most models, not only is the data input simplified but also the logic of the model is also simplified or at least not as comprehensive as the real world situation. It is true that the HASTUS input data was simplified, but unlike most models, the HASTUS logic appeared to be more powerful and comprehensive than the "real world" RUCUS. Thus it was difficult to distinguish the effect of the powerful HASTUS logic from the effect of the simplified data input. It could not be determined how much of the 3% difference was due to simplified input as opposed to, more powerful logic. Since one of the objectives of the project was to test the power of HASTUS logic, the a calibration factor K was not used.

Instead, the HASTUS simulations were compared to the HASTUS base work rule runcut. Likewise the RUCUS simulations were compared to the RUCUS base work rule runcuts.

- o An effort was made to determine how much of the difference K of -3.5% on the base runcuts of HASTUS and RUCUS was due to simplified input data as opposed to more powerful logic. the simplist procedure was to run RUCUS with simplified input data and them compare the results to the HASTUS base runcut. The difference dropped to -2.2%. Since both programs had exactly the same simplified input data, it was concluded that the HASTUS had more powerful logic. This suggests that there is a potential for saving 2.2% on the real world runcuts at the SCRTD if the HASTUS runcutting logic could be employed to produce "street-ready" runcuts.

Task 2: Work Rule Simulations

The purpose of this task was two fold: (1) to determine whether HASTUS could produce consistent results on work-rule change simulations. (consistency is measured by percent change from the base compared to a similar measure of RUCUS work rule simulations); and (2) to determine the relative accuracy of the results. In addition, the cost and flexibility of HASTUS was evaluated compared to RUCUS and manual techniques.

The results of this task have shown that:

- o Under different work rule simulations, HASTUS consistently produces results in line with RUCUS. In five out of six measures HASTUS was within an absolute value of one half of one percent (0.5%) of RUCUS (see Table 4-1) for changes exceeding a magnitude of three percent. The exception is the burdened payhour percent change in the combination work rule simulation, where the difference was still less than one percent (0.9%).

- o It is not unreasonable to expect some variation from RUCUS because the RUCUS solutions differ up to a 2.2 percent from the HASTUS solutions as was found in Task 1. It is also somewhat unclear whether the RUCUS or HASTUS results represent the "best" soloution.

- o Past experience with RUCUS indicates that considerable "fine tuning" of the runcutting logic is ofter necessary to get the minimum costs. The "fine tuning" process may involve dozens of iterations, depending upon the skill of the programmer/analyst. On this project, while a highly skilled programmer/analyst was performing the RUCUS runcuts, the number of iterations was necessarily limited. It is possible that some work rule changes "fit" the RUCUS logic better than others, thus causing some variation in the data. HASTUS runcutting logic does not involve "fine tuning".

- o There is evidence that RUCUS in unskilled hands can produce inconsistent results. Because the RUCUS runcuts made with HASTUS-equivalent data were not subject to as many interactions and refinements as the RUCUS runcuts with real "street-ready" data, it was concluded that RUCUS results are variable depending upon the skill of the user and the amount of attention paid to obtaining the best solution.

- o Because HASTUS uses simplified input data, the consequent runcut results cannot be put "on the street". However the driver runs and summary statistics produced by HASTUS showed great potential as a preprocessor. Looking at the HASTUS runcut results, the manual schedulemaker, can use the pattern of piece sizes and piece matching of the HASTUS output as a guide to runcutting. The schedulemaker does less thinking about runcut strategies because the HASTUS output has determined the overall strategy. A simple test on one route showed this procedure was useful and produced an efficient runcut in less time than was expected.

- o Potential was also suggested for the use of HASTUS as a goal setting mechanism. Since HASTUS shows the total direct payhour costs as well as the total manpower required, it gives the schedulemaker a target. The measure of schedulemaker effectiveness could be how close the actual rencut came to the HASTUS projections. In this sense HASTUS could be used a post-runcut audit total.

SUMMARY OF PERCENT DIFFERENCE ON THREE WORK RULE SIMULATIONS FOR CONSISTENCY OF RESULTS

TABLE 4-1

		RUCUS Real	RUCUS 65	HASTUS
1.	Interline Penalty	YES	NO	NO
2.	Travel Time	YES	NO	NO
3.	Real Reliefs	YES	NO	NO
	Work Rule Change	7 within 8	7 within 8	7 within 8
	Reference Number	8	9	10
4.	Direct Pay % Change	-1.2%	+0.2%	-1.5%
5.	Burdened Payhour % Change	-1.3%	-0.7%	-1.3%
	Work Rule Change	8 within 12	8 within 12	8 within 12
	Reference Number	11	12	13
6.	Direct Payhour % Change	-2.2%	-2.9%	-2.2%
7.	Burdened Payhour % Change	-2.0%	-2.4%	-1.6%
	Work Rule Change	Combination	Combination	Combination
	Reference Number	14	15	16
8.	Direct Payhour % Change	-3.4%	-3.2%	-3.9%
9.	Burdened Payhour % Change	-3.5%	-3.1%	-2.4%

LEGEND:
RUCUS REAL: Represents RUCUS runcuts with real "Streetable" data.
RUCUS 65 : Represents RUCUS runcuts with HASTUS equivalent data.
HASTUS : Represents HASTUS runcuts.

Task 3: Part-Time Simulations

The purpose of this task was to estimate the effect of increasing the percentage of part-time operators on the direct and burdened payhour cost.

The new SCRTD labor contract calls for an increased percentage of part-time operators to be decided through arbitration. In this task simulations for part-time were performed on a selected division's schedules for the following percentages:

0%, 10%, 14%, 20%, 24%, 50%, Maximum percentage.

From the results of this task, the following conclusions were reached:

- The largest saving of direct payhours was achieved with the first 10 percent allowance for part-time operators.
- Burdened payhour savings proceed at a steady rate of about three percent for every 10 percent increase in part-time manpower.
- Direct payhour saving tends to level off after 25 percent part-time operators.

Note that it is beyond the scope of this project to assess the importance of this information to SCRTD. For the transit industry, overall, the information about part-time labor may not be directly transferable. These HASTUS simulations suggest that a part-time provision can produce savings well beyond 15 percent but it depends on whether direct or burdened costs are evaluated. SCRTD fringe costs on the HASTUS simulation were assessed at 220 minutes per full-time operator per day and zero for part-time. These costs were provided after much research and discussion with the SCRTD Finance Department. Different fringe costs for full-time and part-time would undoubtedly produce different results.

Task 4: 1982 Contract Simulation

Besides the undecided part-time driver provisions, the new SCRTD contract contains a change in the definition of a regular operator from seven hours work within a spread of 10 hours, to seven hours work within a spread of nine hours. This is a compromise between the existing contract and one of the HASTUS work rule calibration simulations for "7-within-8" hours spread. It was decided to evaluate the new contract "7-within-9" provision and compare against the "7-within-8" work rule change. The following shows the percent change in each:

	SAVINGS COMPARED TO THE CURRENT CONTRACT	
	"7-within-9"	"7-within-8"
Direct payhours savings	-1.1%	-1.5%
Burdened payhours savings	-0.6%	-1.3%

These results seem reasonable. It will be interesting to see if this projection occurs under the new work rule when it is actually implemented.

4.4 HASTUS Operating Environment

This section examines the operating environment of HASTUS providing some statistics which illustrate differences with RUCUS. The following statistics were drawn from experiences at SCRTD using both RUCUS and HASTUS.

Table 4-2 represents the evaluation of one work rule change applied to the weekday schedules of one division. The one-time set up effort of preparing input data for developing the initial base runcuts are not included. The statistics are representive of a typical work rule change simulation.

From a resource perspective, these statistics show that HASTUS uses a minimum of manpower and computer time. HASTUS uses 98% less manhours compared with the manual technique and 90% less computer time compared with RUCUS. Using HASTUS, it is possible for one person to perform several dozen work rule simulations in one day. A major difference between RUCUS and

TABLE 4-2

WORK RULE CHANGE SIMULATION COMPARISON

	Unit of Measurement	RUCUS	HASTUS	Manual
Interpret Contract Provision as Work Rule	Manhours	1	1	1
Change Input Parameters	Manhours	.5	.5	N/A
Modify Program	Manhours	0-8	0	N/A
Perform Runcut	Manhours	.5	.5	120
Evaluate Results	Manhours	1	1	1
Repeat Runcut Due to Errors in Input	Average	Twice	Twice	Once
Repeat Runcut Due to Modified Logic	Average	Twice	Once	Once
Computer Time[(a)]	CPU Seconds	300	30	N/A
TOTAL Estimated Manhours		3-8	3	122
TOTAL Estimated Computer Costs[(b)]		$1000	$ 100	N/A

[(a)] RUCUS on UNIVAC 11/60
HASTUS on IBM 3033S

[(b)] Assumes
$200/CPU Minute

HASTUS is the skill requirements of the users. To perform RUCUS work rule simulations, the user must be intimately familiar with not only SCRTD work rules but also the RUCUS logic and Fortran source code. A skilled programmer/analyst is usually required to make occasional logic changes. When RUCUS was used for the recent contract negotiations, an estimated 50 percent of the work rule simulations required some sort of program modification. During the calibration effort no program modification of HASTUS was required once the base runcut work rules had been established. All the HASTUS simulations were accomplished without program modification. Consequently the proper use of HASTUS requires not a programmer/analyst but an analyst intimately familiar with the work rules and HASTUS parameters.

5.0 ANALYSIS OF ESTIMATED COST SAVINGS

5.1 Introduction

Although it was not the focus of the study, one quite unexpected result became apparent: HASTUS consistently cut runs which were more efficient than RUCUS. The primary objective of this study was to determine the degree of accuracy of HASTUS in estimating the changes in costs associated with various operator work rules. This unexpected result of the calibration effort generated a series of analyses in an effort to quantify the estimated cost savings. The process which evolved and the results are the subject of this chapter.

5.2 Process

Initially, attempts were made to force RUCUS into various runcutting situations by adjusting the RUCUS parameters to fit HASTUS suggestions such as the numbers of straights, splits, and extraboard pieces of same particular length and the total percent of straights. The purpose was to implement HASTUS strategies and hope that RUCUS would produce less expensive runcuts. All attempts failed, however, because RUCUS's stepwise programming could not operate at the efficiency level of HASTUS's linear programming. Attempts were then made to manually modify a RUCUS runcut again using the suggested strategies of the HASTUS program. This process also failed because of the subjective complexities inherent with manual runcutting. In a final attempt to validate HASTUS, it was decided that the authors of the program, GIRO Inc., should utilize their newly developed runcutting program, MICRO-RUNCUT which makes "street-ready" runcuts. Data necessary to produce a HASTUS runcut, (pull-out, pull-in, and operator relief times) were collected for a large, typical line of the SCRTD and sent to GIRO Inc. for analysis. After a few initial programming problems, a runcut was produced.

5.3 Results

SCRTD Line 30 was selected to compare three runcutting techniques -- RUCUS, Manual, and HASTUS/MICRO-RUNCUT. The results are displayed in Table 5-1. As shown, the cost savings associated with HASTUS are approximately 2.65 percent less than RUCUS. Projected systemwide, in FY83 dollars a 2.65 percent savings in total annual operator wages, fringes, and benefits could represent a savings of up to $4.1 million.

While more tests of this nature are needed before firm conclusions can be reached, this test suggests the potential of HASTUS-MICRO-RUNCUT. Since HASTUS-MICRO-RUNCUT, unlike RUCUS, can also handle part-time operators, HASTUS-MICRO appears to be a promising new scheduling tool.

TABLE 5-1

RUNCUTTING TECHNIQUES COMPARISON FOR
SCRTD LINE 30 WEEKDAY SERVICE

	RUCUS	Manual	HASTUS
Vehicle Hours	486.23	486.23	486.23
Straight Runs	31	34	26
% Straight Runs	72	74	51
2 Piece Runs	12	12	17
3 Piece Runs	0	0	0
Extra Board (Comb)	10	7	8
Biddable Trippers	14	18	19
Drivers	53	53	51
Actual Pay Hours	591:37	587:09	578:05
Manpower Hours @ 3:40 hrs/drivers	194:20	194:20	187:00
Total Pay Hours	785.57	781.29	769.09
% Difference In Total Pay Hours From RUCUS		-0.57	-2.65

Note:

When comparing payhours please note that the RUCUS runcut on this line was not as efficient as the manual runcut. SCRTD has experienced difficulty cutting RUCUS in all cases. As a result, this has precluded introduction of RUCUS systemwide on a line-by-line basis.

6.0 STUDY CONCLUSIONS

The experience gained in this study suggests that HASTUS is a promising and effective tool for estimating costs of proposed work rule changes. As shown in Table 6-1, HASTUS is much faster, less expensive, and involves one-tenth as much CPU time to produce an answer as other available methods. It has the capabability to cover most types of work rule changes. The only changes it cannot handle are changes in relief or travel times because it employes fixed-interval relief times and has no travel time provisions; and changes in report time, because pull-outs are averaged to the nearest interval.

Although RUCUS can handle these minor changes, it has difficulty handling major structural changes such as changes in part-time operators, run-type definitions, and the like. In these situations RUCUS runcutting logic strategies require significant program modification and fine-tuning. HASTUS can better handle simulations in these areas because it has built-in paramaters that allow such major work rule changes to be evaluated.

Futhermore, there is reason to believe that RUCUS produces inconsistent results when presented with different work rule situations because reprogramming of the RUCUS code is necessary, and therefore, RUCUS becomes "analyst dependent." RUCUS was developed based on automating manual techniques. HASTUS, however, is a mathematical model which addresses those situations. This guarantees that HASTUS will use a consistent strategy to produce the runcut.

The results of this study suggest that HASTUS produces more efficient runs than RUCUS. For example, the most inefficient run in terms of pay hours to vehicle hours is a biddable tripper. It was as though HASTUS cut the most efficient biddable trippers first, before cutting the rest of the runs. RUCUS, however, working in a sequential manner cut straights first, then splits, extra board pieces, and trippers, which were leftover.

Less trained and skilled personnel are required to operate HASTUS. Although RUCUS and HASTUS both require personnel with an intimate knowledge of the operator work rules, RUCUS also requires a highly skilled dataprocessing person with

TABLE 6-1

COMPARISON OF METHODS FOR
ESTIMATING COSTS OF PROPOSED
CHANGES IN WORK RULES

Attribute	Manual	RUCUS	HASTUS
Time Required to Answer "What If" Questions	Days to Weeks	Hours to Days	Minutes
Time Needed to Train Users	Years	Months	3 Days
CPU Time in Seconds Used to Produce Answers	None	300	30
Degree of "Optimality"	Low	Medium	High

Note:

HASTUS has been found to produce consistently accurate and reliable measurements.

an intimate knowledge of the RUCUS logic and source code to simulate work rule changes. No such programming skills are needed to operate HASTUS.

In conclusion, HASTUS's features of speed, flexibility, user ease and low cost, suggest that the model can be effectively used to evaluate the numerous combinations of potential work rule changes for labor negotiatons. The HASTUS simulations for any work rules changes considered most likely to be accepted by both transit management and the union could then be verified by producing a "street-ready" runcut version to ensure that the contract changes produce the desired results.

In addition to being used for assessing work rule changes, two other unanticipated uses of HASTUS were identified in the study. These applications include the use of HASTUS as:

- a goal for the relative efficiency of each runcut, and
- a preprocessor for runcutting to provide the runcutter a strategy for efficient runcutting.

Even if HASTUS itself falls short of producing "street-ready" runcuts it nevertheless has the potential to direct RUCUS or manual runcut efforts toward improved costs. Stated differently: when run in tandem with one of the other methods it can suggest a different distribution, ("strategy") of straights, splits, and extraboard runs to produce a lower labor hour cost.

When this study began it was thought that the sole use of HASTUS was in connection with labor negotiations which ordinarily occur every second or third year. Since HASTUS has the potential to help produce more efficient runcuts, HASTUS could be even more valuable for schedulemakers and runcutters on a daily basis as a preprocessor for conventional methods.

The other new potential use of the HASTUS model is as an efficency goal for schedulers. Transit management could use this goal to establish performance objectives. Goals and objectives set in this way would be more sensitive to varying scheduling constraints and would avoid simplistic, across - the board standards like "1.15 pay hour to platform ratios" for all schedules in a system.

In summary the potential of HASTUS as a method for assessing work rule changes was demonstrated in this study. Unexpectedly the other potential applications -- preprocessing and goal setting -- were also identified.

APPENDIX A

MATHEMATICAL FORMULATION OF HASTUS

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HASTUS I : A MATHEMATICAL PROGRAMMING APPROACH TO THE BUS DRIVER SCHEDULING PROBLEM

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ABSTRACT

In this paper, we first present a mathematical programming formulation of the bus drivers scheduling problem in a transit company. Because in general this problem is too large, we introduce a relaxation of the problem and describe a solution strategy. The implementation and results obtained in Québec City are briefly reviewed.

1. The problem

The bus driver scheduling (BDS) problem in a transit company involves establishing at minimum cost for each day of the week, a list of workdays which assign a driver to each bus in the timetable and respect all clauses of the union contract. In the approach discussed here it is assumed that the bus schedule is known and that once the list of feasible workdays is established, the problem is solved. In fact, in most North-American companies, the assignment of workdays to drivers is carried out by the drivers themselves and this selection done on a seniority basis.

The difficulty of the problem arises directly from the kind of service that a transit company must offer and the travel patterns of the population. Fig. 1 illustrates the service level by time of day for Québec City.

We note that the number of vehicles in service may be much greater at peak hours than at off-peak hours. This obviously necessitates either part time drivers, or split-shift workdays for full time drivers, or both. In most companies, unions are refusing or severely restricting the part-time driver solution. Several rules have then appeared defining legal split-shift workdays and working conditions which limit the number and/or compensate the drivers for less desirable workdays. These working conditions are described in more detail in several papers (Blais, 1976, 1980; Sharp, 1975, R.A.T.P., 1979).

We introduce here the basic terminology and some related rules which characterize the problem.

A block is the itinerary of a vehicle between its departure from and its return to the garage. It includes all deadhead time required to take the bus in and out of the garage and to and from the route(s) it services. There are generally short blocks to cover the peak periods and long blocks for the basic service.

