THE POTENTIAL OF COMPUTER-GENERATED MASTER SCHEDULING FOR HIGH SCHOOLS IN NEWFOUNDLAND AND LABRADOR

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THE POTENTIAL OF COMPUTER-GENERATED MASTER SCHEDULING FOR HIGH SCHOOLS IN NEWFOUNDLAND AND LABRADOR

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To my father, Abel,

whose commitment to education

and acceptance of the fisherman's way of life

was a model of which I am extremely proud.

I only wish he were here today.

ABSTRACT

The purpose of this research was to ascertain whether the computer could significantly assist school administrators with the annual construction of the master schedule for high schools throughout Newfoundland and Labrador.

The computer scheduling program which was chosen for this study was the Norwegian Nor-Data School Scheduling System, which was judged to be technically excellent and which had been designed to tackle a high school master scheduling problem very similar to that found throughout the Province.

With the financial support and the technical assistance of Newfoundland and Labrador Computer Services Limited, as well as with the full cooperation of the three participating principals, an intensive eight-day computer scheduling project was undertaken during November of 1982 at Newfoundland and Labrador Computer Services Limited under the direct supervision of Dr. Harald Michalsen, the Norwegian developer of the Nor-Data School Scheduling System. This timetabling project produced the Province's first four useable computer-generated master schedules.

Without any technical or programming difficulty whatsoever, the Nor-Data School Scheduling System very

satisfactorily produced an alternate master schedule for 1982-83 for each of the four selected schools: Ascension Collegiate, Bay Roberts; Gonzaga High School, St. John's; John Burke High School, Grand Bank; and Partanna Academy, Grand Bank.

The major findings of this study were as follows:

1. The Nor-Data School Scheduling System proved to be a locally viable computer scheduling program which has immediate application for all high school administrators throughout Newfoundland and Labrador.

2. Newfoundland and Labrador Computer Services Limited has the technical capability and the programming expertise to competently use the Norwegian Nor-Data School Scheduling System to efficiently produce master schedules for schools throughout the Province.

3. The computer-generated timetables were judged by the majority of the staff of each of the participating schools to be as good as, if not significantly better than, the manually-constructed timetables for 1982-83.

4. Computer-generated master scheduling is a modern functional alternative to the traditional method of manual construction of the school's master schedule.

5. Computer-generated master scheduling could become an immediate reality for high school administrators and an affordable option for School Boards, provided the

Department of Education substantially subsidized the cost to Newfoundland and Labrador Computer Services Limited to schedule schools with the Norwegian Nor-Data School Scheduling System.

6. The Nor-Data School Scheduling System could be purchased from Dr. Harald Michalsen by either Newfoundland and Labrador Computer Services Limited or the Department of Education, so that computer-generated master scheduling could become commercially available to all high school administrators for the 1984-85 school year.

Clearly, the Norwegian Nor-Data School Scheduling System has the potential to immediately become a new and invaluable administrative tool for most, if not all, high school administrators throughout the Province. It could also become the impetus for our adopting more defensible timetabling principles as the real basis on which better scheduling is built.

ACKNOWLEDGEMENTS

This study could not have been completed by the researcher alone. It necessitated a team effort.

The unfaltering support of, and sound guidance from, Dr. Hubert Kitchen, my thesis advisor, was very much appreciated during the long, and sometimes frustrating, organizational stages of this research. It would not have succeeded without his firmly believing in the need for, and the potential of, computer-generated master scheduling for high schools throughout the Province.

The financial support and the technical assistance provided by Newfoundland and Labrador Computer Services Limited is gratefully acknowledged. Its firm and early committment to this computerized master scheduling project was absolutely essential. Without the managerial optimism of Mr. Stephen Andrews and Mr. Harold Miller, as well as the programming expertise of Mr. Neil Dawe and Ms. Mary-Louise Porter, the computer-generated master schedules for the four selected schools would not have been produced by the Norwegian Nor-Data School Scheduling System.

The enthusiastic involvement of Dr. Harald Michalsen, the Norwegian developer of the Nor-Data School Scheduling System, will always be very deeply appreciated. Through his freely providing Newfoundland and Labrador Computer Services

Limited with his computer scheduling program, as well as his eagerly visiting our Province to supervise this master scheduling feasibility study, Dr. Michalsen ensured the success of this research. His on-site expertise proved to be invaluable. For the researcher, the opportunity to work with an internationally renowned computer scheduling expert was truly a unique and most rewarding experience. Much was learned, not only about computerized master scheduling, but also about the basic principles of sound timetabling.

The eager participation of the principals, as well as the full cooperation of the staff, of these four selected schools is an example of team work at its best. It is very much appreciated. It significantly lightened the burden of conducting the final stages of this study. The researcher is particularly indebted to his colleagues: Mr. Frederick Bullen, Principal of Ascension Collegiate at Bay Roberts; Mr. John Martin, Assistant Principal of Gonzaga High School at St. John's; and, Mr. John Tucker, Principal of Partanna Academy at Grand Bank.

Gratitude is hereby expressed by the author to each of these key team members who so willingly contributed to the successful completion of this computerized scheduling feasibility study.

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CHAPTER I

INTRODUCTION

One of the inescapable significant tasks of school administrators is the very challenging annual construction of the master schedule. Not only is the master schedule vital to the efficient and effective operation of the whole school, but also it must be completed prior to the beginning of classes in September. Furthermore, it must be judged by the principal to contain no serious teacher timetable conflict.

A cursory study of a master schedule will indicate where students and teachers are and what they are doing during any period over the curriculum cycle. A thorough evaluation of a master schedule will most likely reveal the philosophy of education to which that school and its administrators adhere. Duly stressing the crucial role of the master schedule in the success of the school, and its effect upon all those who operate within it, Murphy emphatically writes:

> ... the importance of the master schedule can hardly be exaggerated. It abstracts, in words and numbers, the essence of the school. For a given school year, it sets forth in precise detail who is going to do what for every period for every day of the week. Subjects, students, instructors, classrooms are all assigned. From the close study of a master schedule, a canny

> reader can learn much of a school: the programs it offers; the constraint or freedom that affects students' choice of courses; the school's position on the spectrum that runs from ultraconservative to radical; its size, resources, shape--even its philosophy.[1]

Equally cognizant of the importance of the master schedule, Price lucidly writes:

> It is more than a mere chart that indicates where students and teachers must be at any given time. In many ways it can be read like a book, one that reveals the type of learning experiences provided and the degree of flexibility within the school. For instance, the schedule will reveal whether or not the school provides equal time periods for all subjects, recognizes that some students need more exposure to certain subjects, and recognizes that some teachers have special interests and abilities in specific subject areas.[2]

Murphy reports that other school administrators have metaphorically described the singular importance of the master schedule as follows:

> The master schedule is to the high school principal as the musical score is to the concert director, for in either case a soundly planned program, harmonious and tightly knit in all of its component parts, will determine the effectiveness of the individual and his organization.
>
> The schedule is in many cases the principal, if not the only, bulwark standing between the administrator and chaos.[3]

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[1]Judith Murphy, School Scheduling by Computer: The Story of GASP (New York: Educational Facilities Laboratories, 1964), p. 1.

[2]Joseph Price, "An Investigation of the Practices, Problems, and Potential Associated with Computer Generated Master Scheduling for High Schools in Newfoundland and Labrador" (unpublished Master's thesis, Memorial University of Newfoundland, 1974), p. 1.

[3]Murphy, p. 1.

Despite the recognized importance of the master schedule, school administrators throughout the Province of Newfoundland and Labrador are still, as in years past, manually constructing their master schedule. In vogue is the trial-and-error, hand-mosaic technique. A laissez-faire managerial attitude towards timetabling would appear to be prevalent among educators. No specific course on scheduling has been offered by Memorial University of Newfoundland, nor has any significant in-service on better timetabling been initiated by either the Department of Education or the local School Boards to assist school administrators in this basic area of educational administration. The tacit assumption would appear to be that the principal can very easily construct the master schedule; furthermore, that the principal can perform this task very well indeed. It is understandable, therefore, that Price would have made the following recommendations in 1974:

> School districts should endeavor to provide in-service programs which would make school administrators aware of proven scheduling techniques. At present, most administrators are scheduling schools on a trial-and-error basis. In-service programs can help administrators to develop new and improved scheduling procedures and also enlighten them as to new organizational patterns for high schools.
>
> School administrators should not be satisfied with maintaining the status quo in terms of their scheduling practices in high schools. There are many organizational and scheduling innovations taking place in secondary schools elsewhere today. All are not good but many have merit. The means to implement many of these changes are available and every school administrator should take steps to study them and to incorporate worthwhile ideas into his school program.

> The master schedule plays a vital role in the smooth and effective operation of a school. Yet, in its training program for administrators, Memorial University of Newfoundland places very little emphasis on proven scheduling procedures. Therefore, the Department of Educational Administration of the University should include at least one course dealing with scheduling both in a practical and theoretical sense. It is rather ironic that such an important aspect of school administration receives so little attention.
>
> The Department of Education should assume a leadership role in utilizing computers in secondary schools. Studies should be made to determine the feasibility and costs involved in implementing computer scheduling in the Province's high schools.[4]

However, no action has been taken on these laudable recommendations. It is not surprising, therefore, that many school administrators now find this major organizational task of constructing the master schedule not only time-consuming and often very frustrating, but also somewhat unpleasant. With the full implementation of the Reorganized High School Program during 1983-84, school administrators will likely find that the process of building the master schedule will have become a much more complex task. It may well become a near impossible task to satisfactorily complete by the traditional trial-and-error, hand-mosaic approach.

Cognizant of the backwardness of "the state of the art" of school timetabling in England, Brookes succinctly summarizes the situation as follows:

> ... the problems of timetabling have not been the subject of much serious study. It is only recently that any effort at all has been devoted to attempts to introduce a more logical and coherent approach to the subject and little by way of advice and guidance

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[4]Price, op. cit., pp. 210-212.

> exists either in the literature or in the form of training courses. Most timetablers have been obliged to 'learn the trade' from their colleagues and from their own experience. Strange too that amid the lively and ubiquitous debates on curriculum reform, teaching methods, etc., the voice of the timetabler is rarely to be heard and is seldom encouraged to make its presence felt. Neither do timetablers talk a great deal amongst themselves, with the result that each tends to view his timetable both as more complex and as having more unique qualities than other timetables.[5]

The problems associated with school timetabling in Newfoundland and Labrador have received even less attention. Despite the major educational change which is presently being effected through the Reorganized High School Program, the Department of Education has offered only token guidance in timetabling. Its position of non-involvement would appear to be summarized in this casual remark:

> To facilitate uniform course development and ease of scheduling, all high school courses have been designed to carry either a two-credit or a one-credit rating.[6]

Clearly, scheduling has not been a high priority among school administrators. The situation does, however, appear to be changing. The General Advisory Committee of the Department of Education has recently established a provincial committee to investigate computer usage in schools and school board offices. Furthermore, the Department of Education will, if requested, assist schools with timetabling difficulties.

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[5]John E. Brookes, Timetable Planning (London: Heinemann Educational Books, 1980), p. 1.

[6]"Handbook of Senior High Schools of Newfoundland and Labrador," Department of Education, St. John's, Newfoundland, 1980, p. 19.

STATEMENT OF THE PROBLEM

The purpose of this study was to ascertain whether the computer could significantly assist educational administrators in developing the master schedule for high schools throughout Newfoundland and Labrador. It had been reasoned by the researcher that computer-generated master scheduling could potentially be an invaluable asset to educational leaders throughout the Province, for it does seem plausible that "With wise use, the computer can become an effective instrument for bringing about better schools through better scheduling."[7]

With the managerial cooperation and the technical assistance of Newfoundland and Labrador Computer Services Limited, the researcher has conducted a pilot project which involved three high schools and one elementary/junior high school to determine whether the Norwegian Nor-Data School Scheduling System could satisfactorily generate the master schedules which could be used in these schools during the 1982-83 school year in lieu of their manually-constructed timetables.

The objective of this study was to use the computer and the Norwegian Nor-Data School Scheduling System to construct an acceptable alternative 1982-83 master schedule for each of the four selected schools: Ascension Collegiate

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[7]Jack Parker, "Intangibles in the Master Schedule," NASSP Bulletin, LVIII (October, 1974), 81.

at Bay Roberts; Gonzaga High School at St. John's; John Burke High School at Grand Bank; and, Partanna Academy at Grand Bank. Only the original timetabling data which had been used to manually construct the 1982-83 master schedules for these schools was considered by the researcher to be acceptable input data for the production of these alternative 1982-83 computer-generated master schedules.

The other salient research questions which were considered in this study were as follows:

1. Is the Norwegian Nor-Data School Scheduling System a truly locally viable computer scheduling program which has some immediate, or very near future, potential use for high school administrators throughout the Province?

2. Would the teachers at these four participating schools judge their alternative 1982-83 computer-generated timetables to be qualitatively better than their manually-constructed timetables?

3. Given the technical capability and programming expertise of Newfoundland and Labrador Computer Services Limited, could computer-generated master scheduling soon become an affordable option for School Boards throughout the Province.

SIGNIFICANCE OF THE STUDY

At present, computer-generated master scheduling is still outside the realm of possibility for high school

administrators throughout the Province. A province-wide Educational Computing Network simply does not exist, as it does in several other Canadian provinces, notably Ontario. This situation prevails despite the reality that during the past decade several computer scheduling programs have been used successfully in other countries, particularly the United States and England. The pertinent question is: Why does the Province of Newfoundland and Labrador not offer computer-generated master scheduling as a viable, affordable option to its high school administrators? This unanswered question is the basis for this research with the Norwegian Nor-Data School Scheduling System.

Knowing very well the complexity of high school timetabling, and sensing the potential of the computer as a valuable educational tool, some Newfoundland educators are now asking: Could the master schedule be constructed better by computer? A positive answer would have real significance for educators throughout the Province.

The functions and capabilities of the computer are no longer to be held in awe; instead, they are to be fully understood, and to be used to our advantage educationally. Almost without our realizing it, the computer has become an integral part of our daily activities. Undoubtedly, the computer is here to stay as "a powerful tool that is augmenting man's thinking."[8] The crucial question is:

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[8]Peter M. Luba, "Computers in Manitoba Schools," Education Canada, XV (Winter, 1975), 42.

Should not the computer be utilized to possibly improve the administration of schools throughout the Province?

Since the early 1970's, the computer has been used to some extent in Canada for purposes of timetabling, most notably by educators in Ontario. Other countries, such as the United States, England and Norway, have pioneered in the educational use of computers. In contrast, schools and their administrators in Newfoundland and Labrador have been almost totally unaffected by these significant technological advancements. There has been no discernible shift away from the traditional approach to timetabling, despite the fact that various computer scheduling programs have been commercially available, either for construction of the master schedule, or simply for student scheduling.

The researcher has postulated that the Norwegian Nor-Data School Scheduling System, as opposed to other commercially available computer scheduling programs, is potentially useable on a large scale throughout Newfoundland and Labrador as an effective administrative tool for high school administrators who are confronted annually with the complex task of manually constructing the master schedule, which is certain to become even more demanding with the full implementation of the Reorganized High School Program during 1983-84.

It is presumed that this study could provide the impetus for significant change and improvement within this problematic area of school administration, provided the cost

of computer-generated master scheduling can be kept within reason. To argue that the computer must remain a luxury available only to affluent school systems elsewhere is not defensible. Our schools need good management. Apparently, school management could be improved through better master scheduling. Computer-generated master scheduling could be the means by which the Reorganized High School Program is better implemented.

Of the growing impact of computers, Rockart offers this historical perspective:

> During the past three decades, computers have become the most talked about, written about, and ubiquitous machines to be imposed upon mankind. At their birth, they were different, novel, and exciting. Ten to fifteen years ago, it was felt that by the 1970's they would be replacing many of man's functions--including thinking. Today, with a somewhat more realistic view, they are recognized as an increasingly important tool of mankind--one that has the potential for great impact upon the education process.[9]

In recognition of the computer revolution which has truly already begun, Time judged the computer worthy of its 1982 Man of the Year Award. To have this prestigious award usurped by a machine is unprecedented. In defense of Time's Machine of the Year, Freidrich explains:

> There are some occasions, though, when the most significant force in a year's news is not a single individual but a process, and a widespread recognition by a whole society that this process is changing the course of all other processes. That is why, after weighing the ebb and flow of events around the world, Time has decided that 1982 is the year of the computer.

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[9]John Fralick Rockart and Michael S. Scott-Morton, Computers and the Learning Process in Higher Education (New York: McGraw-Hill, 1975), p. 55.

> It would have been possible to single out as Man of the Year one of the engineers or entrepreneurs who master-minded this technological revolution, but no one person has clearly dominated those turbulent events. More important, such a selection would obscure the main point. Time's Man of the Year for 1982, the greatest influence for good or evil, is not a man at all. It is a machine: the computer.[10]

Undoubtedly, "the era of computers is upon us. Computers make the present most interesting and will make the future fascinating."[11] Educational administrators could benefit from fully accepting that reality.

A status report on the Nor-Data School Scheduling System which was submitted to the Norwegian Ministry of Education in 1969 concludes:

> Some years ago the question was: Is it possible to use computers for scheduling? We claim to have given a definite positive answer to that question ....
>
> In our opinion the computer is the only realistic alternative for future scheduling. The current problem is not whether the computer should be used, but how soon the schools will utilize this alternative entirely.[12]

LIMITATIONS OF THE STUDY

This study was limited to the production of the computer-generated master schedule for each of the four selected schools: Ascension Collegiate at Bay Roberts;

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[10]Otto Friedrich, "Machine of the Year: The Computer Moves In," Time, CXXI (January 3, 1983), 10.

[11]Tim Crawford, BASIC Computing: A Complete Course (Toronto: McGraw-Hill Ryerson, 1981), p. 1.

[12]Harald Michalsen, A Working Strategy for General School Scheduling (Trondheim: The Engineering Research Foundation at the Technical University of Norway, 1971), p. 17.

Gonzaga High School at St. John's; and, John Burke High School and Partanna Academy at Grand Bank. Even though these schools were chosen primarily on the basis of the keen interest which their administrators had expressed in computerized scheduling, the researcher would contend that these schools presented the Norwegian Nor-Data School Scheduling System with four very different, yet typical, Newfoundland timetabling problems.

The computer-generated master schedules produced by the Norwegian Nor-Data School Scheduling System were necessarily based exclusively upon the relevant timetabling data which was used during the spring and summer of 1982 to manually construct the 1982-83 master schedules for these four participating schools. No attempt was made by the researcher nor either of the three participating school administrators to alter the already-assigned teacher workloads. The computer-generated master schedules were, therefore, limited to being truly alternate 1982-83 master schedules for these schools. Due to the limitation on the input data, the computer-generated master schedules could not have been modified 1982-83 master schedules.

DELIMITATIONS OF THE STUDY

Three major delimitations were inherent in this computerized scheduling study.

The production of these four computer-generated master schedules was dependent upon two highly technical

factors: firstly, the capabilities of the Norwegian Nor-Data Program; and secondly, its compatibility with the AMDAHL 470-V6.2 computer at Newfoundland and Labrador Computer Services Limited. No attempt was made by Newfoundland and Labrador Computer Services Limited to revise the Nor-Data Program as received from Harald Michalsen, nor was any consideration given by the researcher to endeavoring to obtain an alternate computer scheduling program had a major technical flaw been unexpectedly found in the Nor-Data Program. This study was designed solely around the Nor-Data School Scheduling System. Had the Nor-Data Program been anything less than technically excellent, or in any way incompatible with the computer hardware at Newfoundland and Labrador Computer Services Limited, this study would have been, at its best, incomplete. At its worst, it would have been a colossal failure.

The lack of familiarity of the researcher, as well as that of the participating principals, with computerized master scheduling in general, and the Norwegian Nor-Data School Scheduling System in particular, may have created a communications problem during the very critical timetable construction phase of the study at Newfoundland and Labrador Computer Services Limited at St. John's during November of 1982. However, any adverse effects which the inexperience of these novice computer timetablers may have had on the results of this study were certainly minimized, if not eradicated, by the on-site supervision and expert guidance

of Harald Michalsen, the Norwegian developer of the Nor-Data School Scheduling System.

The comparative evaluation of the 1982-83 manually-constructed teacher timetables versus the computer-generated timetables by the staff of each of the participating schools was necessarily subjective. The subjectivity of the responses of these teachers may have, however, been balanced out by the similarity of the questions on both questionnaires. It could be assumed that the attitude of these ninety-four teachers towards computers in the school could have adversely affected their response to either one of the questionnaires. However, the two-questionnaire approach which the researcher used to obtain their best evaluation of each of their time-tables, coupled with a one hundred per cent response rate from each of these schools, may have negated any halo effect which might have confounded the comparative statistics.

DEFINITION OF TERMS

The major terms which have been used throughout this study are as follows:

Master Schedule

The comprehensive organizational year-long plan which the school administrators have devised for the school which indicates when, where, for how long, and by whom each class will be taught over the curriculum cycle.

School Administrator

The professionally-trained teacher who has the responsibility for the efficient and effective operation of the school.

Manually-constructed Master Schedule

A master schedule which has been constructed by the school administrators through the use of the trial-and-error, hand-mosaic timetabling technique.

Computer-generated Master Schedule

A master schedule which has been totally produced by a large computer through the use of a carefully-chosen computer scheduling program into which the administrators of the school have accurately fed the relevant timetabling data regarding teacher workloads.

Computer Scheduling Program

A commercially-available timetabling applications package which contains a unique set of computer procedural instructions which have been expressly designed to ensure that the computer can satisfactorily generate the school's master schedule provided appropriate and accurate input data has been supplied by the school administrator.

Computer Scheduling

Timetabling by computer as a functional alternative to manual construction of the school's master schedule.

Computer

The versatile and powerful machine which is nothing but a passive combination of circuitry which is unable to perform any task without first being programmed.

Computer Hardware

The physical components of the computer.

Computer Software

The various computer programs which are available commercially either on tape or on disk which are essential for making the computer function as the user would desire.

Sectioning

Student scheduling, or computer assignment of students to courses of their choice after the master schedule has been constructed either manually or by computer.

ORGANIZATION OF THE STUDY

Chapter I provides a general introduction to this computerized master scheduling feasibility study.

The review of related literature, which is presented in Chapter II, focuses upon the merits and disadvantages of computerized scheduling. It also outlines the development of computer-generated master scheduling as a truly viable alternative to manual construction of the school's master schedule.

Chapter III deals with the design of the study. It also contains information about the Norwegian Nor-Data School Scheduling System.

Illustrative timetables from the computer-generated master schedules for Ascension Collegiate, Gonzaga High School, John Burke High School and Partanna Academy are included in Chapter IV to demonstrate how effectively the computer can satisfactorily construct timetables through the Nor-Data School Scheduling System.

Chapter V contains the summary statistics from the comparative evaluation by the teachers of their alternative 1982-83 computer-generated timetables versus their manually-constructed timetables.

The views of the three participating principals are summarized in Chapter VI.

Chapter VII deals with the cost of computer-generated master scheduling with the Nor-Data School Scheduling System.

The conclusions and recommendations of the researcher are contained in Chapter VIII.

CHAPTER II

REVIEW OF RELATED LITERATURE

Computer-assisted scheduling is a relatively recent educational phenomenon. Three decades ago, there was no such facet of educational administration. Scheduling of schools was necessarily done universally by the traditional trial-and-error, hand-mosaic approach.

A quarter of a century ago, computers were still in the early developmental stage. Very few American school administrators had been convinced that the computer could become an invaluable aid in scheduling. Johnson reflects:

> Prior to the sixties the electronic computer was of minor or sporadic interest to college students in the fields of education or to teachers in the schools. College computer centers were few in number and applications of the information processing and remembering machines were seldom met in the schools.[1]

This situation is clearly evidenced by the total lack of literature on computer-assisted scheduling prior to 1960.

Of the widespread attitude of incredulity towards computerized master scheduling during the early 1960's, Murphy writes:

> ... it was widely assumed that the actual building of a master schedule, involving so many variables and calling for so many administrative decisions, was far too complex and subtle for automation.

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[1] M. Clemens Johnson, Educational Uses of Computers: An Introduction (Chicago: Rand McNally, 1971), p. vii.

> Computers, to be sure, have proved themselves invaluable for all kinds of routine data processing in schools, but most people (including computer manufacturers themselves) discounted the feasibility of programming the intricacies of a master schedule. In the face of this general skepticism, experimenters nonetheless persisted in the belief that scheduling could be automated.[2]

In the ensuing years, computer technology has been advanced at an astonishing pace. Computerized scheduling has come, accordingly, to be viewed by more and more school administrators as a viable alternate scheduling approach.

Today, there is ample proof that computer-assisted master scheduling has become an established aspect of educational administration not only in the United States, but also in several other countries, notably England and Norway. The literature, since the mid-1960's, abounds with reports on computer-assisted scheduling.

The ever-increasing number of periodical articles and books dealing with computer-assisted scheduling revolves around two very different timetabling problems.

On the one hand, there is the master scheduling problem which deals with the difficult task of constructing by computer a complete set of timetables for a school by matching the three basic elements of master scheduling: teachers, courses and rooms "in the best possible pattern, avoiding conflicts or resolving them, for the greatest good

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[2]Judith Murphy, School Scheduling by Computer: The Story of GASP (New York: Educational Facilities Laboratories, 1964), p. 1.

for the greatest number of students and teachers."[3]

On the other hand, there is the sectioning problem, which is sometimes referred to as student scheduling or class loading, which deals with the apparently simpler task of assigning the appropriate number of students to each of the class sections within the already-constructed master schedule "in such a way that the pupil is assigned to a class section of every course he has requested, and that each of the class sections to which he is assigned meets at a different time."[4]

Today, unlike two decades ago, the computer software is commercially available in several countries for school administrators to effectively tackle both of these very different timetabling problems.

Whereas this study focuses exclusively upon the master scheduling problem, this review of the literature will necessarily contain some references to the sectioning problem. It will, however, be purposefully de-emphasized, for the researcher is of the opinion that the sectioning problem would have very limited implications for school administrators throughout the Province where fewer than twenty-five schools have an enrolment of more than 500. Furthermore, the researcher strongly contends that the

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[3] Ibid., p. 4.

[4] Duane E. Richardson and John L. Clark, "Subject Promotion and Computer Scheduling," School Progress, XXXVIII (January, 1969), 66.

construction of the master schedule by computer is by far the more important and more challenging organizational task which needs to be studied.

Having experimented during 1973 with the American Stanford School Scheduling System, Price concluded that:

> The basic purpose of this study was to focus attention on master scheduling, its problems and the potential of computer generated master scheduling in the Province of Newfoundland. The researcher feels that this purpose has been achieved and that this research effort has revealed the need for increased attention in this area.[5]

That thesis research with the Stanford School Scheduling System, which was the first systematic study of computerized scheduling to have been undertaken in this Province, produced an incomplete and therefore unuseable computer-generated master schedule for 1973-74 for Lester Pearson Memorial High School at Wesleyville. Nevertheless, Price was encouraged by the results and recommended that:

> Computer scheduling should be thoroughly studied with emphasis on finding a computer scheduling system adaptable to high schools in this province. It is likely that there are many systems available that are worthy of investigation and development.[6]

However, prior to this study, no computer master scheduling program had been found that could have been used successfully by high school administrators throughout

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[5]Joseph Price, "An Investigation of the Practices, Problems, and Potential Associated with Computer Generated Master Scheduling for High Schools in Newfoundland and Labrador" (unpublished Master's thesis, Memorial University of Newfoundland, 1974), p. 212.

[6]Ibid., p. 214.

the Province. It would appear that neither the Department of Education nor Memorial University of Newfoundland has felt compelled to conduct any research in this area during the past decade. Presumably, computerized scheduling was judged not to be an important issue.

COMPUTER SOFTWARE AVAILABLE FOR SECTIONING

Several computer scheduling programs are presently available commercially to facilitate the scheduling of students to classes after the master schedule has been constructed either manually or by computer.

One computer scheduling program which has gained wide use and acceptance by American school authorities is Class Load and Student Scheduling, or CLASS as it is often referred to, which was developed by International Business Machines in the early 1960's. CLASS has been judged to be "extremely valuable in the large conventional high school where many sections of the same course are offered."[7]

Another student scheduling program which is very popular in the United States is Unlimited Potential Data through Automation Technology in Education, or UPDATE, which was developed in 1963 by the Iowa Educational Information Centre of the University of Iowa. It is capable of making "as many as 100,000 tries for one pupil before settling on

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[7]Robert W. Heller, Leonard M. Chaffee, and Ronald G. Davison, "Two Computer-Based School Scheduling Programs Analyzed," NASSP Bulletin, LVIII (March, 1974), 65.

a schedule .... /which/ results in better pupil schedules and better class balance than is the case with hand scheduling."[8]

A third sectioning program which is being used extensively by American school administrators is Student Scheduling: Fixed Time Patterns, or SAFE, which is noted for "its large capacity; i.e., a scheduling speed of 125 students per minute .... /which/ can accommodate semester or full-year courses and produces student and course documentation that reflects mid-year changes."[9]

Similarly, in Canada, computer scheduling programs are commercially available for sectioning. In Manitoba, the Manitoba Student Scheduling System, which was first used in 1972, has proven to be "of invaluable assistance in providing students with 'individual' timetables."[10] In Ontario, the Ontario Student Scheduling System, which is only one of several components of the Educational Computing Network of Ontario, is "a sophisticated and economical system designed to aid in creating student timetables."[11]

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[8]Duane E. Richardson and John L. Clark, "Understanding the Process of Computer Scheduling," School Progress, XXXVIII (February, 1969), 55.

[9]Heller, Chaffee, and Davison, op. cit., p. 66.

[10]"School Administration System," Department of Education, Winnipeg, Manitoba, 1972.

[11]"The Educational Computing Network of Ontario (ECNO)," Ministry of Education, Toronto, Ontario, n.d.

Fast contends that computer-assisted sectioning makes it possible for schools to improve the educational experiences of students by:

> ... providing more time for counsellors to work with individual pupils in the selection of courses to be scheduled;
>
> providing printed schedules either prior to or at the opening of school;
>
> facilitating educational planning through the availability of enrollment, assignment, class size, and related information immediately following the scheduling;
>
> balancing the size and composition of classes; and,
>
> permitting unlimited attempts to schedule a student, which will result in a program of studies preferred by the student.[12]

Whereas sectioning by computer could be advantageous for the very large schools, such as those American schools with enrolments of 1000 or more, it would apparently not be very beneficial for the hundreds of much smaller schools throughout Newfoundland and Labrador. Student scheduling is not the major timetabling problem confronting high school administrators in this Province. The real problem is the master schedule.

Focusing upon the merits of sectioning versus master scheduling, one British educator offers this perspective:

> In 1962, two of the headmaster lecturers at the Ministry's courses, having made enquiries of several

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[12] James J. Fast, "Advantages of Student Scheduling by Computer," NASSP Bulletin, LIII (January, 1969), 30.

> computer experts, agreed that potentially the electronic computer offered enormous possibilities to those faced with the ever increasing task of organising the academic programme of a school, particularly a secondary school. They discovered that in the USA and Canada considerable progress had been made by individuals, universities and computer firms particularly in the direction of 'student scheduling' which is the allocation of students to groups to take specific subjects. This has an application in the British school system, but only to a limited degree, and is hardly the main problem here.[13]

This assessment of the timetabling issue in England in 1975 is very similar, the researcher would argue, to the present timetabling situation in this Province. Obviously, computer sectioning programs would be less useful in this Province than computer master scheduling programs could be.

COMPUTER SOFTWARE AVAILABLE FOR MASTER SCHEDULING

Throughout Canada today, there is no one computer scheduling program that is being used extensively by high school administrators primarily for the construction of the master schedule. The educational computing services which have been established in the provinces of Ontario, Manitoba, Alberta and British Columbia focus primarily upon student scheduling, grade reporting, computer-assisted instruction and student guidance information. Any emphasis upon master scheduling is apparently of a secondary nature.

Illustrative of this Canadian trend is the Manitoba Secondary Schools Computer Network, which was established

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[13] W. E. Egner, "School Timetabling and the Computer," British Journal of Educational Technology, VI (October, 1975), 5.

in 1973. Of its multi-purpose thrust, Luba writes:

> In what ways can the school principals be assisted by the computer? The principal can use the computer to maintain a master student file, including each student's academic credits. Updating and accessing student records becomes a more efficient and, as one Manitoba school principal has indicated, a pleasant task. Furthermore, the terminal can be used outside regular hours. During the past year we experimented with a scheduling package in some high schools using the network utility. The schedules were processed by the computer; conflicts were removed and individual student timetables were printed. Realizing that the printing of student timetables would require several hours of clock time and that the network policy is for schools to do their administrative work only when the terminal is not being used in instruction, the terminal was set up at 4:30 p.m. to print student timetables and was left unattended to continue with the printing until the job was completed. Much to their pleasant surprise the principals found in the morning a complete printout of student timetables neatly piled on the floor. In essence we discovered that the school terminal can be used 24 hours a day barring any computer down time in the absence of an attendant. Some other possible computer uses by school principals are in the areas of student report cards, attendance, school accounting and school payroll. These are being investigated at present for future development.[14]

Clearly, the Manitoba Secondary Schools Computer Network can assist principals with some of the administrative tasks; however, it is not presently being used significantly for the annual construction of master schedules.

In the United States and England today, there exists a variety of very sophisticated computer master scheduling programs which have been expressly designed, and then very significantly perfected, to "complete the entire process

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[14]Peter M. Luba, "Computers in Manitoba Schools," Education Canada, XV (Winter, 1975), 46.

of assigning times, rooms, teachers, and students to classes as required by the school's curriculum."[15]

Two exemplary American programs which focus upon the entire construction of the master schedule are the Generalized Academic Simulation Programs, or GASP, and the Stanford School Scheduling System, which is sometimes referred to as SSSS.

Generalized Academic Simulation Programs

The Generalized Academic Simulation Programs was developed during the early 1960's by Robert Holz at the Massachusetts Institute of Technology at Cambridge. It was first used successfully by three American high schools during the 1963-64 school year. Of the feasibility of programming the intricacies of the master schedule with GASP, Murphy comments:

> GASP has now demonstrated that automation can go beyond sectioning and actually produce the master schedule itself. Not only does the program perform faster and more efficiently than the most ingenious and tireless schoolman, but--much more important--it produces a schedule that takes fuller account of student and teacher preferences, of innovations like team teaching that complicate schedule-making, and of almost any array of circumstances peculiar to the school in question. GASP's value is demonstrable, above all, for schools introducing new practices.[16]

The initial experiences of master scheduling with the Generalized Academic Simulation Programs has apparently demonstrated that:

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[15]Heller, Chaffee, and Davison, op. cit., p. 66.

