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Computer Aided Design of Building Structures:

A Canadian Context

by

Daniel Jarvis Carson, B. Eng.

A thesis submitted to the Faculty of Graduate
Studies in partial fulfilment of the requirements
for the degree of Master of Engineering

Faculty of Engineering

Carleton University

Ottawa, Ontario

August, 1978

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The undersigned recommend to the faculty of Graduate Studies the acceptance of the thesis "Computer Aided Design of Building Structures: A Canadian Context" submitted by Daniel Jarvis Carson, B. Eng. in partial fulfilment of the requirements for the degree of Master of Engineering.

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Preface

This work comprises three main aspects of computer usage in the structural design of buildings: an evaluation of available software; an assessment of the services offered by data centers, to their customers, in the structural engineering profession; and, a survey of the state of computer usage by structural engineers, engaged in the design of buildings.

The author found the first two of these aspects to be the most difficult, and, in setting down his findings and opinions, some errors and omissions have undoubtedly been incorporated. The author sincerely hopes that the readers of this thesis will understand that some errors, are almost impossible to avoid, and that a study of this type could not have been carried out without some risk that unjust statements may have been made about those data centers and programs discussed herein.

Ottawa 1978

Daniel Jarvis Carson

Abstract

The computer programs, applicable to the structural design of buildings, and which are available on a commercial basis from data centers in Canada, have been catalogued. The programs, and their supporting data centers, are discussed and a scheme for the evaluation of programs is proposed. The evaluation scheme is based upon productivity in the design office environment, and has been used to assess a group of programs.

The results of a survey of the state of computer usage, by structural consultants engaged in the design of buildings is presented. These results include budget allocations, hardware preferences, and software preferences of the respondent consulting offices.

The results of the program evaluation are compared to the software preferences of practising consultants as revealed by the survey.

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CHAPTER 1

INTRODUCTION

1.1 Historical Context

There are very few technological developments in the history of mankind that have had as great an impact on all aspects of modern life as the electronic digital computer has had. It has served to open wide many avenues of endeavour which would quite literally never have been pursued without its aid.

In the three decades since the early computers such as ENIAC (University of Pennsylvania 1946) and EDSAC (Cambridge University 1949) were built, the computer has undergone a remarkable growth both in terms of processing power and availability. (1, 2)

The technological developments which have taken place since that time, have raised the status of the computer from that of a technological knick-knack, to that of a vital role player in the everyday affairs of the developed countries of the world. The simultaneous developments in computer hardware and operating-system software have been accompanied by growth in the development and use of numerical methods of analysis. (3, 4) The application of matrix methods to

computerized structural analysis has enabled engineers to cope with structures of enormous size and complexity.

With the combined development of computer hardware and computer software, the capabilities for computer-aided design have come a long way in a short time. Bennett in 1952 was able to analyse by computer a single bay, single storey, frame. (1) Today, analysis of shells involving up to 200,000 degrees of freedom are carried out by structural analysts. (4) The use of the computer has made possible analysis of non-linear behaviour and dynamic behaviour of realistic structures. At the same time, automated design procedures have evolved including the application of optimization techniques to structural design, although the technique itself is still in its infancy. (3)

In the 1960's, computing resources became widely available in Canada from data centers on a commercial basis. The software which was available however, in the 60's, was limited and the engineer who wished to use the computer was, generally speaking, forced to write his own programs. This situation has changed now, with a considerable bank of software in existence at commercial computing centers who make these programs available to their customers.

1.2 Objectives of the Research

The main objective of this study is to assess the present state of computer-aided structural engineering for buildings in Canada. This may be outlined as follows.

(i) To survey the commercially available software, and to assess its scope.

(ii) To study the nature of the service provided by data centers catering to the structural engineers.

(iii) To evaluate the computer program market as it applies to the structural design office.

(iv) To survey the behaviour and attitudes of Canadian structural consultants with respect to the computer as a design office aid.

Objectives (i) and (ii) have been accomplished both through interviews with data center representatives and through the use of programs available from data centers. Objective (iii) has been accomplished by purchasing computer time from a sampling of appropriate commercial data centers,

and using their computer programs in hypothetical design situations for the purpose of evaluation.

These programs were assessed on the basis of the relative merits of the software, and on the support provided by the data centers. The last objective, (iv) was carried out by a questionnaire survey, supplemented with interviews of various consultants.

The benefits of this study may be enumerated as follows:

(i) A concise survey of the commercial software, including the nature of the support offered by data centers is made available to practising engineers.

(ii) Practising engineers are guided in the evaluation of alternative programs.

(iii) Program developers are made aware of the attitudes and apparent needs of practising engineers as expressed by their usage of existing software.

(iv) Practising engineers are given information regarding the activities of their competitors, with respect to the computer.

(v) Data centers are made aware of the needs and interests of an extremely large and relatively unsophisticated group of computer users.

1.3 Scope of the Research

The research carried out for this study has been limited to a discussion of the software which is both commercially available from data centers in Canada, and applicable to the analysis and/or design of building structures.

It should be noted at this time that the term computer is used both to refer to the processing hardware, and to the combination of hardware and software which together permit the engineer to solve problems. The term software has been used throughout this thesis as a synonym for computer program. Data Center, in the context of this thesis, refers to an establishment owning a large computer, from which time may be rented for a price.

CHAPTER 2

THE NATURE OF COMMERCIALY AVAILABLE SOFTWARE

2.1 Introduction

The structural consultant, specializing in the design of building structures, has many options open to him if he wishes to use computer aids. A large firm may find it profitable to organize an in-house hardware facility for data processing. (5) They may also take it upon themselves to develop the necessary software in-house, or to purchase software from a software clearing house or software sharing organization. (6) The advent of relatively powerful mini-computers (7) has made this option quite viable particularly since there now exists a few companies which sell software libraries, compatible with various minis. (8, 9) If an in-house operation is beyond the resources of the consultant, he is forced to buy computing time from a data center. Using a data center computer, one can either use the programs that are available from the data center, on a commercial basis, or, develop one's own software, designed to cater to the specific needs of the individual.