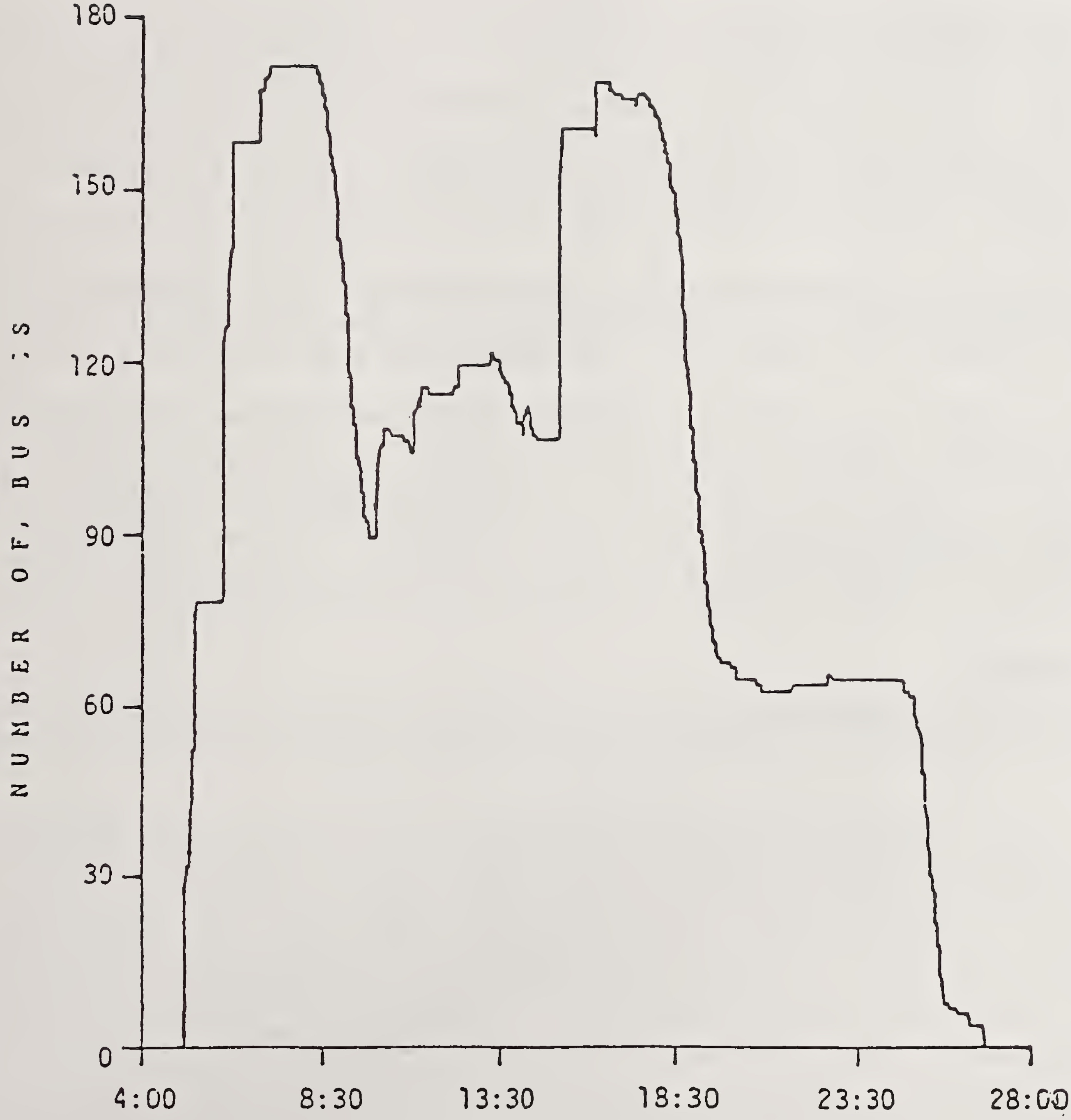


Figure 1 - Level of service by time of day

Relief times are the times corresponding to points on the route where a change of drivers is possible. In general the number of such points is small.

A workday is a daily assignment consisting of one or more pieces of work, which must satisfy the union contract rules.

A piece of work (or piece) refers to the period of time during which a driver works continuously with the same vehicle without a break. Generally the number of pieces of work in a workday is limited (2, 3 or 4) and the pieces must have a minimum duration (2-3 hours).

A tripper is a small piece of work which is normally done in overtime by regular drivers or assigned to stand-by drivers. In general the companies hope for a few or no trippers. By extension and simplicity of notation we consider that a tripper is a workday. However we assume that there is no explicit upper bound on the number of trippers thus insuring the existence of a feasible schedule. Moreover, a high penalty is imposed on trippers.

A block partition is a set of pieces of work which covers exactly the block.

The BDS problem has been described in detail and several approximate solution methods have been proposed. The Proceedings from the two workshops on the BDS problem provide an excellent set of references (Preprints,1975; Proceedings,1980).

In the next section we present a general mathematical programming formulation of the BDS problem. Because in general this problem is too large we introduce a relaxation of the problem and present a solution approach. The application of the system in Québec City (250 buses) is briefly reviewed. In another paper (Carraresi, Gallo, Rousseau, 1980) other alternative solution techniques are explored. The notation used in this paper is similar to the one used in the later paper. We borrow heavily from that paper in the presentation of the model.

2. The model

For simplicity of presentation, we now assume that there are at most two pieces of work in a workday. The extension to three or more pieces of work is done later on; in fact in Québec, we use up to three pieces.

The notation for the model is first introduced. By a pair (ij) we denote a piece of work starting at time i and ending at time j. Only feasible pairs (ij) are considered, that is pairs such that both i and j correspond to either a starting time, ending time or relief time in a given block. Note that (ij) could be feasible relative to several blocks. In the first part of this paper however we assume that (ij) is feasible relative to only one block (this could easily be done by small perturbations). For practical reasons, we also include in the feasible set of pieces of work the null pieces (00).

A quadruplet (ijkh) denotes a workday made up with the feasible pairs (ij) and (kh). Only the workdays (ijkh) which are feasible within the union contract a the company regulations are considered. If (ij) or (kh) is a null piece the workday is either without a break or corresponds to a tripper.

In addition, we define:

L : the number of blocks

K : the number of distinct pieces of work

I : the set of feasible quadruplets (ijkh)

$I(ij) \subset I$: the set of feasible quadruplets (mnkh) where one of the pieces is (ij); it includes the quadruplet (ij00)

T_ℓ : the set of all times which are either relief times, the starting time or the ending time for block ℓ

x_{ijkh} : a binary variable taking value 1 if and only if a driver is assigned to workday (ijkh)

x : the vector with component x_{ijkh}, $(ijkh) \in I$

y_{ij} : a binary variable taking value 1 if the piece (ij) is used to be part of a driver workday. If $y_{ij}=1$, the piece (ij) has been chosen as part of the partition of the given block relative to which it has been defined.

y : the vector with component y_{ij} for <u>all</u> feasible (ij)

c_{ijkh} : the cost of a workday composed of the piece (ij) and the piece (kh) according to the union contract.

The problem can now be formulated as follows:

(2.1) $$\text{Min} \sum_{I} c_{ijkh}\, x_{ijkh}$$

s.t. i) $\sum_{I(ij)} x_{mnkh} - y_{ij} = 0$ for all (ij) except (00)

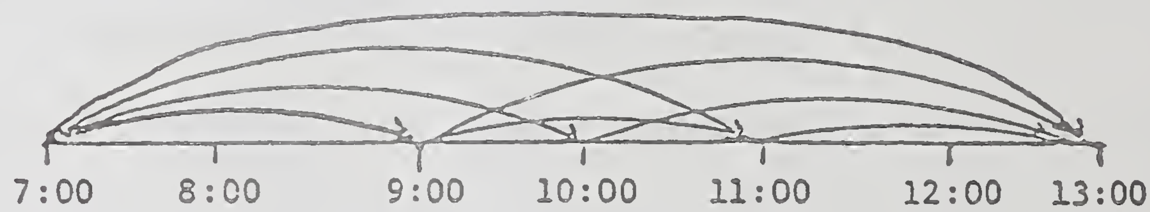
ii) $D\, x \geq d$

iii) $\sum_{i \in T_\ell} y_{ik} - \sum_{j \in T_\ell} y_{kj} = b_k^\ell$ for all $k \in T_\ell$, for all ℓ

$$\text{where } b_k^\ell = \begin{cases} -1 & \text{if } k \text{ is the starting time of block } \ell \\ +1 & \text{if } k \text{ is the ending time of block } \ell \\ 0 & \text{otherwise} \end{cases}$$

iv) $x_{ijkh} = 0,1$, $y_{ij} = 0,1$

The constraints (iii) correspond to the flow formulation used to partition each block ℓ into pieces of work. Fig 2. illustrates the concept. The feasible pieces of work (we are assuming here a minimum lenght of two hours) are represented by arcs and listed in the figure. We have assumed for simplicity that a relief point exists every hour in this example. The indices k in the constraint formulation correspond to points where a change of drivers is feasible and the constraints ensure that a flow of one goes from the origin of the block (7:00) to its end (13:00), using arcs (ij) corresponding to feasible pieces. Constraints (iii) define a flow on an uncapacitated network.



The feasible pieces are

7 - 9	7 - 11	9 - 11	10 - 13
7 - 10	7 - 13	9 - 13	11 - 13

Figure 2. The flow formulation for the partition of a block

With constraint (i) we ensure that any feasible piece (ij) used to partition a block will be used in a workday of type (ijkh) or (mnij).

In fact, given the values of the y_{ij}, i.e. the partition of the blocks into pieces of work, constraint (i) with the objective function can be reformulated into a maximum weight matching problem (described in section 6).

Constraints of type (ii) refer to other constraints of the union contract. Examples of such constraints are:

- a minimum or maximum number of workdays without a break or with a limited break
- a limit on the number of drivers
- a limit on the average length of a workday
- etc.

Unless the problem is small (i.e. the number of blocks is small and thus the number of pieces and workdays is limited), this formulation seems impractical. Given a medium size transit network as in Québec City we can easily generate over ten thousand pieces of work and five million workday variables without considering the flow variables and the difficulty of determining integer solutions for x_{ijkh}. In fact this formulation is nearly equivalent to the set covering formulation found in Heurgon (1972,1975). The set covering formulation was used in Paris to solve the problem one route at a time (drivers were not allowed to change route). However, the formulation (2.1) seems to be more amenable to a solution strategy that can handle very large problems.

3. Solution strategy

The chosen solution strategy is to use the obvious decomposition of the problem into the generation of a partition of each block into pieces of work (constraint (iii)) and the matching problem (constraint (i)) to form workdays. It has to be ensured that constraints (ii) are also satisfied. Three main steps compose this strategy:

Step 1: Using a relaxation of the whole problem we generate a partition of each block into feasible pieces of work that will respect as much as possible the constraint set (ii).

Step 2: Using an assignment algorithm and a heuristic procedure to split the pieces of work into two categories, we solve heuristically the matching problem to obtain a solution to the BDS problem. (Recently, a very fast matching algorithm has been developed by Derigs (Bodin, 1980) and it is planned to eventually replace the assignment algorithm by this matching algorithm)

Step 3: Using a set of heuristic techniques, the solution previously obtained is improved, and it is made sure that constraint set (ii) is respected.

The solution found in all test cases in Québec City and Montréal were either better or comparable to manual solutions. The process has been implemented in Québec City since March 1979 and is currently being developed into a package for the Montréal transit authority. Each of the steps are described in more detail, in the following sections and results from the use of HASTUS I in Québec City are reported.

4. A relaxation of the model: the HASTUS-macro approach

Firstly the integrality of the x variables is relaxed since several methods exist to derive reasonably good integer solutions when a continuous solution has been found. Secondly we assume that the starting times, relief times and ending times for the blocks may only occur at predetermined times $t \in T$, for example every 15 or 30 minutes. In the latter case this means that all bus blocks are approximated to the nearest half hour and relief points are possible at some of or at each half hour period. More complicated schemes could also be devised; for example one could use different time periods for peak and off-peak times. This relaxation of the problem considerably reduces the number of possible pieces of work (ij); however it is important to note that *a piece (ij) may now be feasible relative to several blocks* which also means that x_{ijkh} *may be greater than* 1. All i, j, k, h are now in T.

Moreover, the problem is further relaxed by requiring that the workdays selected, be sufficient to cover the total requirement of drivers per time period (i.e. from one predetermined time to the next), instead of requiring that they exactly cover all the blocks individually. Using the same notation this relaxed problem can be written as follows:

$$(4.1) \quad \text{Min} \sum_{I} c_{ijkh} \, x_{ijkh}$$

$$\text{s.t. i)} \sum_{I(t)} x_{ijkh} \geq N_t \qquad \text{for all } t \in T$$

$$\text{ii)} \; Dx \geq d$$

$$\text{iii)} \sum_{I(pq)} x_{ijkh} \geq Q_{pq} \qquad \text{for all (pq) such that a small block exist from p to q, p, } q \in T$$

$$\text{iv)} \sum_{L(t)} x_{ijkh} \geq K_t \qquad \text{for all } t \in T$$

$$\text{v)} \; x_{ijkh} \geq 0 \quad \text{(integrality is relaxed), } i,j,k,h \in T$$

where:

T : the set of predetermined time which could be relief time, starting and ending times of blocks

I(t) : the set of workdays $(ijkh) \in I$ such that $i \leq t < j$ or $k \leq t < h$

L(t) : the set of workdays $(ijkh) \in I$ with a piece starting at time t ($i=t$ or $k=t$)

N_t : the number of buses in operation during time period starting at t

Q_{pq} : the number of blocks from p to q

K_t : the number of blocks starting at t

The set of constraints (i) ensures that during all periods of the day the number of drivers working is greater than or equal to the number of vehicles in circulation. Constraint (ii) refers to union contract constraints as previously described. In constraint (iii), the number of pieces of work from p to q is at least as large as Q_{pq} the number of small blocks from p to q. A small block is defined by the user as a block that cannot be partitioned and should be allocated as one piece of work to a driver. This generally corresponds to blocks with a duration less than twice the minimum duration of a piece of work.

In constraint (iv) the number of pieces of work beginning at t must at least be equal to K_t the number of blocks starting at t. Finally, x_{ijkh} is a continuous variable that can take any positive value in this relaxation. However for x_{ijkh} to exist there must be a piece (ij) and a piece (kh) each feasible with respect to at least one block.

The HASTUS-macro approach is independently described in several other papers (Blais, 1976, 1980; Rousseau, 1978) and has been used on several occasions to analyse modifications to the drivers' union contract. A package for the utilisation of HASTUS-macro has also been developed (Blais, 1978) and implemented both in Québec City and Montréal and was extensively used by these companies during their last union contract negotiations.

5. Partitioning the blocks

In the present context however, the HASTUS-macro approach is used to help generate a first feasible solution as close as possible to the lower bound it indicates. This is done first by generating an initial block partition that uses similar types of pieces of work and in approximately the same number as indicated by HASTUS-macro. Until recently, this was achieved by first generating for each block a set of partitions made up of pieces used in work-days corresponding to positive variables x_{ijkh} in the optimal solution of (4.1). A linear programming algorithm was then set up to choose one of the partitions generated for each block in order that the pieces thus chose correspond as closely as possible to the solution of the HASTUS-macro problem (4.1). However, we recently adapted our work with Gallo, Carraresi and Davini (Davini, 1980) and will shortly implement in Québec City the technique described here which achieves the same purpose more efficiently. The following problem is considered.

$$\text{(5.1)} \qquad \text{Min } z = \sum_{(ij)} \Big(\sum_{I(ij)} \bar{x}_{mnkh} - \sum_{\ell} y^{\ell}_{ij} \Big)^2 + \sum_{\ell} \sum_{(ij)} d^{\ell}_{ij} \, y^{\ell}_{ij}$$

where $\sum_{i \in T_\ell} y^{\ell}_{ik} - \sum_{j \in T_\ell} y^{\ell}_{kj} = b^{\ell}_{k}$ for all $k \in T_\ell$, for all ℓ

$y^{\ell}_{ij} = 0,1$; $i,j \in T$, $T_\ell \subset T$

$\bar{x}_{mnkh}$ correspond to the optimal continuous solution of (4.1)

y^{ℓ}_{ij} is a binary variable taking value 1 if piece (ij) is used in the partition of block ℓ

d^{ℓ}_{ij} is a penalty associated with the use of the piece (ij) on block ℓ; this penalty takes into account the difference between actual relief time in the bus schedule and approximated relief time on which piece (ij) is defined ($i,j \in T$).

As in problem 2.1, the constraints correspond to the formulation of an uncapacitated flow problem.

This problem can easily be solved with an heuristic procedure. In fact, note that if we consider all the variables not associated with block r fixed, (i.e. y^{ℓ}_{ij}, $\ell \neq r$), the objective function is reduced as follows:

$$\sum_{(ij)} \Big(\sum_{I(ij)} \bar{x}_{mnkh} - \sum_{\ell \neq r} y^{\ell}_{ij} - y^{r}_{ij} \Big)^2 + \sum_{\ell \neq r} \sum_{(ij)} d^{\ell}_{ij} \, y^{\ell}_{ij} + \sum_{(ij)} d^{r}_{ij} \, y^{r}_{ij}$$

$$= \sum_{(ij)} \Big(\Big(\sum_{I(ij)} \bar{x}_{mnkh} - \sum_{\ell \neq r} y^{\ell}_{ij} \Big)^2 - 2y^{r}_{ij} \Big(\sum_{I(ij)} \bar{x}_{mnkh} - \sum_{\ell \neq r} y^{\ell}_{ij} \Big) + (y^{r}_{ij})^2 \Big)$$

$$+ \sum_{\ell \neq r} \sum_{(ij)} d^{\ell}_{ij} \, y^{\ell}_{ij} + \sum_{(ij)} d^{r}_{ij} \, y^{r}_{ij} \; .$$

Because $y_{ij}^r = 0,1 \quad (y_{ij}^r)^2 = y_{ij}^r$, the previous equation can be written as

$$D + \sum_{(ij)} c_{ij}^r \, y_{ij}^r$$

where $\quad D = \sum_{(ij)} \left(\sum_{I(ij)} \bar{x}_{mnkh} - \sum_{\ell \neq r} y_{ij}^{\ell} \right)^2 + \sum_{\ell \neq r} \sum_{(ij)} d_{ij}^{\ell} \, y_{ij}^{\ell}$

and $\quad c_{ij}^r = -2\left(\sum_{I(ij)} \bar{x}_{mnkh} - \sum_{\ell \neq r} y_{ij}^{\ell} \right) + 1 + d_{ij}^r$

and we can define and solve a shortest path problem for block r defined as:

$$P_r: \ \text{Min} \sum_{(ij)} c_{ij}^r \, y_{ij}^r$$

$$\sum_{i \in T_r} y_{ik}^r - \sum_{j \in T_r} y_{kj}^r = b_k^r \qquad \text{for all } k \in T_r$$

$$y_{ij}^r = 0,1 \ .$$

The suboptimal algorithm to solve (5.1) can now be summarized as follows:

1. a) Take any feasible solution y_{ij}^{ℓ} and evaluate z_o the corresponding value of the objective function
   b) Set $k \leftarrow 1$
2. a) Solve successively P_r for r=1...L note $\bar{y}_k$ the solution attained
   b) Evaluate z_k the objective function attained for $y=\bar{y}_k$.
3. a) If $z_k = z_{k-1}$ stop
   b) $k \leftarrow k + 1$ go to 2.