[16]Murphy, op. cit., p. 2.

1. A schedule of great complexity ... can be built by computer at less over-all cost than if it were done by hand by an administrator.

2. The computer-built schedule has fewer conflicts than does the handmade schedule.

3. Class lists, room utilization lists, teacher schedules, and student schedules are extremely accurate. For a modular schedule such lists are almost impossible to develop accurately by hand except at great cost in time and money.

4. The greatest advantage to the school of a computer-built modular schedule is that the scheduler, in the process of generating his master schedule, is able to construct a large number of preliminary schedules. He can analyze each and then incorporate improvements in each succeeding run until he reaches a satisfactory and workable combination of courses, time allocations, teachers, and rooms within the scope the school has indicated.[17]

Having been totally satisfied with the 1964-65 master schedule produced through the Generalized Academic Simulation Programs, one American school administrator summarized his experience in this glowing fashion:

> What once had taken months to accomplish can now be achieved in a relatively short period of time. It is now possible, through the use of the IBM 7094 computer, to construct an entire school program, regardless of its intricacies and complexities, within a minimal span of time and with an optimum of efficiency.[18]

Despite the excellent technical capabilities of the Generalized Academic Simulation Programs, Murphy cautions:

> It has been widely recognized, in recent years, that educational innovations--such as team teaching, teachers' aides, programmed instruction, television--succeed in improving instruction to the extent that they reflect careful, thoughtful, integrated planning.

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[17] Ibid., p. 11.

[18] Ibid., p. 17.

> Applied as stylish gimmicks or imposed by administrative fiat, they are apt to contribute little to a school beyond ready publicity in the local paper.
>
> So with GASP ... it can provide major help in carrying out well-laid plans, and contribute mechanistic patience and accuracy to scheduling a school program that has been carefully designed to reflect administrative policy, recommendation by teachers and guidance staff, student and parent choices. But if the school dreams up a program that won't fit into the existing plant, the computer won't create extra rooms (though it can improve the use to which you put the ones you have). You can't expect the computer to schedule eight classes into a seven-period day. The computer unaided can't solve such chronic problems as how to cram band practice or athletics or an excess of electives into an already crowded schedule. It is essential, in short, for the human scheduler--the principal, or his assistant--to make important decisions before feeding data into the computer.[19]

Even though the Generalized Academic Simulation Programs is a powerful aid in the construction of master schedules, school administrators must realize that:

> It cannot make basic administrative decisions, it cannot solve knotty problems by inventing solutions, it cannot cure flaws inherent in the school's educational program, its planning, or its plant. 'One hundred per cent space utilization, complete freedom of choice of subjects for students, and the satisfaction of all time preferences for instructors, are examples of ideals which will not be realized,' says Mr. Holz.[20]

An independent, comparative assessment of GASP and Class Loading and Student Scheduling, or CLASS, during the early 1970's revealed that each of these scheduling programs had its limitations. The project evaluators discuss the weaknesses of GASP as follows:

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[19] Ibid., pp. 21-22.

[20] Ibid., p. 33.

> Its difficulty lies in the need of the staff to gain proficiency in the skills it demands, and in accepting its assumptions about variability in the school program. The pilot schools found that many of the problems arising from their efforts with GASP stemmed from constraints tied to localized needs or limitations. These included teacher and room problems due to limited physical facilities; problems with irregular lunch periods; the difficulty of scheduling physical education and band classes during the regular school day and the completion of ties between large groups and small group classes.
>
> Timetable construction presented difficulties with the result that the GASP scheduler still had to build a significant portion of his timetable manually and then lock it into GASP. It was also weak in terms of its ability to detect errors in the input data. An improvement that would save much frustration would be some sort of internal safeguard that would prevent spurious information from ruining a total run which, in turn, increases the cost. As it presently stands, one must adopt a "try it and see" approach running the risk of higher computer costs through repetitious error-correcting runs.[21]

It is reasonable to assume that improvements will be continually made to GASP by its creator, Robert Holz. Murphy explains reassuringly:

> ... GASP in its second year of production was already in its first revision. Revisions will continue to be made, partly as the result of practical experience with GASP, partly as the result of advances in relevant theory. The changes to date have come about entirely from production experience with GASP. The basic algorithms and heuristics guiding the program have proven generally satisfactory.[22]

Knowing what the Generalized Academic Simulation Programs can do, as well as what it can not do, Murphy concludes:

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[21] Heller, Chaffee, and Davison, op. cit., pp. 80-81.

[22] Murphy, op. cit., p. 35.

> There is no use undervaluing GASP, as ultraconservative schoolmen tend to do ("It can't be done"), nor in overrating it, as enthusiastic school reformers do ("Computers will solve all our problems"). The impossible will still remain impossible, but GASP will most effectively do "whatever we know how to order it to perform."[23]

Stanford School Scheduling System

The Stanford School Scheduling System was developed during the early 1960's by Robert Oakford, Robert Bush and Dwight Allen at Stanford University in California. It was used successfully for the first time during the 1964-65 school year.

The Stanford School Scheduling System, or SSSS, is noted for its ability to schedule curricular innovations. Regarding this innovative thrust of the Stanford School Scheduling System, Allen writes in a salesmanlike manner:

> ... the freedom to schedule alternatives asks the educator to reexamine his school's objectives, the goals of individual courses, and the overall organization of his instructional program. Therefore, the real mission ... is not just to weave the curriculum, staff, students, and facilities into a whole, but to challenge old patterns and methods by providing alternatives that can range over a far greater curricular, methodological, and administrative spectrum.[24]

As a generalized computer program for constructing master schedules and assigning students to classes, the Stanford School Scheduling System does not significantly differ from GASP. Murphy offers this comparison:

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[23] Ibid., p. 37.

[24] Don D. Bushnell and Dwight W. Allen (eds.), The Computer in American Education (New York: John Wiley & Sons, 1967), p. 52.

> GASP is equipped to schedule as many as 4,000 courses, compared to Stanford's 500, and an unlimited number of students as compared to Stanford's 3,000. On the other hand, the Stanford system can schedule up to 18 teachers per teaching team, as against GASP's 5 (useful for scheduling departmental meetings, extra-curricular activities, etc.), and Stanford, unlike GASP, can specify two alternatives for each course for each student. But from the practical point of view of the schoolman, the two programs are pretty much alike in performance, and differ little in their ability to handle the range of variables an experimenting school might want--with respect to number of class periods, variation in period length, maximum number of modules, daily or weekly meetings, ties among small, medium, and large groups, sequencing of group and course phases, etc.[25]

Within three years of its introduction to American school administrators, the Stanford School Scheduling System, which has been described as "a more sophisticated scheme"[26] than GASP, had conclusively proven its technical capability to satisfactorily construct the master schedule for different schools. Of its growing popularity, Allen proudly comments:

> Thirty-three schedules now in use were constructed at the Stanford Computer Center using SSSS. Twenty-six of these schedules, involving approximately 25,000 students, were used for a complex modular design or flexible schedule. Eleven of the schools were in California, six in Oregon, four in Nevada, four in Colorado, two in Arizona, and one each in Utah, Iowa, Michigan, Arkansas, and Pennsylvania, as well as Yamato High School, an Air Force Dependents school in Tokyo.[27]

Users of the Stanford School Scheduling System did, however, encounter some timetabling difficulties during its

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[25] Murphy, op. cit., p. 41.

[26] Ibid.

[27] Bushnell and Allen, op. cit., p. 55.

early developmental stage. Murphy explains:

> The Stanford people are candid about the difficulties revealed by early runs--notably in sequencing classes in the same subject and in balancing class size. In general, problems in the first area resulted from the schools' failure to specify compatible time patterns and parameters; problems in the second area stemmed from Stanford's assumption that any serious imbalance could best be handled by administrative intervention. With these exceptions, Stanford reports that all schools involved in the first year found general satisfaction in their automated schedules and are continuing in the experiment. Revisions in the system and further school experience in using it are expected to produce much better results.[28]

Cognizant of the need for refinement of the Stanford School Scheduling System, so that it would even better meet the annual master scheduling needs of American high school administrators, Allen elaborates:

> In addition to expanding nearly all of the basic input parameters, several peripheral services have been added to the system. The input parameters for SSSS will presently allow almost any feasible educational design for any high school up to 3500 students (this limit can be expanded). Success in any computer system depends, however, on valid input; often the more complex the system, the more complex the input and, consequently, the more opportunity for human error. To solve this acute problem with scheduling data, a special auditing program has been written to check and flag over one hundred possible logical and clerical errors. This procedure has proved valuable in assuring valid input data; further, it has saved hundreds of hours of manual analysis and correction searches. Even more important, this data-auditing procedure provides a complete analysis of the input requests, enabling the scheduling consultant to predict major problems and potential success prior to actual generation of the schedule. Thousands of dollars have already been saved by avoiding the needless computer runs.[29]

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[28] Murphy, op. cit., p. 42.

[29] Bushnell and Allen, op. cit., pp. 55-56.

Emphasizing the importance of computer scheduling as a means of freeing the school program from conventional restraints and opening the way for curricular flexibility and innovation, Allen argues:

> Communications and transportation have made the vast power of the modern computer available to every school in America. The question is: do schoolmen have the courage and foresight to use the computer now that it is available? With many more students, with much more to teach ... the need for educational innovation has never been more acute. The power of the modern computer stands ready to assist.[30]

COMPUTER SCHEDULING EXPERIMENTS IN NEWFOUNDLAND

Whereas the educational system of the Province of Newfoundland and Labrador has been totally unaffected by the very significant world-wide progress which has been made in computer-assisted master scheduling during the past two decades, a small number of Newfoundland high school administrators were not totally disinterested in computerized scheduling.

Prior to this research with the Norwegian Nor-Data School Scheduling System, three computerized timetabling feasibility projects were undertaken at Newfoundland and Labrador Computer Services Limited during the past decade with three different computer master scheduling programs. Each of these attempts at finding a locally viable computer master scheduling program resulted in incomplete, and

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[30] Murphy, op. cit., p. 42.

therefore unuseable, computer-generated master schedules. Each of these three computer scheduling programs was judged by the participating school administrators as well as the programme analysts at Newfoundland and Labrador Computer Services Limited to be unsuitable for use throughout this Province.

Stanford School Scheduling System

With the cooperation and technical assistance of Newfoundland and Labrador Computer Services Limited, Price experimented with the Stanford School Scheduling System during 1972-73.

In defense of his selection of an American computer scheduling program for thesis research on the potential of computer-generated master scheduling for high schools in this Province, Price logically argues:

> To develop from the very beginning a new computer program necessary to generate a master schedule would have been very complex, and would have required a tremendous knowledge of computer technology, several years of testing, and large financial resources. Since much substantial and pioneering work had previously been done to develop school scheduling computer systems, the researcher elected to choose one from the two most sophisticated systems, or packages, available. These were the General Academic Scheduling Package (GASP) and the Stanford School Scheduling System (SSSS). After investigating these computer scheduling packages, the Stanford School Scheduling System was selected .... because of its flexibility and adaptability to unique school situations.[31]

To fully emphasize the potential of the Stanford School Scheduling System for high school administrators

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[31] Price, op. cit., p. 124.

throughout Newfoundland and Labrador, Price summarizes the success of SSSS in the United States as follows:

> The SSSS has been subjected to a rather thorough test, which began in the summer of 1963 and is continuing through the present. From 1963 to 1968, some 315 schedules were constructed for more than 100 different schools. Having once tried the system, most schools have continued to use it.
>
> Schedules have been constructed for schools ranging in size from 113 students to 4,618 students and ranging in geographical location from Pennsylvania to Yamato, Japan. A few of these schedules have involved only traditional single-phase course structures, but most of them have involved multiphase course structures incorporating many of the educational objectives fostered by flexible scheduling.
>
> The scheduling effectiveness of the SSSS depends to a large extent upon the expectations of the individual user. However, when compared to alternative scheduling systems, the SSSS ranks very favourably. In terms of the number of course requests satisfied, it has proven its capabilities, although it still falls short of the theoretical ideal.[32]

Despite the promise of the Stanford School Scheduling System as a potentially locally viable computer scheduling program, Price encountered limited success in developing the computer-generated master schedule for 1973-74 for Lester Pearson Memorial High School at Wesleyville largely "Because of the inadequacies within the Stanford School Scheduling System ...."[33]

Of the apparent technical deficiencies within the American Stanford School Scheduling System, Price further elaborates:

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[32] Ibid., pp. 139-140.

[33] Ibid., p. 167.

> Generally speaking, the computer was unable to completely schedule any of the grade level schedules. Collectively, this meant that a major portion of the school master schedule was not completed. The manual grade level schedules were all finished and, consequently, the school master schedule was satisfactory to all concerned. All but a few of the restrictive measures such as double periods were honoured by the manual schedule. In order for the computer schedule to achieve its maximized status, all restrictions, except in Industrial Arts and Home Economics had to be removed. This led to an unsatisfactory result because original course plans had to be altered. This meant that the school was back to the age-old problem of modifying the school program to meet scheduling demands. For some undetermined reason the computer assigned almost all four period courses to the same time pattern. That is, the same period on Monday, Wednesday, Thursday and Friday. The only courses in which this did not happen were those that the scheduler changed to four phases of one period each. The computer also scheduled the courses and teachers at the expense of producing many conflicts in student schedules. In other words, the computer master schedule, in its present form, prevented many students from attending several of their required courses.[34]

For several reasons, this first computer-assisted master scheduling feasibility study to be undertaken in this Province, which was endorsed by the Department of Educational Administration at Memorial University of Newfoundland, met with very little success. Accordingly Price concluded that:

> ... the efforts of this study showed that much more varied research will be required before any advantages for computer scheduling can be claimed. The researcher is still optimistic, but before computers can be of any assistance in Newfoundland high schools, either a new system of scheduling must be developed or a system different from the one used in this study must be found. The Stanford School Scheduling System is desiged to accommodate students in a more flexible institution such as a University. In Newfoundland high schools, students spend most of their time in scheduled classes

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[34] Ibid., pp. 173-182.

> with little or no study time and that results in increased scheduling difficulties too great for systems like the SSSS.[35]

It is understandable, therefore, that Price judged that "The Stanford School Scheduling System is not suitable to the needs of Newfoundland high schools given the present operating environment."[36]

Several years later, when advising the researcher regarding this study on computer-generated master scheduling, Price still maintains that:

> Unless SSSS has been extensively revised, it will not prove to be useful to the average Newfoundland school which operates on a 5 hour/7 period day.
>
> I would certainly be hesitant in recommending replication using SSSS. There are many such programs on the market, both in Canada and the United States. A more suitable system might prove to be more productive than my own effort.[37]

Columbia School Scheduling System

During 1979, Columbia Computing Services Limited of Vancouver, British Columbia, initiated a feasibility project with Newfoundland and Labrador Computer Services Limited to ascertain whether its computer master scheduling program, the Columbia School Scheduling System, would be useable throughout Newfoundland and Labrador.

The four St. John's high schools that were selected

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[35] Ibid., p. 196.

[36] Ibid., p. 209.

[37] Letter to researcher from Joseph Price, Fortune Collegiate, Fortune, Newfoundland, February 24, 1982.

for this computerized timetabling project were Beaconsfield High School, Bishops College, Gonzaga High School and Prince of Wales Collegiate.

The Columbia School Scheduling System is presently being used by more than 200 schools in the United States and Canada, particularly British Columbia, Saskatchewan and Alberta. Apparently, there is a high degree of satisfaction among the users of this scheduling system.[38]

With the exception of Gonzaga High School, which did obtain an acceptable computer-generated master schedule for the 1979-80 school year, all of the participants in this timetabling experiment concluded that the Columbia School Scheduling System, with its primary emphasis on the student scheduling problem and the record-keeping task of school administrators, was not a locally viable computer master scheduling program for high schools throughout Newfoundland and Labrador.

Of this frustrating attempt at master scheduling by computer, the principal of Bishops College observed:

> ... the time frame in which this project was to be developed was somewhat constrained. This fact caused those involved to be pressed to find a workable schedule without the necessary preliminary briefing and guidance that might have avoided some of the frustrated effort and futile attempts to apply computer technology to high school scheduling by two well-meaning groups neither of whom fully understood the other's "modus operandi."

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[38]Letter to K. F. Hann from G. A. Campbell, Newfoundland and Labrador Computer Services Limited, St. John's, Newfoundland, March 5, 1979.

A fifth problem immediately recognized by the representative from Columbia Computing Services was that of the lack of free-time for students which is very desirable if the computer is to have the flexibility necessary to provide a workable schedule.

In summary, it is perhaps fair to say that the computer cannot be blamed for some of the problems encountered with this pilot project. Certain conditions that pertain to this school perhaps impeded the full utilization of the computer in the business of building a workable schedule.

In time these conditions may change such that the computer would be of real assistance in our efforts. As it pertains to this pilot project, however, the writer must state that the attempt to use the computer to provide a school schedule was less than satisfactory.[39]

Having experienced a reasonable amount of success with the Columbia School Scheduling System, the assistant principal of Gonzaga High School assessed the project much more favourably. Martin commented:

... the Program has been very educational and ... worth the time and effort expended. We are probably further ahead now than at any other time. Teachers have already received tentative schedules and for the first time all students ... have received Verification Slips for the 1979-80 school year.

I realize that a great deal of updating has to be finished in August because of the failures, transfers, course-request changes, etc., but I look forward to the final printouts. At that time the information available will save a tremendous amount of work and time.

In summary ... the Program has been very worthwhile and has many positive aspects for use in our school.[40]

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[39]Letter to Ralph Alcock from H. Reginald Tilley, Bishops College, St. John's, Newfoundland, June 21, 1979.

[40]Letter to Ralph Alcock from John J. Martin, Gonzaga High School, St. John's, Newfoundland, June 22, 1979.

In view of the many technical problems, as well as the various programming difficulties, which unexpectedly arose during this timetabling project with the Canadian Columbia School Scheduling System, an applications software specialist at Newfoundland and Labrador Computer Services Limited concluded:

> I would not recommend the acquisition of this package as a scheduling system with our school system as it presently operates.[41]

Clearly, Newfoundland and Labrador Computer Services Limited (NLCS) has judged this computerized master scheduling project a failure. One of its senior systems consultants has stated:

> Of the four schools participating in the project, only one, Gonzaga Regional High School, can be considered as having had a successful pilot project. The lack of success of the other schools can be attributed to either the inability of the system to satisfy their needs or the unavailability of school staff members to adequately test the scheduling system.
>
> Since the pilot project, in total, was considered far from successful no further action is anticipated on behalf of NLCS. The system, however, remains resident on the NLCS computer for an indefinite period of time should potential clients require its use. It should be pointed out, however, that the initiative for such usage would necessarily come from potential clients.[42]

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[41] Janet L. Parsons, "Columbia School Scheduling: Post Mortem," Report to Committee Investigating School Scheduling Systems, Newfoundland and Labrador Computer Services Limited, St. John's, Newfoundland, July 12, 1979.

[42] Letter to Melvin Hong from Ralph T. Alcock, Newfoundland and Labrador Computer Services Limited, St. John's, Newfoundland, January 14, 1980.

It is apparent that the Columbia School Scheduling System, like the Stanford School Scheduling System, has very little, if any, potential use for high school administrators throughout Newfoundland and Labrador.

Both of these computerized timetabling feasibility studies may have been unsuccessful because these particular computer master scheduling programs were not really designed to accomplish what the experimenters wanted them to do. The Stanford School Scheduling System was expressly designed for modular and flexible scheduling, not traditional scheduling. The Columbia School Scheduling System is primarily concerned with sectioning and student record-keeping, not master scheduling.

The principles of timetabling upon which these two computer scheduling programs have been developed are seemingly incompatible with the timetabling philosophy and methodology adhered to by high school administrators throughout the Province. Regarding the Stanford School Scheduling System, Price concluded that "Its design can only accommodate schools with flexible scheduling practices."[43] Regarding the Columbia School Scheduling System, Parsons concluded that "At present, this system would be of major use as ... possibly a marks reporting system for our schools."[44]

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[43]Price, op. cit., p. 206.

[44]Parsons, op. cit., p. 7.

Ontario School Scheduling System

During the 1973-74 school year, the Ontario Institute for Studies in Education (OISE) initiated a feasibility study on master scheduling with Newfoundland and Labrador Computer Services Limited using its computer scheduling program, the Ontario School Scheduling System. The only St. John's school that participated in this project was Gonzaga High School.

The NLCS manager of scientific services has informed the researcher that this computerized master scheduling project was a complete failure, possibly due to the incompatibility of the OISE computer scheduling program, the timetabling needs of Gonzaga High School and the computer hardware at Newfoundland and Labrador Computer Services Limited. So problematic were the initial organizational efforts of this experiment that it was aborted before any timetable construction runs were even attempted.

NORWEGIAN NOR-DATA SCHOOL SCHEDULING SYSTEM

A computer scheduling program with a very distinct difference is the Nor-Data School Scheduling System, which was developed during 1966 by Harald Michalsen through the Engineering Research Foundation of the Technical University of Norway at Trondheim in Norway. Unlike most American and Canadian computer scheduling programs, the Norwegian Nor-Data School Scheduling System focuses exclusively upon constructing the school's master schedule.

The Norwegian Nor-Data School Scheduling System does not deal with sectioning, student record-keeping or grade reporting. The singular objective of Harald Michalsen and his associates during the mid-1960's was "to design an operative program system for any Norwegian school and if possible find general principles for solution of the /master/ scheduling problem."[45] Michalsen maintained that the master scheduling problem was not only more complicated, but also significantly more important, than the sectioning problem.

As early as 1970, as many as 100 Norwegian schools had opted for computer-generated master scheduling, for the Nor-Data School Scheduling System was judged initially by Norwegian school administrators to be "quite acceptable and in several ways superior to the manual schedule."[46] Since then, the Nor-Data School Scheduling System has been considerably perfected by its developer. Now, it is being used extensively throughout Norway. Michalsen estimates that as many as 5,000 acceptable master schedules have now been generated through the Nor-Data School Scheduling System, mostly for Norwegian schools. In Norway, computer-generated master scheduling is clearly in vogue.

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[45]Harald Michalsen, A Working Strategy for General School Scheduling (Trondheim: The Engineering Research Foundation at the Technical University of Norway, 1971), p. 15.

[46]Ibid., p. 14.

Since 1970, the Nor-Data School Scheduling System has been used very successfully by school administrators throughout Sweden and Denmark.[47]

Since 1975, the Nor-Data School Scheduling System has been equally as successfully used by more than 100 schools throughout England, but most notably in the city of Manchester where "all the secondary schools which wish to use computer-assisted timetabling have been using it routinely for several years."[48]

Very much satisfied with the first master schedule produced for his school by the Nor-Data School Scheduling System, one high school principal at Manchester reports:

> Wright Robinson High School ... experienced major problems when implementing the 1974-75 lower school curriculum. Many of the original objectives had to be abandoned and temporary solutions adopted because there was insufficient time for a major revision of policy.
>
> During the subsequent year, the school designed alternative lower school structures and investigated their feasibility using the Nor-Data School Scheduling System. The investigation yielded positive results which greatly enhanced the quality of the 1975-76 timetable. Relatively little demand was made on the time of school personnel, which suggests that the computer system could provide all schools with an invaluable aid to the planning and implementation of their curriculum.[49]

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[47] Ibid., p. 15.

[48] Letter to researcher from Brian Whitworth, Local Government Operational Research Unit, Reading, England, March 3, 1982.

[49] M. N. Zarraga and S. Bates, "Computer Timetabling and Curriculum Planning," Educational Research, XXII (February, 1980), 107.

Prior to its being used on a large scale in England, the Nor-Data School Scheduling System was thoroughly tested by the School Timetabling Applications Group (STAG), which had been established by the British Ministry of Education to "investigate the system, as well as any other computer system that purported to produce school timetables."[50]

Following a five-year testing period, the School Timetabling Applications Group concluded that:

> ... the system is technically excellent; if a school submits data that has a solution, the system will ... find the solution or approach to within a fraction of one per cent.[51]

Regarding the capabilities of the Nor-Data School Scheduling System, Zarraga writes:

> The problem with British schools lay in the fact that the great majority of schools submit data that contain impossible and conflicting requests. Because of this, an iterative version of the system was developed that enabled schools to solve timetable problems as they became apparent, rather than wait until the end of the timetable run as had formerly been the case with computer timetabling. (This is analagous to manual timetabling.) The iterative system became operative in 1974, and has since been used with great success on over 100 schools in the UK.
>
> Because the system can be trusted to display clearly impossibilities in the data specification, it was evident that it could be used to great effect when planning a school's curriculum. A school could quickly assess, by the nature and number of impossibilities shown, whether it would be worthwhile to persevere with its current educational philosophy. And, as this exercise could be conducted relatively early in the school year, it would not be too late

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[50] Ibid., p. 108.

[51] Ibid., p. 107.

to make major revisions in school policy if the need arose.[52]

Regarding the iterative approach to computerized scheduling, which is a unique feature of the Nor-Data School Scheduling System, Brookes explains:

> To guarantee the successful completion of a school timetable, a computer system must not only be capable of finding a solution to the specifications where one exists, it must also be capable of dealing with the impossible and conflicting requirements that occur in the majority of British schools. In short, the computer system must be designed so that the operator can analogue the manual method of timetabling. The NOR-DATA School Scheduling System has been designed to do precisely this.
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> The vast majority of timetable specifications contain conflicting and impossible requests. In most cases it is therefore unrealistic to expect a computer system to produce a timetable in a single run. Just as a manual timetabler will modify the initial requirements to overcome timetabling problems, so a computer timetabling system must permit compromise during timetable construction. Rather than construct a set of programs that of itself makes compromise, the NOR-DATA System adopts an approach that enables the school itself to intervene in problems at a time when solutions are easiest to find, leaving the bulk of the tedious construction work to the computer.
>
> In practice this means producing a timetable in several computer runs, stopping at each stage to analyse and correct impossibilities. For obvious reasons we call this the iterative approach.[53]

In comparison with the American-developed Stanford School Scheduling System and the Canadian-developed Columbia School Scheduling System, the Norwegian Nor-Data School

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[52] Ibid., p. 108.

[53] John Brookes, CAST Operator's Manual for the Nor-Data School Timetabling System (London: Local Government Operational Research Unit, 1979), pp. 1-2.

Scheduling System is, in the opinion of the researcher, a much more promising computer master scheduling program which would appear to have immediate potential application for high school administrators throughout Newfoundland and Labrador, as it does in England where the Royal Institute of Public Administration has concluded that "it is safe to say that the Nor-Data System is the most flexible and sophisticated computer timetabling system to appear to date."[54]

Viewing the computer and the Nor-Data School Scheduling System as managerial tools for high school administrators, Brookes comments:

> A final point, but no less important, is that the computer is intended as an aid to the timetabler rather than as his replacement. The computer will not make educational decisions, nor is it right that it should. Rather, the computer helps the timetabler by focusing his attention on the areas of greatest difficulty and at the same time relieves him of much of the routine work of timetable construction. The whole philosophy of the Nor-Data System is based on the premise that all decisions of educational policy are the proper business of the school.[55]

Even though the initial results of scheduling with the Nor-Data School Scheduling System were "very encouraging and superior to any systems previously tried,"[56] the Local

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[54]John Brookes, RIPA User's Guide: Nor-Data Computer Assisted School Timetabling (London: Royal Institute of Public Administration, 1978), p. 1.

[55]Ibid.

[56]LAMSAC Project Report: Computer Assisted School Timetabling (London: Local Authorities Management Services and Computer Committee, 1978), p. 4.

Authorities Management Services and Computer Committee in England initiated a project in 1976 to "evaluate the current status and future potential of computer timetabling and to facilitate the development, use and improvement of computer systems which can contribute to effective and efficient school organisation."[57]

The three computer scheduling programs which were comparatively studied by the Local Authorities Management Services and Computer Committee (LAMSAC) were the Nor-Data School Scheduling System, the British-developed Oxford School Timetabling System and the New Zealand-developed Timetabler System. The two-year-long LAMSAC project found that the Nor-Data School Scheduling System "gave the best performance"[58] technically and "demonstrated the quickest turn-round facility in the Project Managers' exercise."[59] Furthermore, users of the Nor-Data School Scheduling System "gave the impression of being more satisfied"[60] than did the users of the other two scheduling programs.

Sensing as early as 1975 the tremendous potential of the Nor-Data School Scheduling System for British school administrators, Egner comments:

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[57] Ibid., p. 5.

[58] Ibid., p. 36.

[59] Ibid.

[60] Ibid.

> The Nor-Data program was ... amended in 1973, tested in early 1974, and introduced most successfully in the summer of 1974 in the production of 56 timetables. At present the Nor-Data program is used with a UNIVAC series 1100 computer, but it is being currently translated for use on other computers, and then this powerful and largely proven system will be widely available.[61]

Today, the Nor-Data School Scheduling System, which is available in English as well as the Norwegian language, is being used very extensively in Norway, Sweden, Denmark and England. To a lesser extent, it is being successfully used in Ireland and Iceland.

ADVANTAGES OF COMPUTER SCHEDULING

The possible advantages of computer scheduling are many and varied. The literature abounds with arguments for computer-assisted master scheduling.

Computers will, it is argued, usually do a better job of master scheduling than can be done by hand by even the best timetabler. Like others, Richardson argues that:

> Computer scheduling makes it relatively easy for the principal repeatedly to revise and try his master schedule until he feels that he has the best possible master schedule.[62]

The computer can provide the school administrator with multiple accurate copies of teacher, class and room

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[61] Egner, op. cit., p. 12.

[62] Richardson and Clark, "Understanding the Process of Computer Scheduling," p. 55.

timetables. Clark very enthusiastically claims that "Its product is always superior to anything achieved by a good timetabler manually ...."[63] Similarly, Durward reports that "The output from the final computer run has ... been cited as an appreciated 'extra' of computer scheduling. Most of the resulting lists would not be produced under normal methods simply because of lack of time and clerical help."[64]

The manual construction of an acceptable master schedule often requires several weeks of tedious work by the school administrator. Many contend that the computer can much more quickly and efficiently accomplish this very demanding task. Miles reasons that "The speed and accuracy of the computer would seem an ideal aid for this daunting task."[65] Likewise, Dempster believes that "It will save a senior member of staff several weeks of tedious effort, freeing him for more important tasks."[66]

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[63]Harry Clark, "Computerised Timetabling," Computers in Schools, III (May, 1981), 29.

[64]Lynne Durward, "Computerized Scheduling in Vancouver Schools," Research Report to Department of Planning and Evaluation, Board of School Trustees, Vancouver, April, 1973.

[65]Roger Miles, "Computer Timetabling: A Bibliography," British Journal of Educational Technology, VI (October, 1975), 18.

[66]M. A. H. Dempster, D. G. Lethbridge, and A. M. Ulph, "School Timetabling by Computer; A Technical History." Educational Research, XVIII (November, 1975), 25.

Computerized master scheduling could well become the impetus for innovative scheduling which could, some argue, result in better school management. Richardson comments:

> One of the greatest advantages of computer scheduling lies in the fact that it enables the principal to try different innovations in his master schedule and to see the results when the pupils are actually scheduled. Thus, he can use the scheduling program to simulate his school under different conditions. Many attempts toward improved education through changes in the organizational patterns of schools increase the difficulty in building workable master schedules. Among these are (1) ability grouping; (2) team teaching; (3) small modules of time in the school day; and (4) flexible time patterns throughout the school day. Computer scheduling makes it possible and comparatively easy for the principal to test master schedules which include these innovations.[67]

Likewise, Murphy reasons:

> In short, high school reform mandates the greatest possible utilization of existing and future facilities. And here GASP (and comparable or related programs) comes in strong. For, thanks to the adaptability of the program itself and the incredible speed and accuracy of the big computers, a school can build a successful schedule to provide for all kinds of innovations without sacrificing efficient utilization of staff and facilities. One GASP user, the principal of a new and highly unconventional high school, says flatly that to schedule his intricate program by hand is a practical impossibility. 'The money and energy and time demanded by a handmade schedule means we either automate or we go out of business' (i.e., revert to a conventional school program).[68]

The impersonal nature of computer-generated master scheduling may enhance constructive criticism of timetabling

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[67] Richardson and Clark, loc. cit., p. 55.

[68] Murphy, op. cit., pp. 7-8.

practices and principles. Aware of the benefit accruing to a school through better scheduling, Egner speculates:

> It would be easier to study critically a computer-produced timetable than one produced by many hours of human endeavour. It might be possible, moreover, to devise a procedure by which several alternative timetables could be produced, each with different characteristics, and the best one chosen. Also new timetables might be constructed to respond to staff changes at different points in the school year.[69]

Computer scheduling could demonstrate the need for stricter application of the basic techniques and principles of sound timetabling. The arbitrary disposition of teachers, time and classrooms clearly militates against construction of a good master schedule, either by hand or by computer. Focusing upon this aspect of computerized master scheduling, Egner reasons:

> There could possibly be a 'feedback', from the unit producing the timetable, to schools, in view of the wealth of data and experience built up. This could include patterns and types of timetabling and organisation, staff requirements and building needs for various kinds of school patterns, and advice on acceptable and non-acceptable constraints and their influence on timetables--in fact on what could and what could not be done. All this could lead to a more systematic and thorough understanding of how available resources of teachers, equipment and accommodation could be usefully and economically combined.[70]

Computerized master scheduling might necessarily make school administrators more keenly aware of the close relationship between effective scheduling, optimal learning

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[69] Egner, op. cit., p. 6.

[70] Ibid.

and efficient school management. Jacobson concluded that:

> Undoubtedly, the patterns of distribution of the data lend support to the idea that administrators in the automated schools to a greater extent than administrators in the manual schools considered scheduling a more important administrative function than other management functions and financial responsibilities .... It may be implied from these results that administrators who have a particularly keen interest in the scheduling processes and programs are the ones who are willing to undertake novel plans for scheduling by computer ....[71]

Regarding the need for school administrators to know precisely what they aim to do in timetabling, Murphy offers this timely advice:

> The basic, comprehensive rule ... is this: before attempting to use GASP to build a schedule, the school administration must strive for the greatest possible clarity and explicitness in what it is trying to do--educational goals, priorities among them, specifics on such details as time pattern, length of school day, ability and other groups.[72]

The inherent benefits of computerized scheduling have been proclaimed to range from "being better able to satisfy both student and teacher needs and preferences"[73] to the "retention of control and resource allocation (preservation of the so-called 'personal factor') by

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[71]Marjory E. Jacobson, "A Study of Scheduling Practices in High Schools Which Employ and Do Not Employ Data Processing" (unpublished Doctoral dissertation, University of Michigan, Ann Arbor, 1966), p. 259.