A good number of designers who became involved in computer usage early on, found that for many jobs, commercial software was not available and thus were forced to develop in-house programs. In many cases this has proved effective, particularly for turning out tables of concrete sections, when the program is only to be used once rather than to initiate a run every time one has a member to design. The development of such software does cost money and requires in some cases expertise which is not to be found in some of the smaller offices. This situation served to stimulate the growth of what is referred to in this report as commercial software. Commercial software is that class of programs which are available for use at data centers. In most cases the data center takes on some responsibility for supporting and maintaining the programs on their system. For this service a royalty is generally charged and in some cases, royalties are also charged by the original program developer.

The remainder of this chapter is devoted to a discussion of commercially available software. This bank of software has been surveyed, and abstracts of the software available from data centers in Canada are presented in Appendix A. While in general terms, the characteristics of the software are discussed in the text of this chapter, references to specific programs are made only from time to

time, when necessary. Therefore a reading of the abstracts in Appendix A will help to put the discussion in perspective.

2.2 Other Studies

The subject of commercial software has been of interest both to developers and to users for several years. There have been many efforts to assess the available software both in the United States (10, 11, 12) and in Canada. (13, 14, 15, 16) A great deal more software is available in the United States than in Canada. For this reason, the studies undertaken, within the Canadian context, are more applicable to the Canadian reader.

Dr. E. W. Wright in his book 'Structural Design By Computer' (1976) (14) devotes a chapter to the discussion of a sampling of what would be called commercial software. He abstracts the capabilities of the Integrated Civil Engineering System, ICES, particularly the subsystem STRUDL; the Nasa Structural Analysis program, NASTRAN; the Portland Cement Association program library, PCA; and the Canadian Institute of Steel Construction programs, CISC. His work covers many of the most important programs but does not address the subject of the availability of these programs.

A recent paper by A. Firmin et al. 'Computer Programs For Structural Analysis and Design - A Canadian View' (1977) (13), provides a rather complete set of abstracts of the software available from Canadian data centers. The paper also indicates which data centers provide which programs and, further, discusses the reliability and usage of the programs. This paper provides a very good general view of the commercially available software resources in the Canadian context.

The material presented in Appendix A covers a few programs which are not discussed by Firmin et al. Since the present study is concerned with the structural engineering of buildings, the program abstracts are presented in that light.

2.3 Origins of Commercial Software

There are several principal sources of the software which has become available at data centers. Each source has some characteristics which distinguish it from the others, and some insight into the nature of commercial software can be gained from an examination of these sources.

Universities have been leaders in the use and application of computing power as an aid in both research

and design. The very first computers having been built at universities, it is natural that they have become an important source of software. Programs developed in the universities have a few advantages over others in that the development costs are normally written off as research expenses, funded by Government agencies or by Industry and in many cases, are largely developed by graduate students, a highly skilled group of workers who are expected to, and often do, work for little pay. Therefore, the cost of using these programs does not reflect typical development expenses. Also, programs written at universities are usually developed as part of a research effort and, in general, they employ the state-of-the-art techniques for analysis. This of course means that in some cases, the programs lack the durability and practical approach necessary to make them useful in a production environment. It should also be mentioned that universities have a relatively transient population and for this reason, tracking down the original developer of a specific program, to obtain support may be next to impossible. In spite of this, STRESS and ICES STRUDL, perhaps the most widely used programs for frame analysis, were both developed in the university atmosphere at M.I.T. These are special cases however, and are not really representative of the majority of programs developed at universities. STRESS and ICES STRUDL are among the only university developed

programs which have gained wide acceptance as commercial software.

Trade organizations such as the PCA, the CBA and the CISC are committed to the objective of increasing the amount of steel, concrete or masonry construction taking place. They have a vested interest in promoting the use of their respective construction materials. As promotional aids, each of these organizations has been responsible for the development of programs to aid the design of structures using one or another of these various materials. The trade associations have been leaders in the development of design programs, as opposed to analysis programs. This has been a definite boon to the engineering community. Design programs which involve any member selection or member evaluation, are, of necessity tied to the clauses of a specific building code. Programs of this type have therefore, a built in obsolescence as well as regional usefulness. Since their applicability is restricted to the jurisdiction of the specific building code, they are not readily portable. The programs developed by the trade organizations have some definite advantages; being written as promotional aids, they in general, produce high quality results; they are actively supported by the trade organizations; being intended for commercial usage, they are not just a 'spin-off' of some research project. They are

definitely applicable to the design of building structures in Canada.

Government agencies have been responsible for some development of software. They have provided funding for many development projects, and in some cases they have carried out development themselves. The U. S. government has provided funding for the development of programs at universities, such as the ICES project at M.I.T. and in Industry such as NASTRAN by MacNeal-Schwendler Corp. and others. In Canada the government has recently become very active in the field of computer-aided structural engineering.

(15) The Department of Industry Trade and Commerce has worked with the PCA to provide enhanced versions of some of their programs, in order to make them more generally available in Canada. The CAD project at the Department of Public Works (DPW) has devoted a great deal of resources to the development of engineering aids applicable to the Canadian context. Whether or not this bank of DPW software will ever become available to the general public, in the form of commercial software as discussed in this section, is questionable; although it may be made available for in-house use in the future.

The private software developers have produced some significant programs for the commercial market. Being in the software development business for profit, they have produced

useful products. Among those programs which are available, and which have been developed by private developers are: The Systems Professional Library for structural analysis and design, and the STARDYNE analysis program. These are well documented, well supported programs. However, there do tend to be royalties charged for their usage in the data center to offset continued maintenance, updating, and support of the product. This is a price one may be willing to pay for a high quality program, if the program fits the needs of the job.

Consulting firms in Canada may well be characterized as diverse. They tend to be very individualistic in many of their dealings and, of necessity, are competitive. These characteristics are born of the construction industry, and help it to function and thrive here in Canada. In the building design industry the fairly recent emergence of the computing element is a rather unsettling factor, and for those who are finding it difficult to keep pace, the computer is viewed as a necessary evil. The increasing complexity of design codes has resulted in the need, at least to some extent, to use computers to produce efficient designs. These forces have resulted in a very understandable occurrence to wit; there is a good deal of program development taking place in the larger, more progressive consulting firms and yet

there is a marked reluctance on the part of firms developing software, to make their proprietary software available for commercial usage. In spite of this fact, there are some notable exceptions to this trend such as GASPX, developed by Swan Wooster Ltd. of Vancouver B. C. which is available from a data center, as is the OPFRAD series of steel design programs developed by Julius Nagy and Associates Ltd. of Toronto Ont. This reverse trend, of making programs commercially available, may increase as more consultants realize that development costs may be recaptured through the sale of properly documented software. It is not however to be expected that the support for these programs would be as great as that for programs developed by commercial software developers. It can be seen that there is some attraction to programs developed by consultants; one expects software developed in a design environment to have the rugged simplicity and practical approach which makes for truly effective design office aids.