When this algorithm stops, we have a partition of each block into pieces of work defined on periods, closely related to the HASTUS-macro solution. Actual pieces defined on real starting, relief or ending times for the blocks are then cut to correspond as closely as possible to the pieces defined on the periods. We define at this point the set V of feasible pieces of work on real times obtained by this process. The next step consists in building up a first feasible solution.

6. The matching problem

A maximum weight matching problem can be set up to generate the best set of workdays with a minimum number of trippers. This problem can be defined as follows:

(6.1) $$\operatorname{Max} \sum_{I'} \bar{c}_{ijkh}\, x_{ijkh}$$

$$\sum_{I'(ij)} x_{mnkh} \le 1 \qquad (ij)\epsilon V$$

$$x_{ijkh} = 0,1$$

where $\bar{c}_{ijkh} = M - c_{ijkh}$

V : the set of feasible pieces defined on real times resulting from the partitioning of the blocks

I' : the set of feasible workdays using pieces from V

I'(ij) : the set of feasible workdays $(mnkh)\epsilon I'$ where one of the piece is (ij)

M : a large number; it corresponds to the relative penalty associated with a tripper.

Note that contrary to problem (2.1) only the x_{ijkh} which are feasible and use pieces of work previously generated by the partition algorithm are generated. A matching code can be used for the solution of this problem. However, with the currently available code, and the size of the problem generated (500 nodes, 10 000 arcs), it tends to use up a great amount of computer time. Until a more rapid matching code become available, we approximate the problem (6.1) by an assignment type problem that we solve with a minimum cost flow algorithm.

To do this, the set V of pieces of work is first split into two subsets so that there are only very few matching possibilities within each subset and a maximum of matching possibilities between the two subsets. This objective is achieved by following the indications of HASTUS-macro. We put in the first set A the pieces which occur either in the morning or the evening and in set P the remaining afternoon pieces. An afternoon piece in the macro is either the second piece of a workday connected with a morning piece or the first piece of a workday connected with an evening piece. The dummy piece (00) is added to both sets. The cost c_{ijkh} corresponds to the actual cost of the workday (ijkh). If either (ij) or (kh) is the dummy piece (00) c_{ijkh} is the cost of the tripper or the workday without break. The flow problem corresponding to problem (6.1) is described below and with RNET (Grigoriadis, 1979) we are able to solve our problem (500 nodes, 10 000 arcs) in about 15 sec CPU on a CDC 173.

The assignment problem can be written as

(6.2) $$\operatorname{Min} \sum_{I'} c_{ijkh}\, x_{ijkh}$$

$$\sum_{(kh)\epsilon P} (x_{ijkh} + x_{khij}) = 1 \text{ for all } (ij)\epsilon A - (00)$$

$$\sum_{(kh)\epsilon A} (x_{ijkh} + x_{khij}) = 1 \text{ for all } (ij)\epsilon P - (00)$$

$$x_{ijkh} = 0,1$$

The solution obtained uses only feasible workdays; however constraints (ii) of (2.1) may not be respected and several trippers may remain. The heuristic described in the following section is designed to further eliminate the trippers (between 10 and 20 at this step according to our experience in Québec City) and restore feasibility (very slightly violated).

7. A marginal improvement heuristic

The main process of this heuristic involve marginally replacing each partition of each block by an alternate partition. This is achieved as follows:

Step 1: For each block generate the set B_ℓ of all (if not too many) partitions that use only pieces (ij) corresponding to a positive $\bar{x}_{ijkh}$ or $\bar{x}_{khij}$ in the optimal solution of HASTUS-macro (4.1). If insufficient partitions are generated pieces corresponding to null $\bar{x}_{ijkh}$ with a small reduced cost may be used. (See Blais, 1976, for more details.).

Step 2: For each block $\ell=1,\ldots,L$

a) take out first the partition p_o of block ℓ used in the matching problem (either 6.1 or 6.2);
b) consider the resulting set of trippers R_ℓ (composed of trippers in the preceding matching solution and pieces that were matched to pieces of the partition p_o used for block ℓ);
c) choose the partition p_k of B_ℓ, that matched with the trippers of set R_ℓ produces the least cost solution (trippers being highly penalized) which improve feasibility if violated. Replace p_o by p_k and update the matching solution accordingly (p_k may equal p_o).

Step 3: If the solution has improved (cost is reduced or feasibility improved) after considering alternatively each block, go back to step 2. If not, resolve the matching problem (6.1 or 6.2) and stop.

If after these steps a satisfactory solution is not obtained, the solution may be perturbated in different ways to try to achieve a better solution by re-applying Steps 2 and 3 of the heuristic. For example, we arbitrarily increase the number of trippers in the matching solution (by removing a certain number of matches) and reapply the heuristic.

This perturbation applied repeatedly have proved useful to generate solutions with no trippers. In practice however, the CTCUQ is generally satisfied with the first solution produced by the heuristic which may have from 3 to 5 remaining trippers.

At this stage, we could also use any other marginal improvement heuristics in the literature.

8. Variants of the algorithm

8.1. Algorithm modifications for workdays with three pieces of work

In Québec City, workdays with three pieces are permitted and compose in general about ten percent of all workdays. The adaptation of the general strategy described is however straightforward and heuristic in nature. The adaptation of the general formulation (2.1) is direct; variables x_{ijkhmn} are created for such feasible workdays. For the HASTUS-macro formulation, the same comment apply: it is necessary however to limit the number of such variables created, considering only the most probable location in the time table for such workdays. After the partition of the blocks and before the matching problem, it is necessary to pre-match two of the pieces of any three piece workday that emerges from the HASTUS-macro solution. These pre-matched pieces are considered as one piece in the matching problem (6.1 or 6.2). In the marginal improvement heuristic, it may be possible to generate additional three pieces workdays to reduce the number of trippers; such a routine exists in the HASTUS program implemented in Québec City.

8.2. Algorithm modification for workdays without a break

The presence of (and in some cases the necessity for) a certain number of workdays without a break in the solution may considerably reduce the flexibility of the problem and the HASTUS-macro solution may not be as good once these workdays are taken out of the schedule.

We have found it useful to proceed as follows:

- Step 1: Use HASTUS-macro on the whole problem.
- Step 2: Partition the blocks.
- Step 3: Remove from the blocks the pieces corresponding to workdays without a break (make sure there are enough).
- Step 4: Use HASTUS-macro on the reduced problem.
- Step 5: Partition the blocks.
- Step 6: Match the pieces.
- Step 7: Heuristically improve the solution.

9. Results and conclusion

This system has been in operation at the Québec City transit authority (CTCUQ) since March 1979. After a period of test it has been used to generate the assignment of drivers for all schedules (week-days and week-ends). Table 1 shows a continuing reduction of the premium paid by the company since the introduction of HASTUS. Even if HASTUS is still more costly for week-end assignment a total saving of 0,9% which represent an annual saving of $125 000 was achieved. This represents 16% of the premiums (which represent the total potential for savings). The CTCUQ is using the system on an IBM 370/148;

it takes 45 min of CPU time. It has also developed a series of printouts to be used directly by the drivers to sign for their assignments. Other reports are also used for administrative purposes.

Note that the system is used even if a sophisticated package is not available. A computer analyst is responsible for the runs of this system and report the results to the scheduler. Occasionnally, several runs are necessary but most of the time one run is enough. The CTCUQ has been very satisfied with this system. Following these results, the Montréal transit authority (CTCUM) (2 000 buses) has decided to adopt this approach. However, for this project a more sophisticated package is currently under development. This package will include several interactive routines to let the schedulers specify additional constraints and modify the solution produced. Implementation is scheduled to start in January 1981 and several reports are planned. Other researches have also been undertaken to study alternative mathematical programming approaches which could improve further the quality of the solution produced. (Carraresi, 1980).

	Manual solution	HASTUS solution		
	Oct 79	Dec 79	March 80	June 80
Week-days	6,03%	5,51%	5,38%	4,79%
Saturday	3,46%	4,65%	4,45%	3,81%
Sunday	3,70%	5,25%	5,45%	4,60%
Weekly average	5,55%	5,40%	5,28%	4,66%

Table 1 - Premium paid in percentage of total salary

REFERENCES

BLAIS, J.-Y *et al.* (1976)."The Problem of Assigning Drivers to Bus Routes in an Urban Transit System". Publication #44, Centre de recherche sur les transports, Université de Montréal.

BLAIS, J.-Y. (1978). "User Manual for HASTUS-macro". Publication #93, Centre de recherche sur les transports, Université de Montréal.

BLAIS, J.-Y. and ROUSSEAU, J.-M. (1980) "HASTUS: An Evaluation Model for Drivers' Union Contract Negotiation in Transit Companies". Publication #163, Centre de recherche sur les transports, Université de Montréal.

BODIN,L. (1980). Private communication.

CARRARESI, P., GALLO, G., ROUSSEAU, J.-M. (1980). "A Decomposition Approach to Large Scale Bus Drivers Scheduling". Presented at Euro IV Conference, Cambridge, July 1980. Publication #172, Centre de recherche sur les transports, Université de Montréal.

DAVINI, A. (1980). "Il problema della formazione dei 'turni-lavoro' per il personale viaggeante di una azianda publica di transporti urbani". University of Pisa, thesis.

GREGORIADIS, M., HSU, T. (1979). "RNET, The Rutgers Minimum Cost Network Flow Subroutines".User Documentation, Version 3.5. Department of Computer Science, Rutgers University, New Brunswick, New Jersey, Sept. 1979

HEURGON, E. (1972). "Un problème de recouvrement: l'habillage des horaires d'une ligne d'autobus". Revue Française d'Automatique, d'Informatique et de Recherche opérationnelle, Vol. 6, No. 1, pp. 13-29.

HEURGON, E. (1975). "Preparing Duty Rosters for Bus Routes by Computer". Preprints of the Workshop on Automated Techniques for Scheduling of Vehicle Operators for Urban Public Transportation Services, 27-29 April, 1975, Chicago.

Preprints of the Workshop on Automated Techniques for Scheduling of Vehicle Operators for Urban Public Transportation Services, 27-29 April, 1975, Chicago.

Proceedings of the International Workshop on Urban Passenger Vehicle and Crew Scheduling, 15-18 July 1980, Leeds, U.K.

ROUSSEAU, J.-M., DUPUIS, D. and BLAIS, J.-Y. (1979). "Affectation des chauffeurs avec le système HASTUS-macro". Routes et transports, 23, août 1979.

R.A.T.P. (1979). Conditions de travail des machinistes européens. Enquête, 1978. RP-2, Paris.

SHARP, G.P. (1975). "Constraints for Scheduling Operators for Urban Public Transit Systems". Preprints of the Workshop on Automated Techniques for Scheduling of Vehicle Operators for Urban Public Transportation Services: April 27-29, 1975, Chicago, U.S.A.

APPENDIX B

SCRTD OPERATOR (1982) WORK RULES

APPENDIX B

WORK RULES IN EFFECT DURING THE COURSE OF THIS DEMONSTRATION

PASSENGER SERVICE ASSIGNMENTS

Section 1. Classification of Assignments

(a) Work for Operators in passenger service shall be designated as regular assignments, extra assignments, biddable trippers and special events assignments.

(b) Regular Operators will not be required to work trippers in addition to their regular assignments unless they request such work. Except as provided in Article 4, Section 7(b), this does not apply to Extra Operators assigned to a regular assignment by board mark-up. The request by a Regular Operator to work trippers will be made on a prescribed form and filed with the Division Manager at least twenty-four (24) hours prior to 12:01 a.m. on the day the Operator wishes it to become effective. This request to work may be cancelled by the Regular Operator and such cancellation must be filed at least twenty-four (24) hours prior to 12:01 a.m. of the day the Operator wishes to cancel said request to work. These requests must be renewed when Division or System Shake-Ups become effective.

Regular Operators may be required to work before or after their regular assignments in the event of necessary relays, vehicle changes, or emergencies (which includes the miss-out of the Operator who was to relieve the Regular Operator). Regular Operators may also be required to work additional assignments signing on between 8:00 p.m. and 11:59 p.m., the Regular Operator so used will be paid on the basis of continuous time. It is understood that the Regular Operator will not be used in these instances if there is an Extra Operator available to perform this work.

(c) Extra Operators on duty, held for duty, or on the property in uniform on a regular work day and whose use will not result in violation of hours of service or driving time regulations, will perform such assignments as conditions of work require and as directed by supervisorial employees subject to published instructions as to qualifications. It is understood that an Extra Operator not on duty, or held for duty, will not be used if there is an Extra Operator on duty, or being held for duty.

Section 2. Establishment of Regular Assignments

(a) All passenger service work (including preparatory time, pull-in time, deadhead allowance and/or travel time in connection therewith) assigned from each established Division point, except as provided in Article 4, Section 2(d), that can be combined to provide seven (7) or more hours' work within a spread of ten (10) hours and having a regularity of five (5) or more days each calendar week will be established as regular assignments. An exception to this provision would be assignments involved in the making of recovery time reliefs as shown in Section 14 of this Article. The ten (10) hour spread as herein referred to will not include turn-in. Regular assignments will be on the basis of five (5) days per week and in no case will exceed five (5) days per week. The District will designate the off days of regular assignments and establish regular or extra relief assignments composed of off days of regular assignments. Regular work runs may be split only once without the payment of continuous time. A regular work run may not be split after ten (10) hours from initial sign-on time without the payment of continuous time.

In exceptional cases, not to exceed a duration of thirty (30) days, such as the Pomona Fair, assignments may be written which will be an exception to the first paragraph of this Subsection.

(b) Not less than sixty percent (60%) of the total number of all regular weekday assignments shall be straight assignments system wide, not less than seventy-five percent (75%) of the total number of all regular Saturday assignments shall be straight assignments in any Division, and not less than ninety percent (90%) of the total number of all regular Sunday assignments shall be straight assignments in any Division, computed on a man-assignment basis. On holidays, the percentage of straight assignments will be governed by the schedules operated. If weekday schedules are operated, percentage will be sixty percent (60%); if Saturday schedules are operated, seventy-five percent (75%); and if Sunday schedules are operated, ninety percent (90%).

(c) In establishing regular assignments, it will be the policy of the District, through cooperation with the Union, to bring about the best working conditions consistently possible under service conditions. The District agrees the Union representatives will have access to schedule information in the Schedule Division. It is further agreed that Union representatives may appeal a decision to the Superintendent of Schedules, and if the decision of the Superintendent of Schedules is not satisfactory, the Union may appeal to the Manager of Planning and Marketing, whose decision will be final. Copies of all assignments, work runs, biddable trippers, and schedule temporary assignments, will be mailed to the United Transportation Union office as much in advance of posting as is practicable.

Permanent changes in assignments will be posted in the Division for a period of seven (7) days. In the event an assignment change is posted and affects the sign-on time of an Operator the next day and it is posted after the Operator involved has signed off the previous day, or it is posted on his scheduled or assigned days off, the Operator involved will be notified by the District prior to the new sign-on time. If the Operator involved is not notified, the Operator will not be disciplined because of failure to report on time and the earnings of his assignment before the change will be preserved to him. If the change in the assignment is other than one affecting his sign-on time, it will be the responsibility of the Operator to be aware of this change before commencing his assignment for the day.

In the event a tripper is cancelled without notice the preceding day, the Operator affected will be paid for the time lost as a result of such cancellation.

(d) In establishing regular passenger service work runs, rail service work will not be combined with motor coach service work. This restriction as to combining classifications of work applies only to the establishing of regular work runs and not to the performance of work of Extra Operators.

(e) No Operator, Regular or Extra, will be used on service that is normally pulled out of another Division except in cases of emergency operation. Emergency operation, for the purpose of this Section, includes situations requiring immediate relief of Operator or the operation of extra vehicles to maintain service at time of accidents, traffic delays, fires, disasters, hold-ups, and/or [illegible] defense-civil disturbance incidents.

In the event an Operator is used under the emergency conditions outlined above, his use will be governed by the following: Whenever an extra vehicle or a relay is needed on a line, it can be operated out of any Division having jurisdiction over the line; wh[illegible] it is necessary to immediately relieve an Operator, this may re[illegible] from any Division whether that Division has jurisdiction or not. It is understood that in the event of a relay or an emergency relief of an Operator, the Operator pulling the trip will in turn be relieved by an Operator from the Division having specific jurisdiction over the particular assignment within two (2) hours or one (1) round trip, whichever is the longer. Failure to relieve the Operator will result in the payment of applicable penalty to the Operator who should have been assigned to relieve this Operator.

(f) The provisions of this Article will not apply in connection with the suspension of assignments operating in the Pasadena area on New Year's Day due to the impossibility of performing regular service on account of congested and/or disrupted traffic conditions.

It is also understood that due to the increased service requirements on New Year's Day, an Operator may be assigned to work on a line not under the jurisdiction of his Division with the understanding that he will be signed on and off at his own Division and paid applicable deadhead or travel time.

If a situation similar to New Year's Day should arise, exceptions as covered by this Subsection (f) may be agreed upon by mutual consent of the General Superintendent of Transportation and the General Chairman.

(g) This Section does not restrict the District from operating a line, or lines, out of more than one Division.

(h) Not less than ninety percent (90%) of regular work runs will have two (2) consecutive days off, and it is further understood that all additional regular work runs will have scheduled two (2) days off within a seven (7) day work week and said days off may be split. If the number of Sunday assignments is reduced by eight percent (8%) or more from the number in effect on June 1, 1976, the ninety percent (90%) will revert to eighty-five percent (85%).

Section 3. Definition of Straight, Split and Relief Assignments

Regular work runs will be classified as straight, split and relief work runs. A regular work run on which time on duty is computed on a continuous basis is a straight work run; one which includes intermittent service and on which time is not computed on a continuous basis is a split work run; and one made up of the "off" days of three (3) or more regular work runs is a relief work run. No relief work run shall be construed which requires an Operator to sign on and off at other than a single location for any one or more days of a week or month unless he is allowed deadhead time and/or travel time when working a work run which starts or ends at other than his regularly designated Home Terminal.

Section 4. Preparatory Time and Sign-Off Time

All Operators will be allowed a minimum of ten (10) minutes preparatory time for the purpose of getting equipment ready for pulling out. Operators will be allowed five (5) minutes for storing equipment after completion of their assignments or work runs at Division points or outside locations.

Preparatory time and sign-off time shall be considered as work time and made a part of the work run.

Operators driving C.E.A. equipment are excluded from this Section, unless the Operator uses a bus which is to be put into line service when making his relief. In this event the Operator pulling the bus out will be paid preparatory time and the relieved Operator who brings the other bus back will be paid the storing allowance.