[72]Murphy, op. cit., p. 34.

[73]Kenneth A. Krahn, "An Investigation to Determine the Extent of Satisfaction with Computer Scheduling in Wisconsin Secondary Schools" (unpublished Master's thesis, University of Wisconsin, Superior, 1974), p. 16.

the timetabler, who is able to work in more relaxed circumstances, with time for rethinking."[74]

Undoubtedly, computerized scheduling could be used advantageously by school administrators.

LIMITATIONS OF AUTOMATED SCHEDULING

Even though the computer is a versatile and powerful machine which is truly revolutionizing our society, there are some limitations to what the computer can do in school master scheduling.

Firstly, the computer can not think. It must be properly programmed. Heller writes:

> ... the computer can do only what it is told to do. The human mind prescribes the alternatives for the computer and provides the criteria for the computer to make choices. The machine cannot make choices that are not programmed.[75]

This recognized inherent weakness of automated scheduling necessitates that the timetabler work with the greatest possible clarity and explicitness when making timetabling decisions and preparing the input data.

Regarding the inability of the computer to make changes and improvements to the input data, Buchsbaum firmly advises:

> The first expression we should learn in computerese is GIGO. Translated ... this vital acronym simply means

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[74]Clark, op. cit., p. 29.

[75]Heller, Chaffee, and Davison, op. cit., p. 81.

> 'garbage in-garbage out,' and this reminds us of the key element of programming: Whatever you put in, you will get out. The computer itself cannot add anything.[76]

Secondly, computerized scheduling programs lack universal application. Each master scheduling program has apparently been developed expressly to meet the needs of a specific school system or university. Parker comments:

> ... no single scheduling model is apt to meet the many needs of a given school. In fact, a general scheduling system bought part and parcel from an industry or outside education agency may be harmful to segments of the student population because it is geared neither to their needs nor those of the school program.

Of the diversity of scheduling programs available to school administrators, Dempster adds:

> ... the differences between the systems ... are as much due to differing perceptions of the problem as to any technical or programming variations.
>
> In practice, the qualitative judgement of the individual schools themselves must be the ultimate arbiters of the merits or otherwise of any system.[78]

Thirdly, due to lack of technical knowledge about computers and programming as well as limited experience with timetabling by computer, school administrators have some difficulty communicating in computer language about timetable matters. There is a communications gap which could militate against the full utilization of the computer

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[76]Walter H. Buchsbaum, Personal Computers Handbook (Indianapolis: Howard W. Sams, 1980), p. 23.

[77]Jack Parker, "Intangibles in the Master Schedule," NASSP Bulletin, LVIII (October, 1974), 82.

[78]Dempster, Lethbridge, and Ulph, op. cit., pp. 30-31.

by school administrators. Richardson provides this bleak, but realistic, perspective:

> Probably the most formidable problem in computer scheduling of secondary schools is not in computers or computer programs but in communications between the principal and the computer. The computer does not understand the principal and the principal does not understand the computer. Computer scheduling agencies employ staffs of scheduling consultants who serve as interpreters between the principal and the computer. The principal must be able to make his desires known to the computer and must understand output from the computer.
>
> When principals become involved in computer scheduling, they must organize their scheduling procedures more carefully than if they are hand scheduling. They must be able to describe their scheduling plans to the computer in precise terms and must pay careful attention to details. The principal can no longer carry his scheduling plans in his mind or on slips of paper.[79]

In a similar fashion, McIssac writes:

> Any principal knows that scheduling schools is not a trivial matter, and scheduling schools by computer is even less trivial. Communication with the computer requires absolute precision of data. Data preparation requires complete understanding of the problem. Complete understanding demands time, money, and effort. The effective expenditure of time, money, and effort assumes careful and meticulous planning. The alternative to planning and understanding is a technical nightmare.[80]

Fourthly, computer scheduling programs could, some fear, accentuate the dehumanization facet of computerized timetabling. Bush poses these rhetorical questions:

> Will something of vital human importance be lost when this significant central task--constructing the

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[79] Richardson and Clark, loc. cit., p. 57.

[80] Donald N. McIssac Jr., "Flexible Modular Scheduling by Computer," Business Education Forum, XXV (May, 1971), 19.

> school schedule--which has always consumed so much of a principal's time and energy is turned over to a big machine? Is there danger of dehumanizing the process of planning the program? Does the student get less personal attention to his needs and interests under a machine schedule?[81]

Concerning the humanistic values inherent in manual master scheduling versus the feared dehumanization facet of computerized master scheduling, Wiley thoughtfully reflects:

> Dating from the earliest attempts to design a computer-based flexible schedule, the school and the computer have found themselves without the clear-cut ability to communicate in profoundly sensitive areas of need versus the viable programming of these needs. The very nature of the scheduling process in the school does not lend itself to the precision of definition required by the computer. Schoolmen do not live in a realm of yes-no. Rather, they are consistently surrounded by a host of "maybe's" and "if-then" propositions. To shift to a yes-no rationalization may cause the schoolman to give up more attention to student-teacher personality consideration than he may wish to. An example might be the knowledge that Johnny should not be placed in Mr. Johnson's class in Algebra I but rather in Mr. Christian's class. While such a simple problem is easy to accommodate in a flexible schedule as a case of one, when multipled by the large number of knowledges a school has about many students it becomes an impossible kind of trade-off in a computer-generated schedule. One of the major truisms concerning a computerized flexible schedule is that the more specificity the school demands on the student dimension, the less capable are present computer programs to accommodate and generate a viable master schedule for that school.[82]

Lastly, but not least importantly, the laissez-faire attitude of educational leaders toward change, particularly

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[81] Robert N. Bush, "Decision for the Principal: Hand or Computer Scheduling," NASSP Bulletin, XLVII (April, 1964), 141.

[82] W. D. Wiley, "Flexible Scheduling: Some Considerations," Business Education Forum, XXV (May, 1971), 15.

technological innovation which could affect educational practices, may well decelerate the widespread use of computerized master scheduling. Addressing the issue of resistance by educators to the acceptance and use of proven technological innovations, Ahl firmly argues:

> While educators regard themselves as avant garde, in many ways they are tradition-bound and resist change.
>
> Technological solutions to the problems of education may well lie outside the accepted framework, hence educators may not recognize these solutions or even clearly understand the problems. The technological innovation that has taken place in education is very limited and tends to be isolated pieces rather than brand new systems.[83]

To those school administrators who might consider computerized scheduling, Austin offers this cautious advice:

> Too much must not be expected of even the most impressive equipment. The computer is a first class moron. It has the ability to remember what it has been "told," but it cannot exercise judgement. Frequent communication between the computer operator and school staff is needed to keep the interests of the individual student above the technical display of an electronic device.
>
> The computer must not be used as an excuse to sacrifice schedule flexibility for administrative convenience. It must never control schedule design. It should always be relegated to the role of making lighter the human burden of constructing schedules.[84]

Another voices his concern about the real need for computer-generated master scheduling by gently reminding

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[83] Robert J. Seidel and Martin Rubin (eds.), Computers and Communication: Implications for Education (New York: Academic Press, 1977), p. 171.

[84] David B. Austin and Noble Gividen, The High School Principal and Staff Develop the Master Schedule (New York: Columbia University Bureau of Publications, 1965), p. 95.

high school administrators that:

> With the wonders of the computer as an aid to administration being celebrated on every hand, it is easy to forget that well-organized men can organize a school well unelectronically.[85]

PROMISING FUTURE OF COMPUTERIZED SCHEDULING

Despite the recognized limitations of, and some realistic concerns about, computerized master scheduling, there is every indication in the literature dating back to the early 1960's that computer-generated master scheduling is not only a feasible technological innovation but also perhaps a necessary educational administrative tool. As Johnson says "The computer is a fact of life, one of man's principal tools in coping with his environment."[86]

Of the necessity for computerized scheduling, one American educator writes:

> The complexity of the modern secondary school has focused administrators' attention upon computer-based scheduling techniques .... In many of the larger secondary schools, administrators are finding it virtually impossible to develop schedules that cope adequately with the many alternative time patterns required by modern instructional techniques, and at the same time offer the variety of school experiences demanded to prepare our youth adequately.[87]

Similarly, an Ontario high school administrator concluded in the early 1970's that "With the new subject

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[85] Paul A. Lucey, "Until the Computer Arrives," NASSP Bulletin, LI (March, 1967), 96.

[86] Johnson, op. cit., p. vii.

[87] Heller, Chaffee, and Davison, op. cit., p. 64.

promotion system, however, computerization became essential if we hoped to accommodate all the options."[88]

Undoubtedly, computer-generated master scheduling has a very promising future not only in the United States and Canada, but also in several other countries, notably England, Norway, Sweden and Denmark. School administrators in these countries, as well as others, are now, more than ever before, fully recognizing computer-assisted scheduling as a highly desirable, if not a necessary, new dimension of educational administration. Like others, Bushnell reasons that "The promise of computer technology is that the automation of planning for instructional systems could lead to the better education of each individual student."[89]

Stressing the important contemporary technological contribution which computerized timetabling has to offer to the educational system, Bush writes:

> .:. the application of those modern procedures to high school scheduling appears most promising. The use of computers, however, demands a much more thorough analysis of the problems and decisions involved than has been necessary under more straightforward manual systems of scheduling. It is important to identify the appropriate contribution of machine technology. It is erroneous ever to assume that machines will be able to make decisions. They can only implement decisions involving an intricate series of interlocking factors, each of which can be reduced to logical alternatives. Further, the use of the computer can suggest new alternatives to consider, based upon

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[88]"This Computerized Scheduling Also Works for Small Schools," School Progress, XLII (March, 1973), 34.

[89]Bushnell and Allen, op. cit., p. 58.

more sophisticated procedures uniquely related to machine capacity.[90]

Placing the contribution of the computer and the school administrator in the proper perspective, Johnson remarks:

> It is common to find persons who ascribe human-like qualities to the computer, perhaps viewing it as a giant brain. To some, the machine represents a kind of magic box.
>
> The notion that the computer is an intelligent machine is a misnomer since it possesses no inherent reasoning ability. If by some means it were possible to measure the intelligence of a computer, the value would be zero. Rather than a thinking machine, it is more aptly described as a thinking man's machine. The man behind the machine is more important than the machine itself.[91]

Clearly, the potential of computerized scheduling lies with the school administrator in his acceptance of the computer as an administrative tool for modern times and his stricter adherence to the proven techniques and principles of rational timetabling. It must be fully understood that no matter how sophisticated the computer hardware and software, the burden of responsibility for appropriate use of computer scheduling programs still rests with the school administrator.

Of this who-controls-whom relationship between the computer and the school administrator, Richardson explains:

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[90]Robert N. Bush and Dwight W. Allen, A New Design for High School Education (New York: McGraw-Hill, 1964), pp. 5-6.

[91]Johnson, op. cit., p. 5.

> In scheduling, the computer simply performs a task according to rules laid down by the principal. The principal can formulate or change rules as he wishes. He can also step in at any point and change scheduling decisions made by the computer. The computer will follow exactly the instructions given to it, whether these instructions are right or wrong. If the correct instructions are given, the computer will schedule correctly more than 200 pupils per minute. Given erroneous instructions, the computer will schedule incorrectly at the same rate.[92]

There can be no doubt that "Considerable potential exists for using the computer as an administrative aid to school management."[93]

Similarly, Egner has concluded that "Not only can the time and painstaking and sometimes frustrating labours of Heads and colleagues be greatly reduced, but more effective and economical arrangements are within our grasp"[94] through the computer and any one of a number of technically excellent computer master scheduling programs.

Michalsen holds the firm conviction that "Regardless of purely economical evaluations .... The school scheduling problem is ... one of the areas where the computer is expected to be particularly valuable"[95] in the immediate future.

Clearly, computerized scheduling has, as the majority of the literature indicates, a very promising future.

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[92] Richardson and Clark, loc. cit., p. 54.

[93] LAMSAC Project Report, op. cit., p. 35.

[94] Egner, op. cit., p. 14.

[95] Michalsen, op. cit., p. 1.

BASIC PRINCIPLES OF TIMETABLING

The potential of computerized master scheduling is not solely dependent upon the capabilities of the large computer, nor any one specific computer scheduling program. Rather, its widespread use depends largely upon the timetabling skills and organizational creativity of computer-receptive school administrators. It is essential, as some of the literature suggests, that school administrators more strictly apply the basic techniques and principles of sound timetabling, for "Good schedules don't just happen! They require time, effort and much attention to tedious detail."[96]

Regarding the lack of literature on, and studies about, the basic techniques and principles of timetabling, Brookes comments:

> Given the growing complexity of school organization it might be supposed that there has been a parallel development in the understanding of timetabling practices. Regretably this development has not taken place with the result that timetablers find themselves coping in isolation with an administrative problem of ever-increasing difficulty.
>
> Symptomatic of the lack of well-established guidelines for timetabling is the feeling experienced by most timetablers that their labours could have yielded better results in terms of quality and effectiveness. In particular they feel that fewer compromises could have been made in producing the timetable.[97]

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[96] Parker, op. cit., p. 81.

[97] John E. Brookes, C. Dixon, and M. N. Zarraga, STAS Report: The Mechanics of School Timetabling (London: Royal Institute of Public Administration, 1975), p. 3.

Not only in England, but also in Canada and the United States, the practical problems associated with master scheduling have received limited attention. Clearly, the basic techniques and principles of sound timetabling have been studied less, so the literature would indicate, than this important aspect of educational administration deserves.

School scheduling can be improved, as recent studies have shown, but it must be fully realized that:

> One of the major causes of difficulty with timetable construction is the apparent lack of appreciation, by heads of department and timetablers alike, of the simple fact that there are, from a timetabling point of view, desirable and undesirable ways of combining resources.[98]

It seems indefensible that school administrators assume that any initial combination of teachers, courses, rooms and time, coupled later with ad hoc compromises of these interrelated resources, will necessarily produce a good master schedule. As Brookes realistically advocates, "it is ... of central importance to consider the advantages and disadvantages of alternative ways of combining resources."[99]

Sound timetabling is comprised of three stages. Brookes explains:

> First comes the thinking stage which can start with the new academic year .... The thinking stage is concerned with the formulation of objectives and the bringing

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[98]John E. Brookes, Timetable Planning (London: Heinemann Educational Books, 1980), p. 7.

[99]Ibid.

> together of many influences, both internal to the school and external to it. 'Is the present timetable meeting all the demands made on it?' 'Are there new ideas in education that we want to try out in the next timetable?' 'What sort of option scheme are we going to introduce in next year's fourth year?' 'Are we doing enough in the remedial department?' 'Was the introduction of a second foreign language in the first year a good idea?' These are some of the questions that may need to be considered at the thinking stage and, hopefully, to which general answers will be found. In other words, what are the educational objectives that the next timetable must try to satisfy?
>
> Second comes the planning stage. We know in general terms by the time this stage is reached what it is we want to achieve. The next question is 'can it be done?' Timetable planning is concerned with questions of feasibility; with evaluating in terms of resources and their availability whether or not the educational objectives of a school are workable.
>
> Third comes timetable construction, followed by the clerical task--not to be underestimated--of preparing the timetable for general circulation.[100]

The timetabling process has two very significant features. Brookes elaborates:

> First, timetabling is a dynamic process rather than a static one. That is to say the timetabler is not concerned with finding a solution to a problem with fixed parameters, but is rather concerned with the way these parameters can, and often must be changed as a result of interaction with each other and as a result of other pressures. Second, and stemming from the dynamic nature of the problem, timetabling is an interactive process involving a continual cycle of consultation and modification. In most schools it is common to find that the timetabler needs frequently to consult his heads of department and other members of staff as the process continues.[101]

To enable school administrators to deal much more effectively with master scheduling at the planning stage,

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[100] Ibid., p. 2.

[101] Ibid., p. 3.

the British School Timetabling Applications Group (STAG), as a direct result of its experience with the development of the Nor-Data School Scheduling System during the early 1970's, offers some very useful guidelines for timetabling, either manually or by computer.

In order to improve the quality of the timetable, the School Timetabling Applications Group firmly contends that the number of compromises which school administrators typically make to produce a workable master schedule, either manually or by computer, must be reduced. Concerning this fundamental timetabling problem, Brookes elaborates:

> It is easy for a timetabler to forget the compromises he has been forced to make in his efforts to produce a timetable. Nevertheless the following examples will be familiar to most timetablers:
>
> -too many periods of the same subject on the same day for the same class.
>
> -first choice teachers not available in certain periods.
>
> -non-specialist teachers forced to teach specialist subjects.
>
> -classes shared by two or more teachers for the same subject at different times of the week (when continuity would have been preferred).
>
> -multiple periods spanning breaks and lunch.
>
> -reduced number of teaching periods ....
>
> -breaking setting and other requirements involving several classes simultaneously.
>
> -specialist accommodation not always available when needed.
>
> These examples of common compromise, along with others, combine to reduce the quality of the finished timetable.[102]

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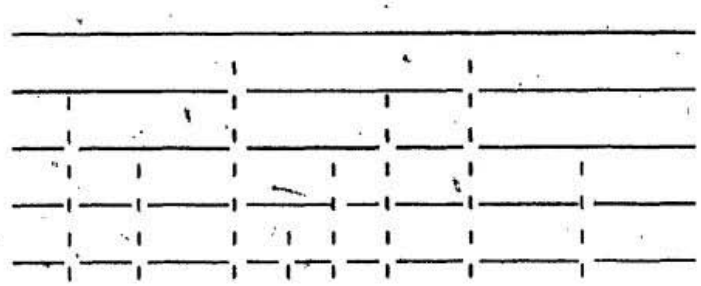
[102]Brookes, Dixon, and Zarraga, STAG Report, p. 3.

PRINCIPLE OF COMPATIBILITY

So that school administrators may avoid many of the forced compromises which are known to adversely affect the quality of the master schedule, the School Timetabling Applications Group strongly recommends the application of the Principle of Compatibility, which is "a guiding principle for constructing teams of resources, whether these are teachers, classes, rooms, or other resources"[103] to ensure that they are not in conflict with each other.

Of this fundamental but practical principle of timetabling, which STAG claims will ensure the effective allocation of teachers, classes, rooms, subjects and time, Brookes offers this general definition:

> The Principle of Compatibility states that given a universal set of resources a hierarchy of sub-sets should be chosen such that the sub-sets at any level are themselves sub-sets (proper or otherwise) of the next higher level.



> Distinct partitions can thus be made from any level to a lower level, showing no overlapping.[104]

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[103] Brookes, Timetable Planning, p. 10.

[104] Brookes, Dixon, and Zarraga, op. cit., p. 10.

To stress the implications of this basic principle of good timetabling, Brookes provides school administrators with this sound advice:

> From a timetabling point of view it is clear that strict adherence to the Principle of Compatibility can make life very much easier. In practice it may be necessary, for sound educational reasons, to depart from the ideal. The important point, however, is for timetablers to appreciate that departures from the Principle of Compatibility necessarily involve a loss of flexibility in timetabling terms, with the consequent possibility of reduction in the quality of education.[105]

This fundamental master scheduling Principle of of Compatibility is briefly explained but well illustrated by the School Timetabling Applications Group in its 1975 report, The Mechanics of School Timetabling. The following selected examples will illustrate how school resources can be more thoughtfully allocated to enhance the quality of the master schedule.

Teacher Teams

In all schools, teams of teachers are required to teach simultaneously for various reasons: to allow students a choice of courses; to permit male-female groups; to reduce the size of a group, etc. The teacher combinations which the school administrator initially chooses, therefore, are very important, for incompatible teacher teams will invariably cause timetable construction problems later. Brookes states very firmly that:

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[105] Ibid.

> The choice of teacher teams from a given pool of teachers is of paramount importance in determining flexibility in timetabling. The ideal choice is that which enables the entire pool of teachers to teach simultaneously if need be for any period of the week.[106]

This figure[107] clearly indicates one of the many ways of inadvertently creating overlapping, and therefore, incompatible teacher teams.

TEACHERS

	1	2	3	4	5	6
Year 1 Group 1	X	X	X			
" " 2	X			X	X	
Year 2 Group 1	X		X			X
" " 2	X	X		X		
Year 3 Group 1	X				X	X
" " 2		X		X		X
Year 4 Group 1		X	X		X	
" " 2		X			X	X
Year 5 Group 1			X	X	X	
" " 2			X	X		X

In this extreme example, each of these teacher teams "overlap (i. e. mathematically are not disjoint) in each case, with the result that there is no flexibility

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[106] Ibid., p. 5.

[107] Ibid., p. 6.

for the timetabler to exploit."[108] It demonstrates very poor timetable planning.

In contrast, the following figure[109] illustrates how teacher teams could be effectively created to permit maximum timetabling flexibility.

TEACHERS

	1	2	3	4	5	6
Year 1 Group 1	X	X	X			
" " 2				X	X	X
Year 2 Group 1	X	X	X			
" " 2				X	X	X
Year 3 Group 1	X	X	X			
" " 2				X	X	X
Year 4 Group 1	X	X	X			
" " 2				X	X	X
Year 5 Group 1	X	X	X			
" " 2				X	X	X

In this simplistic example, there are only two basic teams of teachers which are "disjoint (i.e. non-overlapping) and therefore can be timetabled simultaneously,"[110] which would be ideal timetable planning. In reality, however,

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[108] Ibid., p. 7.

[109] Ibid., p. 8.

[110] Ibid., p. 9.

teacher teams for various option schemes are often not of the same size and composition; therefore, some overlapping sub-sets, or incompatible groups of teachers, would perhaps necessarily exist within the staff of most schools. The important task of the administrator is to minimize, if not eliminate, these overlapping, conflict-prone teacher teams.

Regarding these hypothetical cases, Brookes contends that "These examples underline the importance of thinking very carefully about the initial choice of teams since this obviously affects subsequent choice of teams if the Principle of Compatibility is to be followed."[111]

Cognizant that timetabling is something more than a purely mathematical problem, Brookes writes:

> In many practical cases it will not be possible to form completely compatible teams: staff and teaching situations do not always lend themselves to the neat mathematical requirements of the Principle of Compatibility. The importance of the Principle is however that it helps the timetabler, and the heads of department, to understand and evaluate the effects of their particular resource requirements and thus enables them to work towards a more consistent and logical approach to resource planning.[112]

Class Combinations

Like teacher teams, classes may be combined in different ways for different subjects. Overlapping class combinations could be problematic, as shown in this figure.[113]

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[111] Ibid.

[112] Brookes, Timetable Planning, p. 12.

[113] Brookes, Dixon, and Zarraga, op. cit., p. 12.

CLASSES

	4A	4B	4C	4D
Math	XX	XX		
Math			XX	XX
English	XX			XX
English		XX	XX	

About the possible restriction which these class combinations would impose upon timetable construction, the STAG Report provides this commentary:

> Four 4th year classes are combined in pairs for English and Mathematics, but the class combinations are different for the two subjects--4A + 4B and 4C + 4D for Mathematics, and 4A + 4D and 4B + 4C for English. In other words, the class combinations are not disjoint sub-sets. The immediate consequence of this arrangement is that English and Mathematics cannot be timetabled simultaneously anywhere in the 4th year.[114]

The following figure[115] illustrates how these classes could have been more effectively arranged.

CLASSES

	4A	4B	4C	4D
Math	XX	XX		
Math			XX	XX
English	XX	XX		
English			XX	XX

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[114] Ibid., p. 13.

[115] Ibid., p. 12.

The school administrator has to cope not only with class parallelism within the same grade or at the same level, but also with class parallelism across grades or levels. Brookes argues that timetable arrangements in which parallel groups are extended across grade levels in contravention of the Principle of Compatibility will necessarily "cause considerable loss of flexibility ... and lateral movement."[116]

Overlapping, and therefore very undesirable, class combinations across grades are presented in this figure.[117]

SUBJECTS

	1	2	3	4
4A	X	X	Y	Z
4B	X	X	Y	Z
4C	X	X	Y	Z
4D	X	X	Z	X
4E	X	X	Z	X
4F	X	X	Z	X
3A	X	X	Y	X
3B	X	X	Y	X
3C	X	X	Y	X
3D	X	X	Z	Z
3E	X	X	Z	Z
3F	X	X	Z	Z

[116] Ibid., p. 15.

[117] Ibid., p. 14.

Clearly, forming different groups (e.g., Y and Z) for different subjects (e.g., 3 and 4) across two levels will not benefit the principal. The overlapping groups are most likely to create problems. As Brookes reasons, "insistence on overlapping class combinations is bound to mean a harder task for the timetabler who should thus strive to reconcile such incompatibilities and work towards disjoint class combinations wherever possible."[118]

Units of Time

The school week, which is often a curriculum cycle of six teaching days, is a series of non-continuous periods. Double and triple periods are not usually scheduled across recess and dinner hour.

Brookes explains that "Applied to time itself, the Principle of Compatibility simply states that the units of time allocated to any resource must be compatible with the pattern of the curriculum cycle."[119] To state the obvious, one can not have four double periods in a seven-period day, nor can a teacher conveniently have two triple periods daily for some practical course such as Industrial Arts.

Incompatibility of multiple teaching periods can be shown in the following figure.[120]

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[118] Brookes, Timetable Planning, p. 14.

[119] Ibid.

[120] Ibid., p. 15.

PERIODS

	1	2	3	4	5	6	7	8
Day 1	T			D			T	
Day 2	T			D			T	
Day 3	T			D			T	
Day 4	T			D			T	
Day 5	D		D		D		D	

To clarify this frequently overlooked problem of incompatible time units, Brookes elaborates:

> In a given school there is a single woodwork shop and it is required for 40/40 periods. At a superficial level one might suppose that 100 per cent usage of a resource is not out of the question. But if this is to be achieved there must be complete compatibility between the time units allocated to the resource--in this case the woodwork shop--and the structure of the curriculum cycle in terms of divisions into units of time. In this example, suppose that the craft department wanted to use the woodwork shop for eight triples and eight doubles in a forty-period week that had five days of eight periods, each day divided by breaks after periods 3 and 5. /This figure/ shows diagrammatically why this cannot be done without placing multiple periods across breaks.[121]

Room Combinations

Similar benefits can be obtained by combining rooms in accordance with the basic Principle of Compatibility.

CONCLUSION

It is the opinion of the researcher that, as the literature suggests, school administrators need to adopt,

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[121] Ibid.

a more defensible approach to master scheduling. The task of organizing the school is far too great to be left to the whims and idiosyncrasies of any one educator. Adherence to the basic timetabling Principle of Compatibility would most certainly add the necessary ingredients of consistency and logic regarding resource allocations. Wider use of the computer would definitely enable the timetabler to construct the best possible timetable, mathematically speaking, and possibly, the best possible master schedule, educationally speaking.

Of the ideal versus the reality of master scheduling, Brookes offers this insightful comment:

> In practice it will often be impossible to stick rigidly to the Principle of Compatibility either for sound educational reasons or due to some imbalance in the distribution of resources. In the first place it is essential to realize that, of course, sound educational reasons must not be abandoned simply for the sake of timetabling expediency. What is important is that both timetabler and heads of department must be aware of the constraints imposed on timetable construction by 'sound educational reasons'. The main question here is whether the educational requirements can be satisfied in a way more consistent with the Principle of Compatibility and in many cases careful consideration will show that one can go a long way in this direction.[122]

Of the computer as a labour-saving device, D'Ignazio provides this firm conviction:

> The computer is best used as a tool to help people in their work, not function as a replacement for the worker. No matter what kind of work you do, chances are the computer can magnify your skills, help you learn new ideas and techniques, and make your work

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[122] Ibid., p. 12.

more efficient, more intelligent, more creative, and more interesting.[123]

Of the value of computerized master scheduling, the LAMSAC Report contains this very promising conclusion:

> The Steering Committee have concluded that, given the right conditions ... the computer can provide invaluable assistance in producing school timetables. Computer assistance can result in timetables of better quality than those produced manually. Also alternative curriculum plans can be considered.
>
> The Steering Committee believe that the construction of the timetable is an annual problem which a large majority of schools find very difficult. Any assistance which gives a better quality solution to this problem should be considered because of the multitude of benefits which can ensue. These benefits which follow when computer aid is used include the following:
>
> Better use of resources (teachers, specialists rooms, etc.).
>
> Saving of time for timetabling staff so that they may give more attention to other essential duties.
>
> A thoroughly checked timetable with full or part. copies available for all concerned.
>
> Less stress on timetabler.
>
> An option structure better suited to demand.
>
> A teaching staff more informed on general timetabling possibilities and difficulties and the need for planning.[124]

Undoubtedly, computer-generated master scheduling has established itself as a very promising new dimension of educational administration.

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[123] Fred D'Ignazio, Small Computers: Exploring Their Technology and Future (New York: Franklin Watts, 1981), p. 116.

[124] LAMSAC Project Report, op. cit., p. 37.

CHAPTER III

DESIGN OF THE STUDY

The design and organization of this computerized timetabling study revolves around the Nor-Data School Scheduling System, a Norwegian computer master scheduling program which was developed in 1966, and which has since been considerably improved, by Harald Michalsen.

The singular objective of this computerized master scheduling research with the Norwegian Nor-Data School Scheduling System was to produce complete and useable alternative 1982-83 master schedules for three high schools and one elementary/junior high school within the Province of Newfoundland and Labrador.

This study, which pertains to a new and challenging facet of educational administration, computer-assisted master scheduling, became feasible within the Province during 1982 for several reasons. Had these necessary research conditions not been met, this study would not have been completed.

Firstly, Harald Michalsen, the creator of this very powerful and versatile computer master scheduling program, was agreeable during May of 1982 to provide the researcher without any charge with the English version of the computer tape for the Norwegian Nor-Data School Scheduling System, on the condition that the researcher and his associates

would use the program exclusively for the trial timetable productions which had been initiated by this study.

Secondly, Newfoundland and Labrador Computer Services Limited decided during July of 1982, upon the recommendation of its Manager of Scientific Services, Stephen Andrews, to substantially support this experimental work with the Nor-Data School Scheduling System by providing the researcher free of charge with a computer programmer and the necessary computer time to ascertain whether this Norwegian computer scheduling program could satisfactorily generate the master schedules for the four participating schools. One must fully appreciate that during the 1970's Newfoundland and Labrador Computer Services Limited had unsuccessfully experimented with no fewer than three other computer master scheduling programs. It did not want to participate in yet another unsuccessful computerized timetabling project.

Thirdly, Memorial University of Newfoundland, through the very persistent effort of the Head of the Department of Educational Administration, allocated sufficient funds during September of 1982 to enable Harald Michalsen, who resides at Kloebu near Trondheim in Norway, to visit our Province without remuneration for a two-week period during November of 1982. The four participating school administrators and the two computer programmers could, therefore, benefit from his expert advice during the critical seven-day timetable construction period at Newfoundland and Labrador Computer Services Limited. One must realize that the success of this

master scheduling study was largely, if not solely, dependent upon the on-site availability of Harald Michalsen as our very best timetabling consultant regarding the Nor-Data School Scheduling System. Our use of, and total reliance upon, the User's Guide[1] and the Operator's Manual[2] by themselves could not have ensured success, for these materials, which are very valuable references, were never intended to be used as a "do-it-yourself" guide to computer master scheduling with the Norwegian Nor-Data School Scheduling System.

The inspiration for this study come to the researcher from several sources.

As a high school administrator, the researcher had experienced some difficulties and frustration during the past eight years when manually constructing the annual master schedule for Mountain Feild Central High School at Forteau, Labrador South. Cognizant that most manually-constructed timetables often leave much to be desired, not only from the viewpoint of the recipients (the classroom teachers and the students) but also from the viewpoint of the creators (the school administrators), the researcher had frequently asked: Could the master schedule be produced better, and perhaps more quickly, by computer? Feedback was usually negative.

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[1]John Brookes, RIPA User's Guide: Nor-Data Computer Assisted School Timetabling (London: Royal Institute of Public Administration, 1978), pp. 1-63.

[2]John Brookes, CAST Operator's Manual for the Nor-Data School Timetabling System (London: Local Government Operational Research Unit, 1979), pp. 1-148.

As a graduate student at Memorial University of Newfoundland during 1981-82, the researcher was pleasantly surprised to learn that Joseph Price, a Newfoundland high school administrator, had experimented with the Stanford School Scheduling System during 1972-73. What was most encouraging about that research was that Price, who had failed with that particular American computer scheduling program to produce a satisfactory, useable computer-generated master schedule for 1973-74 for Lester Pearson Memorial High School at Wesleyville, concluded that computerized master scheduling was nevertheless a potentially useful alternative approach to our manually constructing the master schedule by the conventional trial-and-error, hand-mosaic method. Price recommended, therefore, that an effort should be made to find a different, and more promising, computer scheduling system which could effectively deal with the timetabling problems of high school administrators throughout Newfoundland and Labrador. It was he who provided the researcher with the impetus to find that alternative computer master scheduling system.

Through a preliminary search of the literature, the researcher was fortunate indeed to find a very interesting article[3] in which Zarraga and Bates most favourably reported upon the Norwegian Nor-Data School Scheduling System which

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[3]M. N. Zarraga and S. Bates, "Computer Timetabling and Curriculum Planning," Educational Research, XXII (February, 1980), 107-120.

has been used very successfully in England since the early 1970's. Subsequent correspondence from the Local Government Operational Research Unit at Reading in England provided the researcher with some very convincing reports about the technical and timetabling excellence of the Nor-Data School Scheduling System. That article, "Computer Timetabling and Curriculum Planning," was the basis from which this study grew.

PARTICIPATING SCHOOLS

Four schools and their principals were selected to participate in this computerized master scheduling study. Each was chosen for personal and circumstantial reasons, for it was judged inappropriate to choose the participants for this study on the basis of a random selection of high schools throughout the Province.

The only St. John's school involved in this study was Gonzaga High School, which is operated by the St. John's Roman Catholic School Board. During the 1982-83 school year, Gonzaga High School had a staff of thirty-one and an enrolment of approximately 500 boys in Grade Nine and at Levels One and Two of the Reorganized High School Program. The assistant principal, John Martin, was involved in the 1979 experimental work with the Columbia School Scheduling System. He is keenly interested in computerized master scheduling as a futuristic means of effecting better school management.