The role of the data centers, in producing software related to structural engineering, has been of some importance. Data centers, for the most part have given very little to the structural engineering market compared to the commercial data processing market. Again, there are exceptions to the above; Multiple Access of Canada has been responsible for the development of a very advanced level of STRESS as well

as for the continued development of programs such as AMECO 17. Depending on how much business these programs attract to the data centers; royalty charges may be incurred for the usage of such programs. A program which attracts less revenue to the data centers may need to have its development costs paid for through royalties, while popular programs, may attract sufficient business so as not to necessitate the charging of royalties. It goes without saying that programs, developed or enhanced by data centers, tend to be well supported since the development staff are readily available to provide program support. Further ramifications of the data center as a source of commercial software and support will be dealt with in chapter 3. The origins of commercial software have here been categorized into six groups and some characteristics of the software produced by each group have been discussed.

2.4 Scope of Commercial Software

Several engineers have expressed disappointment over the limited nature of the existing commercial software in Canada. (13, 15, 17) In this section, the scope of software available from data centers is surveyed. No attempt is made to discuss the intricacies of some of the more exotic packages, rather the survey is intended to give the reader the impression of the types of software available. It bears

reiteration, that the object of this survey is to assess the programs applicable to building structures. The problems associated with buildings are distinct enough that some general programs are of much narrower use in this field than other special purpose programs, oriented towards the specific problems of building structures. This point is pursued further with respect to specific types of programs throughout the remainder of this chapter.

The software will be discussed by considering categories of analysis and design programs identified in Table 2.1.

TABLE 2.1

Program Classification

Analysis:	Finite Element Analysis
	Frame Analysis
	Special Structures Analysis
	Single Structural Element Analysis
	Simulation
Design:	Concrete Building Frame Design
	Concrete Column Design
	Concrete Beam and Slab Design
	Concrete Foundation Design
	Concrete Wall Design
	Precast Prestressed Concrete Design
	Steel Building Frame Design
	Steel Beam and Composite Beam Design
	Steel Column Design
	Steel Base Plate Design
	Masonry Design
	Timber Design

2.4.1 Analysis Programs

The finite element method of stress analysis has attracted increasing interest since its first applications in the early 1960's. It has enabled engineers to obtain solutions for some problems which would otherwise not have been possible without the use of excessive simplifying assumptions. For many real problems involving complex structural behaviour, finite elements will give a solution to almost any desired degree of accuracy, dependent only upon time, budget, and the accuracy of material properties. The technique has permitted stress analysts to solve problems which could not have been handled by classical elasticity methods. Finite elements have been used effectively for the analysis of many structures including shells, perforated tube buildings, shear walls with openings and various special problems such as 'Y' shaped columns. Notwithstanding this, finite element analysis programs are still used only occasionally in the day to day design of building structures in Canada. That is not to say that they are never used, but that the number of occasions when finite elements are effectively used for building structures, are few. They are expensive to use and require a fairly long start-up time for a user to become reasonably familiar with a finite element package.

Several of the programs, abstracted in Appendix A, may be seen to provide very sophisticated finite elements. In general, the problem of linear elastic small deflection analysis is well handled, some programs have other capabilities which may be useful such as sophisticated dynamic analysis or large deflection analysis. There are programs which permit plastic behaviour, and creep to be included in the analysis. There are programs which contain special elements for modelling shear wall, and special shell structures which might be useful in the analysis of buildings.

The massive matrix manipulations, necessary for the finite element analysis of substantial structures demands that commercially viable packages incorporate well developed solution techniques. While this makes possible the effective use of these programs, for large problems, the programs must be treated with caution. These programs may be very expensive to use if care is not taken in the formulation of the problem and the preparation of data. Usually some form of computer plotting is available for data checking and, in many cases, for presentation of output.

Finite element analysis of structures is an interesting and useful approach when engineering borders on research. While the present discussion would not have been

complete without mentioning the subject, nevertheless, it is felt to be of limited real importance in the design of normal building structures. For most real problems in design of building structures, the analysis, carried out by many frame analysis programs, is more than sufficient. Most finite element programs include bar or beam elements which permit the analysis of frames; however, because of the generality of the programs, in the case of simple static elastic analysis, the use of FEM constitutes an overkill. There exists an abundance of programs capable of performing the analysis of general frames. Unfortunately, there are but a few programs, specifically developed for analysis of building frames. (17) Some of the most well developed programs are so encumbered by excessive versatility, in the form of special problem solving ability, that they become less than useful to a practising structural consultant involved with buildings. The ability of a FEM program such as MARC to handle, "elastic-plastic analysis with kinematic strain hardening in a full nine dimensional stress space", is really of no use to the engineer who is considering the computer as an alternative to the portal method of frame analysis. It is exciting that such advanced analytical capability is commercially available, however, building structures are not often the ideal application of such techniques.

As most building structures, and indeed most engineering structures of any kind may be represented as frameworks, it is not surprising that a plethora of frame analysis programs exist. The matrix formulation of the stiffness method for frame analysis has been readily available for programming for many years. (14) The programming of the stiffness method is relatively simple and straightforward. For example, it involves no integrals, no redundant forces, and it leads to sparse system matrices formed by putting element matrices together in a simple manner. It is understandable that the majority of frame analysis programs are stiffness programs, including in this category, slope-deflection programs. A special case is AMECO which is an implementation of the Hardy Cross relaxation method. This involves an iterative solution of the slope deflection equations, providing the unknown joint forces, without the intermediate step of solving for deflections. Naturally the geometry of the frame is limited to vertical columns and horizontal beams and slabs, although, in the recently released steel design version of AMECO, various standard bracing configurations could be handled. Depending upon the implementation of the methods, both the generalized stiffness method, and the relaxation method, can be usefully applied to the analysis of building frames. The stiffness method requires the solution of simultaneous equations which, for very large structures, can

become very expensive, since the computations involved, increase in an exponential manner with the number of unknown deformations. The iterative relaxation method for frame analysis, involves fewer calculations for very large frames because the number of calculations increases only linearly with the size of the problem.