Section 5. Posting of Regular Work Runs

Each regular work run will have a designated sign-on and sign-off point and time, and an outline of the service to be performed. The District will maintain in each Division a copy of all regular work runs and extra assignments for that Division on a current basis. It is understood that when System Shake-Ups are held, all regular work runs on the system will be posted at each Division at least seventy-two (72) hours in advance of the beginning of the Shake-Up.

Section 6. Establishment and Posting of Recurring Extra Assignments

All recurring passenger service work (including deadhead allowances and/or travel time in connection therewith) which is not included in regular work runs will be included in extra assignments and posted in Run Books or on Bulletin Boards in Operators' rooms. Regular sign-on and sign-off points and times, and an outline of the service to be performed, will be set forth in the assignment sheet as posted.

Section 7. Definition of Extra Assignments

(a) All work for Operators in passenger service, not included in regular work runs, will be classified as extra assignments and will be filled from Extra Board lists as long as Extra Operators are available, except biddable trippers bid in accordance with the provisions of Article 9 and special events assignments as outlined in Section 8 of this Article. Temporary vacancies in regular work runs will be filled from Extra Board lists as provided in Article 13 and will be paid on regular work run basis. It is understood that an Operator under the provisions of this Section, will not be paid less than he would have been paid under the established rule of eight (8) hours' pay time within a spread of eleven (11) hours for Extra Operators.

(b) No Extra Operator, who is marked-up to a regular assignment that signs on prior to 5:00 a.m., will be required to work a tripper after said regular assignment, unless he has submitted a prescribed form indicating he desires such work. This request to work will be handled in the same manner as Regular Operators as indicated in Section 1(b) of this Article.

(c) Temporary vacancies in biddable trippers at Auxiliary Divisions which have been bid in under Article 9 will be filled in accordance with the hold-down provisions of Article 9, and if not bid in on hold-down basis, such temporary vacancies will be filled from the Extra Board lists. Regular Operators will not be required to work their bid trippers on their days off.

Section 8. Definition of Special Events Assignments

Special events assignments are extra pieces of work occurring after 6:00 p.m. and generally do not exceed four (4) hours in duration. Included in the category of special events are occurrences at:

The Coliseum
Olympic Auditorium
Numerous Churches
Greek Theatre
Shrine Auditorium
Parades
Conventions at above locations and at various hotels
Scout Activities
School and College Activities
Lincoln Park Events
Circuses
Rose Bowl Activities
Griffith Park Observatory
Pilgrimage Play
Orange Show at San Bernardino
Baseball Stadiums
Sports Arenas
Convention Centers

but excludes Charter Service or leased motor coach service. Leased motor coach service is that service operated by the District with District Operators and vehicles through lease agreement with other charter companies in our service area.

It is understood that known work of this type that is not assigned to the Extra Board will be posted for choice at Divisions and that it may be bid by Regular Operators. It is also understood that work will not be assigned in such a way that will interfere with the assignment of an Operator on the following day.

Should an Operator working a special event assignment sign-off too late to perform his assignment the next day, his report the next day will be governed by the provisions of Sections 11 and 12 of this Article.

Section 9. Release Periods in Assignments After 8:00 P.M.

(a) No period of release of less than eight (8) hours between assignments, or portions thereof, which occurs between 8:00 p.m. and 5:00 a.m. shall be deducted from time of Operators working such assignments. This time shall be subject to the overtime rule. This rule will not apply to Extra Operators when start of split between assignments commences before 8:00 p.m. and extends beyond 8:00 p.m. It is further understood that regular work runs starting after Midnight and before 5:00 a.m. will be straight work runs.

(b) It is understood that the provisions of Subsection (a) of this Section 9 shall not apply when Operators are working bid special event assignments.

(c) Any period of release of less than thirty (30) minutes within the hours of a regular work run will be paid on a continuous basis and will be subject to the overtime rule. This provision does not apply to the period between a regular work run and a biddable tripper, nor does it apply to the work of an Extra Operator.

Section 10. Release Period in Work Runs or Assignments

Deadheading time and/or travel time is part of the work assignments in the computation of interval of release. Interval of release periods are governed entirely by time actually released from duty, regardless of any minimum allowances provided under this Contract.

Section 11. Beginning and Ending of Day

(a) A day for Operators will commence at the time that they are first required to report and so do at or after 12:01 a.m. and up to and including 12:00 Midnight of any calendar day. It is understood that Operators will have eight (8) or more hours of release from duty before commencing a new day. The spread of hours in a day for the purpose of computing the permissible spread of hours comences at the time an Operator first reports and continues until he completes his assignment in any given day. The spread of hours for the purpose of computing spread overtime commences at the time he first reports and continues until he completes his assignment in any given day with the exception that turn-in time is not included within the spread of hours.

(b) If, in the mark-up of an Extra Board, the Division Dispatcher errs and does not grant an Operator eight (8) or more hours' release from duty before starting his new day, and does not notify the Operator before he reports for his new assignment, the District shall pay that Operator continuous time, at straight time rate of pay, from the time of his sign-off to the time of his sign-on the following day. If the District notified the Operator of the error in Board mark-up at least four (4) hours prior to the Operator's sign-on time the following day, the Operator will be given a new sign-on time and be paid a separate allowance of four (4) hours in addition to all other earnings that day.

(c) This rule only governs the determination of spread hours during which period a day's work is performed and which may include release periods for which Operators are not compensated under applicable rules.

(d) An Operator who works a night or owl run or special event assignment that commences prior to Midnight and continues into the following day, computes his spread from the time he first commences work until his compensation of work on the following day with the further provision that no Operator whose work continues into the following day may work after 10:00 a.m. on the following day until he has had at least eight (8) hours' release from duty.

Section 12. Late Sign-Off

(a) A Regular Operator who signs off late due to the needs of service, and who will not have the required rest referred to above, will be instructed at time of sign-off to report the next day at any time between eight (8) and ten (10) hours after sign-off time, will be placed on his regular assignment at the first opportunity, and will be guaranteed the earnings of his assignment for that day, providing he has complied with the requirements of Subsections (d) through (h) below.

(b) Except as provided in Subsection (c) below, an Extra Operator who signs off late, due to the needs of service, and who will not have the required rest referred to above, will be instructed at time of sign-off to report the next day at any time between eight (8) and ten (10) hours after sign-off time, and will be guaranteed the earnings of his Board Mark-Up as outlined in Article 2, Section 1 or 2, providing he has complied with the provisions of Subsections (d) through (h) below.

Example: An Extra Board Operator is marked up for an assignment that signs on at 1:00 p.m. and off at 9:30 p.m. and on the next day's mark-up is due to report at 6:30 a.m. On the first day he experiences a delay which results in his signing off that day at 11:00 p.m., he will be brought back the succeeding day any time between eight (8) and ten (10) hours and will be guaranteed the earnings of his Board Mark-Up.

(c) Extra Board men marked up originally on the Extra Board for a shine report of 1:00 p.m. or later and who so reports for duty in accordance therewith, will be considered to be available for duty for a period of nine (9) hours. If the Operator violates, he will be brought back after eight (8) hours' rest and will be signed off that day at the time he was previously scheduled except for dealys to service in connection with his P.M. assignments, and his earnings for that day will be preserved. Nothing herein will affect the option of the District to relieve the Operator prior to violation in order to have him available for his next day's regular Board Mark-Up.

(d) If an Operator is late signing off and will not have the eight (8) hours' rest referred to in Section 11 of this Article, he will complete a special late sign-off slip entitled, "Late Sign-Off-Insufficient Rest". This slip will be given to the Division Dispatcher at the time the Operator makes his turn-in.

(e) In the event the Operator is assigned to a Terminal Division or an Auxiliary Division and will not have the eight (8) hours' rest referred to above, he will be required to report by telephone to his Home Division at the District's expense.

(f) Failure on the part of the Operator to report this late sign-off, in the above referred to manner, may result in his being held off his assignment until at least the eight (8) hour rest referred to above is completed. This will be done without penalty to the District. This in no way affects the basic daily guarantee as shown in Article 2.

(g) It will be the responsibility of the Division Dispatcher on duty, upon receipt of this slip, or telephone call, as referred to above, to advise the Operator of this sign-on time as shown in Section 11 of this Article.

(h) Failure of the Division Dispatcher to notify the Operator of his revised sign-on time will result in the Operator reporting for duty eight (8) hours and one (1) minute after sign-off time and he will be guaranteed the hours of this assignment and will be signed off at the time he was previously scheduled except for delays to service in connection with his P.M. assignment.

Section 13. Paddle Boards

The District shall provide Operators with paddle boards for scheduled work that is on a recurring basis. The paddle boards shall include pull-out and pull-in locations and times, and time points. The scheduled work that is on a recurring basis. The paddle boards shall include pull-out and pull-in locations and times, and time points. The District will also endeavor to make available information sheets, whenever practical, that are descriptive of routes of lines, special operating conditions, and other miscellaneous information. The District will make available to Operators in all Divisions throw-away type sheets showing location of restroom facilities on each line. This sheet will be revised whenever necessary.

Section 14. Work Runs—Recovery Time

It shall be the policy of the District to schedule the recovery time as listed below:

(a) The District will provide an average recovery time of at least ten (10) percent for all regular work runs, computed on a systemwide basis.

(b) At least eight-five percent (85%) of all weekday regular straight runs (except owl runs) will have scheduled in them at least one recovery time period, of a minimum of fifteen (15) minutes. At least fifty percent (50%) of the regular straight runs on Saturdays, Sundays, Holidays and owl runs will have scheduled a minimum fifteen (15) minute recovery time period. These percentages will be computed on a systemwide basis.

(c) Should there be assignments that do not conform to Subsections (a) and (b) above, the Union representatives may discuss the case with the Supervisor of Schedules. It is further agreed that Union representatives may appeal a decision to the Superintendent of Schedules and if the decision of the Superintendent of Schedules is not satisfactory, the General Chairman may appeal to the Manager of Planning and Marketing, who shall fully discuss the issue at hand with the General Chairman. It is understood that the Manager of Planning and Marketing's decision will not be subject to the provisions of Article 26.

ARTICLE 5
TRAVEL TIME — DEADHEAD

Section 1. Travel Time Allowances

The travel time allowances will be paid to Operators when required to travel between Divisions and relief points, and/or relief points and Divisions and/or between two relief points.

Section 2. Computation of Travel Time

Travel time allowances shall be based on the following formula for all lines except those shown in Section 3. The basic travel time allowances between Division and relief points will be as follows:

(a) The walking distance from a Division to the relief point based on a walking rate of two and three-quarters (2¾) miles per hour.

The maximum walking time shall be seventeen (17) minutes, except at Division 12 where present reliefs are being made. The walking time will be agreed upon between the District and the Local Chairman.

(b) When (a) is not applicable, the travel time allowance will be the sum of the following items:

(1) The walking distance from a Division to a line of travel based on the walking rate of two and three-quarters (2¾) miles per hour.

(2) One-half (½) of the weekday base headway of the line when travel on the line is necessary. In the event an Operator must use two or more lines while traveling, he will receive one-half (½) of the weekday base headway of the first line and the full weekday base headway on the additional lines used. It is understood that this computation will be made either on the going or return travel movement, whichever is greater, and such allowance used on movements in both directions. If the total of the base headways results in an excess of one-half (½) minute or more, the allowance wil be the next higher minute, if the excess is less than one-half (½) minute it will be dropped.

(3) Schedule weekday base running time.

(4) On Saturdays, the Saturday base running times and one-half (½) or full Saturday base headway will be used, and on Sundays, the Sunday base running times and one-half (½) or full Sunday base headway will be used when applicable.

Section 3. Exceptions to Section 2

On Lines 33 (at Avalon and "D" Streets), 814, 428, 829, 800, 860, 496, 423, 420, 440, 432 and 86, Operators will be paid travel time allowances for scheduled time from Divisions to relief points, or relief points to Divisions. This allowance shall include walking time formula and scheduled running time. Operators' assignments and/or information sheets will show the scheduled vehicles and times that the Operators should use for traveling. Consideration will be given by the District to the addition of other Lines to this exception.

Section 4. The Use of District Buses or Automobiles for Traveling

Whenever it is deemed advisable by the District, District equipment (buses or automobiles) may be furnished to Operators to travel between Divisions and relief points, between relief points and Divisions, or between two relief points in lieu of traveling on District scheduled equipment.

Reliefs from Division 2 at 16th & Maple; 16th & Main, 18th & Figueroa; 15th & Olive, 11th & Olive; from Division 5 on Line 5; from Division 11 on Line 92; and from Division 12 on Line 841, will be made by using District equipment. Reliefs from Division 7 on Line 89 at Santa Monica & Fairfax will be made by using District equipment when Saturday and Sunday schedules are operated.

Travel time allowances for the use of District automobiles or buses will be based on required time and will be agreed to by the District and the Local Chairman.

Section 5. Home Divisions

(a) The Home Division of Operators will be the location where their assignments start and finish, it being understood that such starting and finishing locations will be restricted to the Home Divisions designated in this Article. In all cases, Operators will be returned to starting locations at the completion of their assignments or portions thereof, or shall be paid arbitrary travel time allowances to return them to their Home Division.

(b) The following are established as Home Divisions. Additional Home Divisions shall be designated, established or closed by the District with the understanding that the Union will be notified sufficiently in advance of such action, to allow the negotiating of proper deadhead or travel time allowances.

DIVISION	LOCATION
1	1016 E. 6th Street, Los Angeles
2	720 E. 15th Street, Los Angeles
3	630 W. Avenue 28, Los Angeles
5	2300 W. 54th Street, Los Angeles
6	100 Sunset Avenue, Venice
7	710 San Vicente, West Hollywood
8	14557 Sherman Way, Van Nuys
9	3449 Santa Anita Avenue, El Monte
12	970 Chester Place, Long Beach
— 13	2450 Mulberry Street, Riverside
15	14409 Penrose Street, Sun Valley
18	777 West 190th Street, Los Angeles
— 21	1016 East 6th Street, Los Angeles

Section 6. Exception to Application of Travel Time

Travel time will not be paid for under the following conditions:

(a) Traveling in excercise of seniority choice to take assignment, voluntarily transferring between Divisions, transferring under the requirements of the provisions of Article 12, Section 2(b) (1) and (b) (2), or for the purpose of making a bid at a Shake-Up.

(b) Operators hired at the Employment Division and sent to the Instruction Division or to another Division to enter service.

(c) Operators relieved at their own request, except account of sickness or injury, before the completion of a day's work.

(d) Operators traveling to take over their own assignment after miss-out.

Section 7. Travel Time for Operators Released at Outside Locations

Operators placing themselves in position for service at an outside point instead of traveling on scheduled District vehicles shall be allowed the same travel time allowances provided in this Article. Where combination of service and travel time or other service conditions are involved. Operators so instructed may be required to travel or perform service on District vehicles.

Section 8. Payment of Travel Time

Travel time will be considered as work time and subject to overtime rates, when applicable.

Section 9. Deadhead Allowances

The deadhead allowances will be paid to Operators when required to deadhead between Divisions, Auxiliary Divisions, Terminal Divisions, and/or storage lots.

Section 10. Computation of Deadheading

Deadhead time will be the actual time required in deadheading between locations. Recurring deadhead allowances will be established and will be included in Operators' work runs and assignments. Deadheading may be required on District scheduled vehicles or by the use of District's buses or automobiles. Present allowances for deadheading between outside locations will be continued as now in effect and future allowances will be agreed to by Local Chairman and the Superintendent of Schedules on a fair and equitable basis.

Section 11. Exceptions to the Application of Deadheading

The same exceptions as contained in Section 6 of this Article will apply to deadheading.

Section 12. Payment of Deadhead

Deadhead time will be considered as work time and subject to overtime rates, when applicable.

Section 13. Overnight Deadheading

Overnight deadheading, when service is used in any oneway movement, will not be coupled with service assignment, but will be paid for as a separate allowance on a flat basis of four (4) hours at straight time applicable rate with an additional allowances of two (2) hours at straight time applicable rate when overnight deadheading is between a point west of Pomona and a point east of Pomona.

Section 14. Exception to Miss-Out When Traveling or Deadheading

In the event an Operator is delayed in reaching the relief point when his arbitrary allowance applies and this delay is due to a vehicle being late that would have enabled him to arrive at relief point on time, he will not be charged with a miss-out and will be entitled to pick up his run and will be paid the hours of his assignment. However, it will be

APPENDIX C

SCRTD SCHEDULING POLICY RULES

SCRTD Scheduling Policy Rules

1. The maximum vehicle (platform) time for any run should not exceed 10H25. (This is an RTD Policy defined to enhance operational safety.)

2. The maximum spread (sign-on to sign-off) time on regular runs should not exceed 12H50. (This also is intended to enhance operational safety.)

3. Any regular runs "signing-on" before 5H00 must be held straight through. (Dictated by union contract.)

4. If the second piece of a split run signs-on after 20H00 it is paid from 20H00. (Dictated by contract.)

5. Any runs split less than OH30 are paid straight through. (Dictated by contract.)

6. Any regular run split after the 10H00 is paid from the 10H00. (Dictated by contract.)

7. All trippers are paid time and one-half. (Dictated by contract.)

8. All trippers are guaranteed 2H00. (Dictated by contract.)

APPENDIX D

AN EXAMINATION OF INDUSTRY WORK RULES FOR CONTRACT NEGOTIATIONS

APPENDIX D

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I. DESCRIPTION OF WORK RULES

A. Introduction

Management's ability to develop the best strategies for contract negotiations, to select the best techniques for evaluating changes, and to make the most beneficial trade-offs during negotiations requires a thorough understanding of the implications of changes in a work rule.

Operator work rules fall into two general categories:

- Restrictive Work Rules. These rules restrict the ability of the scheduler to create certain types of runs or an unlimited number of certain types of runs. These include maximum spread time provisons and provisions specifying a minimum percentage of straight runs.

- Compensatory Work Rules. These work rules specify a certain penalty that will be paid on certain types of runs. These rules usually apply to split runs and include spread time penalty, report and turn-in time payments, and guarantee time.

B. Restrictive Work Rules

A maximum spread provison of 13 hours or greater results in little additonal cost to a transit system. When the allowable spread is less than 12.5 hours it becomes difficult to schedule drivers in both peak periods. Maximum spreads of 12 hours and less are extremely costly to the transit sytem as more pieces of work must be assigned to the extra board or more drivers must be hired.

C. Compensatory Work Rules

1. Spread Time Penalty

A spread time penalty provison defines the maximum of spread time allowable before additional payment is required. This time ranges from 10 to 13 hours with the average following between 10.5 and 11 hours, as found in a national survey. A number of systems also establish a "maximum allowable spread time" of between 12 and 16 hours. In most cases, drivers are paid 1.5 times their straight time rate of pay for all hours worked after the spread time penalty begins. In some systems, a flat rate is paid for runs with a certain amount of spread time, while in others, a percentage of the total daily work hours is paid as a penalty.