The largest school involved in this research was Ascension Collegiate, which had a staff of thirty-eight and an enrolment of approximately 700 in Grade Nine and at Levels One and Two of the Reorganized High School Program during the 1982-83 school year. Located at Bay Roberts, Ascension Collegiate is operated by the Avalon North Integrated School Board. Its principal, Frederick Bullen, is very optimistic about the future of computer-assisted master scheduling in the Province.

The other two schools involved in this study were John Burke High School and Partanna Academy, both of which are located at Grand Bank and operated by the Burin Peninsula Integrated School Board.

During 1982-83, John Burke High School had a staff of fourteen and an enrolment of approximately 225 in Grade Nine and at Levels One and Two of the Reorganized High School Program. Its principal is the researcher.

Partanna Academy had during 1982-83 a staff of twenty-six and an enrolment of approximately 500 in Grades Three through Eight. Its principal, John Tucker, shares an equally strong interest in computerized scheduling.

With the exception of Partanna Academy, representative elementary schools were purposefully excluded, for the thrust of this computerized scheduling feasibility study deals with the master scheduling problem at the high school level, particularly as it relates to the Reorganized High School Program. However, since John Burke High School and

Partanna Academy share no fewer than seven of its staff, the researcher welcomed the "split-site" timetabling problem as a challenge, not an impediment, for the Nor-Data School Scheduling System.

Totally, the target population for this study was comprised of over 100 teachers and nearly 2,000 students.

QUESTIONNAIRES

A secondary, but very significant question posed by the researcher was: Would the teachers of these four chosen schools judge the computer-generated timetables to be better than their manually-constructed 1982-83 timetables?

To solicit an answer to that pertinent question, the researcher devised two questionnaires.

The first questionnaire (See Appendix A), which was distributed to these teachers by their respective principal during November of 1982, requested that each teacher, with the exception of special education teachers and full-time administrators, evaluate as objectively as possible his/her 1982-83 manually-constructed timetable. Accompanying each of these initial timetable evaluation questionnaires was a letter of explanation (See Appendix B) from the researcher.

The second questionnaire (See Appendix C), which was distributed in the same manner during December of 1982, asked that each of these teachers evaluate as objectively as possible his/her alternative computer-generated 1982-83 timetable. With this second timetable evaluation questionnaire,

each teacher received from the researcher not only a letter of explanation (See Appendix D), but also a complimentary copy of his/her computer-generated timetable as produced by the Nor-Data School Scheduling System.

Through these questionnaires, the researcher sought a comparative qualitative assessment by the teachers of their 1982-83 manually-constructed timetables versus their computer-generated timetables. On both questionnaires, which had a Likert-type answering scale, the following criteria underscored the questions:

1. Basic subject requirements filled?
2. Workload preferences honoured?
3. Balanced distribution of periods per subject?
4. Overall satisfaction with the timetable?

Furthermore, each teacher was given an opportunity to delineate any unsatisfactory aspects of either timetable. The researcher acknowledges that the responses of teachers were necessarily somewhat subjective in nature.

Each participating school administrator served as a liaison between his staff and the researcher.

NORWEGIAN NOR-DATA SCHOOL SCHEDULING SYSTEM

The Norwegian Nor-Data School Scheduling System was chosen for this research simply because it had been judged, particularly by British educators, to be superior to all of the other commercially available computer master scheduling programs. It has variously been described as "technically

excellent,"[4] "superior to any systems previously tried"[5] and "the most flexible and sophisticated timetabling system to appear to date."[6]

Following a careful analysis of the literature on computer-assisted master scheduling, particularly the books and articles by British authors about the Nor-Data School Scheduling System, the researcher deduced that the Norwegian computer scheduling program developed by Harald Michalsen would be technically capable of very successfully tackling any of the timetabling problems confronting high school administrators throughout Newfoundland and Labrador.

No serious consideration was given to initiating a second feasibility study of the Stanford School Scheduling System, the Columbia School Scheduling System or the Ontario School Scheduling System. Initial efforts during the 1970's at timetabling with these computer scheduling programs had failed. Neither held, in the opinion of the researcher, any further potential for high school administrators in this Province.

A thorough survey of the literature clearly indicated to the researcher that there was no other American, Canadian or British computer master scheduling program which had been

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[4] Ibid., p. 107.

[5] LAMSAC Project Report: Computer Assisted School Timetabling (London: Local Authorities Management Services and Computer Committee, 1978), p. 4.

[6] Brookes, RIPA User's Guide, p. 1.

judged more technically capable and educationally promising than the Norwegian Nor-Data School Scheduling System.

Early Development

Accepting master scheduling as a very challenging computer problem, Harald Michalsen developed the Nor-Data School Scheduling System at the Technical University of Norway during 1966. His assumption was that "a computer program is not only a desirable alternative to manual scheduling, but in many cases ... actually a necessity to have a reasonable chance of satisfying actual requirements."[7]

Regarding its early development, Michalsen reports in his Doctoral dissertation that:

> The original objective was to develop a program to satisfy the local NTH requirement. This work started in January 1966, and as early as summer 1966 a computer made schedule was introduced. It was considered quite acceptable and in several ways superior to a manual schedule.
>
> The first program version was based on relatively simple heuristic principles (they were, however, similar to the more general strategy eventually developed). The objective was reformulated to design an operative program system for any Norwegian school structure and if possible find general principles for solution of the scheduling problem.[8]

The initial assessment of the capabilities of the Nor-Data School Scheduling System by Norwegian educators was

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[7]Harald Michalsen, A Working Strategy for General School Scheduling (Trondheim: The Engineering Research Foundation at the Technical University of Norway, 1971), p. 1.

[8]Ibid., pp. 14-15.

quite favourable. The following figures,[9] which show the number of schools scheduled by the Nor-Data School Scheduling System during the first five years of its use, are clearly indicative of its initial popularity as well as its perceived educational administrative value.

1966: 2 schedules
1967: 4 schedules
1968: 27 schedules
1969: 83 schedules
1970: 100 schedules

Michalsen realistically contended initially that "If the dissatisfaction can be limited to less than 5%, the program should be considered satisfactory from an operative viewpoint."[10] Revisions to the program have guaranteed that user dissatisfaction has been minimal.

Of its initial impact on the teachers and students, Michalsen comments:

> The main impression is that by means of the program system the requirements considered essential are more easily satisfied, while a manual scheduler has better possibilities for utilizing particular circumstances. (To compensate for this the computer made schedules can be adjusted manually.) Newspapers tend to characterize the program system as "studentfriendly" (as opposed to "teacherfriendly"). It would be more appropriate to say that the program gives higher priority to the most important requirements. As a natural consequence the advantages of computer made schedules increase as the problem becomes more complicated.[11]

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[9] Ibid., p. 15.

[10] Ibid., p. 16.

[11] Ibid., p. 17.

Technical Aspects

The computer program for the internationally-used Norwegian Nor-Data School Scheduling System, which consists of some 15,000 to 20,000 FORTRAN[12] instructions, was written by Harald Michalsen during 1966 for the UNIVAC[13] 1108 computer. Since then, the computer program has been revised for use on the IBM 360, as well as the Honeywell, computer. The English version of this Norwegian computer program is totally compatible with the new AMDAHL[14] 470V/6 computer at Newfoundland and Labrador Computer Services Limited.

Concerned initially about the adaptability of the Nor-Data computer program to the Newfoundland computerized scheduling environment, Michalsen firmly states: "I would assume that the IBM-OS version will work on your computer without problems. This is a vital assumption."[15] The fact is, the Nor-Data computer program performs admirably on the AMDAHL computer. There is no technical problem whatsoever.

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[12]FORTRAN is an acronym for FORmula TRANslator, a high-level computer language that is used to perform mathematical computations. Larry Noonan, The Age of Computer Literacy (Toronto: Oxford University Press, 1983), p. 317.

[13]UNIVAC is an acronym for UNIVersal Automatic Computer which was completed by Mauchly and Eckert in 1951. The Age of Computer Literacy, p. 327.

[14]The AMDAHL computer was developed by Gene Amdahl during the mid-1970's at Amdahl Corporation in the United States. It has even greater processing power than the IBM computer.

[15]Letter to researcher from Harald Michalsen; Kloebu, Norway, August 20, 1982.

Most computer scheduling programs have an upper limit regarding how many teachers, subjects and classes they can schedule. Notably, the Nor-Data program has "no upper limit for how large schedules can be handled....."[16]

Unique Timetabling Structure

Unlike other computer master scheduling programs, the Nor-Data School Scheduling System is comprised of three separate but interrelated programs: the FORPROGRAM, the MAINPROGRAM and the OUTPUT PROGRAM.

The FORPROGRAM has the capability to thoroughly check the initial input data to determine whether there are any timetabling impossibilities. The 1978 LAMSAC Report contains this lucid explanation:

> Part I of the FORPROGRAM checks the data for obvious errors such as totals of class periods and periods taught by each teacher. A map of all activities in the submitted data is printed together with lists of class names and room utilisations. A list of Terminal Combinations is set up where a Terminal Combination is a set of conflicting activities because they have a common resource. This means, of course, that these activities cannot be timetabled simultaneously.
>
> Error messages as a result of the FORPROGRAM Part I indicate simple discrepancies in data such as a teacher specified for an activity but the teacher not included on original list of teachers. Another error could be that a pre-assigned activity might include a resource already being used during the period of pre-assignment.
>
> With these errors removed the second part of the FORPROGRAM is applied. FORPROGRAM Part II searches for timetabling impossibilities as well as for severe constraints. The impossibility is referred to by a Terminal Combination number from which teacher and

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[16] Michalsen, op. cit., p. 18.

class may be deducted. This is followed by showing that there are insufficient suitable periods available to satisfy the requirement. Action should normally be taken by amending data to relieve difficulties discovered before proceeding with the MAINPROGRAM.[17]

The MAINPROGRAM of the Nor-Data School Scheduling System constructs the master schedule. It is unique, for it has been expressly designed to "give the user control over timetable construction, both in terms of the priorities in different parts of the school and in terms of how much of the timetable is tackled in any run."[18]

The LAMSAC Report provides this all-encompassing overview:

> The MAINPROGRAM is responsible for constructing the timetable. It is possible for the timetabler to "steer" this construction by deciding on a sequence for offering various parts of the whole problem. Because of large option groups the timetabler may ask for Years 4 and 5 to be constructed first followed, perhaps, by the Sixth form requirements, then option groups in Years 2 and 3, then the rest of Year 3 and finally the remaining parts of Years 1 and 2.
>
> Variations on this could include a steering directive which asked for all activities which included a particular group of teachers, or all activities where essential double periods were involved, etc. The Program itself having set up Terminal Combinations which, in general have mutually conflicting activities will allocate activities in a sequence depending on their degree of freedom. Those activities with the same degree of freedom will be ranked by two other criteria, namely period length and day-conflict. As an activity qualifies to be placed next the program sets up a "conflict picture" of activities still to be placed and positions the activity to cause least conflict with activities still to be placed. This is referred to as the "look ahead" quality of the program. Although the steering directive

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[17] LAMSAC Project Report, op. cit., p. 51.

[18] Brookes, CAST Operator's Manual, p. 1.

given may specify placements to be made the "look ahead" quality considers all the data unless some suppression has been requested. The program may over-ride a steering directive when a difficult situation occurs.

Although the timetabler probably has other considerations, his steering directives will largely depend upon his own evaluation of the degree of freedom each requirement has. Similar reasoning takes place within the computer program. The timetabler can control how much is tackled in one run without removing any data.

After each MAINPROGRAM run a printed summary of the timetable constructed so far is produced together with a list of unfitted activities. The summary is in three parts. The first shows teachers against periods of the timetable cycle stating form or group of pupils they are teaching. The second shows forms against periods of the timetable cycle and the activity of each period. The third is a summary of room allocation.

From this information the timetabler must make changes to accommodate the unfitted lessons. This will usually entail changing staff deployment or breaking distribution rules until an acceptable solution is found. The corrected data which is specified by using further punched cards and adjusted partial timetable are now "frozen" and used as input together with the next iteration for the next FORPROGRAM run. This, in turn, creates an output tape that is used in the next MAINPROGRAM run and the process is continued as necessary.[19]

To fully appreciate the kind and amount of control which the school administrator can have over the computer construction of the master schedule through the MAINPROGRAM is to understand this unique and very significant feature of the Nor-Data School Scheduling System. It should do much to allay the fears of those who claim that, through computer-generated master scheduling, educators and students

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[19] LAMSAC Project Report, op. cit., p. 51.

will necessarily become subservient to the computer. With the MAINPROGRAM of the Nor-Data School Scheduling System, technological expediency should remain secondary to sound educational planning.

The OUTPUT PROGRAM makes the final modifications to the master schedule before printing the school's timetable in full as required by the school administrator.

The LAMSAC Report gives this explication:

> The OUTPUT PROGRAM prints the timetable in an easily understandable form. Facilities exist on the input forms so that the user can eliminate all unwanted codes at this stage and have his own subject names, teacher initials and room numbers, etc. Three main timetables are produced and these are for classes (showing subject, teachers and rooms for each period) for teachers (showing subjects, classes and rooms for each period) and for rooms (showing subject, class and teacher for each period). On the class timetable, multiple periods are shown in 'boxes' of the appropriate size and where classes are taught simultaneously the dividing lines between the classes are omitted. For groups of subjects a collective title may be given if desired instead of subjects being printed but all teachers and rooms used are stated. The teacher timetable indicates lessons where setting is used and free periods are shown as blanks. Individual class and teacher timetables can be printed in addition to the main timetables.
>
> The OUTPUT PROGRAM will update a partial timetable after manual adjustments have been made, it will allocate specific rooms to activities and it will check the completed timetables to ensure that errors have not been introduced during the adjustment process. This program, of course, will not be requested at an intermediate stage of the timetable construction process unless it is required for a special reason.[20]

There should be no doubt that the Nor-Data School Scheduling System is not only uniquely designed but also

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[20] Ibid.

extremely well programmed to effectively tackle the master scheduling problem of most, if not all, schools, whether in Norway or in Newfoundland and Labrador, or elsewhere.

Program Use

Users of the Nor-Data School Scheduling System must fully appreciate two fundamental aspects of computer master scheduling: firstly, how the three separate parts of this program work together as a unit; secondly, how the school and the computer must necessarily interact as a team. This timetabling process is shown diagrammatically in the figure[21] on the following page.

Brookes offers this description of that process:

> Data Preparation - the school will complete a set of pre-printed data tables .... Anyone responsible for using the computer programs must be completely familiar with the data specifications.
>
> Screening - before data are punched on cards for program input, it is important to check visually for obvious errors. This saves both computer time and effort later on.
>
> Running the FORPROGRAM - when screening is completed and any corrections made, the data are punched onto cards and used as input to the FORPROGRAM. Errors in syntax normally must be corrected, and it is important also to eliminate any timetabling impossibilities revealed at this stage.
>
> Steering etc. - when the data is free from error or when the operator is satisfied that further FORPROGRAM runs are unnecessary, the MAINPROGRAM can be run. The first step is to prepare STEERING DIRECTIVES. These convey to the MAINPROGRAM the school's priorities and also draw the program's attention to areas of known difficulty.

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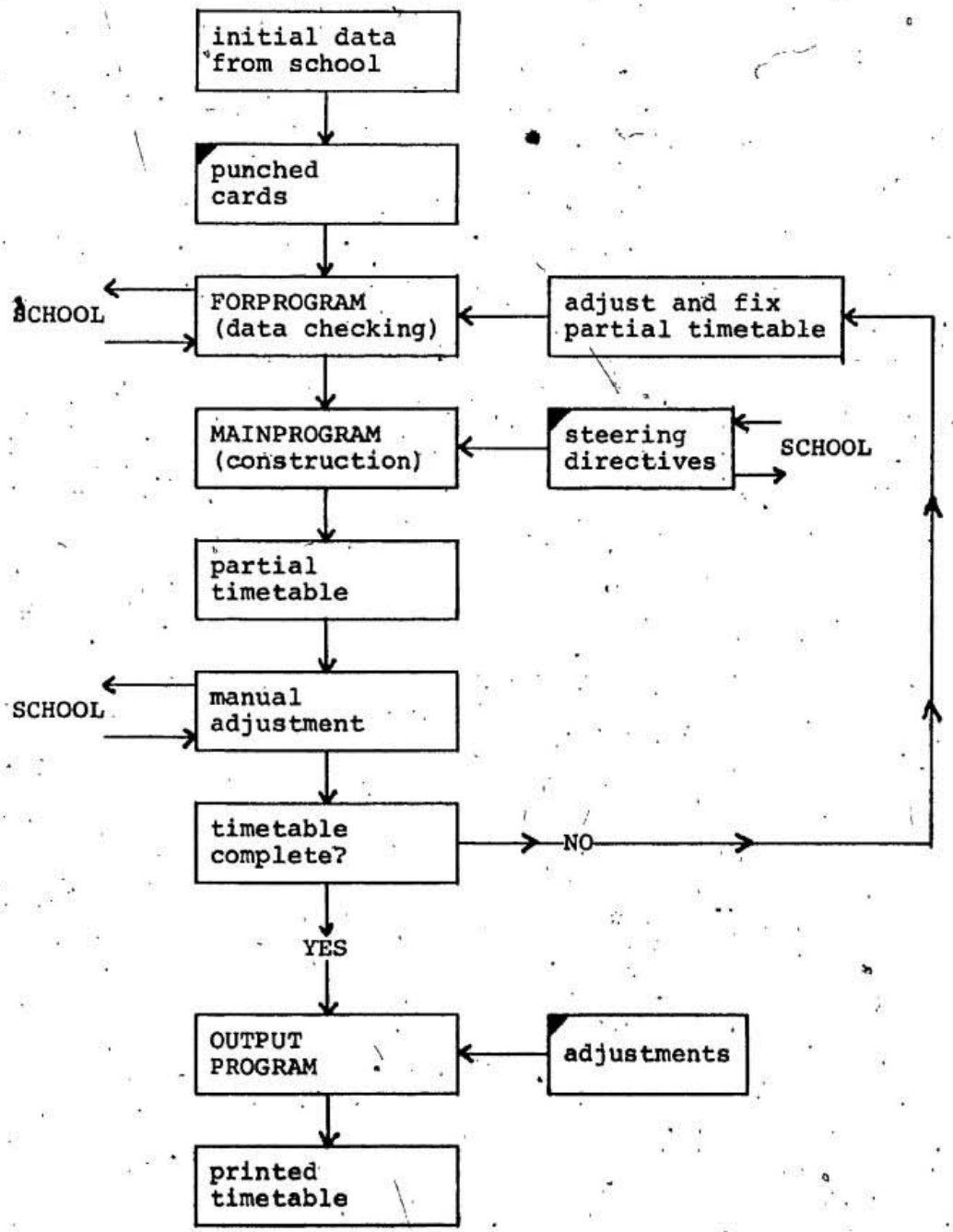
[21] Brookes, RIPA User's Guide, p. 4.

FIGURE 1.

AN OUTLINE OF THE NOR-DATA PROGRAM



Running the MAINPROGRAM - the MAINPROGRAM, which constructs the timetable, can now be run. As well as printing the intermediate version of the timetable constructed, the program also prints a blow-by-blow account of its activities during every run. This account gives details of problems encountered and expected as well as impossibilities met with during construction.

Iteration - at this stage we have normally tackled only a part of the timetable. When the results of the MAINPROGRAM run have been analysed and necessary compromises agreed with the school, it is necessary to freeze the partial timetable so that the next stage of construction can begin. "Freezing" is done via the FORPROGRAM, and it is also necessary to use this part of the system to make sure that impossibilities have not been introduced in other parts of the timetable, as well as to check for errors in the "Freezing" process.

Running the OUTPUT PROGRAM - it may well prove necessary to go through several iterations before a complete or nearly completed timetable can be produced. The OUTPUR PROGRAM is normally used only in the final iteration and updates, checks, and prints the timetable.[22]

Even though the step-wise or iterative mode of the Nor-Data School Scheduling System has been specifically designed to allow the timetabler to communicate effectively with the computer, it is clear to the researcher that a good master schedule is still largely dependent upon the timetabling experience and skills of the school administrator.

The sound advice which Brookes offers to computer programmers is equally applicable to school administrators:

> Unfortunately, running the NOR-DATA system--or any other--is not simply a matter of following a set of instructions cook-book fashion. There are of course a number of procedures that, with increasing familiarity, become routine. But successful use of the System depends to a large extent on the operator's experience,

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[22]Brookes, CAST Operator's Manual, pp. 2-3.

skill, and understanding of the timetabling problem.

> While there is no satisfactory substitute for experience, there is a good deal that can be learned from the experience of others. Some of the more salutory lessons of experience are included throughout this manual in the hope that some of the more unpleasant things that have happened to some can be avoided by others.[23]

Input Data Forms

Accompanying the Nor-Data School Scheduling System are four basic input data forms, which must be thoughtfully and accurately completed by the school administrator.

The first input data form, Table 1: Basic Data (See Appendix E), which is comprised of three major sections, is used to precisely define all of the basic resources to be included in the master schedule.

The teacher survey section is used to list all of the staff, using a series of continuous numbers beginning with 01. It is also used to indicate the total number of teaching periods to be later allocated to each teacher.

The class survey section is used to specify each of the classes to be included in the timetable. It will also show the total number of periods for which each class must be timetabled.

The room survey section is used to indicate all of the rooms in which activities may take place. It must also specify the type of room, as well as its alternative, which may be used for each activity.

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[23] Ibid., p. 3.

Completion of Table 1 usually presents few problems for school administrators. However, Brookes cautions:

> Before the data sheets are converted into records for input to the FORPROGRAM it is advisable to check them visually for any obvious errors. The computer program will of course be far more thorough in its own check, but some of the more common syntactical errors are more easily corrected before cards are punched or records created.
>
> In general terms it is certainly worth spending some time (not too long) looking through the data sheets. Familiarity with the techniques of data specification enables the most obvious mistakes to be found and it is worth noting that a particular error is often repeated by a school in a given data set.
>
> It is also important to stress that syntactical errors are made not only because of carelessness, but because the school may not have understood properly what is required ....[24]

What computerized master scheduling, and Table 1 of the Nor-Data School Scheduling System in particular, require of school administrators is a new perspective on timetable planning. No longer is it acceptable for the school administrator to have only a general idea of what has to be timetabled; now, the school administrator must have, right from the beginning, a precisely written and totally balanced timetabling plan.

The second input data form, Table 2: Basic Plan (See Appendix F), is used to specify which subjects are to be taught by each teacher. Since every aspect of the plan for the master schedule must be specified in appropriate computer language, this table consists of many repetitions

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[24] Ibid., p. 6.

of these basic timetabling elements: the subjects and grades to be taught; the teachers assigned to these various tasks; the option schemes required; the number and type of required periods per subject; and, the types of rooms to be utilized. Several sheets of Table 2 will normally be used by the school administrator for each master schedule, for it is desirable to use one sheet per grade.

Two vital aspects of timetabling are necessarily stressed in this Table.

The technique of day blocking is used to prevent related activities for the same class from being scheduled undesirably on the same day. The explicit distribution instructions which are programmed through this simplistic input-data procedure help significantly to produce the very much desired balanced distribution of periods per subject over the curriculum cycle.

The technique of parallelism is used to schedule two or more option schemes simultaneously not only within the same grade but also across grades. The tremendous advantage of this straightforward input-data procedure lies in its capacity to prevent irreconcilable teacher timetable conflicts.

Regarding the obvious need for thorough and logical timetable planning by school administrators, Brookes offers this advice:

> Especially where there is a predominance of parallel activities (option schemes, setting, blocking, etc.)

> it is almost always a good idea to spend time on preliminary checks of feasibility. Ideally these should have been completed by the school .... All too often however, the planning done at the school proves inadequate ... there is little point in putting off the discovery of impossibilities until a later stage. Planning and evaluation techniques are treated at some length in a separate publication ... here it is possible only to put in a plea that attention should be given to logical errors at the earliest possible stage.[25]

As can be proven by data from Table 2, successful master scheduling by computer depends very significantly upon sound timetable planning, as well as upon meticulous attention to details, by the school administrator.

The third input data form, Table 3: Preassignment and Blocking (See Appendix G), is used to express various constraints which the school administrator judges will most likely produce an acceptable master schedule which utilizes the resources of the school to maximum practical advantage.

Five major types of timetabling constraints may be imposed by the timetabler upon some of the activities to be timetabled. These constraints, each of which has a specific input data code,[26] are as follows:

Code 1: MUST)
) absolute constraints
Code 2: MUST NOT)

Code 3: HIGHLY UNDESIRABLE)
)
Code 4: UNDESIRABLE) relative constraints
)
Code 5: DESIRED)

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[25] Ibid.

[26] Brookes, RIPA User's Guide, p. 28.

The significant difference between absolute and relative timetabling constraints is that "absolute constraints are never violated by the program, whereas relative constraints will often be sacrificed to gain a better timetable in other respects."[27]

These examples are illustrative of the effect that these timetabling constraints could have upon the timetable. A code 1 constraint would guarantee that a triple period of Industrial Arts is scheduled during the afternoon, which is the only time when it is practical to have three consecutive periods with any class. A code 2 constraint would ensure that a split-site teacher, who needs some time for commuting between schools, is not scheduled to teach period one at the high school, and then immediately afterwards, period two at the elementary school. Such an infeasibility would simply not be timetabled. A code 3 constraint would indicate to the computer that it is highly undesireable to schedule two single periods of any six-period Mathematics course on any one day of a six-day curriculum cycle. Such a constraint would most likely produce a balanced distribution of periods for all of the Mathematics courses.

Through thoughtful application of the preassignment and blocking constraints, the school administrator is able to meaningfully influence the computer timetabling process by "transferring the individual school's experience about its

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[27] Ibid.

timetabling problems to the program system."[28] This unique feature of the Nor-Data School Scheduling System very much enhances its being used successfully by a substantial number of schools outside of Norway.

The fourth input data form, Table 4: Output Modification (See Appendix H), which is comprised of three major sections, is used to improve the general appearance and the readability of the computer printout of the completed master schedule.

The first section enables the school administrator to add the initials of the teachers to replace the number codes which had been used throughout the earlier stages of construction of the timetable. This makes the master schedule easily readable by the teachers as well as by the timetabler.

The second section allows the school administrator to print the individual name or number of each room which is used for teaching purposes. Any teacher can, therefore, readily determine where any activity is taking place.

The third section permits the school administrator to describe the different subjects within each of the option schemes. This descriptive information, which appears on the timetable of each teacher, is particularly helpful when the school has extensive option schemes.

As a direct result of these cosmetic improvements

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[28] Brookes, CAST Operator's Manual, p. 39.

which are effected through Table 4, the timetables for the teachers, as well as for the different classes and rooms, that are produced by the Nor-Data School Scheduling System are quite readable.

Stressing the importance of accurately completing these input data sheets, Brookes forcefully argues:

> It is vital to understand that the computer will attempt to do exactly what you ask it to. Unlike the human brain, a computer lacks peripheral vision and cannot be expected either to 'understand' the information presented to it or to compensate for information that is missing altogether. Although every precaution is taken in the program to check that the information is sensible and meaningful, it is of the utmost importance to take special care when completing the data sheets: final responsibility for errors of specification must inevitably be the user's.[29]

NEWFOUNDLAND FEASIBILITY STUDY

This Newfoundland computer scheduling feasibility study with the Norwegian Nor-Data School Scheduling System was conducted at Newfoundland and Labrador Computer Services Limited during the eight-day working period from November 22 through December 1, 1982.

Directly involved with this timetable construction process, and of invaluable assistance to the researcher, were Harald Michalsen, the developer of the Nor-Data School Scheduling System; Frederick Bullen, principal of Ascension Collegiate; John Martin, assistant principal of Gonzaga High School; John Tucker, principal of Partanna Academy; Stephen

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[29]Brookes, RIPA User's Guide, p. 1.

Andrews, manager of scientific services at Newfoundland and Labrador Computer Services Limited; Neil Dawe, a programmer analyst; and Mary-Louise Porter, a computer programmer.

Successfully produced through the Norwegian Nor-Data School Scheduling System were three very acceptable computer-generated master schedules for 1982-83: one for Ascension Collegiate at Bay Roberts; one for Gonzaga High School at St. John's; and one for the split-site schools of John Burke High School and Partanna Academy at Grand Bank.

STRUCTURED INTERVIEW WITH PARTICIPATING PRINCIPALS

To elicit the considered opinion of each of the three participating principals, the researcher conducted a structured interview (See Appendix I) with each of John Martin, Frederick Bullen and John Tucker during April of 1983.

Each was separately questioned about the computer-generated alternative master schedule which had been produced for his school for the 1982-83 school year, as well as about the possible future of computerized master scheduling throughout the Province with the Norwegian Nor-Data School Scheduling System.

TREATMENT OF THE DATA

Since the data for this study has been collected from several sources, the analysis of the various types of data is presented separately in the following chapters.

CHAPTER IV

ANALYSIS OF COMPUTER-GENERATED MASTER SCHEDULES

During November of 1982, very acceptable alternative 1982-83 master schedules were easily produced by computer at Newfoundland and Labrador Computer Services Limited with the Norwegian Nor-Data School Scheduling System for Ascension Collegiate, Gonzaga High School, John Burke High School and Partanna Academy.

SAMPLE TIMETABLES

Illustrative timetables from these computer-generated master schedules are presented throughout this chapter to demonstrate conclusively that the computer and the Norwegian Nor-Data School Scheduling System can be effectively used by school administrators throughout Newfoundland and Labrador.

Teacher Timetables

Table I on the following pages, which is the computer-generated timetable for the vice-principal of John Burke High School, shows an excellent teacher timetable.

It provides, the researcher would argue, a perfect distribution of periods for Consumer Mathematics 1202 at Level One and Advanced Mathematics 2201 at Level Two, as well as an acceptable balance of periods for Matriculation Mathematics in Grade Nine. Furthermore, the distribution

TABLE I

COMPUTER-GENERATED TIMETABLE FOR THE VICE-PRINCIPAL OF JOHN BURKE HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1			
2			
3	M.MATH. IX* L.Payne 102	M.MATH. IX* L.Payne 102	M.MATH. IX* L.Payne 102
4	ADV.MATH.2201 L-2* L.Payne 107	ADV.MATH.2201 L-2* L.Payne 108	ADV.MATH.2201 L-2* L.Payne 105
5	CON.MATH.1202 L-1* L.Payne Lib.		CON.MATH.1202 L-1* L.Payne Lib.
6	M.MATH. IX* L.Payne Lib.	CON.MATH.1202 L-1* L.Payne Lib.	
7			M.MATH. IX* L.Payne 102

*Student Option Scheme

TABLE I (continued)

Day Four	Day Five	Day Six
M.MATH. IX* L.Payne 102	CON.MATH.1202 L-1* L.Payne Lib.	
ADV.MATH.2201 L-2* L.Payne 107	M.MATH. IX* L.Payne 102	
CON.MATH.1202 L-1* L.Payne Lib.	M.MATH. IX* L.Payne 102	M.MATH. IX* L.Payne 102
		CON.MATH.1202 L-1* L.Payne 105
		ADV.MATH.2201 L-2* L.Payne 102
	ADV.MATH.2201 L-2* L.Payne 107	

*Student option scheme

of time remaining for administrative duties is reasonable. Little fault can be found with this teacher timetable, other than the undesirability of teaching in several classrooms, which is a direct result of room usage in the manual schedule.

On the following pages, Table II shows the computer-generated timetable for the head of the English department at Ascension Collegiate.

A careful evaluation will show that there is a nearly perfect distribution of periods for each of the three classes of Literary Heritage 2201 at Level Two of the Reorganized High School Program. A reasonable spread of periods exists for both classes of Language 1101 at Level One and all three classes of Language 2101 at Level Two. In addition, the nine non-teaching periods are, in the opinion of the researcher, most satisfactorily allocated.

One must appreciate that the ideal distribution of periods for each subject is rarely found in any timetable. Many factors in the school environment, coupled with time-tabling constraints necessarily imposed upon some activities by the timetabler, militate against the ideal balancing of thirty-three periods for eight courses over a six-day curriculum cycle of forty-two periods. Despite the small imperfection discernible in this teacher timetable, it could certainly have been used during 1982-83 in lieu of its manually-constructed counterpart.

Table III on pages 113 and 114, which is the computer-generated timetable for the teacher librarian at Gonzaga High

TABLE II

COMPUTER-GENERATED TIMETABLE FOR THE HEAD OF THE ENGLISH DEPARTMENT AT ASCENSION COLLEGIATE

Per.	Day One	Day Two	Day Three
1	LANG.1101 L-1D* L.Gosse 215		LIT.HER.2201 L-2D* L.Gosse 215
2	LIT.HER.2201 L-2A* L.Gosse Lang.Rm.	LIT.HER.2201 L-2A* L.Gosse Lang.Rm.	LIT.HER.2201 L-2A* L.Gosse Lang.Rm.
3	LIT.HER.2201 L-2C* L.Gosse Lang.Rm.	LIT.HER.2201 L-2C* L.Gosse Lang.Rm.	LIT.HER.2201 L-2C* L.Gosse Lang.Rm.
4	LANG.2101 L-2A* L.Gosse Lang.Rm.	LANG.2101 L-2C* L.Gosse Lang.Rm.	LANG.2101 L-2C* L.Gosse Lang.Rm.
5	LIT.HER.2201 L-2D* L.Gosse Lang.Rm.	LIT.HER.2201 L-2D* L.Gosse 215	
6		LANG.1101 L-1D* L.Gosse 215	LANG.2101 L-2D* L.Gosse Lang.Rm.
7			LANG.1101 L-1C* L.Gosse Lang.Rm.

*Student option scheme

TABLE II (continued)

Day Four	Day Five	Day Six
LANG.1101 L-1D* L.Gosse 010		LIT.HER.2201 L-2D* L.Gosse 215
LIT.HER.2201 L-2A* L.Gosse Lang.Rm.	LIT.HER.2201 L-2A* L.Gosse Lang.Rm.	LIT.HER.2201 L-2C* L.Gosse Lang.Rm.
LANG.2101 L-2A* L.Gosse Lang.Rm.	LIT.HER.2201 L-2C* L.Gosse Lang.Rm.	LANG.2101 L-2C* L.Gosse Lang.Rm.
LIT.HER.2201 L-2C* L.Gosse Lang.Rm.	LANG.1101 L-1C* L.Gosse Lang.Rm.	LIT.HER.2201 L-2A* L.Gosse Lang.Rm.
LIT.HER.2201 L-2D* L.Gosse 215	LANG.2101 L-2A* L.Gosse Lang.Rm.	
	LIT.HER.2201 L-2D* L.Gosse 215	LANG.2101 L-2D* L.Gosse Lang.Rm.
	LANG.2101 L-2D* L.Gosse Lang.Rm.	LANG.1101 L-1C* L.Gosse Lang.Rm.