Of those programs which are applications of a general stiffness analysis, the degree of sophistication varies greatly. At the low end of the scale, there are simple building frame programs which neglect axial strains and shear deformations, considering only flexural deformation of line members, connected at points, and loads applied only at joints. The more well developed (in the sense of sophisticated analysis features) programs include: axial, shearing, and flexural deformations. They permit the user to specify a finite joint size, as well as permitting degrees of freedom to be linked (as a concrete slab links frames). They are also capable of performing P- Δ analysis. Additional features available in some programs, are elastic support conditions, semi-rigid joint connections, and simulated construction sequence loading. There are programs which, while they are basically frame analysis programs, provide some simple finite elements to enable enhanced structural models to be analysed. Some of the commercially available programs for frame analysis,

permit the structural topography to be defined by a grid in 2 or 3 dimensions; a feature which can save enormous efforts in coding joint coordinates and member connectivities, and also reduce error.

Good quality plotting of frames, for data checking, is not as readily available as it is with the finite element programs. There are however, some frame analysis packages which do offer plotting such as; STRESS 3.0 at Multiple Access or SDRC SAGS/DAGS, and the STRU-PAK MAP programs at CDC.

The frame analysis programs which are available, offer a variety of capabilities and permit the analysis of frames with varying degrees of sophistication. They do this only in the narrow context of the general matrix stiffness formalism. The gaps in the commercial software for frame analysis do not occur because of a lack of sophisticated analytical capability, but rather because of the lack of well developed special purpose programs which incorporate valid simplifications of the general frame and, result in more efficient preparation of data and reduced computer costs. For example, there is no stiffness analysis program on the market, in Canada, for the specific analysis of large 3 dimensional building frames, consisting of rigid floors with 3 degrees of freedom each (2 translational and 1 torsional in

plan) and vertical elements connected to nodes with 3 degrees of freedom each (2 rotational, and 1 translational). This type of program is known to exist in some offices which have invested in the development of the program in-house. A number of authors (14, 17, 18) have indicated that the needs of engineers can be fulfilled more effectively by this type of special purpose program, rather than by the general purpose programs such as ICES STRUDL II.

There are still many gaps which need to be filled in the bank of commercial software with practical special purpose programs. Professional program developers tend to be reluctant to sacrifice the generality of their programs (in so doing, making the program applicable to only a very specific problem) even though the need for such special programs is serious and has been demonstrated by many authors writing on this subject. The potential savings, in monetary terms, in development and use of special purpose frame programs, such as the one just described, may be in the order of several thousand dollars for large structures, not to mention the fact that such a program permits the analysis of a model which very closely resembles the behaviour of the real structure.

This discussion of the general stiffness method would not be complete without the following comment. As many structural engineers have learned (the hard way) the matrix stiffness method in all its generality of organization, and basic simplicity of approach, contains a number of pitfalls and traps which the novice user rarely manages to avoid. These errors usually exhibit themselves as a singularity in the stiffness matrix and can cost the user weeks spent in frustrated search through the input data for an error which will never be found without help from someone who knows, or by starting at page 1 of a recent textbook on matrix structural analysis.

Special structures analysis programs is a category of programs capable of analysing more than just a single element. They are not, general frame analysis programs. In this miscellaneous category, there are several programs which are commercially available. These do not include continuous beams or column stack programs which fit easily into the category of individual element analysis, which is discussed later in this section.

This category includes a few programs, BRICK 1 and BRICK 2 from the Clay Brick Association, and Systems Professional's EQKSWL which calculate the properties of walls and the

distribution of lateral (wind or earthquake) forces to the individual walls. These are potentially useful to building designers, working in areas of high seismic activity.

The program MITAS developed by Martin Marietta Corp. calculates thermal loads on structures. Although the documentation claims that the program is potentially useful for analysis of buildings, it is questionable whether there is in fact any application for such a restricted program since many frame analysis programs permit the application of thermal forces in combination with other loadings.

The program, PCA/FLOOR, solves by finite differences, the stress distribution in an L shaped floor slab supported by a core wall and external columns. There is also a set of programs, CSTRES, available from Computer Sciences of Canada, which carry out stress calculations for a set of shells, plates, rings, and arches; however, there are serious deficiencies in the available documentation for the CSTRES programs. The only other program, classed as a special structures analysis program is PIERANAL, developed by Babcock and Wilcox, which is capable of analysing a bridge pier by the moment distribution method. The pier analysed, is essentially a frame of up to 3 storeys or 9 bays. These programs, with the exception of the shear wall analysis programs, are not likely to have many applications in building structural engineering,

but they do exist at various data centers. It is in the interest of completeness that they are mentioned.

Single Structural Element Analysis programs fall into two main categories: Beam analysis, and Column analysis programs. The column analysis programs are of two types. The first type performs a stability analysis of a column member and there are several of these; COLUMN, from Computer Sciences of Canada, STRU-PAK/BEAMCOL, and STRU-PAK/ELASTCOL. The second type, carries out the column load accumulation calculations, providing the reduced live loads and the dead loads at each storey level. This latter type is potentially more useful to a practising engineer than is the former, since it relieves the engineer of a very routine, repetitive task required for the design of all multistorey buildings; one which often has to be redone due to changes as the design progresses. The stability analysis programs are of little importance to building designers who rarely are called upon to carry out such an analysis.

The other category of Single Structural Element Analysis programs are the beam analysis programs, for the analysis of continuous beams, or continuous beams with columns above and below. The software available for this type of problem can handle non-prismatic sections and employ either the slope-

deflection method or the moment distribution method. Although some programs are intended for the analysis of bridges, subjected to moving live load, there are some which will perform patterned live load analysis for maximum moments. These are potentially useful programs which are perhaps too often overlooked, or duplicated.

The last class of analysis programs dealt with in this report are the simulation programs. These are not abstracted in Appendix A but are discussed here, briefly. There are several packages, capable of carrying out the digital simulation of a continuous system. This type of program could be used for the dynamic response of structures to a given excitation. Their potential usefulness as a design office aid however is questionable. The future may see this sort of analysis become practical but in today's market there exist more functional dynamic analysis methods which have already gained acceptance by practising engineers.