2. Guarantee Time

Guarantee time takes a number of different forms. In most systems, regular operators are guaranteed eight hours per day and 40 hours per week, but the provison for extra operators varies widely among transit systems. In almost all systems, an extra operator is guaranteed 40 hours per week but often there is either a short or no daily guarantee.

The lack of a daily guarantee for extra operators can significantly reduce a system's operating cost as less non-work time is paid. For example, an extra operator works the following hours during a week:

Monday	10 hours
Tuesday	6-1/2 hours
Wednesday	7-1/2 hours
Thursday	10-1/2 hours
Friday	5-1/2 hours
	40 hours

If there is no daily guarantee, the driver is guaranteed only a 40 hour week, and the driver in the example above would receive pay for 42.25 hours.* However, if there was an eight hour daily guarantee, the driver would receive eight hours pay for Tuesday, Wednesday, and Thursday and would receive overtime for time worked in excess of eight hours on Monday and Thursday, receiving 46.75 hours pay for the week, an increase of over 10 percent.

* 40 hours of actual work time plus 1 1/2 time for the work over eight hours on Monday and Thursday.

Another type of guarantee time is the guarantee of a certaain amount of pay hours within a given spread time, such as a guarantee of eight hours pay in a 10-hour spread. This provsion could greatly increase the cost of long split runs by having a large amount of penalty time paid for no work. A large transit system estimated that a guarantee of six hours pay in a 9-2/3 hour spread would increase the average pay-time for an extra operator from 41.06 to 44.36 hours per week.

3. Minimum Tripper Length

This provision specifies the minimum allowable pay time for a piece of work. It ranges from one to three hours with two hours being the most common provision. The cost impact of this work rule depends on the nature of the peak service which a transit system provides. If a system has a very sharp peak and operates a large number of short pieces of work (1 to 2 hours), then a three hour minimum could be very costly as the pay time will be much greater than the time worked.

4. Maximum Tripper Length

This provision specifies the maximum length a piece of work can be before it must be made a straight run. This time is generally between 6.5 and 7.5 hours. This provison can be costly as it can greatly increase the amount of guarantee time which must be paid for runs of 6.5 to 7.5 hours instead of linking that run with a very short 1 to 1.5 hours run for a reduction or elimination of guarantee time.

5. Minimum Unpaid Break Between Any Two Pieces of Work

This provision defines the minimum length of time allowed between two pieces of work which can be unpaid. Most contracts state that if the break between two pieces of work is less than one hour, the pieces must be paid as if they were one piece.

6. Report and Turn-in Pay

This provision specifies an amount of time which is paid to a driver when he begins and finishes work. This is to compensate the driver for the time required to prepare for the day's work and to turn in the required reports at the end of the day. Most systems give approximately 10 minutes at the beginning of the day and 5 minutes for turn-in. An increase in report or turn-in time directly increases costs and reduces the pay-time-to-plaform-time ratio.

D. Paid Breaks: Layover and Lunch Break

A number of contracts provide for a paid lunch break and specify an amount of layover which must be provided on each trip. The lunch break ranges from 15 to 30 minutes while layover ranges from three to 10 minutes.

The necessity of giving a lunch break and a minimum amount of layover on each trip directly increases the cost of providing a given level of service. Providing a lunch break necessitates either skipping a trip a some point, working the break into the schedule, or having an additional driver serve a trip whiel the driver takes a break. A guaranteed amount of layover increases the number of buses reuqired to provide a given level of service and also increases unproductive time.

E. Part-Time Drivers

Drivers' unions have consistently attempted to gain shorter spread times before penalties apply, shorter maximum spread time, or report and turn-in time, paid breaks (lunch and layover), and more guaranteed pay within a shorter time period. Management has generally resisted these and has recently begun seeking part-time drivers to counteract the cost increases caused by other work rules. The use of part-time drivers reduces the amount of guarantee and spread time which must be paid, as they can work very short periods of time in the peak periods and are not guaranteed a minimum amount of pay time. Part-time drivers also normally receive only a minimum amount of fringe benefits, reducing this cost substantially. The use of part-time drivers allows management to schedule a higher percentage of straight runs for regular operators and reduces the number of runs with long, costly spread times. Most contracts with part-time drivers provisios limit the percentage of drivers and the type of work they may be assigned. Obviously, the greater the percentage of part time drivers allowed, the better management will be able to control costs.

The use of part-time drivers allows management to eliminate the types of runs that unions have identified as undesirable -- those with long spread time and with little pay time. This has often been stated as the goal of the work rule changes proposed by the unions. Part-time drivers also lessen the impact of an increased peak to base ratio and allows new express or additional peak service to be introduced at a more reasonable cost.

The use of part-time drivers also meets the need of many people for part-time work. Increasingly, people are seeking alternatives to full-time work and are looking for opportunities to work part-time. This includes mothers who do not want to be away from their children for the entire day, self-employed persons who need the security of a regular income but want time for other pursuits, and students who most work to support themselves in school.

F. Summary

Over years of contract negotiations work rules have been established which prohibit or specify additional compensation for certain types of work. The added compensation has been successful in reducing drivers' negative perception of work with long spread times. An analysis of the order in which runs were chosen for a sample transit revealed that after early straight runs, the most desirable runs were split runs with large spread bonuses. This indicates that many drivers may prefer runs with longer spreads and high pay and argues against restrictive work rules which prohibit this type of run. There is potential for management to increase productivity by achieving trade offs relaxing restrictive rules and increasing compensatory rules.

Accomplishing this requires that management be able to accurately evaluate changes in work rules. The next chapter describes the techniques to accomplish this.

II. WORK RULES IN CONTRACT NEGOTIATIONS

A. Introduction

Transit systems throughout the country are being increasingly pressed to reduce costs and increase productivity. The possible elimination of federal operating subsidies and the reduction in other funds to cities has led transit management to consider negotiating union contract that bring about a decrease in operating costs. Inasmuch as labor costs consist of approximaltely 70 to 80 percent of total operating costs and the costs of work rules are costs above the cost of actual platform time, work rule provisons should receive increased scrutiny. The primary means available to increase productivity is to reduce the amount of penalty time which is paid when no work is being performed. Productivity, generally measured by the ratio of pay time to platform time, is governed by contract work rules. Any major advance in driver productivity will require that work rules be changed.

While management views work rules as an added cost of operation over and above the actual platform time needed to provide service, the union views the work rules as guaranteeing a certain quality of work. In contract negiotiations, management must recognize these differing points of view and offer trade-offs to the union for changes in work rules.

B. Productivity Bargaining

One attempt by management to increase productivity is "productivity bargaining". The goal of productivity bargaining is to increase productivity by offering employees benefits for the increases. The New York City Transit Authority has been the only major transit system to actively pursue "productivity bargaining" and has adopted two "productivity provisions:

1) A provison of the union contract allows COLA to be paid to operator and imployees for savings in productivity. A real savings must be obtained which is not the result of a reductin in

manpower or service. A three person committee consisting of the union, management, and an outside representative must agree on the productivity savings.

2) A recent clause was adopted which states as its goal to save up to 20 minutes or more work per operator.

The weakness of these provisons and their lack of success is a result of their emphasis on terms and work rules that are not specified in the union contract. The potential for reducing costs in this area is small. The most significant and costly work rules are specified in the union contract. Work rules which are not specified in the contract should be able to be changed at management's discretion and any bargaining with these rules will only weaken management's ability to reduce cost and increase productivity. The only work rule changes which can be effective are changes in the union contract which take place when negotiating renewal of the contract.

C. The Contract Negotiating Process

Preparation for contract negotiations must begin far in advance of management and labor sitting down at the bargaining table. Typically, management prepares for negotiations by developing a list of proposed contract changes and estimating the cost or savings of each change. Several months before the first meetings, management will receive a copy of the union's proposed changes. Using one of the cost estimation techniques described earlier, costs are established for each contract item. To effectively negotiate, management should understand the nature of these costs and the interaction of various work rules. This is particularly important if managment is to attain trade-offs which will increase productivity and are acceptable to the union membership.

Negotiating a contract is a "horse trading" process. The labor union is not going to give up provisons which they have achieved over year of negotiations without something in return. The challenge ot management is to make trades that both incrase porductivity and satisfy the union. To accomplish this, management must be able to accurately estimate the cost of each work rule and the combined costs of several work rule changes. management is often reluctant to put "concrete" numbers on specific items as this makes it difficult for mangement and the union to do any sort of negotiating which would make the final package acceptable to both the transit authority board and the union membership. However, whether the numbers are actually used in negotiations or not, management must know the cost implications of each change to effectvely negotiate. If the contract goes to arbitration, the cost estimates will support management's proposals and increase the probability of work rules being relaxed.

Existing methods of work rule cost estimating and a lack of knowledge of the implications of work rule changes have prevented management from seriously attempting to change work rules. The level of uncertainty of estimation techniques and the difficulty of evaluating the combined affect of several work rule changes have resulted in management generally opposing any changes proposed by the union and have prevented any negotiations in the area.

The HASTUS program demonstrates the potential for signifcantly improving this process. The program will not only evaluate the combined impact of work rule changes but will also serve as an educational tool that will give management an increased understanding of work rules. This will improve management's ability to negotiate the union contract.

APPENDIX E

RESULTS OF FIRST AND SECOND CALIBRATION TECHNIQUES

APPENDIX E

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I. INTRODUCTION

A. Conclusions Reached

The results of the first and second calibration techniques produced the following conclusions which suggested further work was necessary:

- The effect of the two HASTUS vehicle data simplifications, fixed interval and no travel time, on the total cost could not be determined with either of the calibration techniques. Without this knowledge, error and adjustment factors could not be determined, therefore calibration with RUCUS could not be completed.

- HASTUS was working correctly and produced results that obeyed all the union contract work rules and pay provisions.

- HASTUS seemed to be producing optimal solutions each time a work rule was changed. The most immediate effect was that HASTUS was producing more efficient runs than RUCUS in every category unless artificially constrained. For example, the most inefficient run in terms of payhours to vehicle hours, is a biddable tripper and it seemed HASTUS cut the most efficient biddable trippers first, before cutting the rest of the runs. RUCUS works in a sequential manner cutting straights, splits, extra board, and finally the trippers, which are leftover. Since all the runs are interrelated, making a bad run at the beginning of a runcut can have a ripple effect resulting in several more inefficient runs. RUCUS logic does not have a "look ahead" capability to get around this limitation.

- HASTUS simulates optimal runcutting, it does not simulate RUCUS runcutting. HASTUS was not designed for simulating RUCUS logic and, consequently, it is probably impossible to make HASTUS results look like RUCUS.

- o Both RUCUS and HASTUS need to be operated by personnel with an intimate knowledge of the operator work rules. For some work rule simulations, RUCUS requires a highly skilled data processing person with an intimate knowledge of the RUCUS logic and source code. This latter requirement is usually not necessary for HASTUS except in extreme situations.

B. Results Acheived

Following is a detailed description of the first and second calibration results. A two phased calibration approach was undertaken using the RUCUS runcutting program on the current weekday schedules of SCRTD Operating Division 1, as follows:

Phase 1: Existing Work Rules - HASTUS would be compared against a RUCUS runcut under the existing work rules to arrive at a "base" for work rule simulations.

Phase 2: Three Comparision Simulations - Subsequently, three work rule changes would be evaluated by both HASTUS and RUCUS.

It was believed that if HASTUS predicted a certain percentage increase or decrease for a given work rule change and RUCUS verified the results with the same percentage change, the predicting accuracy of HASTUS would be validated. The results of this initial calibration, rather than proving the accuracy of HASTUS, raised more questions about the whole technique.

Regarding Existing Work Rules:

- o HASTUS had to be artifically constrained to produce the same number of straight runs as RUCUS.

- o RUCUS produced 75% straight runs instead of the contractual minimum of 60%.

- o HASTUS also had to be constrained to the same number of drivers as RUCUS or else it would cut substantially more operators.

- o HASTUS had to be artificially constrained to produce the same number of trippers as RUCUS.

- o HASTUS was still 2.8% less expensive than RUCUS. It was unknown as to whether this was caused by the fixed interval limitation or the optimizing logic of HASTUS.

- o HASTUS cut nearly 70% of the straight runs exactly 8 hours long resulting in no overtime or 8-hour quarantee time being paid.

- o This situation was unrealistic and may have contributed to the lower cost.

- o HASTUS violated one work rule, which in effect dictates that no piece of work on the extra board and tripper can operate between approximately 10:00 a.m. and 1:00 p.m.

<u>Regarding Three Comparison Simulations:</u>

- o Running HASTUS unconstrained by the artificical rules identified in 3.1.1 and 3.1.2, produced a result 5.7% less expensive than the base RUCUS, with 5% more manpower.

- o These results widened the discrepancy between RUCUS and HASTUS.

- o The marginal cost differences on the three work rule change simulations were widely inconsistent.

- o Where RUCUS projected a .74% decrease, HASTUS projected a 1.76% decrease. Where RUCUS projected a 1.77% <u>increase</u>, HASTUS projected a 1.67% <u>decrease</u>.

- o Both RUCUS and HASTUS need to be operated by personnel with an intimate knowledge of the operator work rules. For some work rule simulations, RUCUS requires a highly skilled data processing person with an intimate knowledge of the RUCUS logic and source code. This latter requirement is usually not necessary for HASTUS except in extreme situations.

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- It was later determined that the three RUCUS simulations were improperly and inefficiently performed by an inexperienced user, leading to erroneous results.

The net of effect of these initial results was the recognition that further work and a revised approach on HASTUS calibration was necessary.

II. REVISED CALIBRATION APPROACH

The revised calibration approach involved the following considerations:

- Correct the illegal extra board work.

- Simulate more realistic straight run costs.

- Redo the RUCUS simulations correctly.

- Determine the effect of the optimizing logic of HASTUS by successively applying more artifical constraints to the HASTUS Existing Work Rule (base) solution so that it more closely approximates the RUCUS base. The rationale for this approach was that eventually it could be said that any remaining discrepancy was due to the effect of fixed intervals.

- After completing the above remove the artificial constraints to produce an unconstrained HASTUS base, which would be less expensive. The difference between the constrained and unconstrained HASTUS base solutions would represent the effect of linear programming optimization. The result would be the development of two adjustment factors, one for optimization and one for fixed intervals, which could be applied to the work rule simulation results.

- Finally, run new HASTUS work rule simulations and compare them against the RUCUS simulations.

III. REVISED CALIBRATION RESULTS

A. New RUCUS Base

The RUCUS simulations for the on-going contract negotiations involved the production of a new Division One base runcut which reflected the exsisting work rules, and it was called RUCUS New Base 88. The "88" refers to the interline penalty applied to the mixing of pieces between two routes. Since HASTUS does not make a distinction between routes it was decided to re-runcut this RUCUS base with a zero penalty for interlining. This run became the new Base for the HASTUS comparision and is called RUCUS New Base 00. The results of the three RUCUS runcuts -- Old Base, New Base 88 and New Base 00 -- are summarized below.

Table 1

SUMMARY OF RUCUS BASE (EXISTING WORK RULES) RUNCUTS

DESCRIPTION	OLD RUCUS BASE	RUCUS NW BS 88	RUCUS NW BS 00
1. PLATFORM HRS.	2312:54	2312:54	2312:54
2. REPORT	69.20	69:15	69:15
3. VEHICLE HRS.	2382:14	2382:09	2882:09
4. TRAVEL	25:54	28:50	28:50
5. GRANTEE	89:24	111:14	109:05
6. OVERTIME	300:53	220:52	222:18
7. TOT PAY HRS.	2748:20	2743:05	2742:22
8A. NO. OF DRIVERS	255	261	260
8B. NO. OF STRATES.	152	157	151
9. AVG. SPREAD	---	---	---
10. AVG. PAY. HRS.*	10:15	9:57	10:02
11. AVG. VEH. HR.*	8:58	8:45	8:49
12. PAY/VEH. RATIO	1.154	1.132	1.131

* = EXCLUDING BIDDABLE TRIPPERS

Comparing the RUCUS 88 with RUCUS 00, we are led to conclude that there is little difference between them. Consequently it was decided to use RUCUS 00 as the base for future HASTUS calibration efforts.

B. Correction of Illegal Extra Board

To consider the illegal extra board runs, a new parameter was added to HASTUS that satisfied all the work rule legalities by preventing tripper and extra board runs working between 10:00 a.m. and 1:00 p.m. The HASTUS run which achieved this result with RUCUS OO is called CN 45 BS 3 and is summarized below.

Table 2

RUCUS OO vs. CN 45 BS 3

DESCRIPTION	RUCUS NEW BS 00	HASTUS CN45BS3
1. PLATFORM HRS.	2312:54	2380:30
2. REPORT	69:15	---
3. VEHICLE HRS.	2382:09	2380:30
4. TRAVEL	28:50	28:50
5. GRANTEE	109:05	58:40
6. OVERTIME	222:18	179:51
7. TOT PAY HRS.	2742:22	2647:51
8. NO. OF DRIVERS	260	260
8A. NO. OF STRATES	151	151
9. AVG. SPREAD	---	9:55
10. AVG. PAY HRS.*	10:02	9:38
11. AVG. VEH. HR.*	8:49	8:48
12. PAY/VEH. RATIO	1:151	1.112

* = EXCLUDING BIDDABLE TRIPPERS

Most significantly, there is a 3.4% difference in payhours between HASTUS and RUCUS.

C. More Realistic Straight Run Costs

To consider simulating more realistic straight run costs, it was suggested that instead of a fixed interval of 60 minutes, a 45 to 65 minute interval would accomplish the goal of generating overtime and make-up. This would mean that runs around eight hours would never be cut at exactly eight hours but at the nearest multiple of fixed interval. The effort could be achieved with 45, 50, and 55 minute intervals, but a survey of the sample Division One database showed that the average actual relief time interval was 66 minutes, so an interval of 65 minutes was desirable. Initially a 45 minute interval was tried, but it did not produce sufficient cost increases. The payhour effects of various interval sizes on straight runs near eight hours are shown below.

Table 3

EFFECT OF INTERVAL SIZE ON RUN COSTS

Interval Size (minutes)	Vehicle Hours	Guarantee Premium	Overtime Premium	Total
60	8:00	0	0	0
45	7:30	30	0	30
45	8:15	0	8	8
50	7:30	30	0	30
50	8:20	0	10	10
55	7:20	40	0	0
55	8:15	0	8	8
65	7:35	25	0	25
65	8:40	0	20	20
70	7:00	60	0	60
70	8:10	0	5	5

The 65 minute interval provided a better ratio of guarantee and overtime, as well as being similar to the actual Division One relief point average of 1-hour-6 minutes.

The results of the 65 minute interval are summarized below under the run called CN 65 BS1. HASTUS run CN 45 BS3 is shown for comparison.