*Student option scheme

School, impressively demonstrates the elusive prefectly-balanced teacher timetable.

Its perfection, however, makes it appear somewhat unreal. Clearly, if the computer and the Nor-Data School Scheduling System are free to produce that which is ideal, it will.

On pages 115 and 116, Table IV presents the computer-generated timetable for one of the three Grade Five homeroom teachers at Partanna Academy.

The distribution of periods for all eight subjects for this teacher is most reasonable. The four non-teaching periods have been allocated in a most acceptable manner.

Careful analysis of the remaining ninety teacher timetables produced by these four computer-generated master schedules will clearly reveal, as the researcher has found, that the overwhelming majority of them have the same or very similar qualities which would make them very acceptable to not only the school administrators but also the teachers and the students. It could be argued, therefore, that these computer-generated timetables, if they had been used during 1982-83, could only have enhanced the learning environment of these four schools.

Class Timetables

Like the teacher timetables, the sixty-four class timetables produced by these four computer-generated master schedules have an easily recognizable good quality, one that

TABLE III

COMPUTER-GENERATED TIMETABLE FOR THE TEACHER LIBRARIAN AT GONZAGA HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1			
2	W.GEOG.3202 L-1* T.McGrath 01	W.GEOG.3202 L-1* T.McGrath 21	W.GEOG.3202 L-1* T.McGrath 13
3			
4			
5	NFLD.CUL.1200 L-1* T.McGrath 14	NFLD.CUL.1200 L-1* T.McGrath Lib.	NFLD.CUL.1200 L-1* T.McGrath 14
6		CAN.LAW 2104 L-2* T.McGrath 13	
7			

*Student option scheme

TABLE III (continued)

Day Four	Day Five	Day Six
W.GEOG.3202 L-1* T.McGrath 21	W.GEOG.3202 L-1* T.McGrath 13	W.GEOG.3202 L-1* T.McGrath 23
NFLD.CUL.1200 L-1* T.McGrath Lib.	NFLD.CUL.1200 L-1* T.McGrath 14	NFLD.CUL.1200 L-1* T.McGrath Lib.
CAN.LAW 2104 L-2* T.McGrath 10		CAN.LAW 2104 L-2* T.McGrath 13

*Student option scheme

TABLE IV

COMPUTER-GENERATED TIMETABLE FOR A GRADE FIVE HOMEROOM TEACHER AT PARTANNA ACADEMY

Per.	Day One	Day Two	Day Three
1	MATH. 5B R.Barter 108	ENG. 5B R.Barter 108	HEA. 5C R.Barter 109
2	HEA. 5A R.Barter 107	MATH. 5B R.Barter 108	MATH. 5B R.Barter 108
3	ENG. 5B R.Barter 108	ENG. 5B R.Barter 108	ENG. 5B R.Barter 108
4	ENG. 5B R.Barter 108	SCI. 5B R.Barter 108	ENG. 5B R.Barter 108
5		SOC.STU. 5B R.Barter 108	
6	REL,ED. 5B R.Barter 108	MATH. 5B R.Barter 108	SCI. 5B R.Barter 108
7	SOC.STU. 5B R.Barter 108	ENG. 5B R.Barter 108	HEA. 5A R.Barter 107

TABLE IV (continued)

Day Four	Day Five	Day Six
MATH. 5B R.Barter 108	MATH. 5B R.Barter 108	MATH. 5B R.Barter 108
ENG. 5B R.Barter 108	ENG. 5B R.Barter 108	ENG. 5B R.Barter 108
ENG. 5B R.Barter 108	SOC.STU. 5B R.Barter 108	ENG. 5B R.Barter 108
MATH. 5B R.Barter 108	ENG. 5B R.Barter 108	REL.ED. 5B R.Barter 108
SOC.STU. 5B R.Barter 108		SOC.STU 5B R.Barter 108
HEA. 5B R.Barter 108	HEA. 5C R.Barter 109	SCI. 5B R.Barter 108
REL.ED. 5B R.Barter 108	HEA. 5B R.Barter 108	

is sought by teachers and school administrators alike.

That highly desirable timetable quality can be very readily detected, the researcher contends, in the following representative computer-generated class timetables.

Table V presents the very highly satisfactory class timetable for the two Level Two classes at John Burke High School.

A careful analysis will show a perfect distribution of periods, that is, one period per day, for subjects in the following two-credit student option schemes: Literature, Mathematics, Science and Social Studies. Since no fewer than twenty-four of the forty-two teaching-learning periods of the six-day curriculum cycle are required for these four major subject areas at Level Two, it could well be argued that, with this computer-generated class timetable, the fifty-six Level Two students and their teachers at John Burke High School would be optimally scheduled for at least fifty-seven per cent of the time.

Furthermore, each of the six remaining one-credit student option schemes are very satisfactorily scheduled, even though the distribution of periods for these three-period courses do not meet the ideal of one period every other day. It could be judged to be a very realistic distribution of this portion of the class timetable.

On pages 120 and 121, Table VI shows the very well balanced class timetable for one of the four Grade Nine classes at Gonzaga High School.

TABLE V

COMPUTER-GENERATED CLASS TIMETABLE FOR STUDENTS AT LEVEL TWO AT JOHN BURKE HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1	Bio.3201;KG;Lab. Phys.Sci.2205:ES;106 Phys.3204;WW;108	Text.2106;SG;HER W.Work.2107;WT;IAR Gen.Bus.2101;LC;107 Fr.2101;MS;105	Bio.3201;KG;Lab. Phy.Sci.2205;ES;107 Phys.3204;WW;108
2	Lit.Her.2201;LK;107 Lit.Her.2201;RN;102	Lit.Her.2201;LK;107 Lit.Her.2201;RN;102	Lit.Her.2201;LK;107 Lit.Her.2201;RN;102
3	Phy.Ed.2100;GD;Gym. F.Serv.2105;SG;HER M.Work.2102;WT;IAR	Lang.2101;RN;104 Lang.2102;CR;107	Lang.2101;RN;104 Lang.2102;CR;107
4	Adv.Math.2201;LP;107 Voc.Math.2202;LC;108 Aca.Math.2203;ES;106	Adv.Math.2201;LP;108 Voc.Math.2202;LC;104 Aca.Math.2203;ES;106	Adv.Math.2201;LP;105 Voc.Math.2202;LC;103 Aca.Math.2203;ES;106
5	W.Hist.3201;CR;107 W.Geog.3202;WW;108	Bio.3201;KG;Lab. Phy.Sci.2205;ES;106 Phys.3204;WW;108	W.Hist.3201;CR;107 W.Geog.3202;WW;108
6	D.Plan.1101;WT;IAR Can.Law 2104;MS;105 Can.Econ.2103;WW;102	W.Hist.3201;CR;107 W.Geog.3202;WW;108	D.Plan.1101;WT;IAR Can.Law 2104;MS;105 Can.Econ.2103;WW;108
7	Rel.Ed.3109;CR;107 Rel.Ed.2109;WW;108	Rel.Ed.3109;CR;107 Rel.Ed.2109;WW;108	Dem.2102;CR;107 Dem.2102;WW;108

TABLE V (continued)

Day Four	Day Five	Day Six
Lit.Her.2201;LK;107 Lit.Her.2201;RN;104	W.Hist.3201;CR;107 W.Geog.3202;WW;108	W.Hist.3201;CR;107 W.Geog.3202;WW;108
Adv.Math.2201;LP;107 Voc.Math.2202;LC;103 Aca.Math.2203;ES;106	Lit.Her.2201;LK;107 Lit.Her.2201;RN;104	Lit.Her.2201;LK;103 Lit.Her.2201;RN;102
Dem.2102;CR;107 Dem.2102;WW;108	Lang.2101;RN;104 Lang.2102;CR;107	Phy.Ed.2100;GD;Gym. F.Serv.2105;SG;HER M.Work.2102;WT;IAR
Phy.Ed.2100;GD;Gym. F.Serv.2105;SG;HER M.Work.2102;WT;IAR	Dem.2102;CR;107 Dem.2102;WW;108	D.Plan.1101;WT;IAR Can.Law 2104;MS;105 Can.Econ.2103;WW;108
Bio.3201;KG;Lab Phy.Sci.2205;ES;106 Phys.3204;WW;108	Bio.3201;KG;Lab Phy.Sci.2205;ES;104 Phys.3204;WW;108	Rel.Ed.3109;CR;107 Rel.Ed. 2109;WW;108
Text.2106;SG;HER W.Work.2107;WT;IAR Gen.Bus.2101;LC;107 Fr.2101;MS;105	Text.2106;SG;HER W.Work.2107;WT;IAR Gen.Bus.2101;LC;103 Fr.2101;MS;105	Adv.Math.2201;LP;102 Voc.Math.2202;LC;103 Aca.Math.2203;ES;106
W.Hist.3201;CR;107 W.Geog.3202;WW;108	Adv.Math.2201;LP;107 Voc.Math.2202;LC;103 Aca.Math.2203;ES;104	Bio.3201;KG;Lab Phy.Sci.2205;ES;102 Phys.3204;WW;108

TABLE VI

COMPUTER-GENERATED CLASS TIMETABLE FOR STUDENTS IN GRADE NINE (GROUP B) AT GONZAGA HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1	Gen.Sci.;KC;35	Phy.Ed.;BF;Gym.	Gen.Sci.;KC;35
2	Hist.;AM;21	Fr.;KR;10 Fr.;SL;22 Geog.;FH;23	Fr.;KR;10 Fr.;SL;22 Geog.;FH;23
3	Rel.Ed.;SL;31	Hist.;AM;21	Hist.;AM;21
4	M.Math.;BD;01	M.Math.;BD;01	M.Math.;BD;01
5	Eng.;SL;13	Eng.;SL;13	Eng.;SL;13
6	Fr.;KR;10 Fr.;SL;31 Geog.;FH;25	Gen.Sci.;KC;35	Rel.Ed.;SL;31
7	M.Math.;BD;01	M.Math.;BD;01	M.Math.;BD;01

TABLE VI (continued)

Day Four	Day Five	Day Six
Gen.Sci.;KC;35	Gen.Sci.;KC;35	Gen.Sci.;KC;35
Fr.;KR;10 Fr.;SL;22 Geog.;FH;23	Fr.;KR;10 Fr.;SL;22 Geog.;FH;23	Fr.;KR;10 Fr.;SL;24 Geog.;FH;22
Hist.;AM;21	Hist.;AM;21	Hist.;AM;21
M.Math.;BD;01	Phy.Ed.;BF;Gym.	M.Math.;BD;01
Eng.;SL;24	Eng.;SL;13	Eng.;SL;14
Rel.Ed.;SL;30	M.Math.;BD;01	Rel.Ed.;SL;25
M.Math.;BD;01	Eng.;SL;23	Eng.;SL;23

Even a cursory assessment of this computer-generated class timetable will reveal a perfect distribution of periods for each of the six-period courses of General Science, French, History and Geography. Likewise, the major courses of English and Mathematics as well as the minor courses of Religious Education and Physical Education, which have a total of eight, ten, four and two periods respectively, have been extremely well allocated by the computer.

Table VII presents the highly satisfactory class timetable for one of the eight Level One classes at Ascension Collegiate.

A close examination of this computer-generated class timetable will indicate that there exists for these students a perfectly balanced distribution of periods for all of their nine courses. Such optimal scheduling offsets the frustrating problems that students and teachers alike encounter when periods of any course are located in a cluster, thus leaving two or three teaching days before the next class.

Despite the fact that several of these courses have been scheduled for the same time slot on every day of the six-day curriculum cycle, which would be judged by some to be a negative quality, this class timetable should be, the researcher contends, more advantageous to these students and their teachers than other timetables which are manually constructed much less mathematically perfectly.

On pages 125 and 126, Table VIII provides the very reasonable timetable for one of the three Grade Four classes

TABLE VII

COMPUTER-GENERATED CLASS TIMETABLE FOR STUDENTS AT LEVEL ONE (GROUP B) AT ASCENSION COLLEGIATE

Per.	Day One	Day Two	Day Three
1	Nfld.Cul.1200;CN;211	Nfld.Cul.1200;CN;210	Nfld.Cul.1200;CN;211
2	Geol.2203;SP;P.Lab.	Geol.2203;SP;P.Lab.	Geol.2203;SP;P.Lab.
3	Art 1200;LW;A.Rm. Fr.2101;BS;125 Geol.3203;MC;P.Lab.	Art 1200;LW;A.Rm. Fr.2101;BS;125 Geol.3203;MC;P.Lab. Can.Econ.2103;AS;214	Art 1200;LW;A.Rm. Fr.2101;BS;125 Geol.3203;MC;P.Lab.
4	Fr. 2100;BS;125	Art 1200;LW;A.Rm. Can.Law 2104;AS;212	Fr.2100;BS;125
5	Them.Lit.1200;EN;211	Them.Lit.1200;EN;211	Aca.Math.1203;MS;205
6	Aca.Math.1203;MS;204	Aca.Math.1203;MS;204	Them.Lit.1200;EN;211
7	Lang.1101;LW;L.Rm.	Rel.Ed.1100;RBS;213	Lang.1101;LW;215

TABLE VII (continued)

Day Four	Day Five	Day Six
fld.Cul.1200;CN;210	Nfld.Cul.1200;CN;211	Nfld.Cul.1200;CN;21
eol.2203;SP;P.Lab.	Geol.2203;SP;P.Lab.	Geol.2203;SP;P.Lab.
rt 1200;LW;A.Rm. r.2101;BS;125 eol.3203;MC;P.Lab. an.Econ.2103;AS;214	Art 1200;LW;A.Rm. Fr.2101;BS;125 Geol.3203;MC;P.Lab.	Art 1200;LW;A.Rm. Fr.2101;BS;125 Geol.3203;MC;P.Lab Can.Econ.2103;AS;21
rt 1200;LW;A.Rm. an.Law 2104;AS;213	Aca.Math.1203;MS;203	Art 1200;LW;A.Rm. Can.Law 2104;AS;212
ca.Math.1203;MS;205	Fr.2100;BS;125	Them.Lit.1200;EN;21
nem.Lit.1200;EN;211	Lang.1101;LW;010	Aca.Math.1203;MS;20
l.Ed.1100;RBS;213	Them.Lit.1200;EN;210	Rel.Ed.1100;RBS;211

TABLE VIII

COMPUTER-GENERATED CLASS TIMETABLE FOR STUDENTS IN GRADE FOUR (GROUP C) AT PARTANNA ACADEMY

Per.	Day One	Day Two	Day Three
1	MATH. C.Marsh 403	ENG. C.Marsh 403	MATH. C.Marsh 403
2	ENG. C.Marsh 403	MATH. C.Marsh 403	ENG. C.Marsh 403
3	PHY.ED. C.Marsh Gym.	FR. E.Emberley 403	ENG. C.Marsh 403
4	ENG. C.Marsh 403	ENG. C.Marsh 403	FR. E.Emberley 403
5	REL.ED. C.Marsh 403	SCI. C.Marsh 403	ENG. C.Marsh 403
6	ART C.Marsh 403	REL.ED. C.Marsh 403	HEA. C.Marsh 403
7	SOC.STU C.Marsh 403	MUS. E.Hillier Mus.Rm.	SCI. C.Marsh 403

TABLE VIII (continued)

Day Four	Day Five	Day Six
MATH. C.Marsh 403	ENG. C.Marsh 403	MATH. C.Marsh 403
ENG. C.Marsh 403	CRA. C.Marsh 403	ENG. C.Marsh 403
ENG. C.Marsh 403	MATH. C.Marsh 403	ENG. C.Marsh 403
MATH. C.Marsh 403	ENG. C.Marsh 403	PHY.ED. C.Marsh Gym.
SOC.STU. C.Marsh 403	SOC.STU. C.Marsh 403	SCI. C.Marsh 403
ENG. C.Marsh 403	HEA. C.Marsh 403	FR. E.Emberley 403
MUS. E.Hillier Mus.Rm.	MATH. C.Marsh 403	ART C.Marsh 403

at Partanna Academy.

It is notable that the fourteen periods required for the various aspects of the English program at the elementary level are extremely well allocated. Similarly, the eight periods of Mathematics are very satisfactorily distributed. No unacceptable imbalance exists in the allocation of the periods for either one of the eight remaining subjects.

Room Timetables

Just as the class and teacher timetables can prove the high quality of these computerized master schedules, the eighty-five room timetables can convincingly demonstrate how the physical facilities of these schools can be utilized for maximum educational value.

Table IX gives the room timetable for one of the three Grade Nine homerooms at John Burke High School.

Like the seven other academic classrooms which are used at John Burke High School, it is nearly fully utilized. Its ninety-five per cent usage compares very favourably with that of the other classrooms, which range from eighty-three to ninety-eight per cent utilization.

On pages 130 and 131, Table X shows the satisfactory room timetable for one of the five Level One homerooms at Gonzaga High School.

It is noteworthy that this computer-scheduled room is utilized not only one hundred per cent of the six-day curriculum cycle, but also exclusively for social studies.

TABLE IX

COMPUTER-GENERATED ROOM TIMETABLE FOR ROOM 102 AT JOHN BURKE HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1	LANG.1101 L-1* R.Noseworthy	ENG. 9A R.Noseworthy	GEN.BUS.1101 L-1* L.Chan
2	LIT.HER.2201 L-2* R.Noseworthy	LIT.HER.2201 L-2* R.Noseworthy	LIT.HER.2201 L-2* R.Noseworthy
3	M.MATH. 9A* L.Payne	M.MATH. 9A* L.Payne	M.MATH. 9A* L.Payne
4	ENG. 9B R.Noseworthy	THEM.LIT.1200 L-1* R.Noseworthy	LIT. 9A R.Noseworthy
5	LIT. 9A R.Noseworthy	THEM.LIT.1200 L-1* R.Noseworthy	LIT. 9A R.Noseworthy
6	M.MATH. 9A* L.Payne	ENG. 9B R.Noseworthy	M.MATH. 9A* L.Payne
7	ENG. 9A R.Noseworthy	ENG. 9B R.Noseworthy	M.MATH. 9A* L.Payne

*Student option scheme

TABLE IX (continued)

Day Four	Day Five	Day Six
M.MATH. 9A* L.Payne	ACA.MATH.1203 L-1* L.Chan	LANG.1101 L-1* R.Noseworthy
LANG.1101 L-1* R.Noseworthy	M.MATH. 9A* L.Payne	LIT.HER.2201 L-2* R.Noseworthy
LIT. 9A R.Noseworthy	M.MATH. 9A* L.Payne	M.MATH 9A* L.Payne
ENG. 9A R.Noseworthy	ENG. 9C L.Keeping	THEM.LIT.1200 L-1* R.Noseworthy
THEM.LIT.1200 L-1* R.Noseworthy	ENG. 9A R.Noseworthy	
ENG. 9B R.Noseworthy		ADA.MATH.2201 L-2* L.Payne
GEN.BUS.1101 L-1* L.Chan	ENG. 9B R.Noseworthy	PHY.SCI.2205 L-2* E.Sheppard

*Student option scheme

TABLE X

COMPUTER-GENERATED ROOM TIMETABLE FOR ROOM 21
AT GONZAGA HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1	REL.ED.1102 L-1E L.Lipinski	NFLD.CUL.1200 L-1A A.Meaney	REL.ED.1102 L-1E L.Lipinski
2	HIST. 9B A.Meaney	W.GEOG.3202 L-1A* T.McGrath	W.HIST.3201 L-2R* A.Meaney
3	W.HIST.3201 L-2R* A.Meaney	HIST 9B A.Meaney	HIST. 9B A.Meaney
4	NFLD.CUL.1200 L-1A A.Meaney	W.HIST.3201 L-2R* A.Meaney	NFLD.CUL.1200 L-1A A.Meaney
5	CAN.LAW 2104 L-2A* A.Meaney	CAN.ECON.2103 L-2A* A.Meaney	CAN.LAW 2104 L-2A* A.Meaney
6	W.HIST.3201 L-2A* A.Meaney	W.HIST.3201 L-2A* A.Meaney	W.HIST.3201 L-2A* A.Meaney
7	CAN.ECON.2103 L-2R* B.Thorne	CAN.ECON.2103 L-2R* B.Thorne	CAN.ECON.2103 L-2R* B.Thorne

*Student option scheme

TABLE X (continued)

Day Four	Day Five	Day Six
NFLD.CUL.1200 L-1A A.Meaney	REL.ED.1102 L-1E L.Lipinski	NFLD.CUL.1200 L-1A A.Meaney
W.GEOG.3202 L-1A* T.McGrath	W.HIST.3201 L-2R* A.Meaney	REL.ED. L-2A L.Lipinski
HIST 9B A.Meaney	HIST. 9B A.Meaney	HIST. 9B A.Meaney
W.HIST.3201 L-2R* A.Meaney	NFLD.CUL.1200 L-1A A.Meaney	HIST 9C C.Doyle
CAN.ECON.2103 L-2A* A.Meaney	CAN.LAW 2104 L-2A* A.Meaney	CAN.ECON.2103 L-2A* A.Meaney
W.HIST.3201 L-2A* A.Meaney	W.HIST.3201 L-2A* A.Meaney	W.HIST.3201 L-2A* A.Meaney
CAN.ECON.2103 L-2R* B.Thorne	CON.STU.1202 L-1A* F.Hickey	W.HIST.3201 L-2R* A.Meaney

*Student option scheme

Furthermore, the homeroom teacher can conveniently use this social studies room for approximately eighty-five per cent of his teaching. Such a favourable room timetable could only enhance the teaching/learning environment of these students and their social studies teacher at Gonzaga High School.

An analysis of the other fifteen homeroom timetables for Gonzaga High School reveals well scheduled activities with room utilization ranging from eighty-three per cent in one case to the ideal of one hundred per cent in five cases.

Table XI on pages 133 and 134 presents the homeroom timetable for one of the eight Level Two classes at Ascension Collegiate.

This mathematics room is effectively utilized one hundred per cent of every teaching day. Whereas the vice-principal can use this classroom for more than eighty-three per cent of his mathematics classes, the head of the school's mathematics department has been scheduled to use it for only thirty-three per cent of his total teaching time. This somewhat undesirable feature is a reflection of the method of utilizing rooms in the manually-constructed master schedule.

An assessment of the other twenty-two academic room timetables for Ascension Collegiate indicates very effective scheduling with room utilization ranging from seventy per cent in one case to one hundred per cent in eleven cases.

Table XII on pages 135 and 136 provides the timetable for one of the three Grade Six classes at Partanna Academy.

TABLE XI

COMPUTER-GENERATED ROOM TIMETABLE FOR ROOM 204
AT ASCENSION COLLEGIATE

Per.	Day One	Day Two	Day Three
1	ACA.MATH.2203 L-2D C.Drover	ACA.MATH.2203 L-1D G.Drover	ACA.MATH.1203 L-1D M.Stevens
2	ACA.MATH.2203 L-2C M.Stevens	ACA.MATH.2203 L-2C M.Stevens	ACA.MATH.2203 L-2C M.Stevens
3	ACA.MATH.1203 L-1C D.Neil	ACA.MATH.2203 L-2E C.Drover	ADV.MATH.2201 L-2A C.Drover
4	ACA.MATH.2203 L-2F W.Gosse	ADV.MATH.2201 L-2A C.Drover	ACA.MATH.2203 L-2F W.Gosse
5	VOC.MATH.2202 L-2G W.Gosse	VOC.MATH.2202 L-2G W.Gosse	ACA.MATH.2203 L-2B W.Gosse
6	ACA.MATH.2203 L-2B W.Gosse	ACA.MATH.2203 L-2B W.Gosse	VOC.MATH.2202 L-2G W.Gosse
7	ADV.MATH.1201 L-1A D.Neil	ACA.MATH.1203 L-1F M.Stevens	ACA.MATH.1203 L-1G M.Stevens

TABLE XI (continued)

Day Four	Day Five	Day Six
ACA.MATH.2203 L-2D C.Drover	ACA.MATH.2203 L-2D C.Drover	VOC.MATH.2202 L-2G W.Gosse
ACA.MATH.2203 L-2C M.Stevens	ACA.MATH.2203 L-2C M.Stevens	ADV.MATH.2201 L-2A C.Drover
ACA.MATH.2203 L-2F W.Gosse	ADV.MATH.2201 L-2A C.Drover	ADV.MATH.2201 L-2A C.Drover
ADV.MATH.2201 L-2A C.Drover	ACA.MATH.1203 L-1B M.Stevens	ACA.MATH.2203 L-2C M.Stevens
VOC.MATH.2202 L-2G W.Gosse	ACA.MATH.2203 L-2E C.Drover	ACA.MATH.2203 L-2D C.Drover
ACA.MATH.2203 L-2B W.Gosse	VOC.MATH.2202 L-2G W.Gosse	ACA.MATH.2203 L-2B W.Gosse
ACA.MATH.1203 L-1F M.Stevens	ACA.MATH.2203 L-2B W.Gosse	ACA.MATH.1203 L-1F M.Stevens

TABLE XII

COMPUTER-GENERATED ROOM TIMETABLE FOR ROOM 114
AT PARTANNA ACADEMY

Per.	Day One	Day Two	Day Three
1	SOC.STU. 6C D.Jackman	MATH. 6C A.Evans	MATH. 6C A.Evans
2	FR. 6C Y.Powell		ENG. 6C D.Jackman
3	ENG. 6C D.Jackman	ENG. 6C D.Jackman	ENG. 6C D.Jackman
4	ENG. 6C D.Jackman	FR. 6C Y.Powell	FR. 6C Y.Powell
5	MATH. 6C A.Evans	ENG. 6C D.Jackman	SOC.STU. 6C D.Jackman
6	MUS. 6C E.Hillier	SOC.STU. 6C D.Jackman	REL.ED. 6C A.Evans
7	REL.ED. 6C A.Evans	SCI. 6C A.Evans	MATH. 6C A.Evans

TABLE XII (continued)

Day Four	Day Five	Day Six
MATH. 6C A.Evans		HEA. 6C A.Evans
FR. 6C Y.Powell	MATH. 6C A.Evans	MATH. 6C A.Evans
ENG. 6C D.Jackman	ENG. 6C D.Jackman	ENG. 6C D.Jackman
MUS. 6C E.Hillier	ENG. 6C D.Jackman	ENG. 6C D.Jackman
HEA. 6C A.Evans	SOC.STU. 6C D.Jackman	REL.ED. 6C A.Evans
SCI. 6C A.Evans	SCI. 6C A.Evans	MATH. 6C A.Evans
SOC.STU. 6C D.Jackman	ENG. 6C D.Jackman	ENG. 6C D.Jackman

A close analysis will show that the ninety-five per cent room utilization provides these students and their teachers with a very reasonable distribution of periods for each of the eight courses offered in Grade Six.

Further analysis of the other sixteen room timetables for Partanna Academy will reveal very satisfactory distribution of periods per course with room utilization ranging from ninety to ninety-eight per cent.

Split-site Timetables

Just as the teacher, class and room timetables have been very satisfactorily produced by the Nor-Data School Scheduling System, so have the split-site teacher timetables been quite reasonably constructed for the seven teachers who have teaching duties at both John Burke High School and Partanna Academy.

Table XIII clearly demonstrates how effectively the physical education teacher, who is a shared teaching unit assigned to the staff of Partanna Academy, can be scheduled at both John Burke High School and Partanna Academy.

Careful analysis of this split-site teacher timetable will reveal that, even though the periods for several of the seventeen courses are not ideally distributed, which may well be an inherent timetabling problem associated with the allocation of such a large number of two-period courses, the physical education teacher does have functional blocks

TABLE XIII

COMPUTER-GENERATED TIMETABLE FOR PHYSICAL EDUCATION TEACHER AT JOHN BURKE HIGH SCHOOL AND PARTANNA ACADEMY

Per.	Day One	Day Two	Day Three
1	PHY.ED. 9B G.Devereaux Gym. John Burke	TUT. 7A G.Devereaux Lib. Partanna	TUT. 7A G.Devereaux 108 Partanna
2	PHY.ED. 9A G.Devereaux Gym. John Burke	HEA. 7C G.Devereaux Mus.Rm. Partanna	HEA. 7C G.Devereaux 109 Partanna
3	PHY.ED.2100 L-2* G.Devereaux Gym. John Burke	PHY.ED.(Girls) 8B G.Devereaux Gym. Partanna	PHY.ED.(Boys) 8B G.Devereaux Gym. Partanna
4	PHY.ED.1100 L-1* G.Devereaux Gym. John Burke	PHY.ED.(Girls) 8A G.Devereaux Gym. Partanna	PHY.ED. 7B G.Devereaux Gym. Partanna
5			
6	HEA. 7A G.Devereaux 116 Partanna	HEA. 7B G.Devereaux 117 Partanna	HEA. 7A G.Devereaux 112 Partanna
7	PHY.ED. 7B G.Devereaux Gym. Partanna	PHY.ED. 7A G.Devereaux Gym. Partanna	HEA. 8A G.Devereaux 114 Partanna

*Student option scheme

TABLE XIII (continued)

Day Four	Day Five	Day Six
PHY.ED. (Boys) 8A G.Devereaux Gym. Partanna		PHY.ED. (Boys) 8B G.Devereaux Gym. Partanna
PHY.ED. (Girls) 8B G.Devereaux Gym. Partanna	PHY.ED. (Girls) 8A G.Devereaux Gym. Partanna	HEA. 8A G.Devereaux 114 Partanna
	PHY.ED.1100 L-1* G.Devereaux Gym. John Burke	PHY.ED.2100 L-2* G.Devereaux Gym. John Burke
PHY.ED.2100 L-2* G.Devereaux Gym. John Burke	PHY.ED.1100 L-1* G.Devereaux Gym. John Burke	PHY.ED. 9C G.Devereaux Gym. John Burke
HEA. 7B G.Devereaux 117 Partanna	PHY.ED. 9B G.Devereaux Gym. John Burke	PHY.ED. (Boys) 8A G.Devereaux Gym. Partanna
PHY.ED. 7A G.Devereaux Gym. Partanna	PHY.ED. 9A G.Devereaux Gym. John Burke	PHY.ED. 7C G.Devereaux Gym. Partanna
PHY.ED. 7C G.Devereaux Gym. Partanna	PHY.ED. 9C G.Devereaux Gym. John Burke	

*Student option scheme

of teaching time at each of these schools. There are, for example, two days, Day Two and Day Three, which are utilized exclusively for Grades Seven and Eight at Partanna Academy. Similarly, the major portion of Day One and Day Five is used for physical education classes at John Burke High School.

Accordingly, travel to the appropriate school, which has been minimized due to their close proximity, can be very conveniently undertaken either before nine o'clock, during recess, during dinner hour, or during a non-teaching period. In terms of the required teacher travelling time, which is one of the several inevitable constraints imposed upon the timetabling problem by shared personnel, this split-site timetable imposes no difficulty whatsoever upon the physical education teacher for John Burke High School and Partanna Academy.

Table XIV, which is the combined room timetables for the home economics teacher at John Burke High School and Partanna Academy, offers further substantial evidence of the capability of the Nor-Data School Scheduling System to very effectively schedule split-site teachers.

A thorough examination of this split-site timetable will show not only an excellent distribution of periods for each of the ten home economics courses, but also extremely favourable blocks of teaching time at John Burke High School as well as at Partanna Academy. Notably, all of the classes on Day Four and Day Six have been scheduled most favourably for the home economics teacher and her students at John Burke

TABLE XIV

COMPUTER-GENERATED ROOM TIMETABLE FOR HOME ECONOMICS TEACHER AT JOHN BURKE HIGH SCHOOL AND PARTANNA ACADEMY

Per.	Day One	Day Two	Day Three
1	HOME EC. 7A S.Glavine Home Ec.Rm. Partanna	TEX.CRA.2106 L-2* S.Glavine Home Ec.Rm. John Burke	CLO.1101 L-1* S.Glavine Home Ec.Rm. John Burke
2	HOME EC. 7A S.Glavine Home Ec.Rm. Partanna	HOME EC. 9A S.Glavine Home Ec.Rm. John Burke	HOME EC. 9B S.Glavine Home Ec.Rm. John Burke
3	F.SER.2105 L-2* S.Glavine Home Ec.Rm. John Burke	HOME EC. 7B S.Glavine Home Ec.Rm. Partanna	HOME EC. 8A S.Glavine Home Ec.Rm. Partanna
4	FOOD.1100 L-1* S.Glavine Home Ec.Rm John Burke	HOME EC. 7B S.Glavine Home Ec.Rm. Partanna	HOME EC. 8A S.Glavine Home Ec.Rm. Partanna
5	HOME EC. 8A S.Glavine Home Ec.Rm. Partanna	HOME EC. 8B S.Glavine Home Ec.Rm Partanna	HOME EC. 7A S.Glavine Home Ec.Rm. Partanna
6		HOME EC. 8B S.Glavine Home Ec.Rm Partanna	
7			

*Student option scheme

TABLE XIV (continued)

Day Four	Day Five	Day Six
	HOME EC. 7B S.Glavine Home Ec.Rm. Partanna	HOME EC. 9B S.Glavine Home Ec.Rm. John Burke
HOME EC. 9A S.Glavine Home Ec.Rm John, Burke	HOME EC. 8B S.Glavine Home Ec.Rm. Partanna	HOME EC. 9B S.Glavine Home Ec.Rm. John Burke
	FOOD.1100 L-1* S.Glavine Home Ec.Rm. John Burke	F.SER.2105 L-2* S.Glavine Home Ec.Rm. John Burke
F.SER.2105 L-2* S.Glavine Home Ec.Rm. John Burke	FOOD.1100 L-1* S.Glavine Home Ec.Rm. John Burke	
HOME EC. 9B S.Glavine Home Ec.Rm. John Burke	CLO.1101 L-1* S.Glavine Home Ec.Rm. John Burke	HOME EC. 9A S.Glavine Home Ec.Rm. John Burke
TEX.CRA.2106 L-2* S.Glavine Home Ec.Rm. John Burke	TEX.CRA.2106 L-2* S.Glavine Home Ec.Rm. John Burke	HOME EC. 9A S.Glavine Home Ec.Rm. John Burke
CLO.1101 L-1* S.Glavine Home Ec.Rm. John Burke		

*Student option scheme

High School. The amount of travelling time required of this teacher has, therefore, been considerably reduced. It could be argued that this split-site timetable is not only student-friendly but also teacher-friendly, for it would appear to have been constructed equally advantageously for both.