There are a great many programs which have been covered in this discussion and although there are apparent gaps in the analysis capabilities commercially available; in general, a wide range of computer analysis capability is now available in this country.

2.4.2 Design Programs

Design programs that are on the market constitute the remainder of this discussion. Although there is not the same spectrum of programs available for design, there is still substantial design oriented software available. The term design, in this context, applies to programs which are capable of selecting at least one of the section parameters, such as the reinforcement, or, in some instances, programs which will assess a given section subjected to given loading, with respect to some specific code requirements. In this age of rapidly changing codes, with changes occurring even in the basic philosophies of design, it becomes increasingly difficult to keep up to date. Program developers are reluctant to devote resources to low return programs. At the same time, as the design process becomes increasingly complex, the computer becomes a much valued aid in design. For these reasons, a great many of the design programs available, originate with the trade associations which are in touch with upcoming code changes and have a vested interest in promoting the use of a specific construction material.

In this section, the comments tend to be directed at specific programs rather than at overall trends. This is necessary because many of the programs have very distinct characteristics.

2.4.2.1 Concrete Design Programs

This type, like all design programs, tend to be specific to one structural element such as a beam or column. There are few programs which will automatically generate the design of an entire building. This is a reflection of the fact that there is only a limited market for those that do exist. It seems clear that engineers like to have more control over their design than these programs permit. Nevertheless, there do exist some general programs which deserve discussion. In Appendix A there are three programs which have been classed as concrete building design programs. ICES STRUDL II RC was a valiant attempt to provide a complete, integrated building design capability but unfortunately, the RC design segment of the ICES STRUDL program package has fallen into such disrepair, it may be considered non-functioning. That leaves two programs, AMECO and PCA/ESTIM. AMECO can perform a complete design of columns, beams and slabs. The program is completely automatic but has been shown by J. C. K. Lam to overdesign (19) by approximately 20%. This program unfortunately is apparently too automatic for some engineers to feel comfortable in using it for final designs. The PCA/ESTIM program is intended only to be used for preliminary designs since it cannot handle lateral loads. Most engineers seem reluctant to trust the final design product of either of these programs.

It has been rightly said (17) that an engineer needs to involve his own judgement and intuition in his design before he feels comfortable with it. These automated, complete designs, incorporate many assumptions which are not always explained clearly in the documentation, leading to a lack of confidence in the designs produced. It is useful however to be able to test different concepts at the preliminary design stage or to obtain a preliminary cost for a structural scheme. For that type of problem, these programs are well suited.

Concrete column design programs are such useful tools that many consultants developed their own versions before commercial programs became available. There are now three programs available commercially. Two programs (PCA/COL and SP/CONCOL) provide the same capabilities; design of reinforcement for a given section subjected to axial load and uni-or biaxial bending. The third program, (PCA/LS) combines the load accumulation calculations for a column stack, with the reinforcement design capabilities. These programs all perform their design using an Ultimate Strength Design approach (also known as the Strength method) as specified in ACI 318; unfortunately, the available version of SP/CONCOL has been slow in being brought up to date.

As was the case with columns, so it is with slabs and beams. There are a few programs on the market for the design of reinforced concrete beams and slabs. The PCA provides the most up to date and generally useful slab design program, PCA/ADOSS. There are older versions of the PCA slab program still available but these will most likely be replaced with the more sophisticated ADOSS. The only other slab design program available, is a Systems Professional copy of an early PCA program. The programs all apply an equivalent frame approach and employ the Ultimate Strength Design method as specified in ACI 318. There are a few programs for design of concrete beams, (SP/CB, SP/NONP, **BEAM). The two Systems Professional programs enable the engineer to analyse and design a continuous concrete beam, either prismatic or non-prismatic. The third program **BEAM applies a Working Stress approach. It is of limited use in today's design environment.

There are three commercial programs for the design of footings. The PCA/MATS program is the most general, having the ability to analyse and design a combined footing or mat foundation using the finite element method to model the foundation as a plate resting on an elastic soil. The reinforcement is designed using Ultimate Strength design. Systems Professional, COFTG will design an individual column footing, square or rectangular, or a combined footing for 2

columns. OPFRAD/BAPLAF will design a spread footing for individual columns. The advantage of the BAPLAF program is its ability to be linked with the frame analysis program OPFRAD/FLOBIM from which it obtains the column loads.

The programs available for the design of concrete walls are limited. Systems Professional has programs for the design of bearing walls, shear walls, and retaining walls. These programs all apply a Working Stress design approach. The PCA has developed a program for the analysis and design of wall beam frames. This is a very specific program and could be classed as a special structures analysis program. It carries out the reinforcement design of the wall beams. The number of times one might have use for such a program is quite limited.

The Prestressed Concrete design programs available are of use only to those directly involved in the design of precast, prestressed beams. These are designed generally by engineers employed in the prestressed concrete industry and are rarely designed by structural consultants. The precast industry has been diligent about developing tables of standard products including precast prestressed sections. This has resulted in a situation where most engineers do not need to become involved in precast, prestressed member design.

Unfortunately, the problem of post-tensioned construction is not dealt with at all in commercially available programs.

The scope of Concrete design programs has now been discussed and the results are clear. There are programs available for the design of most concrete elements. The programs have been developed primarily by the Portland Cement Association, with the Systems Professional copying many of the PCA programs and, adding a few of their own. The programs best maintained, and most carefully updated are the PCA programs.

2.4.2.2 Steel Design Programs

The available programs for the design of steel structures and steel structural elements follow roughly the same pattern as the Concrete design programs do. There are a few programs available which are capable of performing an automatic design of an entire frame. These are three: AMECO, CISC/RESST, ICES STRUDL, all of which will perform a design of a 3 dimensional steel structure. The RESST program is intended specifically as a preliminary design evaluation program since it is not capable of handling horizontal loads. AMECO and ICES STRUDL CSA S16 are intended to be more than just preliminary design aids, offering fully developed design

capabilities. These programs however suffer from the same problem as do the automatic concrete building design programs; that engineers are reluctant to employ such highly automated systems. Both AMECO and ICES STRUDL CSA S16 are expensive to run for just preliminary design. A fourth program CISC GALE-STRIF offers preliminary design capabilities for 2 dimensional steel frames. All of these programs, fortunately incorporate Canadian code specifications. Only RESST however incorporates the requirements of CSA S16.1 1974 Limit States Design. All of the programs carry out cost estimating of the structural steel. In general these programs provide a good way of evaluating structural schemes and are admirably suited to performing preliminary designs.