Table 4

EFFECT OF 65 MINUTE FIXED INTERVAL

DESCRIPTION	RUCUS NEW BS00	HASTUS CN45BS3	HASTUS CN65BS1
1. PLATFORM HRS.	2312:54	2380:30	2373:28
2. REPORT	69:15	---	---
3. VEHICLE HRS.	2382:09	2380:30	2373:28
4. TRAVEL	28:50	28:50	28:50
5. GRANTEE	109:05	58:40	83:32
6. OVERTIME	222:18	179:51	187:39
7. TOT PAY HRS.	2742:22	2647:51	2673:29
8. NO. OF DRIVERS	260	260	260
8A. NO. OF STRATES.	151	151	151
9. AVG. SPREAD	---	9:55	---
10. AVG. PAY. HRS.*	10:02	9:38	9:44
11. AVG. VEH. HR.*	8:49	8:48	8:46
12. PAY/VEH. RATIO	1.131	1.112	1.126

* = EXCLUDING BIDDABLE TRIPPERS

The 65 minute interval, reduced the discrepancy between HASTUS and RUCUS from 3.5% to 2.5%. This reduction is positive but the remaining difference is still unexplained.

D. Application of Artificial Constraints

Through the successive application of non-contractual constraints on HASTUS, it was hoped that the results would converge with RUCUS and the difference could be explained in terms of these constraints. The term "artificial" means that it is more restrictive than current practices and the labor contract. The following artificial constraints were applied in succession:

(1) Maximum drivers = 261
(2) Minimum 151 straights
(3) 36 trippers
(4) 18.5% of the runs must be extra board (same as RUCUS)
(5) Minimum work time of extra board set to 6 hours 30 minutes.
(6) Minimum inside spread for extra board set to 4 hours 20 minutes instead of 3 hours 15 minutes.

The successive runs of HASTUS-MACRO which imposed the above artificial constraints are described as follows:

	Name		Constraints
(1)	CN65BS1	o	Manpower: 261
		o	Percent straight: 60.2%
		o	Number of trippers: 36
(2)	CN65BS2	o	Exactly the same as CN65BS1 but with the following constraint: 18.5% of the runs must be extra board
(3)	CN65BS3	o	Exactly the same as CN65BS2 but with the following constraint: minimum work time for extra board is 6-hours-30 minutes.

(4) CN65BS8 o Exactly the same as CN65BS3 but with the following constraint: minimum lunch break (inside spread) was changed from 3 hours-15-minutes to 4-hours-20 minutes.

The table below shows the results of successively applying the artificial constraints.

Table 5

RESULTS OF ARTIFICIAL CONSTRAINTS ON REVISED CALIBRATION

DESCRIPTION	RUCUS NW BS 00	HASTUS CN65BS1	HASTUS CN65BS2	HASTUS CN65BS3	HASTUS CN65BS8
1. PLATFORM HRS.	2312:54	2373:28	2373:28	2373:28	2373:28
2. REPORT	69:15	---	---	---	---
3. VEHICLE HRS.	2382:09	2373:28	2373:28	2373:28	2373:28
4. TRAVEL	28:50	28:50	28:50	28:50	28:50
5. GRANTEE	109:05	83:32	93:31	94:02	120:13
6. OVERTIME	222:18	187:39	194:30	194:30	207:42
7. TOT PAY HRS.	2742:22	2673:29	2690:19	2690:50	2730:13
8. NO. OF DRIVERS	260	260	260	260	260
8A. NO. OF STRATES	151	151	151	151	151
9. AVG. SPREAD	---	---	---	---	---
10. AVG. PAY HRS*	10:02	9:44	9:44	9:44	9:55
11. AVG. VEH. HR.*	8:49	8:46	8:43	8:41	8:44
12. PAY/VEH. RATIO	1.151	1.126	1.133	1.133	1.150

* = EXCLUDING BIDDABLE TRIPPERS

The results of applying the artificial constraints looked promising, especially in CN65BS8. However, closer analysis of CN65BS8 showed that it was not truly emulating the RUCUS 00 results. For example, on the extra board RUCUS 00 has 48 runs with an average spread of 13 hours 3 minutes. CN65BS8 with the same number of extra board runs has an average spread of 11 hours-54-minutes, which is fully one hour less spread time.

Several runs were tried in an attempt to remove the artificial constraints, specifically the 18.5% maximum extra board and the minimum or maximum trippers. This series of runs was labelled CN65BSX thru CN65BSX7. The results of reclosing the constraints produced widely varying results, expecially in the extra board which soared up to 73 runs in one case.

APPENDIX F

RESULTS OF THIRD CALIBRATION TECHNIQUE

APPENDIX F

TABLE OF CONTENTS

I. INTRODUCTION

To perform the third calibration it was decided to perform a series of RUCUS runcuts that would progressively change the input data to look more like HASTUS until the data was exactly the same. The progression illustrates the quantitative effect of the data simplification as follows:

(1) RUCUS runcut with actual subs and full travel-time file - equivalent to "on-the-street."

(2) RUCUS runcut with actual subs and full travel-time file, but no penalty for interlining. (Interline penalties reduce the number of runs which have pieces from more than one route.)

(3) RUCUS runcut with actual subs and a zero travel-time file.

(4) RUCUS runcut with HASTUS subs and a zero travel-time file.

(5) HASTUS runcut with HASTUS subs and no travel-time file.

The input data for the last RUCUS runcut (4) and the HASTUS runcut (5) are identical. Comparing the results of RUCUS "on-the-street" runcut (1) with the HASTUS equivalent RUCUS runcut (4) would show the effect of the two HASTUS simplifications: Fixed Interval Reliefs and no travel-time file. Comparing RUCUS (4) with HASTUS (5) would show the effect of any logic differences.

The RUCUS/HASTUS runcut progression was to be done on the base work rules (current contract). After the calibration factors for the HASTUS data simplifications had been obtained, then a series of the work rule change simulations were to be run on both RUCUS and HASTUS. If the results of these simulations showed a consistent change in the total payhours then HASTUS could be considered at least as accurate as RUCUS. It was decided to use RUCUS work rule change simulations, that had been recently performed on the test division one, as part of the RTD's ongoing labor contract negotiations. These particular RUCUS runcuts simulations were considered of the highest quality because they were performed by the RTD's most experienced

RUCUS Systems Analyst who was responsible for the original RUCUS runcutting installation.

To further complete the analysis and provide another data point for evaluating the effect of the HASTUS simulations, it was decided to perform the three work rule change simulations using RUCUS but with the HASTUS equivalent input data. Finally the same three work rule simulations were to be performed by HASTUS.

The three work rule changes selected are described as follows:

(1) 7 within 8 - The current definition of a regular run; is any work that can be combined to make 7 hours of work within a spread of 10 hours must be made into a regular run. All other pieces can be put on the extraboard, where some pay provisions are less restrictive. The work rule change involved modifying this provision such that any 7 hours of work within an 8-hour spread must be made a regular run.

(2) 8 within 12 - The current contract specifies that extraboard combinations are guaranteed 8 hours pay within a spread of 11 hours after which the run is paid at time and a half. The work rule change was to make this a guarantee of 8 hours pay within a spread of 12 hours after which overtime is paid.

(3) Combination - 7 within 8, 8 within 11, 8 within 12 - This would be a combination of three work rule changes, combining the previous two simulations of 7 within 8 and 8 within 12 along with a third. The third change involved changing the guarantee pay of a regular run from 8 hours within a spread of 10 hours, to 8 hours within a spread of 11 hours after which overtime would be paid.

These work rules are fundamental to RTD runcut productivity, and are representative of the type of change RTD would anticipate in future labor contracts. The new RTD contract resulted in a compromise work rule change calling for the definition of a regular run to be 7 hours work within a spread of 9 hours instead of 10 hours. While not part of the calibration effort, a HASTUS simulation on 7 within 9 was run for reference purposes. Another major aspect of the contract negotiations was a management desire to increase the eligible part-time from 10% to cover 20%. Since RUCUS does not cut part-time drivers, the only method to simulate this work rule change was by rough manual estimation of HASTUS. A series of HASTUS runcuts were made on a range of part-time percentages for reference purposes.

Table 1 provides an itemized summary of the HASTUS and RUCUS runcuts performed as part of this calibration effort.

II. DETAILED RESULTS

Following are the results of the third and final calibration technique presented for the following activities.

- o Base (Existing) Work Rules -- A progression of runcuts on existing work rules from actual "streetable" data through to HASTUS equivalent data.
- o Work Rule Simulations -- Three work rule changes on RUCUS, HASTUS and RUCUS with HASTUS data.
- o Part-time Simulations -- HASTUS simulations on various percentages of part-time driver provisions.
- o 1982 Contract Simulation -- A HASTUS simulation of the estimated saving from the recently negotiated RTD labor contract.

Runcut and payhour statistics for each of the runcuts are contained in Appendix G. Note that reference number associated with Table 1, Summary of Runcuts, should be used with comparing statistics.

A. Base Work Rule Calibration

The purpose of this task was to evaluate the effect of the HASTUS-MACRO vehicle data simplification, by comparing RUCUS runcuts with real relief points and full travel time to RUCUS and HASTUS-MACRO runcuts with Fixed Interval reliefs and No Travel Time. The results would quantify the effect of data simplification and the logic differences between RUCUS and HASTUS.

Table 2, Progressive Runcut Comparison on Existing Work Rules, shows the results of this task. Total direct payhour (line 16) represents the total scheduled

SUMMARY TABLE OF RUNCUTS FOR THIRD CALIBRATION TECHNIQUE

Table 1

Reference Number	Runcut Name	Program Name	Interline Penalty	Travel Time	Subs (Blockdata)	Work Rule Change
1	RUCUS BASE	RUCUS	Yes	Yes	ACTUAL	EXSISTING WORK RULES
2	BASE NEGOTIATIONS	RUCUS	YES	YES	ACTUAL	EXSISTING WORK RULES
3	RUCUS 00	RUCUS	NO	YES	ACTUAL	EXSISTING WORK RULES
4	RUCUS NT	RUCUS	NO	NO	ACTUAL	EXSISTING WORK RULES
5	RUCUS 65+	RUCUS	NO	NO	65 Minutes	EXSISTING WORK RULES
7.	MACRO BASE	HASTUS - MACRO	NO	NO	65 Minutes	EXSISTING WORK RULES
8.	RUCUS 7/8 Neg.	RUCUS	YES	YES	ACTUAL	REGULAR RUN DEFINITION 7 WITHIN 8
9.	RUCUS 65+ 7/8	RUCUS	NO	NO	65 Minutes	REGULAR RUN DEFINITION 7 WITHIN 8
10.	HASTUS 7/8	HASTUS - MACRO	NO	NO	65 Minutes	REGULAR RUN DEFINITION 7 WITHIN 8
11.	RUCUS 8/12 Neg.	RUCUS	YES	YES	ACTUAL	EXTRABOARD GUARANTEE 8 WITHIN 12 HOURS
12.	RUCUS 65+ 8/12	RUCUS	NO	NO	65 Minutes	EXTRABOARD GUARANTEE 8 WITHIN 12 HOURS
13.	HASTUS 8/12	HASTUS - MACRO	NO	NO	65 Minutes	EXTRABOARD GUARANTEE 8 WITHIN 12 HOURS
14.	RUCUS COMB.	RUCUS	YES	YES	ACTUAL	COMBINATION 7 WITHIN 8, 8 in 11, 8 in 12
15.	RUCUS 65+ COMB.	RUCUS	NO	NO	65 Minutes	COMBINATION 7 WITHIN 8, 8 in 11, 8 in 12
16.	HASTUS COMB.	HASTUS - MACRO	NO	NO	65 Minutes	COMBINATION 7 WITHIN 8, 8 in 11, 8 in 12
18.	HASTUS 10%	HASTUS - MACRO	NO	NO	65 Minutes	10% PART-TIME - EXSISTING WORK RULE
19.	HASTUS 14%	HASTUS - MACRO	NO	NO	65 Minutes	14% PART-TIME
20.	HASTUS 20%	HASTUS - MACRO	NO	NO	65 Minutes	20% PART-TIME
21.	HASTUS 24%	HASTUS - MACRO	NO	NO	65 Minutes	24% PART-TIME
22.	HASTUS 50%	HASTUS - MACRO	NO	NO	65 Minutes	50% PART-TIME
23.	HASTUS 85%	HASTUS - MACRO	NO	NO	65 Minutes	85% PART-TIME
24.	HASTUS 7/9	HASTUS - MACRO	NO	NO	65 Minutes	REGULAR RUN DEFINITION 7 WITHIN 9 NEW CONTRACT

PROGRESSIVE RUNCUT COMPARISON ON EXSISTING WORKRULES

FROM ACTUAL DATA TO HASTUS EQUIVALENT

Table 2

1.	Runcut Name	RUCUS Base	RUCUS 00	RUCUS-NT	RUCUS 65+	HASTUS-Base
2.	Ref. Number	2	3	4	5	7
3.	Base Exsisting Workrules	YES	YES	YES	YES	YES
4.	Interline Penalty	YES	NO	NO	NO	NO
5.	Travel Time	YES	YES	NO	NO	NO
6.	Actual Reliefs	YES	YES	YES	NO	NO
	Run Stats.					
7.	Straights	158	151	152	155	119
8.	Splits	53	61	50	55	76
9.	Extra Board Comb.	50	48	57	65	62
10.	Biddable Trippers	41	36	36	22	30
11.	Part-Time	N/A	N/A	N/A	N/A	N/A
12.	Total Regular	211	212	202	210	195
13.	Total Full-Time	261	260	259	275	257
14.	% Straights	75%	71%	75%	74%	61%
	Runcut Costs					
15.	Vehicle Hours	2382	2382	2382	2391	2391
16.	Total Direct Payhours	2743	2743	2736	2707	2646
17.	Ratio Payhour/Vehicle	1.151	1.151	1.149	1.132	1.107
18.	Difference From Base	___	0	-7	-36	-97
19.	% Difference From Base	___	0	-0.3%	-1.3%	-3.5%
20.	Fringe Payhours	957	953	950	1008	942
21.	Total Burdened Payhours	3700	3696	3686	3716	3588
22.	Ratio Burdened Pay/Vehicle	1.553	1.552	1.547	1.554	1.501
23.	Difference From Base	___	-4	-14	+15	-112
24.	% Difference From Base	___	-0.1%	-0.4%	+0.4%	-3.0%

Legend

RUCUS BASE - This is a RUCUS runcut using 1979 contract provisions, with real data suitable for putting on the street.

RUCUS 00 - Exactly the same as RUCUS BASE, but without any interline penalities.

RUCUS NT - Exactly the same as RUCUS 00, but without a travel time file.

RUCUS 65+ - Exactly the same as RUCUS NT, but using HASTUS equivalent subs (vehicle data).

HASTUS BASE - This is a HASTUS-MACRO runcut using 1979 contract provisions on the same Division One data as RUCUS.

payhours, with all collaterals of report, premium and overtime, including overtime for biddable trippers. Total burdened payhours (line 21) represents total direct payhours plus fringe payhours of 220 minute per total full-time operator (line 13).

The rationale for burdened payhours should be explained. Burdened payhours represent the addition of fringe benefit costs to the direct payhours. Fringe benefit costs are such items as vacation pay, sick leave, health benefits, pension contribution and other fixed costs. Unlike the other collaterals, such as overtime and premium guarantee, fringe costs are not dependent upon how many vehicles hours an operator operates, but on whether he/she is full-time or not. For purposes of work rule estimation the fringe costs per full-time operator have been translated into payhours so that commparison analysis can be more easily performed. It is the policy of the SCRTD Finance Department that fringe costs represent 220 minutes per day per full-time operator. Part-time operators are assessed zero fringe costs. Consequently, reducing one full-time operator through any number of part-time operators will represent a saving of at least 220 minutes pay per day.

HASTUS was set to optimize on total burdened payhours, but the RTD often only considers total direct payhours; consequently, both values are presented for all analyses. To simplify analysis, the percent difference from the RUCUS Base, reference 2, has been calculated for both direct and burdened payhours (lines 9 and 24, respectively).

The effect of no interline penalty is shown by comparing RUCUS 00 (ref. 3) with RUCUS Base (ref. 2). There is 0% difference on direct payhours and only a tenth of one percent on burdened; therefore, the effect of no interline penalty is negotiable.

The effect on No Travel Time is also negotiable; only 7 hours lower on total direct payhours. This contrasts with nearly 29 hours paid in travel time on the RUCUS BASE (2). The obvious conclusion is that travel pay elimination is replaced by increased premium for 8-hour guarantee.

The effect of 65 minute Fixed Interval subs, on RUCUS 65+ (ref. 5) compared to RUCUS Base (ref. 2) is somewhat more complex. Total direct payhours are reduced by 1.3% (36 hours) but total burdened payhours increase by 0.4% (15 hours), because there is an increase in manpower of 14 operators which affects the decrease in direct payhours. Generally speaking, there is no relationship between changes in direct and burdened payhours. If the runs are shorter the overtime costs go down, but the manpower goes up, increasing the burdened cost.

RUCUS 65+ (ref. 5) represents a refinement over the parameters of the previous RUCUS runs, but it is acknowledged that further refinement, aimed at taking maximum advantage of the Fixed Interval subs, might produce on somewhat lower total burdened payhours. However, a lower cost might increase the direct cost. Remembering that one purpose of this task was to develop a factor for using fixed interval subs, an estimate could be made by averaging the percent differences (lines 19 and 24). The result would be about -1%. An alternative to using a factor would be to always compare the work rule simulations to the individual base runcuts instead of a common base runcut. For example, HASTUS-MACRO simulations would be compared to the HASTUS-MACRO base, the RUCUS F'xed Interval simulations would be compared to the RUCUS fixed interval base, and the RUCUS real relief simulations would be compared to the RUCUS real relief base. Since the objective of the calibration effort was consistency of results, with results expressed not as total payhours but as (%) percent difference from a base, the approach is less confusing.

Of particular note is the strong consistency of runcut statistics among all the RUCUS runcuts when compared to HASTUS. HASTUS-MACRO was set to cut a minimum 61% straight runs. The contract specifies a minimum 60% straights. All the RUCUS runcuts cut over 70% straights. It is apparent that HASTUS-MACRO is taking maximum advantage of the contract work rules. This is a possible explanation of why HASTUS-MACRO (ref. 7) is over 2% less expensive than RUCUS 65+ (ref. 5) with exactly the same data. Subsequent runcuts on the simulations showed that the 2% was highly consistent, suggesting that the RTD may be able to derive a significant cost saving on the existing schedules through an improved runcutting strategy. A 2% saving represents $1.95 million annually if applied system-wide.

To summarize the conclusions of the task, it was found that:

(1) The effects of No Interline Penalty and No Travel Time were negligible.