Analysis of the remaining teacher and classroom timetables for the shared personnel at John Burke High School and Partanna Academy reveals computer-generated schedules which should be most acceptable to these teachers and their students.

Unacceptable Timetabling Arrangements

Even though the vast majority of the teacher, class and room timetables produced for these four schools by the Nor-Data School Scheduling System are highly satisfactory, a small number of the timetables could be judged to contain some unacceptable timetabling arrangements.

Table XV presents a somewhat unacceptable teacher timetable for the French teacher at John Burke High School.

Firstly, the imbalanced distribution of periods for seven of the nine courses is unsatisfactory. This undesirable bunching of classes is most impractical for French in Grade Nine. Secondly, the six non-teaching periods are allocated in an unfavourable manner. Whereas the teacher has two non-teaching periods on Day Four as well as Day Six, all seven periods are scheduled on Day One and Day Five, which leaves

TABLE XV

COMPUTER-GENERATED TIMETABLE FOR THE FRENCH TEACHER AT JOHN BURKE HIGH SCHOOL

Per.	Day One	Day Two	Day Three
1	GEOG. 9C M.Snook 105	FR.2101 L-2* M.Snook 105	FR. 9A* M.Snook 105
2	GEOG 9C M.Snook 105		
3	CAN.ISS.1201 L-1* M.Snook 105	CAN.ISS.1201 L-1* M.Snook 105	CAN.ISS.1201 L-1* M.Snook 105
4	FR.2100 L-1* M.Snook 105	FR. 9B* M.Snook 105	FR. 9B* M.Snook 104
5	FR. 9A* M.Snook 105	FR. 9A* M.Snook 105	FR. 9A* M.Snook 105
6	CAN.LAW 2104 L-2* M.Snook 105	FR. 9B* M.Snook 105	CAN.LAW 2104 L-2* M.Snook 105
7	NFLD.CUL.1200 L-1 M.Snook 105	NFLD.CUL.1200 L-1 M.Snook 105	NFLD.CUL.1200 L-1 M.Snook 105

*Student option scheme

TABLE XV (continued)

Day Four	Day Five	Day Six
NFLD.CUL.1200 L-1 M.Snook 105	FR. 9B* M.Snook 105	
	NFLD.CUL.1200 L-1 M.Snook 105	SOC.STU. SP.ED. M.Snook 101
FR. 9B* M.Snook 105	FR.2100 L-1* M.Snook 105	CAN.ISS.1201 L-1* M.Snook 105
CAN.ISS.1201 L-1* M.Snook 105	FR.2100 L-1* M.Snook 105	CAN.LAW 2104 L-2* M.Snook 105
	GEOG. 9C M.Snook 105	
FR.2101 L-2* M.Snook 105	FR.2101 L-2* M.Snook 105	SOC.STU. SP.ED. M.Snook 101
FR. 9A* M.Snook 105	CAN.ISS.1201 L-1* M.Snook 105	NFLD.CUL.1200 L-1 M.Snook 105

*Student option scheme

the teacher without any additional preparation time on these two days of the six-day curriculum cycle. Thirdly, only three of the four required periods for geography in Grade Nine have been scheduled for this teacher. This incomplete teacher timetable creates a serious scheduling problem, for not only is this teacher not available to teach that fourth period of geography in Grade Nine, but also one of the three Grade Nine classes must inevitably have this fourth period of geography taught to them by another teacher. Who that second geography teacher will be depends solely upon which teachers happen to have a non-teaching period at that time. Such unplanned assignment of even one teaching period is unacceptable to the teachers as well as the timetabler.

This slightly incomplete teacher timetable, with its accompanying incomplete Grade Nine class timetable, is the only unresolved teacher timetable conflict in the computer-generated split-site master schedule for John Burke High School and Partanna Academy. Coincidentally, the same irreconcilable teacher timetable conflict exists in the manually-constructed master schedule for John Burke High School for 1982-83.

It can be argued, as the researcher has concluded, that this problematic teacher timetable conflict is not the fault of the Nor-Data School Scheduling System, but rather the adverse side-effect of the initial allocation of several incompatible teaching teams involving this French teacher. The computer printout indicates that it is mathematically

impossible to schedule this French teacher for one hundred per cent of the teaching workload which had been originally assigned to him for the 1982-83 school year.

To eradicate this unacceptable teacher and classroom timetable conflict, one would necessarily need to modify the initial teaching workload of this French teacher. Since the researcher was restricted to using the same data which had been used to manually construct the master schedule for John Burke High School, no attempt was made through modification of data to remove this teacher timetable conflict from the computer-generated alternative 1982-83 master schedule for John Burke High School.

Whereas the computer and the Norwegian Nor-Data School Scheduling System can readily prove the infeasibility of certain aspects of timetable planning, it is the school administrator who must make sound timetable changes in order to allow the computer and the Nor-Data School Scheduling System the freedom to produce a conflict-free master schedule.

Commendable Timetable Improvements

The manually-constructed master schedule for 1982-83 for Ascension Collegiate contains no fewer than three teacher timetable conflicts. Each conflict had been judged to be so problematic that the school administrators were obligated to conclude that no further adjustments could be manually made to their workable master schedule which would resolve

these teacher timetable conflicts.

Nevertheless, the computer-generated alternative master schedule for 1982-83 for Ascension Collegiate, which was so very easily produced by the Norwegian Nor-Data School Scheduling System, very satisfactorily resolved all three of these unacceptable teacher timetable conflicts. Such a substantial improvement over the manually-constructed master schedule can only properly be assessed in the most favourable manner. The improvement is remarkable and most commendable, for it could mean better scheduling for Ascension Collegiate as well as other high schools throughout the Province as a direct result of computerized master scheduling. Clearly, that which is timetable possible will be most favourably scheduled by the Nor-Data School Scheduling System.

The computer-generated master schedules for Gonzaga High School and Partanna Academy did not effect any similar substantive improvements, for the manually-constructed master schedules for these schools contained no unsolvable teacher timetable conflicts.

COMPUTER PRINTOUT MATERIAL

The computer printout of the master schedule which has been produced by the Nor-Data School Scheduling System is truly voluminous in comparison to the limited number of typed or handwritten teacher and classroom timetables that are usually available for distribution to the staff from the manually-constructed master schedule. The significant

difference lies in the amount and different kinds of useable information which becomes readily available to the school administrator through the computer-generated master schedule.

The sheer volume of output data is most impressive. The computer-generated master schedule for Gonzaga High School contains seventy computer printout pages. The printout of the master schedule for Ascension Collegiate consists of ninety-nine pages. The master schedule for the split-site schools of John Burke High School and Partanna Academy is comprised of no fewer than 103 pages.

The different types of information, each of which is very comprehensive, which can be so quickly and conveniently generated by the Nor-Data School Scheduling System, could be advantageously used not only by the school administrators but also by the staff and Board Office personnel.

The useable types of salient scheduling information produced by the Nor-Data School Scheduling System, in the standard printout sequence, are as follows:

1. School and master schedule identification data.
2. Summary master scheduling job statistics.
3. Total computer time used to generate the master schedule.
4. Cost of required computing time.
5. Identification of any remaining problematic and undesirable aspect of the finished master schedule.
6. Skeleton class timetables (subject numbers only) for all homerooms.

7. Skeleton teacher timetables (grade numbers only) for all of the staff.

8. Skeleton room timetables (grade numbers only) for all rooms used for instructional purposes.

9. Summary class timetables (subject, teacher and room) for all homerooms.

10. Summary teacher timetables (subject, grade and room) for all of the staff.

11. Summary room timetables (subject, grade and teacher) for all rooms used for instructional purposes.

12. Standard class timetables (teacher, subject and room fully identified in typical manner) for all homerooms.

13. Standard teacher timetables (subject, grade and room fully identified in typical manner) for all of the staff.

14. Standard room timetables (grade, subject and teacher fully identified in typical manner) for all rooms used for instructional purposes.

15. Optional blank teacher timetables for special education teachers and full-time school administrators.

What makes this scheduling information all the more valuable for school administrators is the quality and the readability of the computer printout material.

The overall quality of these four computer-generated alternative master schedules is, in the opinion of the researcher, clearly superior to that of the manually-constructed master schedules for 1982-83 for Ascension

Collegiate, Gonzaga High School, John Burke High School and Partanna Academy. This, coupled with the readily discernible high quality of these computer printouts, provides the school administrator with a wealth of invaluable data which would not otherwise be available.

The usefulness of this scheduling information is further enhanced by the obvious readability of the computer printout material. The computer timetabling language and the layout of the printed material so closely resembles the typical timetabling terminology and the format of teacher timetables that it is doubtful, the researcher would contend, that any experienced school administrator would have any difficulty reading and fully understanding any part of the printouts of these four master schedules. Certainly, any difficulty which one might initially encounter with fully comprehending this computer printout material would be resolved as soon as one could gain some practical experience with computerized master scheduling.

CHAPTER V

TEACHER ASSESSMENT OF COMPUTER-GENERATED TIMETABLES

It could be argued that the assessment of the master schedule by its creator, the school administrator, will not necessarily be the same as the collective assessment by the staff of their individual teacher timetables. This rather subjective evaluation could well be influenced by several factors, many of which are of an intangible nature.

The staff of Ascension Collegiate, Gonzaga High School, John Burke High School and Partanna Academy were, therefore, asked to evaluate as objectively as possible not only their alternative computer-generated teacher timetables but also their manually-constructed teacher timetables for 1982-83. By administering two questionnaires (See Appendices A and C) during late 1982, which focused upon the purported basic criteria for the evaluation of teacher timetables, the researcher sought teacher assessment of their individual teacher timetables in order to compare as reliably as possible the alternative computer-generated master schedules with the already manually-constructed master schedules for the 1982-83 school year.

Excluded necessarily from this clearly-defined target population were the three full-time school administrators, the eleven special education teachers and one non-teaching

guidance counsellor. The teaching workload of the remaining ninety-four regular classroom teachers at these four schools ranged from three to thirty-eight periods over the six-day curriculum cycle of forty-two periods.

The questionnaire statistics, whose validity can only be enhanced by a questionnaire response rate of one hundred per cent, clearly indicate that teacher assessment of their individual computer-generated timetables was generally better than that of their manually-constructed timetables for 1982-83.

QUESTIONNAIRE RESPONSES

A comparative analysis of the questionnaire responses by item follows.

Basic Requirements for Different Subject Areas

The first question on both questionnaires was: "Have the basic requirements for your subject area(s) been met?"

Table XVI shows that the staff of each of the four participating schools judged their alternative computer-generated teacher timetables to have better met the basic timetabling requirements for their different subject areas than did their manually-constructed timetables for the 1982-83 school year.

For example, whereas only six, or seventeen per cent, of the staff of Ascension Collegiate judged their manually-

TABLE XVI

THE DEGREE TO WHICH THE TEACHERS JUDGED THEIR TIMETABLES TO HAVE MET THE BASIC TIMETABLING REQUIREMENTS FOR THEIR DIFFERENT SUBJECT AREAS

	Manually-constructed Timetables						Computer-generated Timetables					
	Ascension	Gonzaga	John Burke	Partanna	Total		Ascension	Gonzaga	John Burke	Partanna	Total	
Staff Responses	34	26	16	18	94	100%	34	26	16	18	94	100%
Very satisfactorily	6	11	4	3	24	26%	17	17	9	8	51	55%
Reasonably satisfactorily	23	13	9	13	58	62%	15	5	6	9	35	37%
Somewhat unsatisfactorily	4	2	3	2	11	11%	2	1	1	0	4	4%
Very unsatisfactorily	1	0	0	0	1	1%	0	3	0	1	4	4%

constructed timetables to have very satisfactorily met their basic timetabling requirements, as many as seventeen of them, or fifty per cent, very satisfactorily assessed this aspect of their computer-generated timetables. This difference represents a substantially better assessment of this aspect of the computer-generated timetables by as much as thirty-three per cent of the teachers at Ascension Collegiate.

It is noteworthy that the staff of each of the other three participating schools likewise assessed this aspect of the computer-generated timetables to be significantly better. At Gongaza High School, the teacher assessment was twenty-three per cent better; at Partanna Academy, twenty-eight per cent better; and at John Burke High School, no less than thirty-one per cent better.

Overall, only eight per cent of these ninety-four teachers negatively assessed the computer-generated timetables in terms of its not meeting their basic timetabling requirements.

Teaching Workload Preferences

The second question on each of the questionnaires was: "Have your workload preferences been met?"

Table XVII clearly indicates that a large number of the teachers at each of these schools judged the computer-generated teacher timetables to have much better provided them with their teaching workload preferences than did their 1982-83 manually-constructed timetables.

TABLE XVII

THE DEGREE TO WHICH THE TEACHERS JUDGED THEIR TIMETABLES TO HAVE PROVIDED THEM WITH THEIR TEACHING WORKLOAD PREFERENCES

	Manually-constructed Timetable						Computer-generated Timetable					
	Ascension	Gonzaga	John Burke	Partanna	Total		Ascension	Gonzaga	John Burke	Partanna	Total	
Staff Responses	34	26	16	18	94	100%	34	26	16	18	94	100%
Very satisfactorily	9	7	6	2	24	26%	19	14	8	5	46	49%
Reasonably satisfactorily	20	17	6	10	53	56%	15	8	8	11	42	45%
Somewhat unsatisfactorily	5	2	4	6	17	18%	0	3	0	2	5	5%
Very unsatisfactorily	0	0	0	0	0	0%	0	1	0	0	1	1%

Only twenty-four teachers from these participating schools, or twenty-six per cent of them, judged that their manually-constructed timetables very satisfactorily provided them with their teaching workload preferences. In contrast, no fewer than forty-six teachers, or nearly fifty per cent, concluded that the computer-generated timetables well provided them with their teaching workload preferences. Such a large difference is clearly indicative of the extent to which the computer-generated timetables were perceived to be superior to their 1982-83 manually-constructed timetables in terms of its fulfilling their various teaching workload preferences.

Overall, only six per cent of these ninety-four teachers unfavourably assessed this aspect of the computer-generated teacher timetables.

Balanced Distribution of Periods per Subject

The third question on each of the questionnaires was: "Do you have an acceptable distribution of periods per subject over the six-day curriculum cycle?"

Table XVIII reveals that most of the teachers at each of these schools judged the computer-generated timetables to have a more acceptable distribution of periods per subject over the six-day curriculum cycle than did their manually-constructed timetables for 1982-83.

Fifty-six per cent of the teachers at Ascension Collegiate perceived that the computer-generated timetables offered them a highly satisfactory distribution of periods

TABLE XVIII

THE DEGREE TO WHICH THE TEACHERS JUDGED THEIR TIMETABLES TO HAVE PROVIDED THEM WITH A REASONABLY BALANCED DIDTRIBUTION OF PERIODS PER SUBJECT OVER THE SIX-DAY CURRICULUM CYCLE

	Manually-constructed Timetables						Computer-generated Timetables					
	Ascension	Gonzaga	John Burke	Partanna	Total		Ascension	Gonzaga	John Burke	Partanna	Total	
Staff Responses	34	26	16	18	94	100%	34	26	16	18	94	100%
Very satisfactory	9	14	3	4	30	32%	19	15	7	9	50	54%
Reasonably satisfactory	20	12	9	10	51	54%	15	9	7	7	38	40%
Somewhat unsatisfactory	5	0	4	2	11	12%	0	0	2	2	4	4%
Very unsatisfactory	0	0	0	2	2	2%	0	2	0	0	2	2%

per subject over the six-day curriculum cycle; however; only twenty-six per cent of these thirty-four teachers equally as favourably evaluated this aspect of their manually-constructed timetables. Most of the teachers at John Burke High School and Partanha Academy similarly assessed this aspect of their timetables. With the exception of Gonzaga High School, which apparently has a very good set of manually-constructed timetables, the computer-generated timetables provided teachers with a more balanced, and therefore more acceptable, distribution of periods for the various courses which they teach.

Only six per cent of the teachers negatively judged this aspect of their computer-generated timetables whereas fourteen per cent unfavourably assessed this facet of their manually-constructed timetables.

Overall Satisfaction with Timetables

The fourth question on the questionnaire pertaining to the manually-constructed timetables was: "Overall, how would you categorize your manually-constructed timetable for 1982-83?"

Its counterpart on the questionnaire pertaining to the computer-generated timetables was: "Overall, how would you categorize your computer-generated timetable for 1982-83?"

Table XIX shows, somewhat surprisingly, that these teachers, who so favourably rated their computer-generated

TABLE XIX

THE DEGREE TO WHICH THE TEACHERS JUDGED THEIR TIMETABLES TO HAVE OVERALL SATISFACTORILY MET THEIR TIMETABLING REQUIREMENTS

	Manually-constructed Timetables						Computer-generated Timetables					
	Ascension	Gonzaga	John Burke	Partanna	Total		Ascension	Gonzaga	John Burke	Partanna	Total	
Staff Responses	34	26	16	18	94	100%	34	26	16	18	94	100%
Very satisfactory	5	18	1	1	25	27%	6	7	5	4	22	24%
Reasonably satisfactory	23	8	7	11	49	52%	20	10	8	10	48	51%
Somewhat unsatisfactory	5	0	7	5	17	18%	7	6	3	4	20	21%
Very unsatisfactory	1	0	1	1	3	3%	1	3	0	0	4	4%

timetables over their manually-constructed timetables when answering each of the three previous questions, did not do so when answering this question.

A more detailed analysis reveals that the reasonably favourable overall assessment which was given to the computer-generated timetables by the staff of John Burke High School and Partanna Academy was apparently offset by the somewhat negative overall assessment which was given to the computer-generated timetables by the staff of Gonzaga High School. The staff of Ascension Collegiate apparently perceived no noteworthy overall difference between the computer-generated timetables and their 1982-83 manually-constructed timetables.

Not to be overlooked is the twenty-one per cent who unfavourably assessed their manually-constructed timetables and the twenty-five per cent who negatively evaluated their computer-generated timetables. It would appear that some criteria other than that which were used in the previous three questions influenced this qualitative assessment of these two types of timetables. One can only speculate, so the researcher would contend, about whatever subtle and intangible factors may have negatively influenced this very subjective and personal teacher assessment of the manually-constructed 1982-83 timetables versus the alternative computer-generated timetables.

Comparative Assessment of Computer Timetables

The fifth question on the questionnaire pertaining to the computer-generated timetables was: "How does your computer-generated timetable compare with your 1982-83 manually-constructed timetable?"

Table XX reveals that twenty-one per cent of these teachers judged the alternative computer-generated timetables to be definitely better than the 1982-83 manually-constructed timetables. Furthermore, fifty-one per cent of the teachers at these four participating schools, who judged the computer-generated timetables to be quite acceptable, considered them to be very similar to their manually-constructed timetables. Totally, as many as sixty-seven of these teachers, or seventy-two per cent of them, very favourably assessed their computer-generated timetables.

To have obtained initially a user satisfaction rate of seventy-two per cent is, in the opinion of the researcher, very convincing evidence that the Norwegian Nor-Data School Scheduling System can very satisfactorily produce the master schedule for high schools throughout Newfoundland and Labrador.

One must appreciate that this research was restricted to use of the same timetabling data which was used to produce the manually-constructed master schedules for 1982-83. No effort was made to improve these master schedules by modifying any of the original timetabling data. If different timetabling decisions had been made by the

TABLE XX

QUALITATIVE ASSESSMENT BY TEACHERS OF THEIR ALTERNATIVE 1982-83 COMPUTER-GENERATED TIMETABLES IN COMPARISON WITH THEIR MANUALLY-CONSTRUCTED TIMETABLES

	Computer-generated Timetables					
	Ascension	Gonzaga	John Burke	Partanna	Total	
Staff Responses	34	26	16	18	94	100%
Definitely better	6	1	9	34	19	21%
Very similar	20	16	4	8	48	51%
Somewhat unsatisfactory	7	6	3	5	21	22%
Much Worse	1	3	0	2	6	6%

researcher and participating principals to effect better teacher timetables, it could be argued, as the researcher has concluded, that the majority of the twenty-two per cent who viewed the computer-generated timetables to be somewhat unsatisfactory may very well have received improved timetables which would have been assessed much more favourably. The potential user satisfaction rate could, therefore, be higher than this initial seventy-two per cent. Through better timetable planning, the dissatisfaction could be conceivably reduced to a more acceptable level.

Useability of Computer-generated Timetables

The sixth question on the questionnaire pertaining to the computer-generated timetables was: "Would you judge this computer-generated timetable to be immediately useable in your school?"

Table XXI shows that forty-one per cent of these teachers concluded that the computer-generated timetables could have been used immediately within their school in lieu of their 1982-83 manually-constructed timetables. Another fifty per cent judged that the computer-generated timetables could be used provided some minor adjustments and improvements were made.

In total, no fewer than eighty-five of these teachers, or ninety-one per cent of them, favourably evaluated their computer-generated teacher timetables in terms of immediate

TABLE XXI

TEACHER ASSESSMENT OF THE USEABILITY OF THEIR ALTERNATIVE 1982-83 COMPUTER-GENERATED TIMETABLES IN LIEU OF THEIR MANUALLY-CONSTRUCTED TIMETABLES

	Computer-generated Timetables					
	Ascension	Gonzaga	John Burke	Partanna	Total	
Staff Responses	34	26	16	18	94	100%
Yes, definitely	11	13	10	4	38	41%
Yes, with minor adjustments	19	9	6	13	47	50%
No, somewhat unsatisfactory	3	1	0	1	5	5%
No, most undesirable	1	3	0	0	4	4%

useability. Such a highly positive comparative assessment of these alternative 1982-83 computer-generated timetables is, in the opinion of the researcher, further substantial proof that the Norwegian Nor-Data School Scheduling System can satisfactorily produce the master schedule for high schools throughout Newfoundland and Labrador.

Unsatisfactory Aspects of Timetables

The seventh question on the questionnaire pertaining to the computer-generated timetables was: "Would you list below any unsatisfactory aspects of your computer-generated timetable?"

Its counterpart on the questionnaire pertaining to the manually-constructed timetables was: "Would you list below any unsatisfactory aspects of your present timetable for 1982-83?"

The various unsatisfactory aspects of the manually-constructed timetables were as follows:

1. Imbalanced distribution of periods for some courses over the six-day curriculum cycle.

2. Irreconcilable teacher timetable conflicts.

3. Having to teach one period of another teacher's workload due to an unsolvable timetable conflict.

4. Two or more periods of the same course occurring on the same day.

5. All three periods of a one-credit course occurring on two or three consecutive teaching days.

6. All six periods of a two-credit course occurring on five, or fewer, consecutive teaching days.

7. Having only single periods in a practical or laboratory-orientated course.

8. Having a double period in an academic course when it is not necessary nor requested.

9. Having one group of students three or more periods during one day.

10. Having a double period in two different courses with the same students during one day.

11. Having the last period every day with the same students for the same course.

12. Two or more consecutive school days without a non-teaching period.

13. Two or more non-teaching periods occurring on the same day.

14. Two or more consecutive non-teaching periods.

15. Occurrence of the same course in the same time slot every day over the curriculum cycle.

16. Assignment of a supervision period in lieu of a potential regular teaching period.

17. Not having a double period as requested for a specific academic course.

18. Allocation of an insufficient number of periods for a course.

19. Allocation of too many periods for an academic course.

20. Having two or more consecutive periods in different courses with the same students in the same classroom.

21. A double period divided by recess or dinner hour.

22. A student option scheme militating against effective use of a specialist room.

23. Intermittent teaching periods militating against effective use of non-teaching time of specialist teachers.

24. Having components of the same course taught by two or more teachers.

25. Having to teach in several different classrooms.

Some thirty-eight teachers elected not to itemize any unsatisfactory aspects of their manually-constructed timetables. There was a close relationship, the researcher observed, between those teachers who very satisfactorily rated their manually-constructed timetables and those who chose not to enumerate any undesirable aspects of their 1982-83 manually-constructed timetables. This trend was most noticeable in the responses from the staff of Gonzaga High School.

The various unsatisfactory aspects of the computer-generated timetables were as follows:

1. Imbalanced distribution of periods for some courses over the six-day curriculum cycle.

2. All three periods of a one-credit course occurring on two or three consecutive teaching days.

3. All six periods of a two-credit course occurring on five, or fewer, consecutive teaching days.

4. Having only single periods in a practical or laboratory-orientated course.

5. Having a double period in an academic course when it is not necessary nor requested.

6. Having one group of students three or more periods during one day.

7. Two or more non-teaching periods occurring on the same day.

8. Two or more consecutive non-teaching periods.

9. Two or more school days without a non-teaching period.

10. Occurrence of the same course in the same time slot every day of the six-day curriculum cycle.

11. Not having a double period as requested for a specific academic course.

12. Having two or more consecutive periods in different courses with the same students in the same classroom.

13. Majority of non-teaching periods occurring during the first period of the day.

14. Having too many double periods.

15. Having the first period every day with the same students for the same course.

16. Having a double period in a one-credit academic course.

17. Having to teach in several different classrooms.

18. Having two or more periods of any course scheduled in a pedagogically unsound and undesirable manner.

As many as forty-two teachers did not enumerate any unsatisfactory aspect of the computer-generated timetables. There was clearly a close relationship between the teachers who very favourably assessed their alternative computer-generated timetables and those who did not mention any undesirable aspect about them.

It is noteworthy that the computer-generated master schedules could alleviate the following problematic aspects of the manually-constructed timetables:

1. Irreconcilable teacher timetable conflicts.

2. Having to teach one period of another teacher's workload due to an unsolvable timetable conflict.

3. Double periods divided unacceptably by recess or dinner hour.

4. Imbalanced distribution of periods for some courses over the six-day curriculum cycle.

5. Having to teach in several different classrooms.

6. Intermittent teaching periods militating against the most effective use of non-teaching time of specialist teachers.

Since the objective of this research with the Nor-Data School Scheduling System was to reproduce four master schedules which had already been manually constructed, these alternative computer-generated 1982-83 master schedules

could not possibly have eliminated a large number of the undesirable aspects of the manually-constructed timetables.

Without modifying the initial timetable plans for these schools, computerized master scheduling could not eliminate the following unsatisfactory aspects of these manually-constructed master schedules:

1. Having only single periods in a practical or laboratory-orientated course.

2. Allocation of insufficient teaching time for one or more courses.

3. Allocation of too much teaching time for one or more courses.

4. Substitution of a supervision period for a potential regular teaching period.

5. Having components of an academic course taught by two or more teachers.

6. A student option scheme militating against effective use of a specialist room.

7. Having one group of students three or more periods every day.

8. Having two or more periods of any course scheduled in a pedagogically unsound and undesirable manner.

Undoubtedly, these problems, which exist unacceptably in the computer-generated as well as the manually-constructed master schedules, are timetable planning issues. Each must be resolved through educationally sound timetable planning prior to the computer timetable construction stage; otherwise,

it is unrealistic to expect the Nor-Data School Scheduling System to effect significant improvements in the alternative master schedules for these four participating schools.

Desired Characteristics of Teacher Timetables

The most highly rated teacher timetables contain several desirable features.

The most desired characteristics of the best teacher timetables, as mentioned by these teachers in response to the last question on their questionnaires, are as follows:

1. A balanced distribution of periods for each of the different courses taught over the six-day curriculum cycle.

2. Allocation of one period per day for each of the two-credit courses.

3. Allocation of one period every other day for each of the one-credit courses.

4. Allocation of at least one double period for each practical or laboratory-orientated course.

5. A minimum of one non-teaching period per day.

6. No clustering of non-teaching periods.

7. No clustering of periods in any course.

8. No consecutive double periods with the same group of students.

9. No double period in any academic course unless specifically requested,

10. No supervision of a study periods for students.

11. No more than one double period in any of the two-credit courses.

12. Allocation of blocks of non-teaching time for specialist teachers required to do some teaching.

13. Avoidance of a three-day, or longer, gap between periods in any course.

14. Allocation of functional blocks of teaching time for split-site teachers to work satisfyingly at both schools.

15. No irreconcilable teacher timetable conflict.

16. No occurrence of the same course in the same time slot every day of the six-day curriculum cycle.

17. Allocation of appropriate amount of teaching time for each course.

18. Not having two or more consecutive periods in different courses with the same students in the same classroom.

19. Not having a double period divided by recess or dinner hour.

20. Not having components of the same course taught by two or more teachers.

21. All classes scheduled in the same subject area classroom.

22. Student option schemes which enhance optimal teaching and learning time as well as effective use of each specialist classroom.

23. All periods for each course scheduled in a pedagogically sound and desirable manner.

24. A teaching workload comprised of courses of one's choice in keeping with one's interest and experience.

25. Teaching all of one's courses in the same classroom.

CONCLUSION

Unquestionably, some teacher timetables can, and must, be better constructed to provide optimal teaching and learning situations. Clearly, the Norwegian Nor-Data School Scheduling System has effected some improvements in these alternative computer-generated 1982-83 master schedules. Truly significant timetabling improvements can only be effected, however, through sound timetable planning. With educationally sound timetable planning, the Nor-Data School Scheduling System can become an invaluable asset to high school administrators throughout Newfoundland and Labrador.

CHAPTER VI

PRINCIPALS' ASSESSMENT OF COMPUTER-GENERATED TIMETABLES

To elicit an assessment of these computer-generated master schedules from the viewpoint of the administrators of these schools, the researcher conducted during the spring of 1983 a structured interview with each of the participating principals: Frederick Bullen of Ascension Collegiate; John Martin of Gonzaga High School; and, John Tucker of Partanna Academy.

The master schedules produced by the Non-Data School Scheduling System were very favourably assessed by all three of these school administrators. No computer programming deficiencies were perceived by these interviewees to be associated with their alternative computer-generated 1982-83 master schedules.

INTERVIEW RESPONSES

A synthesis of their independent interview responses by item follows.

General Reaction of Staff

The first question posed during each of these tape-recorded interviews was: "What was the general reaction of your staff to their alternative computer-generated timetables

for 1982-83 with respect to their workload preferences and the distribution of periods for their different courses?"

Without exception, these school administrators had observed that their staff had reacted very favourably to their alternative computer-generated timetables. Overall, the distribution of periods per course was judged to be clearly as good as, if not better than, that produced by their manually-constructed 1982-83 master schedules. Each felt that there was no difference in the workload preferences of their teachers, for this aspect of the master schedules had been predetermined prior to the completion of their manually-constructed master schedules.

Unexpected Problems with Teacher Timetables

The second question was: "Did any of your staff present you with any unexpected problems about their computer-generated timetables? If so, what types of problems were they?"

Each principal indicated that there were no serious unexpected problems which the teachers had with their computer-generated timetables. These alternative 1982-83 teacher timetables were very well received by the staff of each school, largely because the majority of these timetables embodied many of the scheduling features which are most desired by the majority of teachers.

Such a lack of problems would suggest that the quality of these computer-generated master schedules is very high.

Favourable Comparison of Master Schedules

The third question was: "In what ways might you have judged the computer-generated master schedule to be better for your school than the manually-constructed 1982-83 master schedule?"

Each principal mentioned several ways in which the computer-generated master schedule is significantly better.

For example, the computer-generated master schedule for Ascension Collegiate contains no teacher timetable conflict. In contrast, the manually-constructed master schedule contains no fewer than three undesirable teacher timetable conflicts which are so problematic that they had been judged to be unsolvable by the trial-and-error, hand-mosaic approach. For the several teachers so adversely affected by this very serious timetabling problem at Ascension Collegiate, the satisfactory resolution of all three of these teacher timetable conflicts is a significant improvement over the manually-constructed 1982-83 master schedule.

The computer-generated master schedule for Gonzaga High School was constructed within three days by the Nor-Data School Scheduling System. By comparison, the completion of the manually-constructed 1982-83 master schedule required as many as eight working days. For the assistant principal of Gonzaga High School, this very significant reduction in the time that is normally required to manually construct the master schedule is extremely attractive.

The computer-generated master schedule for Partanna Academy provided not only the staff with a better distribution of periods per course, but also the school administrators with a much more comprehensive package of useful information about the timetable for each teacher, each grade and each classroom. For the staff and administration of Partanna Academy, these changes are perceived to be very significant improvements which could only be effected by computerized scheduling.

Better distribution of periods for teachers, a more comprehensive package of useful information for the school administrators, a significant reduction in the time normally required for manual timetable construction and the resolution of apparently unsolvable teacher timetable conflicts offer very convincing proof to these school administrators that the Norwegian Nor-Data School Scheduling System is a truly locally viable computer master scheduling program.

Unfavourable Comparison of Master Schedules

The fourth question was: "In what ways might you have judged the computer-generated master schedule to be worse than the manually-constructed 1982-83 master schedule?"

Each of these school administrators very adamantly maintain that there is no aspect of the computer-generated master schedules which is worse than the 1982-83 manually-constructed master schedules. The consensus of these school administrators is that better master schedules were produced by computer by the Nor-Data School Scheduling System.

Assessment of Computer-generated Master Schedules

The fifth question was: "Overall, how would you assess the computer-generated master schedule for your school?"

Cognizant of the apparent superior quality of these alternative teacher, grade and classroom timetables as well as the very positive feedback from the staff, each of these school administrators would unhesitatingly rate the computer-generated master schedule for his school as excellent. From an administrative point of view, the Norwegian Nor-Data School Scheduling System can generate more useful timetabling information more quickly, more easily and significantly more accurately than can possibly be done manually.

Continuation of Computer-generated Master Scheduling

The sixth question was: "Given the opportunity, would you elect to have the 1983-84 master schedule for your school produced by computer by the Norwegian Nor-Data School Scheduling System? If so, why? If not, why not?"

These three school administrators would welcome the opportunity to have their 1983-84 master schedules produced by the Nor-Data School Scheduling System. Each contends that computer-assisted master scheduling would be advantageous for all concerned. Teachers and students would have better timetables. Principals would not only save time during the timetable construction stage but also have access to much more pertinent and useable timetabling information.

Cost of Computer-generated Master Scheduling

The seventh question was: "Would your School Board likely be agreeable to pay a reasonable amount for this school management service? If so, why? If not, why not?"