There are several programs, capable of selecting steel beams and designing composite steel-concrete sections. At the most simple level, there are programs for the investigation of a preliminary section, and the selection of alternative sections if the preliminary section proves unsatisfactory. In this category are: programs for selecting rolled sections; a program for designing a composite section; and a program for designing a welded steel girder. These programs are all written to comply with AISC code specifications. There are two other programs which deal with somewhat larger problems: CISC/FSSP 2 is capable of the design of an entire floor of

beams and girders based upon the requirements of CSA S16-1969. This program is well suited to the economic evaluation of various flooring schemes, like the CISC/RESST program. The other program, available in Canada, is OPFRAD/FLOBIM which performs an entire frame analysis, and sizes all the beams in the frame, in accordance with CSA S16-1969. Both of these programs are capable of being linked to column design programs, and are both well suited for use by Canadians, incorporating the Canadian code requirements.

There are four programs for the design of steel columns. As was the case with steel beams, there are two programs which are American products, incorporating AISC code specifications. These programs will evaluate a given section for axial loading and bending about both axes, as well as provide alternative section selections. CISC/CSP2 and OPFRAD/KOLUM will perform essentially the same task, in accordance with CSA S16-1969. These latter two are probably more useful to Canadians simply because they incorporate the Canadian code specifications.

The last category of steel design programs are the base plate design programs. In this category there are two programs available in Canada: OPFRAD/BAPLAF and, SP/BASPLT. These programs both select a steel base plate for a given

column load. OPFRAD/BAPLAF will select the plate in accordance with Canadian code specifications. It will also design a Reinforced Concrete footing as previously discussed. SP/BASPLT is an American oriented program which sizes the plate in accordance with AISC 1969 code specifications. These are both functional programs and may be useful if one has a great many base plates to design.

Overall, there exists a fair spectrum of programs for design of steel structural elements which are applicable to building design. In the Canadian context, of course, the programs which incorporate Canadian design code specifications are the most practical. Fortunately, there are several of these including the CISC programs; the OPFRAD series; AMECO and the CSA S16 version of ICES STRUDL.

2.4.2.3 Masonry Design Programs

Engineered masonry construction has only recently become an area of active design work. As a result of this, the number of masonry design programs available in Canada is relatively limited. The programs previously discussed as concrete bearing wall and concrete shear wall design programs; developed by Systems Professional, can also handle brick or block masonry design. The only other masonry design program,

CBA/BRICK 3, will design a multistorey load-bearing shear wall, in accordance with the provisions of NBC 1970 and NBC 1975. This program is designed to be linked with the analysis programs BRICK 1 and BRICK 2 and, as a set, provide a useful design aid for engineering plain and reinforced masonry in Canada.

2.4.2.4 Timber Design Programs

Despite the enormous amount of timber used in building construction in this country there are no commercially available design programs which apply Canadian timber design specifications. There are two Systems Professional programs which will design a glu-lam beam or a sawn timber beam. Both of these programs however, are applications of American timber standards. The author is aware that some Canadian programs for timber design are in the developmental stages, but to date none have become available at data centers.

2.4.3 Optimization

There are no programs available from Canadian data centers which provide optimization capabilities with the exception of some limited optimization which may be carried out with ICES STRUDL II. It may be fairly stated that, in

spite of the intensive research into the application of numerical optimization to structural design, taking place at universities; the introduction of optimization to design offices in Canada is still some time away.

CHAPTER 3

A REVIEW OF DATA CENTER SERVICE IN CANADA

3.1 Introduction

In the preceeding chapter the subject of commercially available software was discussed. That discussion however covered only one aspect of the subject. In this chapter the service provided by data centers, to complement their software is discussed.

A glance through the "Yellow Pages" of any major urban center in Canada under the heading "Data Processing Service" reveals that an abundance of firms are busy selling computer time. Of course, not all the firms which sell computer time, provide the engineering software discussed in the previous chapter. Those data centers which do supply the engineering software, previously discussed, also provide varied hardware configurations: different operating systems, including different file editing capabilities; and different support for the software. The specific goal of this chapter is to provide a very brief introduction to the facilities of each data center operating in Ottawa and environs which provide engineering software applicable to building structures.

The introduction includes the main hardware provided by the centers, an index of the application software available through the centers, and some comments on the support offered for their application software. The strengths and weaknesses of the various hardware systems are not discussed in this thesis. Other authors have pursued this subject. A good survey of computer hardware is provided by E.W. Wright, in his book "Structural Design by Computer" 1976. (14)

The information presented in this chapter was obtained through interviews with data center representatives, through study of brochures and manuals published by data centers, and through personal experiences in dealing with data centers as a customer.

It is hoped that this information may serve as a useful guide to Canadian structural consultants trying to find their way through the Data Processing marketplace.

3.2 The Data Centers

In that the purpose of this chapter is to discuss the data centers which cater to the software needs of structural consultants, the remaining sections of the chapter are devoted to a snapshot view of the service obtainable in Ottawa. In Ottawa Ontario there are approximately 60 firms which advertise data processing services in the "Yellow Pages". Of the 60, only 12 provide any application software related to structural engineering. These 12 are the subject of the remainder of this chapter and they are listed in Table 3.1 with their respective abbreviations. This list is exhaustive for Ottawa, but is also representative of the services provided all across Canada. The data centers listed in Table 3.1 also provide their services in most of the urban centers throughout Canada. The distribution of services is presented in Table 3.2. As may be clearly seen from this table, the services offered by the data centers are distributed widely across the country. Although there may be local omissions, the material presented herein is felt to be largely applicable in the major urban centers of Canada.