(2) The effect of using 65 minute fixed interval reliefs is about 1%.

(3) The fixed interval factor will be accounted for by always comparing to the respective base runcut.

(4) The global optimizing logic of HASTUS-MACRO produced more cost efficient runcuts than RUCUS, suggesting that current RUCUS and manual logic strategies can be improved.

B. Work Rule Simulations

The purpose of this task was to determine whether HASTUS-MACRO could produce results of work-rule change simulations consistently. Consistency is measured in terms of how close the % (percent) change from the base was, compared to a similar measure of RUCUS work rule simulations. Another purpose of this task was to determine the relative accuracy of the results. Finaly the cost and flexibility of HASTUS-MACRO operation are evaluated compared to RUCUS and manual techniques.

Table 3 is a Summary of Percent Difference on Three Work Rule Simulations for Consistency of Results. The most significant comparison to be made is between RUCUS with real reliefs and HASTUS-MACRO. In this instance, the results show that HASTUS-MACRO in 5 out of 6 measures was with one-half of one percent (0.5%) of RUCUS. The one exception is the burdened payhour % change (line 9) in the combination work rule simulation, where the difference was still less than one percent (0.9%). These results are reasonably consistent with RUCUS. It is not unreasonable to expect variation from RUCUS because the RUCUS solutions have up to a 2% difficiency to make up. It is possible the HASTUS-MACRO results represent the "true" picture and it is RUCUS that is providing the variation. This possibly is strengthened by examining the RUCUS 65+ work rule simulation results, which were made with

SUMMARY OF PERCENT DIFFERENCE ON THREE WORK RULE SIMULATIONS FOR CONSISTENCY OF RESULTS

Table 3

	RUCUS Real	RUCUS 65	HASTUS
1. Interline Penalty	YES	NO	NO
2. Travel Time	YES	NO	NO
3. Real Reliefs	YES	NO	NO
Work Rule Change	7 within 8	7 within 8	7 within 8
Reference Number	8	9	10
4. Direct Payhour % Change	-1.2%	+0.2%	-1.5%
5. Burdened Payhour % Change	-1.3%	-0.7%	-1.3%
Work Rule Change	8 within 12	8 within 12	8 within 12
Reference Number	11	12	13
6. Direct Payhour % Change	-2.2%	-2.9%	-2.2%
7. Burdened Payhour % Change	-2.0%	-2.4%	-1.6%
Work Rule Change	Combination	Combination	Combination
Reference Number	14	15	16
8. Direct Payhour % Change	-3.4%	-3.2%	-3.9%
9. Burdened Payhour % Change	-3.5%	-3.1%	-2.4%

Legend:

RUCUS Real: Represents RUCUS runcuts with real "Streetable" data.

RUCUS 65 : Represents RUCUS runcuts with HASTUS equivalent data.

HASTUS : Represents HASTUS runcuts.

HASTUS like data. It shows considerably wider variations from both HASTUS-MACRO and RUCUS with real reliefs. Recognizing that the RUCUS 65 runcuts were not subject to as many interactions and refinements as the RUCUS with real reliefs, suggests that RUCUS results can be variable depending upon the skill of the user and the amount of attention paid to getting the best solution. This suggests another use for HASTUS-MACRO, as an audit tool to evaluate the productivity of manual and RUCUS runcuts during the regular scheduling cycle against the true potential as expressed by HASTUS-MACRO. This process would have the effect of reducing the number of RUCUS interactions or manual optimizations before an acceptable runcut is produced.

For purposes of work rule change simulation the most important criterion is consistently with established techniques and these results suggest HASTUS-MACRO is reasonably consistent with RUCUS. It is probably impossible to prove which of either RUCUS or HASTUS-MACRO is producing the most correct simulation results.

In summary, the results of this task have shown that:

(1) HASTUS-MACRO produces consistent results with RUCUS work rule simulations using real relief data.

(2) There is evidence that RUCUS in unskilled hands can produce inconsistent results.

(3) A significant new use for HASTUS-MACRO would be as a preprocessor or past audit tool to estimate the target potential of a new set of schedules.

C. Part-Time Work Rule Simulation

The purpose of this task was to estimate the effect of increasing the percentage of part-time operators on the direct and burdened payhour cost. The new RTD labor contract calls for an increased percentage of part-time operators to be decoded through arbitration. In this task, simulations for part-time were performed on the division one schedules for the following percentages:

Part-Time Percent	Reference Number
0%	7
10%	18
14%	19
20%	20
24%	21
50%	23
Max %	24

These simulations were run on the existing division one schedules without modification. The results should be qualified because the proposed part-time percentage increase would be the result of adding additional service. Furthermore, no reductions of current full-time operators are to take place. While simulations using additional service were not performed, the results should be comparable.

Figure 1, Graph of Percent (%) Saving Through Part-Time Operator Utilization, shows increased saving plotted against increased percentage of part-time, for both direct and burdened payhours. Examination of this graph shows that, as expected, the burdened payhours decrease at a greater rate than direct payhours. Using this graph and Table 4, HASTUS-MACRO Comparison of Part-Time Runcuts, the following broad conclusions can be reached.

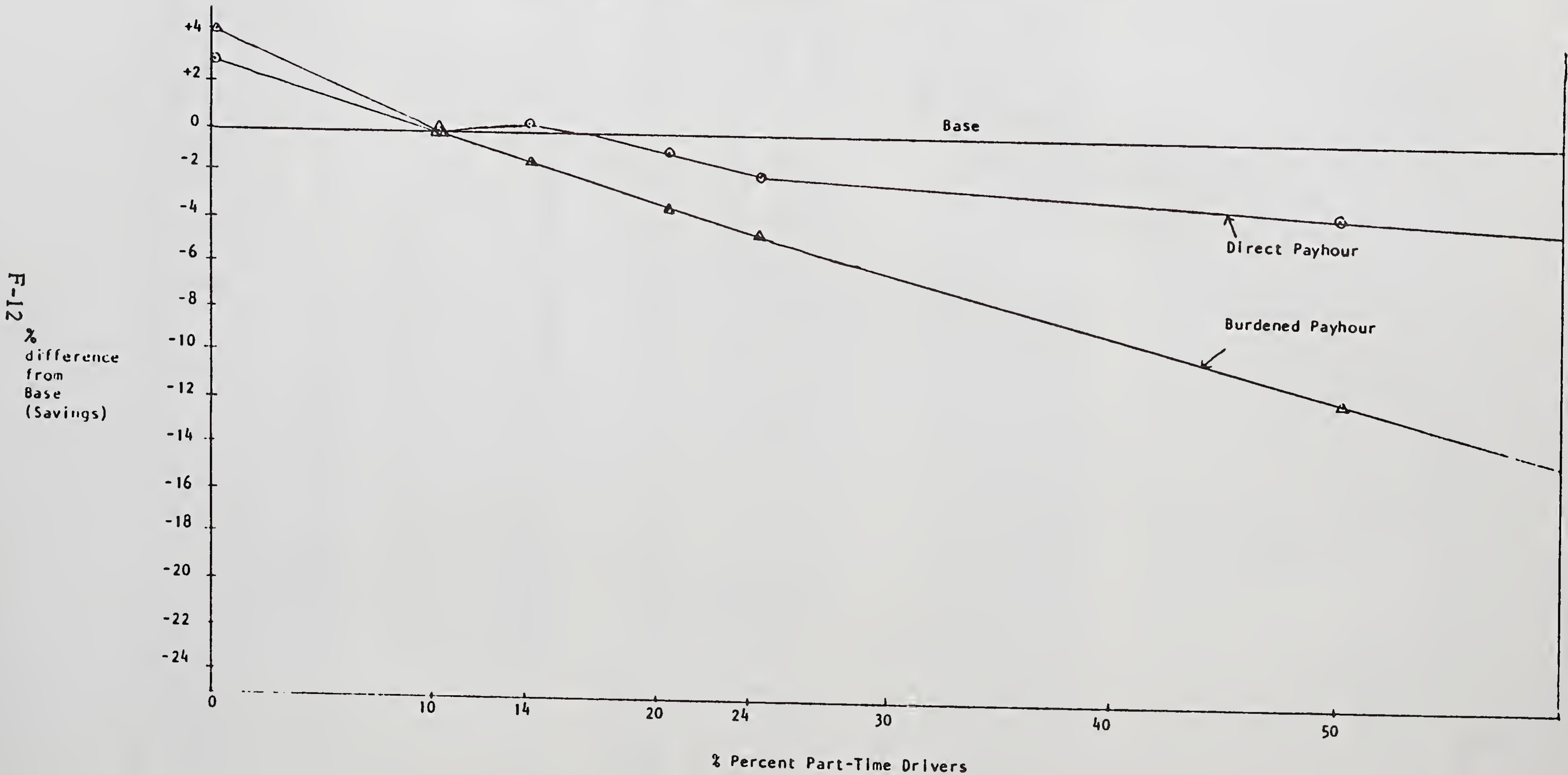
(1) The largest saving of direct payhours was achieved with the first 10% allowance for part-time operators.

(2) Burdened payhours savings proceeds at a steady rate of about 3% for every 10% increase in part-time manpower.

(3) Direct saving tends to level off after 25% part-time operators.

It is beyond the scope of this project to assess the importance of this information to the SCRTD. In terms of the transit industry in general, the information about part-time labor may not be directly transferable. These HASTUS simulations suggest that part-time can produce savings well beyond 15%

Figure 1. Graph of % Saving Through Part-Time Operator Utilization



HASTUS-MARCO COMPARISON OF PART-TIME RUNCUTS

Table 4

1.	Runcut Name	HASTUS 0%	HASTUS10%	HASTUS 14%	HASTUS 20%	HASTUS 24%	HASTUS 50%	HASTUS 85%
2.	Ref. Number	7	18	19	20	21	23	24
3.	Base Exsisting Workrules	NO	YES	NO	NO	NO	NO	NO
	Run Stats.							
7.	Straights	119	118	113	112	113	93	43
8.	Splits	76	76	72	71	72	59	27
9.	Extra Board Comb.	62	44	39	30	23	1	1
10.	Biddable Trippers	30	30	30	30	30	30	30
11.	Part-Time	0	47	66	95	114	235	400
12.	Total Regular	195	194	185	183	185	152	70
13.	Total Full-Time	257	238	224	213	208	153	71
13.A	Total Manpower	257	285	290	308	322	387	471
14.	% Straights	61%	61%	61%	61%	61%	61%	61%
	Runcut Costs							
15.	Vehicle Hours	2391	2391	2391	2391	2391	2391	2391
16.	Total Direct Pay	2646	2569	2576	2548	2526	2479	2470
17.	Ratio Payhours/Veh.	1.107	1.074	1.077	1.066	1.056	1.037	1.033
18.	Difference From Base	+77	____	+7	-21	-43	-90	-99
19.	% Difference From Base	+3.0%	____	+0.3%	-0.8%	-1.7%	-3.5%	-3.9%
20.	Fringe Payhours	942	873	821	781	763	561	260
21.	Total Burdened Payhour	3588	3441	3397	3329	3289	3040	2730
22.	Ratio Burdened Pay/Veh.	1.501	1.439	1.421	1.392	1.376	1.271	1.142
23.	Difference From Base	+147	____	-44	-112	-152	-401	-711
24.	% Difference From Base	+4.3%	____	-1.3%	-3.3%	-4.4%	-11.7%	-20.7%

but it depends on whether direct or burdened costs are evaluated. Fringe costs on the RTD HASTUS simulation were assessed at 220 minutes per full-time operator and zero for part-time. These costs were provided after much research and discussion with the RTD Finance Department. Different fringe costs for full-time and part-time would undoubtedly produce different results.

D. 1982 Contract Simulation

Besides the undecided part-time driver provisions, the new RTD contract contains a change in the definition of a regular operator from 7 hours work within a spread of 10 to 7 hours work within a spread of 9 hours. This is a compromise between the existing contract and one of the HASTUS work rule calibration simulations for 7 within 8 hours spread. It was decided to evaluate the new contract 7 within 9 provision and compare against the 7 within 8 work rule change. The following table shows the percent change in each:

	7 within 9	7 within 8
Direct payhour saving	-1.1%	-1.5%
Burdened payhour saving	-0.6%	-1.3%

These results seen are reasonable. It will be interesting to see if this proportion occurs under the new work rule when it is actually implemented in the next few months.

APPENDIX G

HASTUS/RUCUS RUNCUT STATISTICS AND COMPARISONS FOR THIRD CALIBRATION TECHNIQUE

APPENDIX G

Runcut Statistics and Comparisons for Third Calibration Techfnique

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Runcut Statistics and Comparisons
for
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Table 6

RUCUS/HASTUS Runcut Comparison on Work Rule Simulation of
Defining a Regular Run as 7 Hours Within 8 Hours Spread

1. Runcut Name	RUCUS BASE	RUCUS Neg 7/8	RUCUS 65+ BASE	RUCUS 65+ 7/8	HASTUS BASE	HASTUS 7/8
2. Ref. Number	2	8	5	9	7	10
3. Base Existing Work rules	yes	no	yes	no	yes	no
4. Interline Penalty	yes	yes	no	no	no	no
5. Travel Time	yes	yes	no	no	no	no
6. Reliefs	yes	yes	no	no	no	no
Run Stats.						
7. Straights	158	150	155	163	119	96
8. Splits	53	40	55	30	76	62
9. Extra Board Comb.	50	61	65	73	62	97
10. Biddable Trippers	41	40	22	28	30	30
11. Part-time	N/A	N/A	N/A	N/A	N/A	N/A
12. Total Regular	211	196	210	193	195	158
13. Total Full-Time	261	257	275	266	257	255
14. % Straights	75%	77%	74%	84%	61%	61%
Runcut Costs						
15. Vehicle Hours	2382	2382	2391	2391	2391	2391
16. Total Direct Pay	2743	2709	2707	2714	2646	2607
17. Ratio Payhours/Veh.	1.151	1.137	1.132	1.135	1.107	1.090
18. Difference from Base	—	-34	—	+7	—	-39
19. % Difference from Base	—	-1.2%	—	+0.2%	—	-1.5%
20. Fringe payhours	957	942	1008	975	942	935
21. Total Burdened Payhour	3700	3651	3716	3689	3588	3542
22. Ratio Burdened Pay/Veh.	1.553	1.532	1.554	1.543	1.501	1.481
23. Difference from Base	—	-49	—	-27	—	-46
24. % Difference from Base	—	-1.3%	—	-0.7%	—	-1.3%

Table 7

RUCUS/HASTUS RUNCUT Comparison on Work rule Simulation of

Paying Extraboard 8 Within 12

1. Runcut Name	RUCUS BASE	RUCUS 8/12	Rucus 65+ BASE	RUCUS 65+ 8/12	HASTUS BASE	HASTUS8/12
2. Ref. Number	2	11	5	12	7	13
3. Base Exsisting Work Rules	yes	no	yes	no	yes	no
4. Interline Penalty	yes	yes	no	no	no	no
5. Travel Time	yes	yes	no	no	no	no
6. Actual Reliefs	yes	yes	no	no	no	no
Run Stats.						
7. Straights	158	155	155	162	119	111
8. Splits	53	51	55	39	76	72
9. Extra Board Comb.	50	51	65	66	62	74
10. Biddable Trippers	41	35	22	26	30	30
11. Part-time	N/A	N/A	N/A	N/A	N/A	N/A
12. Total Regular	211	206	210	201	195	183
13. Total Full-Time	261	257	275	267	257	257
14. % Straights	75%	75%	74%	81%	61%	61%
Runcut Costs						
15. Vehicle Hours	2382	2382	2391	2391	2391	2391
16. Total Direct Pay	2743	2684	2707	2646	2646	2587
17. Ratio Payhours.Veh.	1.151	1.127	1.132	1.107	1.107	1.082
18. Difference from Base	—	-59	—	-61	—	-59
19. % Difference from Base	—	-2.2%	—	-2.9%	—	-2.2%
20. Fringe Payhours	957	942	1008	979	942	942
21. Total Burdened Payhour	3700	3626	3716	3625	3588	3529
22. Ratio Burdened Pay/Veh.	1.553	1.522	1.554	1.516	1.501	1.476
23. Difference from Base	—	-74	—	-91	—	-59
24. % Difference from Base	—	-2.0%	—	-2.4%	—	-1.6%

Table 8

RUCUS/HASTUS RUNCUT COMPARISON ON COMBINATION OF WORK RULES 7 WITHIN 8, WITHIN 11, 8 WITHIN 12

1. Runcut Name	RUCUS BASE	RUCUS COMB.	RUCUS 65+ BASE	RUCUS 65+ COMB.	HASTUS BASE	HASTUS COMB.
2. Ref. Number	2	14	5	15	7	16
3. Base Existing Work Rules	YES	NO	YES	NO	YES	NO
4. Interline Penalty	YES	YES	NO	NO	NO	NO
5. Travel Time	YES	YES	NO	NO	NO	NO
6. 65 Minute Reliefs	YES	YES	NO	NO	NO	NO
Run Stats.						
7. Straights	158	138	155	139	119	94
8. Splits	53	62	55	54	76	61
9. Extra Board Comb.	50	51	65	74	62	102
10. Biddable Trippers	41	30	22	3	30	30
11. Part-time	N/A	N/A	N/A	N/A	N/A	N/A
12. Total Regular	211	200	210	193	195	155
13. Total Full-Time	261	251	275	267	257	257
14. % Straights	75%	69%	74%	72%	61%	61%
Runcut Costs						
15. Vehicle Hours	2382	2382	2391	2391	2391	2391
16. Total Direct Pay	2743	2650	2707	2620	2646	2559
17. Ratio Payhours.Veh.	1.151	1.112	1.132	1.096	1.107	1.070
18. Difference from Base	—	-93	—	-87	—	-87
19. % Difference from Base	—	-3.4%	—	-3.2%	—	-3.9%
20. Fringe Payhours	957	920	1008	979	942	942
21. Total Burdened Payhour	3700	3570	3716	3599	3588	3501
22. Ratio Burdened Pay/Veh.	1.533	1.450	1.554	1.505	1.501	1.464
23. Difference from Base	—	-130	—	-117	—	-87
24. % Difference from Base	—	-3.5%	—	-3.1%	—	-2.4%

Reference Number: 2

Runcut Name: RUCUS Negotiations Base with Actual Subs

Vehicle Data Type: Actual subs with real relief points

Division Number: One

Runcut Description: A RUCUS runcut with exsisting work rules, using actual subs with real relief points. Includes full travel time file. Equivalent to "on-the-street".