These school administrators are of the opinion that their School Boards would, or at least should, be receptive to a reasonable expenditure for computer-assisted scheduling, particularly if it can be proven that schools could be better managed through better scheduling. The financial restraints under which the School Boards are presently operating would certainly militate against their fully financing computer-assisted master scheduling, especially if it were deemed to be an optional, rather than an essential, school management service.

The principal of Ascension Collegiate would argue that computer-assisted master scheduling has already become a prerequisite for effective management of approximately 700 students and forty teachers. Full implementation of the Reorganized High School Program during 1983-84 will only heighten the manual scheduling problems at Ascension Collegiate.

Potential Market for Computerized Master Scheduling

The eighth question was: "Do you sense that there is a potential market for computer-generated master scheduling throughout this Province, possibly with the Norwegian Nor-Data School Scheduling System? If so, why? If not, why not?"

These principals feel strongly that there is a need for school administrators to seriously consider alternative methods of timetabling. The traditional trial-and-error, hand-mosaic approach to timetabling is no longer adequate nor appropriate, especially for scheduling the larger high schools. There is, then, these principals would argue, a potential market for computerized master scheduling throughout the Province. Furthermore, these principals sense that the Norwegian Nor-Data School Scheduling System could be most advantageously used by high school administrators throughout Newfoundland and Labrador.

The growth, and eventual size, of that market would depend upon the method used to inform school administrators of the merits, as well as the cost, of computer-generated master scheduling. These principals feel that high school administrators would be eager to avail of this management service, provided the cost per master schedule were within reason. An initial user fee which would be judged to be exorbitant would most likely militate against province-wide use of the Norwegian Nor-Data School Scheduling System. Endorsement of, and financial support for, the Nor-Data School Scheduling System by the Department of Education would very significantly enhance its immediate marketability and eventual widespread use by high school administrators and School Boards throughout the Province.

Clearly, the need and the market for computerized scheduling exist. The prohibiting factor could be the cost.

Advent of Computerized Master Scheduling

The ninth question was: "Do you foresee the advent of computerized master scheduling in this Province being somewhat accelerated by this study? Elaborate."

Each of these principals holds the view that this timely study on master/scheduling, which coincides with the introduction of the Reorganized High School Program with its inherent timetabling problems, has already made a number of principals aware of the potential of computer-generated master scheduling. Each is optimistic that this momentum, which was further heightened through the computer scheduling seminar which was held at Memorial University of Newfoundland with Harald Michalsen during November of 1982, will continue to grow with the dissemination of the findings of this study.

Each principal is equally adamant that the advent of computerized master scheduling in this Province can only be accelerated through a carefully planned province-wide approach to the promotion of computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System as a truly locally viable alternative to our trial-and-error, hand-mosaic approach to timetabling. Such a comprehensive promotion of a new and challenging facet of educational administration would, they argue, necessarily require the full support of the Department of Education, Memorial University of Newfoundland, the Newfoundland Teachers' Association, the School Administrators Council,

the Newfoundland and Labrador School Trustees Association, and Newfoundland and Labrador Computer Services Limited.

These principals sense that the demand for computer-assisted master scheduling presently exists among high school administrators throughout the Province. They believe that now it the opportune time to promote a fresh approach to master scheduling. They are optimistic that computerized master scheduling will soon become an integral dimension of our educational system.

Role of the Department of Education

The tenth question was: "What role should the Department of Education play in the promotion of this aspect of educational administration? Elaborate."

The view of these school administrators is that the Department of Education definitely has a key role to play in the promotion of computer-generated master scheduling. Their rationale is two-fold. Firstly, these principals sense that proper timetabling of the Reorganized High School Program to ensure that students can select the courses of their choice is a near impossible task to accomplish by the traditional trial-and-error, hand-mosaic approach. The Department of Education has an obligation to ensure that the Reorganized High School Program is not only fully implemented, but also well scheduled, so that students may receive the maximum benefit from the substantially revised senior high school program. Secondly, these principals

sense that much better master schedules can be produced by computer through the Norwegian Nor-Data School Scheduling System.

A timetabling consultant is clearly needed at the Department of Education to promote a progressive policy on computer-generated master scheduling as a means of better implementing the Reorganized High School Program.

Role of Memorial University of Newfoundland

The last question was: "What role should Memorial University of Newfoundland play in the promotion of this aspect of educational administration? Elaborate."

These school administrators feel very strongly that Memorial University of Newfoundland through its Department of Educational Administration has a very important role to play in the promotion of better timetabling through computer-generated master scheduling.

The very least that the Department of Educational Administration should do is to offer, both at the graduate and under-graduate level, a course on the basic principles and techniques of sound timetabling. This practical approach to timetabling should focus upon computerized master scheduling as a new and very promising dimension of educational administration.

Perhaps a practical course on computerized master scheduling could be a prerequisite for a Master's Degree in Educational Administration.

CONCLUSION

Each of these participating school administrators provided the researcher with a very positive assessment of his alternative computer-generated 1982-83 master schedule.

Each of these principals is strongly supportive of computerized master scheduling as a highly desirable new facet of educational administration.

Each principal firmly believes that the Norwegian Nor-Data School Scheduling System could be advantageously used by high school administrators throughout the Province.

Each is hopeful that computerized master scheduling will soon become a reality for high school administrators throughout Newfoundland and Labrador.

CHAPTER VII

COST ANALYSIS OF COMPUTER-GENERATED MASTER SCHEDULING

Whereas the manual construction of the school's master schedule is by its very nature a no-cost item for school administrators, computer-generated master scheduling can be a somewhat expensive aspect of school management. The computer timetabler must necessarily pay for computing time as well as the time used by a computer programmer, both of which could be very costly.

Required for this feasibility study of the Norwegian Nor-Data School Scheduling System were seven representative individuals, each with quite different but complementary work experiences: Harald Michalsen from Norway; the four participating school administrators; and, two computer programmers at Newfoundland and Labrador Computer Services Limited. As a team, all worked on this timetabling project for one week. In addition, the researcher, the two computer programmers and Harald Michalsen worked an extra three days. The total man-time used was, therefore, forty-seven regular working days.

COST ANALYSIS OF NOR-DATA FEASIBILITY STUDY

An analysis of the cost of the various aspects of this feasibility study follows.

Batch Runs

With the Nor-Data School Scheduling System, the master schedule is produced through three distinct stages: the FORPROGRAM, the MAINPROGRAM and the OUTPUT PROGRAM.

To successfully initiate construction of the master schedules for Ascension Collegiate, Gonzaga High School, John Burke High School and Partanna Academy, it was necessary to execute and print by computer no fewer than twenty-seven FORPROGRAMS at a total cost of $271.39 for computing time.

To ensure production of a satisfactory master schedule for each of these schools, a total of thirteen MAINPROGRAMS were necessarily run at a total cost of $706.09 for computing time.

To obtain the best possible master schedule for each of these schools, with multiple copies of the final version for all involved in this study, as many as eighteen OUTPUT PROGRAMS were executed at a cost of $399.61 for computing time.

The total cost of computing time for these fifty-eight batch runs was $1,377.09.

The average cost per school for this aspect of the feasibility study was $344.27.

Computer Terminal Sessions

After the initial timetabling data, which has been very thoughtfully and accurately prepared by the principal in Tables 1 and 2 (See Appendices E and F), has been

keypunched by a data preparation operator, the production of the school's master schedule is controlled by the timetabler and the computer programmer at a computer terminal.

To produce satisfactory master schedules for these four schools, the computer programmers required a total of twenty-five working sessions at the computer terminal. The total cost of this computing time was $1,110.57.

The average cost per school for this aspect of the feasibility study was $277.64.

Man-Time

Assigned to this timetabling project by Newfoundland and Labrador Computer Services Limited were one programmer analyst and one computer programmer whose hourly wage was $37.00 and $28.00 respectively. In addition, there was a data preparation operator, whose hourly wage was $16.00, who worked intermittently on this project for two days.

The man-time cost accumulated during this eight-day timetabling session totalled $3,013.10.

The average cost per school for this aspect of the feasibility study was $753.28.

Total Cost of Project

The total cost of this feasibility study of computer-generated master scheduling with the Nor-Data School Scheduling System was $5,500.76.

The average cost per school for its computer-generated master schedule was $1,375.19.

No-Cost Factor

For this feasibility study, there was no man-time cost for either the four school administrators or Harald Michalsen. Each of the principals had been granted paid leave by his School Board. Harald Michalsen had volunteered to assist the researcher to prove the local application of his computer master scheduling program.

Had it been necessary to include the salary of the four principals, as well as a consultant's fee for Harald Michalsen, this aspect of the feasibility study could have cost as much as $5,000.00 or more.

Sample User Fees

Quite obviously, the cost of computer-generated master scheduling for high schools throughout the Province could be exorbitant. Without a province-wide educational computing network system, as does exist in several other provinces of Canada, the cost of computer-generated master scheduling could very much militate against its acceptance and widespread use by school administrators who might very well welcome the opportunity to avail of this very promising school management service.

Regarding the projected cost of computer-generated master scheduling, one employee of Newfoundland and Labrador Computer Services Limited has reasoned:

> It is difficult to project the cost of computer-generated timetables for high schools throughout the province as the costs would vary greatly depending on

> the size and complexity of the schools as well as the expertise of both the timetablers and the computing personnel.[1]

For a school which is relatively easy to schedule, as was Gonzaga High School in this feasibility study, the cost to the School Board could be as follows.

TABLE XXII

SAMPLE USER COST FOR MASTER SCHEDULE "A"

JOB COMPONENTS	COST
3 FORPROGRAMS	$ 30.00
3 MAINPROGRAMS	150.00
3 OUTPUT PROGRAMS	30.00
1 Master Schedule	20.00
Computer Terminal Sessions	300.00
Disk and Tape Storage	50.00
Man-Time	250.00
License Fee for Harald Michalsen	200.00
	$1,030.00

A charge of approximately $1,000.00 for a computer-generated master schedule would, the researcher reasons, not likely be well received by School Boards in this Province.

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[1] Letter to researcher from Mary-Louise Porter, Newfoundland and Labrador Computer Services Limited, St. John's, Newfoundland, February 4, 1983.

For a school which is more difficult to schedule, as was the split-site schools of John Burke High School and Partanna Academy, the cost to the School Board could be as follows.

TABLE XXIII

SAMPLE USER COST FOR MASTER SCHEDULE "B"

JOB COMPONENTS	COST
8 FORPROGRAMS	$120.00
8 MAINPROGRAMS	600.00
4 OUTPUT PROGRAMS	80.00
2 Master Schedules	40.00
Computer Terminal Sessions	500.00
Disk and Tape Storage	50.00
Man-Time	450.00
License Fee for Harald Michalsen	200.00
	$2,040.00

An annual charge of approximately $2,000.00 for a computer-generated master schedule would, in the opinion of the researcher, be promptly rejected by School Boards throughout the Province, for their present policy of fiscal restraint would simply not permit such an expenditure for a school management service, particularly if computerized scheduling was judged an optional method of timetabling.

With reference to these projected sample user fees for computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System, a computer programmer at Newfoundland and Labrador Computer Services Limited very thoughtfully advises:

> Please note that the costs cited ... are not intended to be estimates of any future timetabling in which NLCS may be involved, and that any rates quoted are subject to change. Also, any conclusions that may be drawn from this information ... are not necessarily those of NLCS.[2]

Apparently, the cost of computer-generated master scheduling with the Nor-Data School Scheduling System could very well be beyond the financial capability of School Boards throughout Newfoundland and Labrador.

It is possible, however, that computer-generated master scheduling might cost the user substantially less than these estimates would suggest.

COST OF NOR-DATA SYSTEM TO BRITISH USERS

In England, where the Nor-Data School Scheduling System has been used successfully since 1971, each Local Education Authority has been charged an initial fee, which is partly determined by the number of schools within its jurisdiction, which gives it "the right to use the system in its present form in perpetuity."[3]

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[2] Ibid., p. 3.

[3] LAMSAC Project Report: Computer Assisted School Timetabling (London: Local Authorities Management Services and Computer Committee, 1978), p. 52.

The Royal Institute of Public Administration (RIPA) in England has offered the Nor-Data School Scheduling System to British school administrators on the following terms,[4] effective September of 1977.

TABLE XXIV

BRITISH CHARGES FOR NOR-DATA SYSTEM

Secondary Schools per Local Education Authority	Lump Sum Payment*	Four Instalments
Under 20	$ 9,000	$ 2,700
20 - 29	13,500	4,050
30 - 49	18,000	5,400
50 - 74	22,500	6,750
75 - 99	28,125	8,437
100 - 149	33,750	10,125
150 and over	45,000	13,500

*Converted from British pound = $2.25

Obviously, this is a much cheaper and more realistic method of obtaining computer-generated master scheduling with the Nor-Data School Scheduling System.

There are, however, additional expenses which are associated with computer-generated master scheduling with the Nor-Data School Scheduling System in England. The LAMSAC Report elaborates:

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[4] Ibid.

Support services required after the period of initial training will be made available on separately agreed terms.

The training course for operators of the system will consist of three parts:

1. The first part, lasting 4 weeks, will deal with:

   General principles of school timetabling.
   Data requirements of system.
   System's main operating features.

2. The second part, lasting 3 weeks, will be spent in the trainee's own authority engaging in computer production of timetables from practice data provided. Assistance during this time will be given generally by telephone.

3. There will be a final week when trainees meet to discuss problems.

The fee for this operators' training course will be $2,700 for the first trainee and will include up to five days of consultancy service within the authority during the Summer timetabling period. Any further service required will be at the rate of $112 per day plus actual travelling and subsistence expenses. The fee for additional trainees will be $1,350 per person.[5]

Should the Nor-Data School Scheduling System be used widely throughout the Province in the near future, it would be advantageous, the researcher has concluded, for School Boards to obtain the exclusive right to use the Nor-Data School Scheduling System, as the British Local Education Authorities have done. Even though the initial expenditure would be high, it would be much cheaper in the long term than a user's fee per computer-generated master schedule.

Either way, computer-generated master scheduling is an expensive proposition.

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[5] Ibid.

TRENDS IN THE COST OF COMPUTERIZED TIMETABLING

A decade or so ago, computer programming of any kind was very expensive. Computer technology was still very much in its infancy. The cost to the user was understandably high. Computer programming was an unaffordable option for thousands of potential users.

Today, computer programming of all kinds is much less expensive. World-wide, the age of the computer has arrived. Accordingly, the cost to the user, the educator as well as the businessman, is predictably decreasing each year. Computer programming has now become an affordable option for most potential users.

Decreasing Cost

The literature on computers as an invaluable aid to teachers and school administrators clearly indicates that the cost of computers and computer programming is steadily declining. Furthermore, the cost to the user is most likely to be even further reduced in the immediate and foreseeable future.

Regarding this clearly discernible trend in the cost of computer programming, Foley realistically argues:

> ... the computer's impact on education will be major during the next decade since the computer now represents the only significant educational cost that is decreasing and will continue to decrease in the foreseeable future.[6]

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[6]John F. Foley, "The Affordable Computer," Momentum, X (December, 1979), 8.

Others have echoed the same contention. Appraising the province-wide educational computer system which has been operational in Manitoba since 1973, Luba enthusiastically reports:

> What is more important, the computer usage and data transmission costs are dropping in a period of the highest level of world wide inflation known to man. Manitoba has experienced a significant reduction in computer usage cost during the past two years. Coupled with the development of provincial data route lines and alternative data transmission systems, the Manitoba Department of Education operates today a network with a 25% increase in services at a cost which is 28.2% less than two years ago. There are indications that costs will be dropping more in the not too distant future.[7]

Assessing the Generalized Academic Simulation Programs (GASP) shortly after its introduction to American schools in 1963, Murphy concludes:

> One thing is quite clear: as schools gain experience in the use of GASP, cost go down markedly. For one thing, they learn to perfect their preparation of data, thereby minimizing mistakes and reducing the number of computer runs required. The scheduler becomes more adept and imaginative in interaction with his electronic partner, and develops a sixth sense that enhances his understanding of what the computer can and cannot do.[8]

Adamantly contending that "computers are going to become increasingly cost effective as a mechanism to assist the learning process,"[9] Rockart states unequivocally:

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[7]Peter M. Luba, "Computers in Manitoba Schools," Education Canada, XV (Winter, 1975), 48.

[8]Judith Murphy, School Scheduling by Computer: The Story of GASP (New York: Educational Facilities Laboratories, 1964), p. 45.

[9]John Fralick Rockart and Michael S. Scott-Morton, Computers and the Learning Process in Higher Education (New York: McGraw-Hill, 1975), p. 75.

> ... it is relatively clear that computer costs per program run will decrease, perhaps greatly, and therefore computers will provide more cost-effective competition for alternate ways of delivering learning.[10]

Should these very encouraging predictions regarding the cost efficiency of the large computer not materialize, others reason that the microcomputer will fill the void. Johnston argues:

> Our aim is not to make microcomputers the answer, but a tool in search of the answer. Any tool that can relieve teachers, counselors, and administrators from some of the mountains of paperwork should be investigated. With the cost of microcomputers coming down, most schools will be able to acquire one.[11]

Province-wide Educational Computing Networks

Fifteen years or so ago, when computerized master scheduling was first introduced to educators, the computer scheduling systems were often feasibility studies which had their origin at some university. For example, the Stanford School Scheduling System, which was developed and promoted during the mid-1960's by Robert Oakford at Stanford University at Stanford in California, was used initially by selected high schools in California and nearby states. Only a limited number of schools were involved.

Today, countries such as Britain and Norway, states such as California and Iowa, and provinces such as Ontario

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[10] Ibid., p. 67.

[11] Raymond B. Johnston, "Microcomputers: Tools in Search of Answers," NASSP Bulletin, LXV (November, 1981), 124.

and Manitoba systematically promote the computer in schools for administrative as well as instructional purposes. Each has developed a comprehensive educational computing network which makes computing services available to educators and students regardless of location.

Regarding this trend as a more economical means of making computers readily available to teachers and school administrators, Johnson comments:

> The trend is toward the establishment of large computer centers which can serve more school systems. The centers offer economic advantages by helping to make data-processing and management services available to smaller schools.[12]

In Manitoba, for example, the cost of the province-wide Schools Computer Network, which consists of a central computer located at Winnipeg with computer terminals in all of the schools, has been the sole financial responsibility of the Department of Education since 1973. It has been judged to be the most economical method of providing the schools with full access to the computer for instructional and administrative purposes.

Of this comprehensive government-supported approach to making computers accessible to all students and educators, Campbell very realistically concludes:

> It is our view then, that remote batch terminals connected to large central computers will be the most economical way to provide quality computing power

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[12] M. Clemens Johnson, Educational Uses of Computers: An Introduction (Chicago: Rand McNally, 1971), p. 77.

to a large number of educational users, both instructional and administrative.[13]

Apparently, quality computing power can become readily and economically available to school administrators through a comprehensive educational computing network.

CONCLUSION

Even though computer-generated master scheduling is very expensive, and it is known that the Norwegian Nor-Data School Scheduling System would be no exception to this universal reality, it should be possible, the researcher has concluded, for this Province to develop a government-sponsored educational computing network through Newfoundland and Labrador Computer Services Limited which would make the Nor-Data School Scheduling System available to all school administrators at an affordable price for School Boards.

The crucial issue of cost versus benefit could well be resolved through our acceptance of the plausible premise that "With wise use, the computer can become an effective instrument for bringing about better schools through better scheduling."[14]

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[13]Graham M. Campbell and Lars C. Jansson, "Computer Costs and Capabilities For Instruction and Administration," NASSP Bulletin, LVIII (March, 1974), 63.

[14]Jack Parker, "Intangibles in the Master Schedule," NASSP Bulletin, LVIII (October, 1974), 81.

CHAPTER VIII

SUMMARY AND RECOMMENDATIONS

The results of this computer-generated master scheduling feasibility study with the Norwegian Nor-Data School Scheduling System are condensed in this final chapter.

SUMMARY

Here are the findings and conclusions of this study.

Statement of the Problem

The purpose of this study was to ascertain whether the Norwegian Nor-Data School Scheduling System could satisfactorily produce the master schedules for four selected schools in this Province.

The three research questions posed were as follows:

1. Is the Norwegian Nor-Data School Scheduling System a locally viable computer master scheduling program which has some immediate, or very near future, potential use for high school administrators throughout the Province?

2. Would the teachers of these four selected schools judge their computer-generated alternative 1982-83 timetables to be better than their manually-constructed timetables?

3. Given the technical capability and programming expertise of Newfoundland and Labrador Computer Services Limited, could computer-generated master scheduling soon become an affordable option for School Boards throughout the Province?

Procedure

To answer these basic research questions regarding computerized master scheduling, three school administrators were invited to work at Newfoundland and Labrador Computer Services Limited with Harald Michalsen and the researcher for a period of one week during November of 1982 to attempt to construct their 1982-83 master schedules by computer with the Norwegian Nor-Data School Scheduling System.

Prior to this timetabling session, the staff of each of the four participating schools were asked to complete a questionnaire regarding their 1982-83 manually-constructed timetables.

Following the successful completion of this timetabling project, the staff of each of the participating schools were asked to complete a questionnaire regarding their computer-generated alternative 1982-83 timetables.

A structured interview was conducted separately with each of the three participating school administrators to ascertain their views on the computer-generated alternative 1982-83 master schedules produced by the Norwegian Nor-Data School Scheduling System.

Summary of Findings

Without any technical or programming problems of any kind whatsoever, a highly satisfactory alternative 1982-83 master schedule was produced by computer by the Norwegian Nor-Data School Scheduling System for each of the four participating schools: Ascension Collegiate at Bay Roberts; Gonzaga High School at St. John's; John Burke High School at Grand Bank; and, Partanna Academy at Grand Bank.

No timetabling difficulties were encountered by either of these school administrators which could not be resolved quickly and satisfactorily by the Nor-Data School Scheduling System.

It would appear to the researcher, as well as to the other three participating school administrators, that schools throughout Newfoundland and Labrador would have no unique or highly problematic timetabling needs which could not be tackled most effectively by the Norwegian Nor-Data School Scheduling System.

The Norwegian Nor-Data School Scheduling System operated flawlessly on the new AMDAHL 470V/6 computer at Newfoundland and Labrador Computer Services Limited. With respect to program execution time, the AMDAHL computer was significantly faster than the IBM computer, a feature which very much impressed Harald Michalsen.

The majority of the teachers at these participating schools indicated that their computer-generated alternative

1982-83 timetables contained fewer undesirable scheduling features. Accordingly, they gave the computer-generated timetables a better qualitative assessment than they had earlier given to their manually-constructed timetables which they were using during the 1982-83 school year.

Conclusions

As a result of this successful computer-generated master scheduling feasibility study with the Norwegian Nor-Data School Scheduling System, the researcher has reached the following conclusions:

1. The Norwegian Nor-Data School Scheduling System is a truly locally viable computer master scheduling program which has immediate application for all high school administrators throughout the Province.

2. Newfoundland and Labrador Computer Services Limited has the technical capability and the programming expertise to competently use the Norwegian Nor-Data School Scheduling System to efficiently produce a satisfactory master schedule for any school throughout Newfoundland and Labrador.

3. The Norwegian Nor-Data School Scheduling System can opportunely provide high school administrators with a functional alternative to manual construction of the master schedule by the traditional trial-and-error, hand-mosaic approach, one which has been much questioned and somewhat discredited recently with the advent of the Reorganized

High School Program with its inherent timetabling problems.

4. Computer-generated master scheduling could be commercially available from Newfoundland and Labrador Computer Services Limited as early as the spring of 1984 to school administrators who wish their master schedule produced by the Nor-Data School Scheduling System.

5. Computer-generated master scheduling can only become an immediate reality and an affordable option for School Boards throughout the Province if the Department of Education were to substantially subsidize the cost to Newfoundland and Labrador Computer Services Limited to profitably schedule schools with the Nor-Data School Scheduling System.

6. Should the Department of Education decide to subsidize computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System as a means of better scheduling the Reorganized High School Program, then computer-generated master scheduling could very well be commercially available to all high school administrators throughout the Province by the spring of 1985.

7. Computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System would be most beneficial for high schools, split-site schools, all-grade schools and junior high schools throughout Newfoundland and Labrador. It could, of course, be used advantageously for scheduling elementary schools. It would not, however, have any application for primary schools.

8. Without the immediate advent of computer-generated master scheduling in this Province, the manual scheduling of schools, particularly those offering the Reorganized High School Program, will be a very difficult administrative task for any school administrator to do well. Without computer-generated master scheduling, high schools throughout the Province may be faced with a very serious perennial managerial handicap.

RECOMMENDATIONS

As a supplement to the findings and conclusions of this study, the researcher would make the following recommendations:

Recommendations for Implementation

1. The Department of Education should immediately promote computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System as a functional alternative to manual construction of the master schedule for high schools throughout the Province.

2. Newfoundland and Labrador Computer Services Limited and the Department of Education should immediately seek a sound financial arrangement with Harald Michalsen for the exclusive right to use the Nor-Data School Scheduling System throughout the Province, preferably on terms similar to those presently being used by the Royal Institute of Public Administration in England.

3. The Department of Education should immediately assume a prominent leadership role in the use of computers in our schools for administrative as well as instructional purposes by establishing, or causing to be established, through Newfoundland and Labrador Computer Services Limited as soon as financially feasible a province-wide Educational Computing Network, possibly one similar to the Manitoba Secondary Schools Computer Network, to ensure that computer programming will in the very near future be accessible to all schools throughout the Province for instructional and administrative purposes.

4. The Department of Education should create within its Division of Instruction as soon as possible the position of Timetabling Consultant whose responsibility it would be to actively promote sound timetabling practices in schools throughout the Province by advocating stricter adherence to the basic principles of rational timetabling and by coordinating computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System as a means of better scheduling the Reorganized High School Program.

5. Newfoundland and Labrador Computer Services Limited should, in consultation with the Department of Education, devise a progressive marketing strategy for the Norwegian Nor-Data School Scheduling System to ensure that computerized master scheduling will be fully available to high school administrators within two years at an affordable price to School Boards throughout the Province.

6. The Department of Education should, in consultation with Newfoundland and Labrador Computer Services Limited, strongly recommend to the Minister of Education that the Provincial Government subsidize computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System in order to ensure that this highly desirable and clearly beneficial school management service is equally available to all schools in the very near future as an affordable managerial option for School Boards throughout the Province.

7. Memorial University of Newfoundland should offer at the graduate level through its Department of Educational Administration at least one practically-orientated course on the basic principles and techniques of rational time-tabling with appropriate emphasis on computer-generated master scheduling as a modern functional alternative to manual construction of the school's master schedule. In addition, the Department of Educational Administration should offer a timetabling simulation course so that some school administrators could acquire some meaningful training in constructing a useable master schedule by computer. Perhaps, one of these courses could be a prerequisite for the degree of Master of Education in Educational Administration.

8. School Boards throughout the Province should very actively promote computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System,

which automatically enhances stricter adherence to the basic principles and techniques of sound timetabling, as a means of not only better scheduling the Reorganized High School Program, but also better scheduling the junior high grades as well.

9. The Newfoundland Teachers' Association should endorse computerized master scheduling with the Norwegian Nor-Data School Scheduling System not only as a modern alternative to the traditional approach of manual construction of the school's master schedule, but also as a means of providing teachers and students with a potentially better teaching-learning environment through better scheduling.

10. The School Administrators' Council should most actively promote computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System as a modern functional alternative to our traditional method of manually constructing the school's master schedule, and as the answer to the very complex and challenging task of scheduling the Reorganized High School Program, to ensure that high school administrators can more competently provide students and teachers alike with the best of all possible timetables.

11. The Newfoundland and Labrador School Trustees Association should endorse computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System as a means of promoting well-scheduled, and therefore well-managed, high schools throughout the Province of Newfoundland and Labrador.

12. The School Boards and the Department of Education should immediately initiate appropriate inservice for high school administrators on computer-generated master scheduling with the Nor-Data School Scheduling System. Inservice assistance regarding technical and programming matters could be provided by Newfoundland and Labrador Computer Services Limited.

Recommendations for Further Research

The basic purpose of this study was to focus attention upon computer-generated master scheduling and to determine the potential application of the Norwegian Nor-Data School Scheduling System for school administrators throughout the Province. This research effort has clearly revealed that computer-generated master scheduling with the Norwegian Nor-Data School Scheduling System is indeed a modern functional alternative to manual construction of the school's master schedule, which could be used most advantageously by all high school administrators throughout Newfoundland and Labrador.

The researcher would make these recommendations for further research in the area of computerized scheduling:

1. A study could be undertaken to ascertain whether there exists in Canada a computer master scheduling program which might be judged to be technically better, and perhaps even more applicable to our master scheduling needs, than is the Norwegian Nor-Data School Scheduling System.

2. A study could be conducted to determine the extent to which sectioning, or student scheduling, with another computer scheduling program might be beneficially used by high school administrators throughout the Province.

3. A study could be initiated to explore the potential use of the microcomputer in the production of the school's master schedule with the Norwegian Nor-Data School Scheduling System, or another computer scheduling system which might be judged to be more suitable for adaptation to the microcomputer.

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APPENDIX A

QUESTIONNAIRE #1: TEACHER EVALUATION OF MANUALLY-CONSTRUCTED TIMETABLES

TEACHER EVALUATION OF MANUALLY-CONSTRUCTED TIMETABLES

Please evaluate your present timetable for 1982-83 by responding to the following questions as objectively as possible.

1. Have the basic requirements for your subject area(s) been met?
   (_____) Yes, very satisfactorily
   (_____) Reasonably satisfactorily
   (_____) Somewhat unsatisfactorily
   (_____) No, very unsatisfactorily

2. Have your workload preferences been met?
   (_____) Yes, very satisfactorily
   (_____) Reasonably satisfactorily
   (_____) Somewhat unsatisfactorily
   (_____) No, very unsatisfactorily

3. Do you have an acceptable distribution of periods per subject over the six-day curriculum cycle?
   (_____) Yes, very satisfactory
   (_____) Reasonably satisfactory
   (_____) Somewhat unsatisfactory
   (_____) No, very unsatisfactory

4. Overall, how would you categorize your manually-constructed timetable for 1982-83?

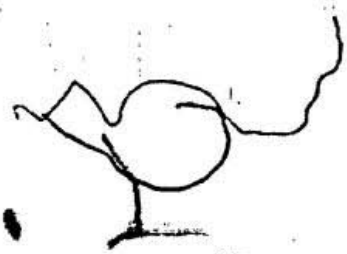
   (_____) Very satisfactory

   (_____) Reasonably satisfactory

   (_____) Somewhat unsatisfactory

   (_____) Very unsatisfactory

5. Would you list below any unsatisfactory aspects of your present timetable for 1982-83?



APPENDIX B

LETTER OF EXPLANATION TO TEACHERS ACCOMPANYING QUESTIONNAIRE #1

LETTER OF EXPLANATION TO TEACHERS
ACCOMPANYING QUESTIONNAIRE #1

75 Main Street
Grand Bank, Nfld.
November 8, 1982

Dear Fellow Teacher:

Enclosed please find a Questionnaire regarding your present timetable for 1982-83.

I am conducting my Thesis Research on computer-generated master scheduling. The objective is to ascertain whether computer-generated timetables would be feasible and perhaps better in our educational system. Ascension Collegiate* is one of four schools which has been selected for this study.

The computer master scheduling program which I have chosen is the Norwegian Nor-Data School Scheduling System, which was developed in 1966 by Dr. Harald Michalsen through the Engineering Research Foundation of the Technical University of Norway at Trondheim. Its developer, Dr. Michalsen, will be arriving in Newfoundland on November 19 for a two-week period to work with me and your principal, Mr. Frederick Bullen, on this research project at Newfoundland and Labrador Computer Services Limited at St. John's.

What I would appreciate your doing is as follows:

1. At this time, evaluate your present manually-constructed timetable as objectively as possible.

2. Early in December, evaluate your alternative computer-generated timetable for 1982-83, which I will provide for you.

Enclosed you will find an addressed envelope so that you may conveniently return your questionnaire to Mr. Bullen, who will in turn forward all of the completed questionnaires to me.

Thank you for your time and cooperation. It is truly appreciated.

Yours very truly,

Melvin Small
MUN Graduate Student

*A similar personalized letter was forwarded to the teachers at the other three participating schools.

APPENDIX C

QUESTIONNAIRE #2: TEACHER EVALUATION OF COMPUTER-GENERATED TIMETABLES

TEACHER EVALUATION OF COMPUTER-GENERATED TIMETABLES

Please evaluate your alternative computer-generated timetable for 1982-83 by responding to the following questions as objectively as possible.

1. Have the basic requirements for your subject area(s) been met?

   (_____) Yes, very satisfactorily

   (_____) Reasonably satisfactorily

   (_____) Somewhat unsatisfactorily

   (_____) No, very unsatisfactorily

2. Have your workload preferences been met?

   (_____) Yes, very satisfactorily

   (_____) Reasonably satisfactorily

   (_____) Somewhat unsatisfactorily

   (_____) No, very unsatisfactorily

3. Do you have an acceptable distribution of periods per subject over the six-day curriculum cycle?

   (_____) Yes, very satisfactory

   (_____) Reasonably satisfactory

   (_____) Somewhat unsatisfactory

   (_____) No, very unsatisfactory

4. Overall, how would you categorize your computer-generated timetable for 1982-83?

(_____) Very satisfactory

(_____) Reasonably satisfactory

(_____) Somewhat unsatisfactory

(_____) Very unsatisfactory

5. How does your computer-generated timetable compare with your 1982-83 manually-constructed timetable?

(_____) Definitely better

(_____) Very similar

(_____) Somewhat unsatisfactory

(_____) Much worse

6. Would you judge this computer-generated timetable to be immediately useable in your school?

(_____) Yes, definitely

(_____) Yes, with minor adjustments

(_____) No, somewhat unsatisfactory

(_____) No, most undesirable

7. Would you list below any unsatisfactory aspects of your computer-generated timetable?

APPENDIX D

LETTER OF EXPLANATION TO TEACHERS
ACCOMPANYING QUESTIONNAIRE #2

LETTER OF EXPLANATION TO TEACHERS
ACCOMPANYING QUESTIONNAIRE #2

75 Main Street
Grand Bank, Nfld.
December 6, 1982

Dear Fellow Teacher:

During November, you were asked to evaluate your manually-constructed timetable for 1982-83. The full cooperation of the staff of Gonzaga High School* was very much appreciated.