TABLE 3.1

DATA CENTERS PROVIDING STRUCTURAL ENGINEERING APPLICATION
SOFTWARE

Canadian General Electric Company Limited	CGE
Computel Limited	Computel
Computer Sciences Canada Limited	CSC
Comshare Limited	Comshare
Control Data Corporation Cybernet Services	CDC
Dataline Systems Limited	Dataline
Industrial Life - Technical Services	IST
International Business Machines Canada Limited	IBM
I.P. Sharp and Associates	IPS
Multiple Access Computer Group	MA
Systems Dimensions Limited	SDL
Société de Mathématique Appliquée Inc.	SMA

TABLE 3.2

CITIES SERVED BY DATA CENTERS LISTED IN TABLE 3.1

CITY	DATA CENTERS
Calgary	CGE, Computel, CSC, CDC, Dataline, IPS, IBM, MA, SDL
Charlottetown	CDC
Edmonton	Computel, CDC, CSC, IPS, IBM, MA
Halifax	Computel, CDC, IPS, IBM
Hamilton	Comshare, CDC, Dataline, IPS, IBM
Kitchener	CDC, IPS, IBM
London	Comshare, CSC, CDC, IPS
Montreal	CGE, Computel, CSC, Comshare, CDC, Dataline, IPS, IST, IBM, MA, SDL, SMA
Ottawa	Computel, CSC, Comshare, CDC, Dataline, IPS, IST, IBM, MA, SDL, SMA

CITY

DATA CENTERS

Quebec City

Computel, CSC, CDC, IST, IPS,
IBM, SDL, SMA

Regina

CDC, IPS, IBM

St. John

CDC

St. John's

CDC, IBM

Sarnia

Comshare

Toronto

CGE, Computel, CSC, Comshare,
CDC, Dataline, IPS, IBM, MA,
SDL, SMA

Vancouver

CGE, Computel, CSC, Comshare,
CDC, Dataline, IPS, IBM, MA

Victoria

Computel, CDC, IPS, IBM

Winnipeg

Computel, CSC, CDC, IPS, IBM,
MA.

3.3 Services Provided By Data Processing Centers

The data centers discussed in this chapter are businesses which make money by selling computer services. The services they sell however, are varied. For this reason it is difficult and dangerous to make any generalized statements about all data centers. Therefore the preliminary comments in this section will be brief.

The main commodity, sold by data centers, is computer processing time. To enhance their sale of this item the data centers are always willing, and in general, able to provide support for the use of their system. This type of system support is comprised of documentation for, and demonstrations of, the operating system facilities, including the file editing system and the Job Control Language (JCL) features. This level of support is a universal minimum. The support available for the engineering application software packages is above and beyond the general system support. The individual program support is carried out with varying degrees of vigour among the data centers. In general, data centers provide at least one copy of the documentation for their application software. Some data centers maintain a group of support staff, including structural engineers who are familiar with the software packages. Other data centers are only willing to put the user in touch with the original software developers. For

a structural engineer using a large program for the first time, it is preferable if the data center can provide program support quickly, from among the staff of the center. It is also advantageous for the data center to be providing support for their programs if they are maintaining an old version of a program on their system.

The remainder of this chapter is devoted to the individual data center services. In the following pages an attempt has been made to honestly assess the support attitude of the data centers. In some cases however, the comments are based solely on documentation published by the data centers, and not on any personal experiences. For each data center, the program packages available on their system are noted. The description of each of these programs may be found in Appendix A.

Data Center: Canadian General Electric Co. Ltd

Processing Hardware: IBM 370/165

Structural Engineering Application Software:

CGE has two classes of application software: programs maintained by CGE in their Library Software Index; and programs made available for use by other users in the Network Software Services (NSS).

Library Software

- STRESS
- others for which documentation was not available

Network Software Services

- SDRC Library
- ANSYS
- NASTRAN
- others for which documentation was not available

Structural Engineering Support Attitude:

CGE claims to have three levels of support for the Software Library programs. Unfortunately, all the structural engineering application software falls into the lowest category which implies that the documentation and software should be self supporting. In other words, no

active program support is undertaken for the structural engineering application software. In fact, despite repeated requests for the documentation of programs listed in the CGE library index under engineering application, none was forthcoming even on a loan basis. The programs made available through CGE NSS are in no way supported by CGE. All the support for NSS programs must come from the third party which originally made the program available through NSS. In short, CGE offers little support for the engineering users of their data centers.

Data Center: Computel Ltd.

Processing Hardware: IBM 370/168
IBM 360/65
UNIVAC 1108

Structural Engineering Application Software:

ICES STRUDL II IBM and UNIVAC VERSIONS
ICES TABLE I

CISC CSP2
CISC FSSP2

PCA - All PCA programs can be made available
upon request

Structural Engineering Support Attitude:

Representatives of Computel claim that they offer support from technical consultants as well as from their own engineering support staff. Some application programs are maintained with only minimum system support. From discussions with the Computel support staff it may be inferred that most of their structural engineering application software receives only system support in the form of aid in preparation of JCL files.

Data Center: Computer Sciences Canada Ltd.

Processing Hardware: UNIVAC 1108

Structural Engineering Application Software:

ANSYS
GASPX
SDRC Library
STRESS
BEMANL
COLUMN
CBA Library
CSTRES
PCA/ADOSS
PCA/COL
PCA/BRIDGE
BEMDES
CISC/FSSP2
CISC/CSP2

Structural Engineering Support Attitude:

CSC indicates that they provide varied levels of support for their application software ranging from:

- (1) fully supported
- (2) key personnel support
- (3) 3rd party support
- (4) self supporting

The engineering application software listed above, receives level 3 or 4 support depending upon the program.

Data Center:

Comshare Ltd

Processing Hardware:

XEROX SIGMA 9

Structural Engineering Application Software:

ASAS

SDRC Library

PCA/COL

PCA/PLATE Predecessor of ADOSS

PCA/FLOOR

PCA/FRAME

PCA/LS

PCA/ESTIM

PCA/STMFR

PCA/MATS

PCA/BRIDGE

STRESS

ANSYS

NASTRAN

Structural Engineering Support Attitude:

Comshare provides each of its users with a technical representative to assist the client with problem definition, technical problems, and basic day to day operating difficulties. Further, Comshare maintains a software support group to provide additional technical support when necessary. This group is available for direct contact. One feature of the Comshare support attitude is their soliciting of user feed-back in the form of Software Improvement/Difficulty reports. In general, Comshare provides good support.

Data Center: Control Data Corporation CYBERNET Services

Processing Hardware: CDC CYBER 170's
various CDC CYBER 70's
and CDC 6000's

Through CYBERNET services, a user is able to access many CDC computers throughout the world.