Run Statistics

1.	Number of straights	158
2.	Number of splits	53
3.	Number of extra board combinations	50
4.	Number of biddable trippers	41
5.	Number of part-time	N/A
6.	Total regualar runs	211
7.	Total full-time	261
8.	Total manpower	261
9.	% of straights	75%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	28:50
12.	Preminum guarantee	111:24
13.	Overtime	220:39
14.	Total direct payhours	2743:02
15.	Ratio payhours/vehicle hours	1.151
16.	Fringe payhours	957
17.	Total burdened payhours	3700:02
18.	Ratio burdened payhours/vehicle hours	1.553

Reference Number: 3

Runcut Name: RUCUS BASE, no interline penalty with actual subs.

Vehicle Data Type: Actual subs with real relief points

Division Number: One

Runcut Description: A RUCUS runcut with existing work rules, using actual subs, with real relief points. Includes full travel time file. Penalties for mixing runs between routes (interlining) have been removed.

Run Statistics

1.	Number of straights	151
2.	Number of splits	61
3.	Number of extra board combinations	48
4.	Number of biddable trippers	36
5.	Number of part-time	N/A
6.	Total regualar runs	212
7.	Total full-time	260
8.	Total manpower	260
9.	% of straights	71%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	*
12.	Preminum guarantee	*
13.	Overtime	*
14.	Total direct payhours	2743
15.	Ratio payhours/vehicle hours	1.151
16.	Fringe payhours	953:20
17.	Total burdened payhours	3696:20
18.	Ratio burdened payhours/vehicle hours	1.552

* Not available at time of writing

Reference Number: 4

Runcut Name: RUCUS Base, with actual subs and no travel time file.

Vehicle Data Type: Actual subs with real reliefs

Division Number: One

Runcut Description: A RUCUS runcut with exsisting work rules, using actual subs, with real relief points. No travel time file and no interline penalties.

Run Statistics

1.	Number of straights	152
2.	Number of splits	50
3.	Number of extra board combinations	57
4.	Number of biddable trippers	36
5.	Number of part-time	N/A
6.	Total regualar runs	202
7.	Total full-time	259
8.	Total manpower	259
9.	% of straights	75%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	*
12.	Preminum guarantee	*
13.	Overtime	*
14.	Total direct payhours	2736
15.	Ratio payhours/vehicle hours	1.149
16.	Fringe payhours	949:40
17.	Total burdened payhours	3685.40
18.	Ratio burdened payhours/vehicle hours	1.547

* Not available at time of writing

Reference Number: 5

Runcut Name: RUCUS Base with 65 minute subs

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A RUCUS runcut, with exsisting work rules, using HASTUS equivalent 65 minute fixed interval subs. No travel file was used or paid. Input data is equivalent to HASTUS.

Run Statistics

1.	Number of straights	155
2.	Number of splits	55
3.	Number of extra board combinations	65
4.	Number of biddable trippers	22
5.	Number of part-time	N/A
6.	Total regualar runs	210
7.	Total full-time	275
8.	Total manpower	275
9.	% of straights	74%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	145:45
13.	Overtime	170:32
14.	Total direct payhours	2707:12
15.	Ratio payhours/vehicle hours	1.132
16.	Fringe payhours	1008:20
17.	Total burdened payhours	3715:32
18.	Ratio burdened payhours/vehicle hours	1.554

Reference Number: 4

Runcut Name: RUCUS Base, with actual subs and no travel time file.

Vehicle Data Type: Actual subs with real reliefs

Division Number: One

Runcut Description: A RUCUS runcut with exsisting work rules, using actual subs, with real relief points. No travel time file and no interline penalties.

Run Statistics

1.	Number of straights	152
2.	Number of splits	50
3.	Number of extra board combinations	57
4.	Number of biddable trippers	36
5.	Number of part-time	N/A
6.	Total regualar runs	202
7.	Total full-time	259
8.	Total manpower	259
9.	% of straights	75%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	*
12.	Preminum guarantee	*
13.	Overtime	*
14.	Total direct payhours	2736
15.	Ratio payhours/vehicle hours	1.149
16.	Fringe payhours	949:40
17.	Total burdened payhours	3685.40
18.	Ratio burdened payhours/vehicle hours	1.547

* Not available at time of writing

Reference Number: 5

Runcut Name: RUCUS Base with 65 minute subs

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A RUCUS runcut, with exsisting work rules, using HASTUS equivalent 65 minute fixed interval subs. No travel file was used or paid. Input data is equivalent to HASTUS.

Run Statistics

1.	Number of straights	155
2.	Number of splits	55
3.	Number of extra board combinations	65
4.	Number of biddable trippers	22
5.	Number of part-time	N/A
6.	Total regualar runs	210
7.	Total full-time	275
8.	Total manpower	275
9.	% of straights	74%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	145:45
13.	Overtime	170:32
14.	Total direct payhours	2707:12
15.	Ratio payhours/vehicle hours	1.132
16.	Fringe payhours	1008:20
17.	Total burdened payhours	3715:32
18.	Ratio burdened payhours/vehicle hours	1.554

Reference Number: 7

Runcut Name: HASTUS Base

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, with exsisting work rules, using 65 minute fixed interval subs. No travel time file was permitted.

Run Statistics

1.	Number of straights	119
2.	Number of splits	76
3.	Number of extra board combinations	62
4.	Number of biddable trippers	30
5.	Number of part-time	N/A
6.	Total regualar runs	195
7.	Total full-time	257
8.	Total manpower	257
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	61:00
13.	Overtime	194:20
14.	Total direct payhours	2646:15
15.	Ratio payhours/vehicle hours	1.107
16.	Fringe payhours	942:20
17.	Total burdened payhours	3588:20
18.	Ratio burdened payhours/vehicle hours	1.501

Reference Number: 8

Runcut Name: RUCUS Negotiation 7 with 8 simulation on actual subs.

Vehicle Data Type: Actual subs with real relief points

Division Number: One

Runcut Description: A RUCUS runcut simulation, using actual subs with real relief points. With the following work rule change:

(1) Definition of regular runs is 7 hours work within a spread of 8 hours, instead of 7 hours within a spread of 10 hours.

Run Statistics

1.	Number of straights	150
2.	Number of splits	46
3.	Number of extra board combinations	61
4.	Number of biddable trippers	40
5.	Number of part-time	N/A
6.	Total regualar runs	196
7.	Total full-time	257
8.	Total manpower	257
9.	% of straights	77%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	28:38
12.	Preminum guarantee	72:46
13.	Overtime	225:04
14.	Total direct payhours	2708:37
15.	Ratio payhours/vehicle hours	1.137
16.	Fringe payhours	942:20
17.	Total burdened payhours	3650:57
18.	Ratio burdened payhours/vehicle hours	1.532

Reference Number: 9

Runcut Name: RUCUS, with 65 minute subs, 7 within 8 simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A RUCUS runcut, using 65 minute fixed interval HASTUS equivalent subs and no travel time. With the following work rule change:

(1) Definition of regular runs is 7 hours work within a spread of 8 hours, instead of 7 hours with a spread of 10 hours.

Run Statistics

1.	Number of straights	163
2.	Number of splits	30
3.	Number of extra board combinations	73
4.	Number of biddable trippers	28
5.	Number of part-time	N/A
6.	Total regualar runs	193
7.	Total full-time	266
8.	Total manpower	266
9.	% of straights	84%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	*
12.	Preminum guarantee	*
13.	Overtime	*
14.	Total direct payhours	2714
15.	Ratio payhours/vehicle hours	1.135
16.	Fringe payhours	975:20
17.	Total burdened payhours	3689:20
18.	Ratio burdened payhours/vehicle hours	1.543

* Data not available at time of writing.

Reference Number: 10

Runcut Name: HASTUS 7 within 8 simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. With the following work rule change:

(1) Definition of regular runs is 7 hours work within a spread of 8 hours, instead of 7 hours within a spread of 10 hours.

Run Statistics

1.	Number of straights	96
2.	Number of splits	62
3.	Number of extra board combinations	97
4.	Number of biddable trippers	30
5.	Number of part-time	N/A
6.	Total regualar runs	158
7.	Total full-time	255
8.	Total manpower	255
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0
12.	Preminum guarantee	31:07
13.	Overtime	185:03
14.	Total direct payhours	2607:05
15.	Ratio payhours/vehicle hours	1.090
16.	Fringe payhours	935:00
17.	Total burdened payhours	3542:05
18.	Ratio burdened payhours/vehicle hours	1.481

Reference Number: 11

Runcut Name: RUCUS Negotiation 8 within 12 simulation on actual subs

Vehicle Data Type: Actual subs with real relief points

Division Number: One

Runcut Description: A RUCUS runcut simulation, using actual subs with real relief points. With the following work rule change:

(1) Pay extraboard 8 within 12 hours instead of 8 within 11 hours.

Run Statistics

1.	Number of straights	155
2.	Number of splits	51
3.	Number of extra board combinations	51
4.	Number of biddable trippers	35
5.	Number of part-time	N/A
6.	Total regualar runs	206
7.	Total full-time	257
8.	Total manpower	257
9.	% of straights	75%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	25:50
12.	Preminum guarantee	63:55
13.	Overtime	211:54
14.	Total direct payhours	2683:48
15.	Ratio payhours/vehicle hours	1.127
16.	Fringe payhours	942:20
17.	Total burdened payhours	3626:08
18.	Ratio burdened payhours/vehicle hours	1.522

Reference Number: 12

Runcut Name: RUCUS using 65 minute subs, 8 within 12 extraboard

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A RUCUS runcut, using 65 minute fixed interval. HASTUS equivalent subs and no travel time. With the following work rule change:

(1) Pay extraboard 8 hours within 12 hours spread instead of 8 within 11 hours.

Run Statistics

1.	Number of straights	162
2.	Number of splits	39
3.	Number of extra board combinations	66
4.	Number of biddable trippers	26
5.	Number of part-time	N/A
6.	Total regualar runs	201
7.	Total full-time	267
8.	Total manpower	267
9.	% of straights	81%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	*
12.	Preminum guarantee	*
13.	Overtime	*
14.	Total direct payhours	2646
15.	Ratio payhours/vehicle hours	1.107
16.	Fringe payhours	979:00
17.	Total burdened payhours	3625
18.	Ratio burdened payhours/vehicle hours	1.516

* Data not available at time of writing.

Reference Number: 13

Runcut Name: HASTUS 8 within 12 simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. With the following work rule change:

(1) Pay extraboard 8 hours within 12 hours spread instead of 8 within 11 hours.

Run Statistics

1.	Number of straights	111
2.	Number of splits	72
3.	Number of extra board combinations	74
4.	Number of biddable trippers	30
5.	Number of part-time	N/A
6.	Total regualar runs	183
7.	Total full-time	257
8.	Total manpower	257
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	20:07
13.	Overtime	175:50
14.	Total direct payhours	2586:52
15.	Ratio payhours/vehicle hours	1.082
16.	Fringe payhours	942:20
17.	Total burdened payhours	3529:12
18.	Ratio burdened payhours/vehicle hours	1.476

Reference Number: 14

Runcut Name: RUCUS Negotiation combination simulation on actual subs

Vehicle Data Type: Actual subs with real relief points

Division Number: One

Runcut Description: A RUCUS runcut simulation, using actual subs with real relief points. With the following work rule changes:

(1) Definition of regular run is 7 hours within 8 hours spread instead of 7 within 10.

(2) Regulars are paid 8 within 11 instead of 8 within 10.

(3) Extraboards are paid 8 within 12 instead of 8 within 11.

Run Statistics

1.	Number of straights	138
2.	Number of splits	62
3.	Number of extra board combinations	51
4.	Number of biddable trippers	30
5.	Number of part-time	N/A
6.	Total regualar runs	200
7.	Total full-time	251
8.	Total manpower	251
9.	% of straights	69%

Runcut Costs

10.	Vehicle hours and report	2382:09
11.	Travel	25:46
12.	Preminum guarantee	24:26
13.	Overtime	217:23
14.	Total direct payhours	2649:44
15.	Ratio payhours/vehicle hours	1.112
16.	Fringe payhours	920:20
17.	Total burdened payhours	3570:04
18.	Ratio burdened payhours/vehicle hours	1.450

Reference Number: 15

Runcut Name: RUCUS combination simulation with 65 minute subs

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A RUCUS runcut simulation, using HASTUS equivalent 65 minute fixed interval subs, and the following work rule changes:

(1) Definition of regular run is 7 hours within 8 hours spread instead of 7 hours with 10 hours spread.

(2) Regulars are paid 8 within 11, instead of 8 within 10 hours spread.

(3) Extraboards are paid 8 within 12, instead of 8 within 11 hours spread.

Run Statistics

1.	Number of straights	139
2.	Number of splits	54
3.	Number of extra board combinations	74
4.	Number of biddable trippers	3
5.	Number of part-time	N/A
6.	Total regualar runs	193
7.	Total full-time	267
8.	Total manpower	267
9.	% of straights	72%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	*
12.	Preminum guarantee	*
13.	Overtime	*
14.	Total direct payhours	2620
15.	Ratio payhours/vehicle hours	1.096
16.	Fringe payhours	979:00
17.	Total burdened payhours	3599:00
18.	Ratio burdened payhours/vehicle hours	1.505

* Data not available at time of writing.

Reference Number: 16

Runcut Name: HASTUS Combination Simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. With the following work rule changes:

(1) Definition of regular run is 7 hours within 8 hours spread instead of 7 within 10.

(2) Regulars are paid 8 within 11, instead of 8 within 10.

(3) Extraboards are paid 8 within 12 instead of 8 with 11.

Run Statistics

1.	Number of straights	
2.	Number of splits	94
3.	Number of extra board combinations	61
4.	Number of biddable trippers	102
5.	Number of part-time	30
6.	Total regualar runs	N/A
7.	Total full-time	155
8.	Total manpower	257
9.	% of straights	257
		61%

Runcut Costs

10.	Vehicle hours and report	
11.	Travel	2390:55
12.	Preminum guarantee	0:0
13.	Overtime	0:20
14.	Total direct payhours	167:34
15.	Ratio payhours/vehicle hours	2558:50
16.	Fringe payhours	1.070
17.	Total burdened payhours	942:20
18.	Ratio burdened payhours/vehicle hours	3501:10
		1.464

Reference Number: 18

Runcut Name: HASTUS 10% part time simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. With exsisting work rules but also calculating 10% part-time.

<u>Run Statistics</u>

1.	Number of straights	118
2.	Number of splits	76
3.	Number of extra board combinations	44
4.	Number of biddable trippers	30
5.	Number of part-time	47
6.	Total regualar runs	194
7.	Total full-time	238
8.	Total manpower	285
9.	% of straights	61%

<u>Runcut Costs</u>

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	23:30
13.	Overtime	154:24
14.	Total direct payhours	2568:49
15.	Ratio payhours/vehicle hours	1.074
16.	Fringe payhours	872:40
17.	Total burdened payhours	3441:29
18.	Ratio burdened payhours/vehicle hours	1.439

Reference Number: 19

Runcut Name: HASTUS 14% part-time simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time with the following work rule change:

(1) 14% part-time labor instead of 10%.

Run Statistics

1.	Number of straights	113
2.	Number of splits	72
3.	Number of extra board combinations	39
4.	Number of biddable trippers	30
5.	Number of part-time	66
6.	Total regualar runs	185
7.	Total full-time	224
8.	Total manpower	290
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	17:18
13.	Overtime	167:29
14.	Total direct payhours	2575:42
15.	Ratio payhours/vehicle hours	1.077
16.	Fringe payhours	821:20
17.	Total burdened payhours	3397:02
18.	Ratio burdened payhours/vehicle hours	1.421

Reference Number: 21

Runcut Name: HASTUS 24% part-time simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. with the following work rule change:

(1) 24% part-time instead of 10%.

<u>Run Statistics</u>

1.	Number of straights	113
2.	Number of splits	72
3.	Number of extra board combinations	23
4.	Number of biddable trippers	30
5.	Number of part-time	114
6.	Total regualar runs	185
7.	Total full-time	208
8.	Total manpower	322
9.	% of straights	61%

<u>Runcut Costs</u>

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	10:40
13.	Overtime	124:27
14.	Total direct payhours	2526:02
15.	Ratio payhours/vehicle hours	1.056
16.	Fringe payhours	762:40
17.	Total burdened payhours	3288:42
18.	Ratio burdened payhours/vehicle hours	1.376

Reference Number: 22

Runcut Name: HASTUS 50% part-time simulation

Vehicle Data Type: 65 minute fixed interval subs.

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, suing 65 minute fixed interval subs and no travel time. With the following work rule change:

(1) 50% part-time instead of 10%.

Run Statistics

1.	Number of straights	93
2.	Number of splits	59
3.	Number of extra board combinations	1
4.	Number of biddable trippers	30
5.	Number of part-time	235
6.	Total regualar runs	152
7.	Total full-time	153
8.	Total manpower	387
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:00
12.	Preminum guarantee	3:19
13.	Overtime	85:10
14.	Total direct payhours	1479:24
15.	Ratio payhours/vehicle hours	1.037
16.	Fringe payhours	561:00
17.	Total burdened payhours	3040:24
18.	Ratio burdened payhours/vehicle hours	1.271

Reference Number: 23

Runcut Name: HASTUS 85% part-time simulation

Vehicle Data Type: 65 minute fixed interval subs.

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. With the following work rule change:

(1) 85% part-time instead of 10%.

Run Statistics

1.	Number of straights	43
2.	Number of splits	27
3.	Number of extra board combinations	1
4.	Number of biddable trippers	30
5.	Number of part-time	400
6.	Total regualar runs	70
7.	Total full-time	71
8.	Total manpower	471
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0
12.	Preminum guarantee	3:19
13.	Overtime	75:23
14.	Total direct payhours	2469:37
15.	Ratio payhours/vehicle hours	1.033
16.	Fringe payhours	260:20
17.	Total burdened payhours	2729:57
18.	Ratio burdened payhours/vehicle hours	1.142

Reference Number: 24

Runcut Name: HASTUS New contract 7 within 9 simulation

Vehicle Data Type: 65 minute fixed interval subs

Division Number: One

Runcut Description: A HASTUS-MACRO runcut, using 65 minute fixed interval subs and no travel time. Based on the only known change to the old contract.

(1) Definition of a regular runis changed to 7 hours within 9 hours, instead of 7 within 10 hours.

Run Statistics

1.	Number of straights	108
2.	Number of splits	69
3.	Number of extra board combinations	82
4.	Number of biddable trippers	30
5.	Number of part-time	N/A
6.	Total regualar runs	177
7.	Total full-time	259
8.	Total manpower	259
9.	% of straights	61%

Runcut Costs

10.	Vehicle hours and report	2390:55
11.	Travel	0:0
12.	Preminum guarantee	47:58
13.	Overtime	178:54
14.	Total direct payhours	2617:47
15.	Ratio payhours/vehicle hour	1.095
16.	Fringe payhours	949:20
17.	Total burdened payhours	3567:07
18.	Ratio burdened payhours/	1.500

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NOTICE

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