I am now delighted to present you with a copy of your computer-generated timetable for 1982-83. It is yours to keep!

In order to complete my Thesis, I do wish that you objectively evaluate your computer-generated timetable. I respectfully request, therefore, that you complete the attached questionnaire at your earliest convenience, and return it to your principal, Mr. John Martin, who will again forward all of your completed questionnaires to me.

Thank you very much for your time and cooperation, as well as your interest in computerized timetabling.

Yours very truly,

Melvin Small

MUN Graduate Student

*A similar personalized letter was forwarded to the teachers at the other three participating schools.

APPENDIX E

NOR-DATA TABLE 1: BASIC DATA

THE NOR-DATA SCHOOL SCHEDULING SYSTEM

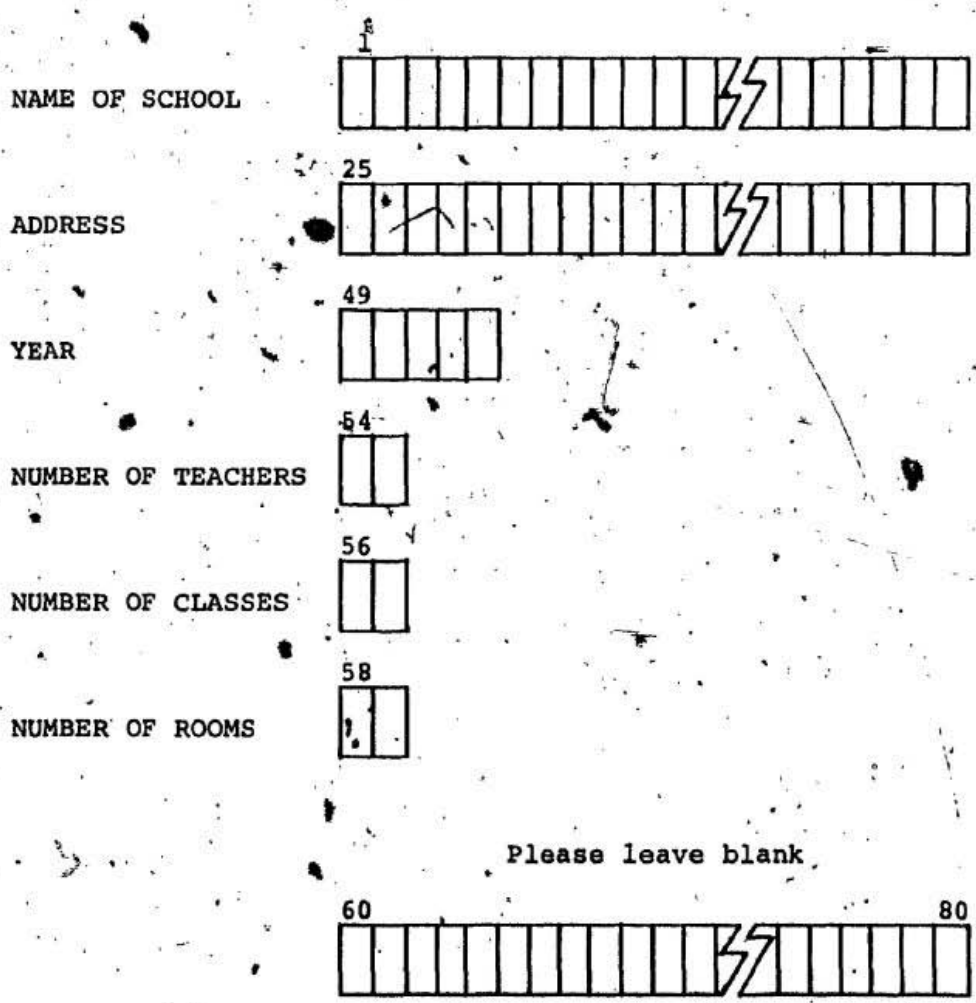
TABLE 1: BASIC DATA

TEACHER SURVEY

CLASS SURVEY

ROOM SURVEY

COMPONENT SETTING



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	TEACHER SURVEY																		CLASS SURVEY						
No.	NAME													No. Per.					CLASS			No. Per.		Room Pre.	
01																									
02																									
03																									
04																									
05																									
06																									
07																									
08																									
09																									
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21																									
22																									
23																									
24																									
25																									
26																									
27																									

*Original form contains fifty data entry lines.

27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

ROOM SURVEY

Room Type	NAME	No.	Alt. Clrm	ALTERNATIVE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Table 1b Component Setting

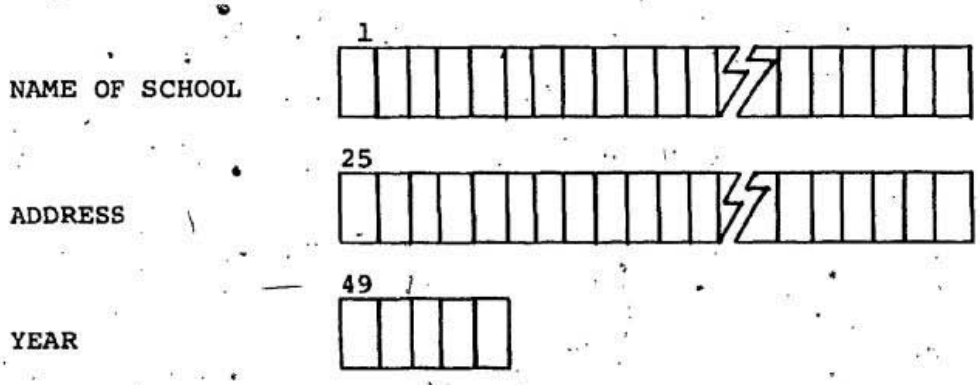
FIRST	LAST	No.	REF.			
	1	2	3	4	5	6

APPENDIX F

NOR-DATA TABLE 2: BASIC PLAN

THE NOR-DATA SCHOOL SCHEDULING SYSTEM

TABLE 2: BASIC PLAN



1 2 3	4 5 6	7 8	9 10	11	12	13 14 15	16 17	18 19	20	21	22 23 24	25 26
Activity												
Act.No.												
Class	No.of Per.	Tea.	Rm. type	D	T	No.of Per.	Tea.	Rm. type	D	T	No.of Per.	Tea.
Parallel												
Parallel												
Parallel												
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Parallel												
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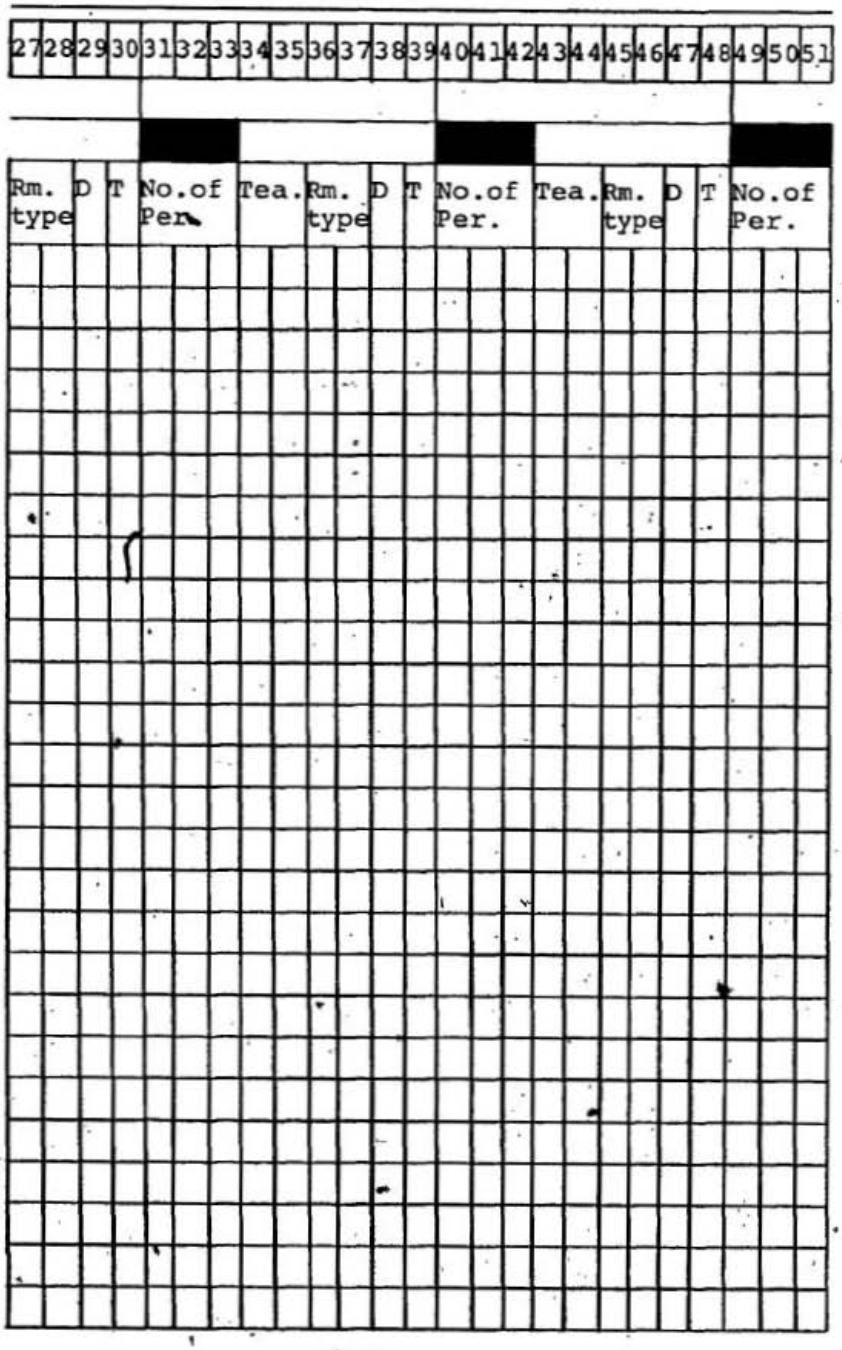
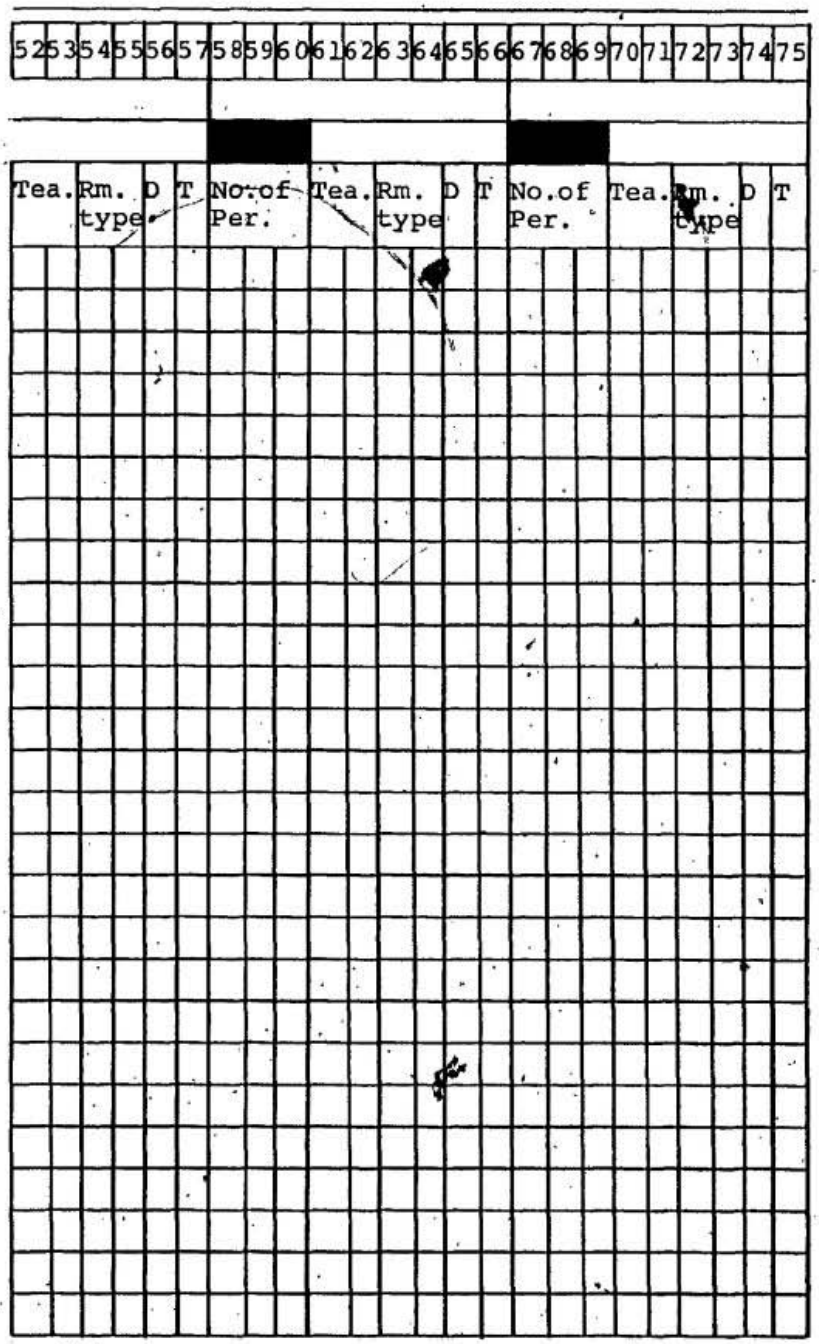
Parallel												

*Original form contains fifty data entry lines.


27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51
Rm. type
D
T
No.of Per.
Tea.
Rm. type
D
T
No.of Per.
Tea.
Rm. type
D
T
No.of Per.

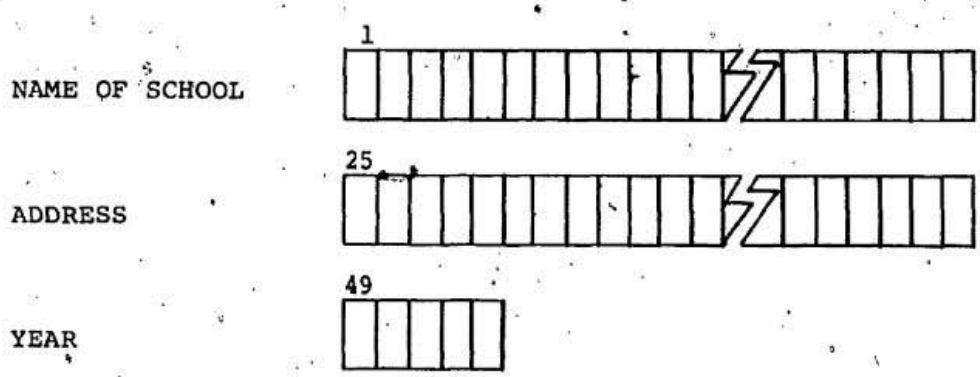

52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75
Tea.
Rm. type
D
T
No. of Per.
Tea.
Rm. type
D
T
No. of Per.
Tea.
Rm. type
D
T

APPENDIX G

NOR-DATA TABLE 3: PREASSIGNMENT AND BLOCKING

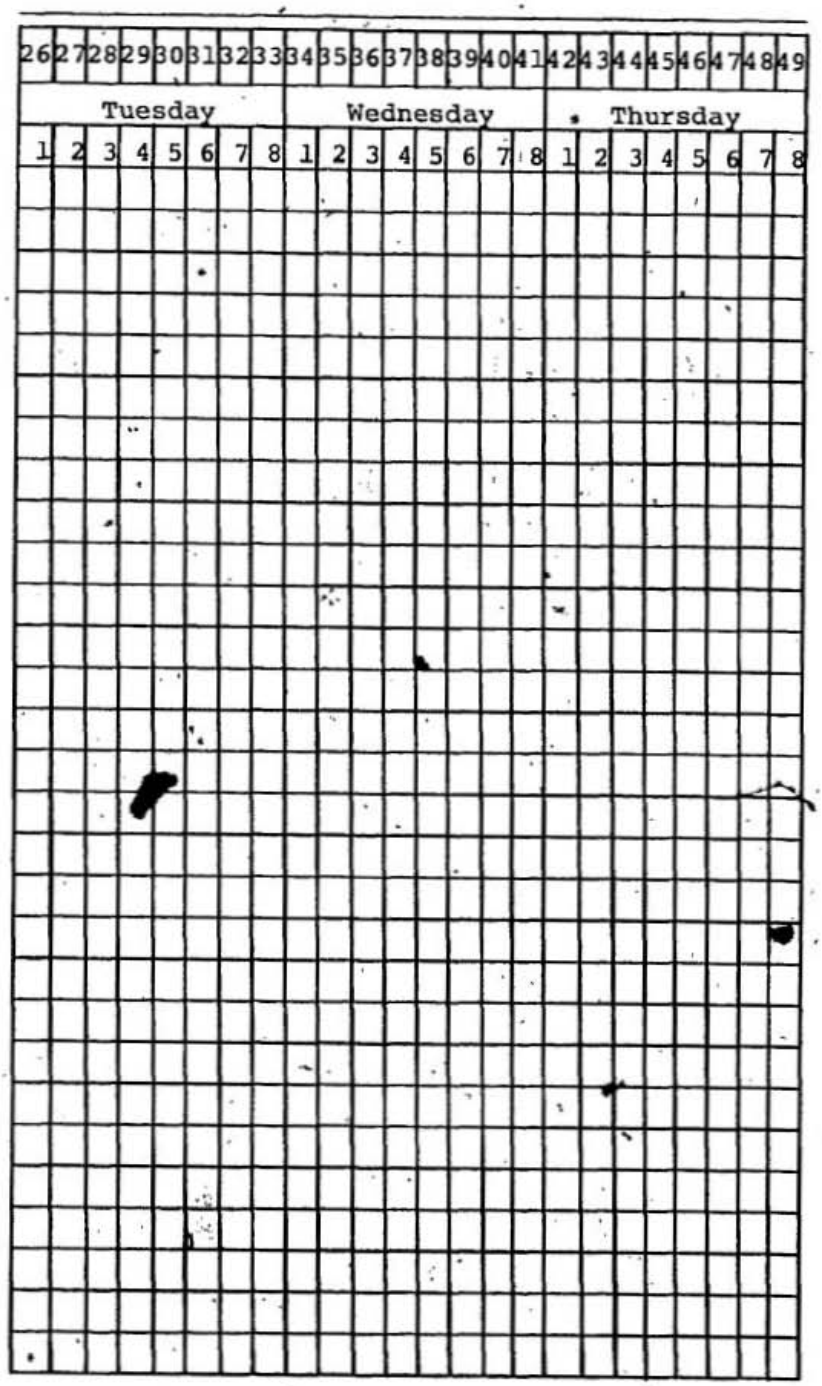
THE NOR-DATA SCHOOL SCHEDULING SYSTEM

TABLE 3: PREASSIGNMENT AND BLOCKING



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Type		Class			Act.			Tea.			Room Type			No.			Monday								
																	1	2	3	4	5	6	7	8

*Original form contains fifty data entry lines.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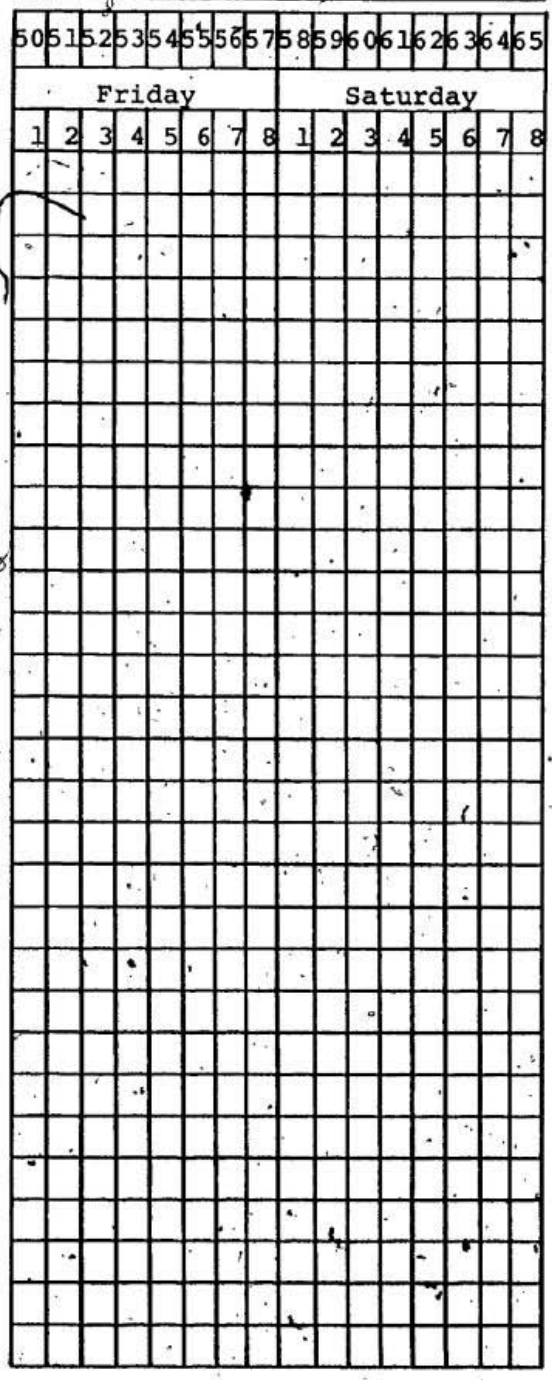
Tuesday
Wednesday
Thursday
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8

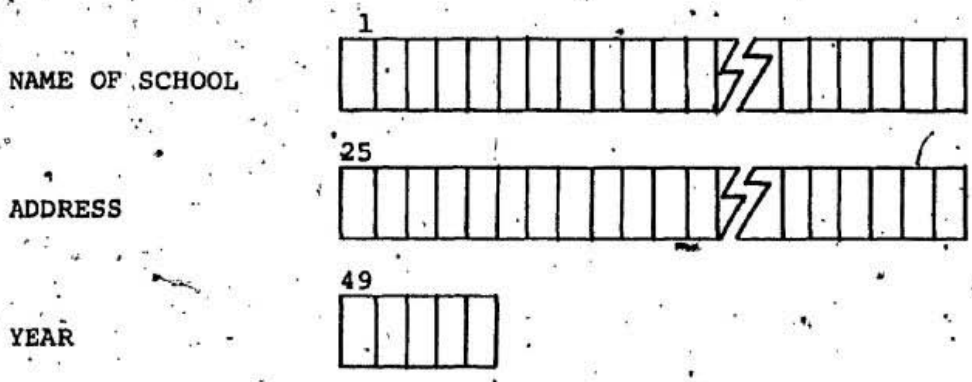

50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65
Friday
Saturday
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8

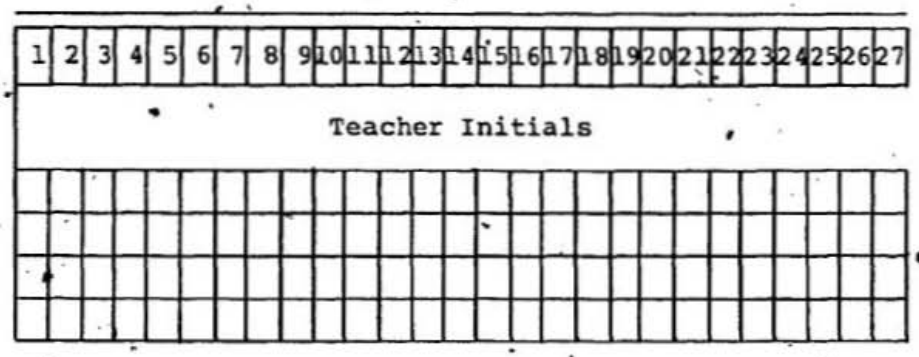
APPENDIX H

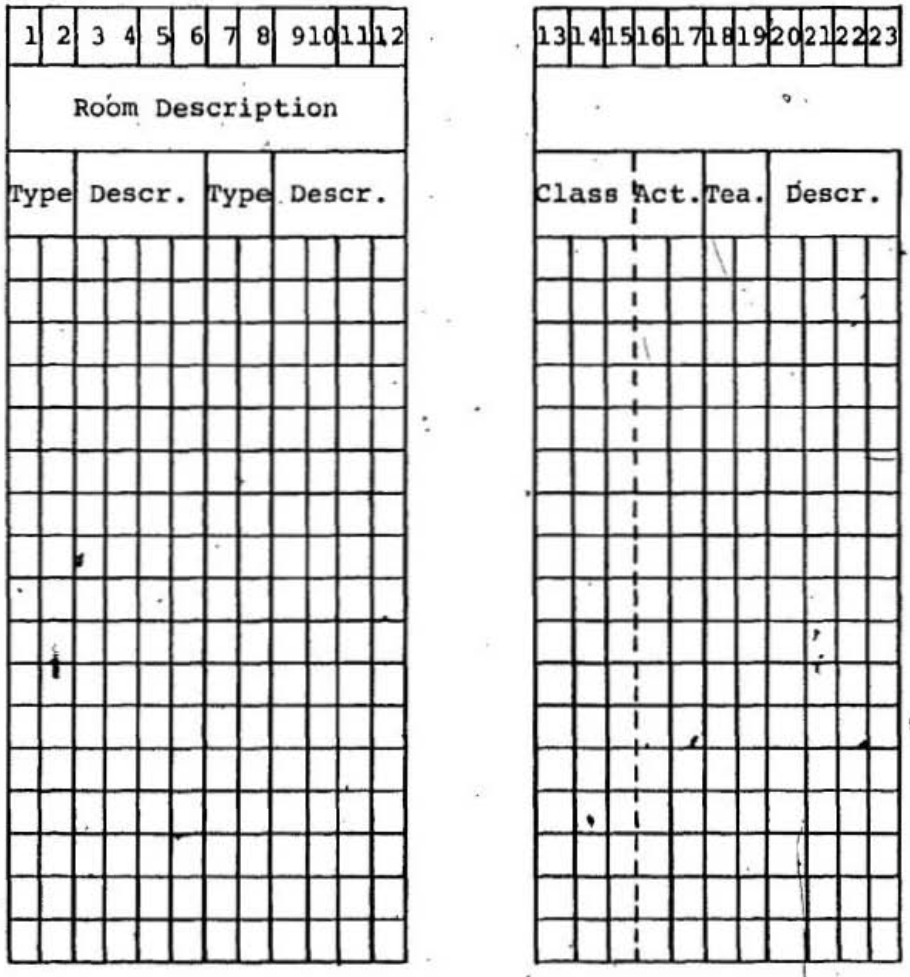
NOR-DATA TABLE 4: OUTPUT MODIFICATION

THE NOR-DATA SCHOOL SCHEDULING SYSTEM

TABLE 4: OUTPUT MODIFICATION







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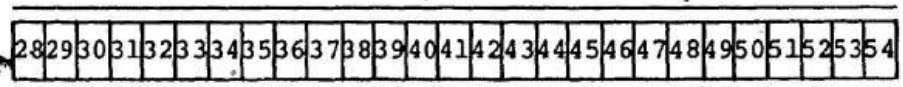
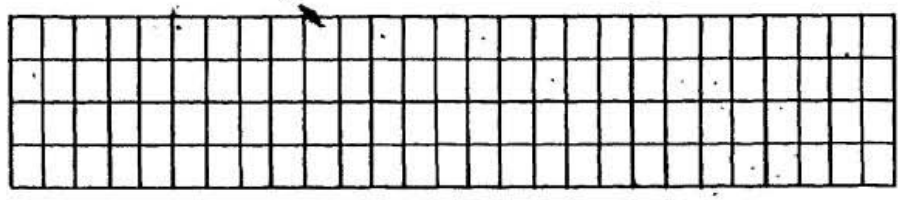
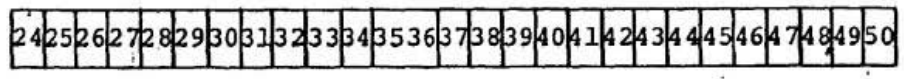
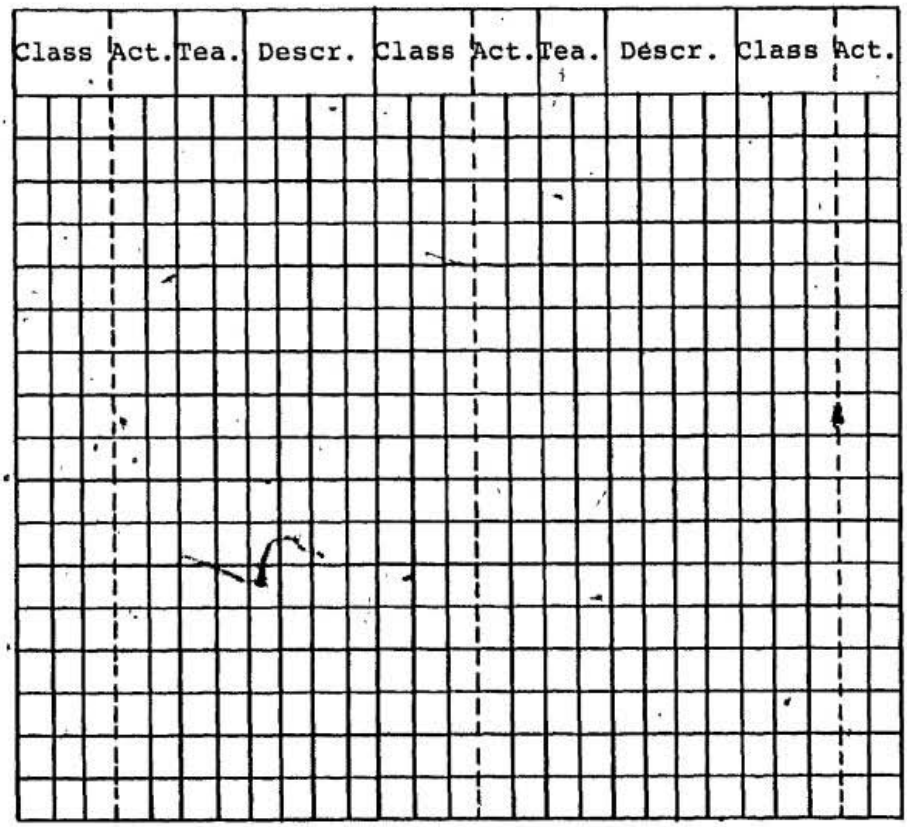
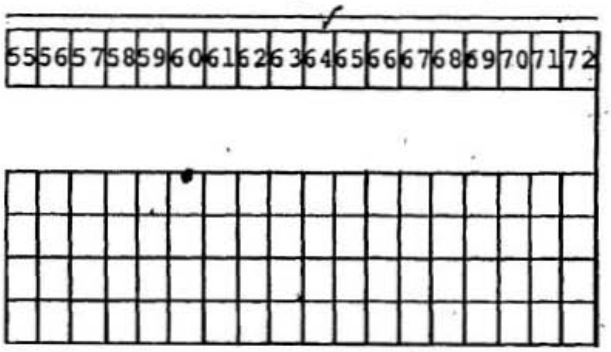






Description of Free Choice Subjects

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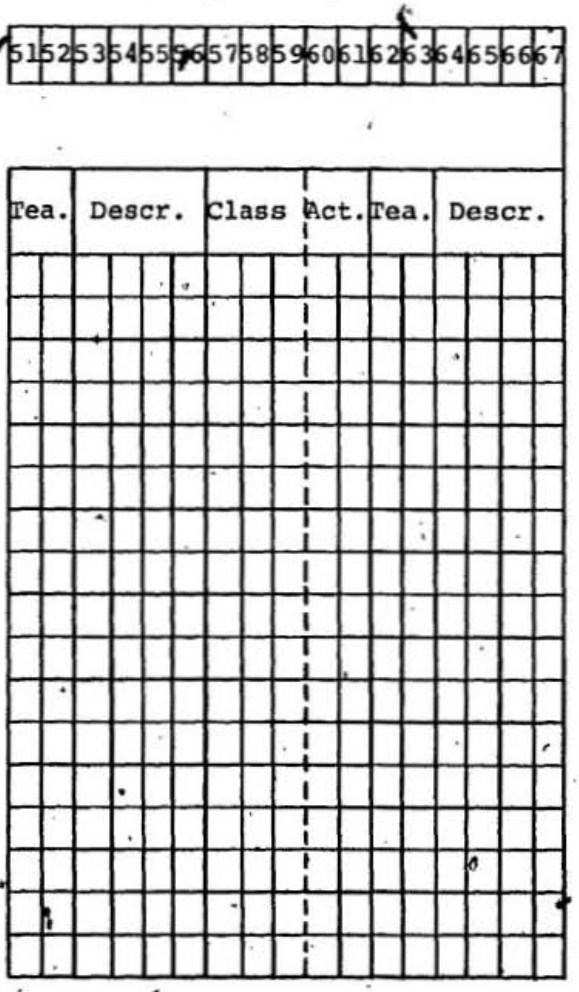
51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67
Tea.
Descr.
Class
Act.
Tea.
Descr.

APPENDIX I

STRUCTURED INTERVIEW WITH PRINCIPALS

STRUCTURED INTERVIEW WITH PRINCIPALS

1. What was the general reaction of your staff to their alternative computer-generated timetables for 1982-83 with respect to their workload preferences and the distribution of periods for their different courses?

2. Did any of your staff present you with any unexpected problems about their computer-generated timetables? If so, what types of problems were they?

3. In what ways might you have judged the computer-generated master schedule to be better for your school than the manually-constructed 1982-83 master schedule?

4. In what ways might you have judged the computer-generated master schedule to be worse than the manually-constructed 1982-83 master schedule?

5. Overall, how would you assess the computer-generated master schedule for your school?

6. Given the opportunity, would you elect to have the 1983-84 master schedule for your school produced by computer by the Norwegian Nor-Data School Scheduling System? If so, why? If not, why not?

7. Would your School Board likely be agreeable to pay a reasonable amount for this school management service? If so, why? If not, why not?

8. Do you sense that there is a potential market for computer-generated master scheduling throughout this Province, possibly with the Norwegian Nor-Data School

Scheduling System? If so, why? If not, why not?

9. Do you foresee the advent of computerized master scheduling in this Province being somewhat accelerated by this study? Elaborate.

10. What role should the Department of Education play in the promotion of this aspect of educational administration? Elaborate.

11. What role should Memorial University of Newfoundland play in the promotion of this aspect of educational administration? Elaborate.