Structural Engineering Application Software:

Systems Professional Library
SDRC Library
STRU-PAK Library
MRI/STARDYNE
ANSYS
MITAS
EAC/EASE2
CDC/MARC
CDC/NASTRAN

Structural Engineering Support Attitude:

CDC offers very comprehensive support services for their application software. They employ a large number of structural engineers as well as analysts and programmers to provide system and software support. The support made available from CDC is professional. They provide highly qualified personnel, either from within their organization, or from the program developers, to offer assistance whenever necessary.

Data Center: Dataline Systems Ltd.

Processing Hardware: 4 DEC System ID's

Structural Engineering Application Software:

1130 STRESS

PCA/PLATE Predecessor of ADOSS

PCA/COL

PCA/STMFR

PCA/FLOOR

PCA/LS

PCA/MATS

CISC/CSP

An early version of AMECO was once available on the Dataline System. Its present status is unknown.

Structural Engineering Support Attitude:

Dataline provides only basic system support for their application software listed above. As a business, they cater primarily to financial-economic and statistical analysis users. They employ no structural engineers for support staff and in general, expressed the attitude that the software should be self supporting.

Data Center:

I.P. Sharp and Associates Ltd.

Processing Hardware:

AMDAHL V6

IBM 360/75

Structural Engineering Application Software:

Planeframe

Structural Engineering Support Attitude:

I.P. Sharp has adapted the above program to APL and is therefore able to provide some limited support for the program. They do not, however, employ any structural engineers, and therefore problems may be difficult to communicate. The firm is, in general, not oriented towards engineering application support.

Data Center: Industrial Life-Technical Services Inc.

Processing Hardware: IBM 370/168
AMDAHL 470/V6

Structural Engineering Application Software:

ICES STRUDL II
ICES TABLE II
PCA/COL
PCA/BRIDGE
PCA/PLATE Predecessor of ADOSS
PCA/STMFR

Structural Engineering Support Attitude:

IST offers various levels of support for different programs, however, all of the structural engineering application software, listed above, is classed as "Unsupported but Updated". Recently however, IST has become much more active in their support of engineering software. They now offer the support of structural engineers in Toronto and Montreal, with expertise in structural analysis. Also, they offer seminars on the usage of specific programs. IST has purchased SMA since this research was carried out, and all the programs, offered by SMA, are now offered and supported by IST.

Data Center: International Business Machines Canada Ltd.

Processing Hardware: IBM 370/145

Structural Engineering Application Software:

BEAM

CONBEAM

FRANAL

COLUMN

PCA/PLATE Predecessor of ADOSS

PCA/BRIDGE

PCA/FLOOR

TEES

STRESS

TRUSSA

TRUSSC

Structural Engineering Support Attitude:

IBM is willing to provide detailed documentation for their programs, and is prepared to demonstrate the usage of any program. They provide little else in the way of support other than system support.

Data Center: Multiple Access Computer Group

Processing Hardware: IBM 370/168
CDC CYBER 72
CDC 6600

Structural Engineering Application Software:

AMECO 17
BEAMANAL
CISC/GALE-STRIF
CISC/CSP2
CISC/FSSP2
OPFRAD Series
PCA/COL
PCA/LS
PCA/ESTIM
PCA/ADOSS
PCA/MATS
STRESS 3.0
SAP IV
ANSYS
NASTRAN
STARDYNE

Structural Engineering Support Attitude:

MA is heavily committed towards support for engineering applications. They have several structural engineers who are active in the enhancement and support of their software. They have a very positive attitude towards support of the above products.

Data Center: Systems Dimensions Ltd.

Processing Hardware: IBM 370/168
IBM 360/85

Structural Engineering Application Software:

ICES STRUDL II

NASTRAN

PCA/ADOSS

PCA/STMFR

PCA/LS

PCA/COL

Structural Engineering Support Attitude:

For all of the software listed above, SDL provides support via the vendor interface only. They maintain a recent version of the programs and one copy of the documentation for the program. It seems that SDL provides little more than the basic system support for their application software in structures.

Data Center: Société de Mathématique Appliqué Inc.

Processing Hardware: IBM 370/165
CDC 6600
CDC 7600
PDP 11
CDC CYBER 73

Structural Engineering Application Software:

PSU ICES STRUDL
ICES STRUDL II
NASTRAN
ANSYS
SAP IV
PCA/COL
PCA/ESTIM
PCA/FLOOR
PCA/FRAME
PCA/BRIDGE
PCA/MATS
PCA/ADOSS
PCA/STMFR
STRESS
CISC/CSP2
CISC/FSSP2
PIERANAL
ANGIR

Structural Engineering Support Attitude:

SMA maintained an engineering department for structural analysis support of some programs. For some programs,

the support was shared between SMA and the developer.

SMA was recently purchased by IST who took over their operations. It seems that some of the software which has not been used for some time may be dropped, and the support for the engineering software will probably follow the pattern of support within IST which is quite good.

CHAPTER 4

EVALUATION OF COMMERCIAL SOFTWARE

4.1 Need for Evaluation

In the preceeding chapters, the commercial software available at data centers in Canada, and the services provided by the respective data centers were discussed. As a result of these discussions, it should be clear that there exists a great deal of available software, with applications in structural engineering; and several data centers which support and promote the use of such software. The question which now arises is: what software should one use, and from which data center should the software be accessed? Naturally, one would like to use the best combination of services however, this becomes difficult when the term 'best' is not clearly defined and thus, the 'best combination' is not obvious. The comparative evaluation of similar programs is the subject of this chapter. The principle objective of the discussion herein, is to clarify the features of software and of support which enhance the usefulness of the combination. A comprehensive system of evaluation criteria are defined and discussed with this objective in mind.

Once the designer has made the initial decision to use computer aids for a given task, many subsequent decisions become necessary. A decision must be made as to whether or not to use the available software, or to develop one's own program. This decision must be based upon whether or not there exists software which satisfies the engineer's needs in terms of analytical or design capability and whether the software is not only available, but also economical to use. The assessment of the analytical and design capabilities of existing software has been carried out by many authors and is discussed in chapter 2. Assuming that an individual has decided to use commercial software, and has been successful in locating several programs which satisfy the designer's needs, how does one then decide which program to use?

Although it is not difficult to list the benefits of computer aids it is always difficult to assess all of the benefits quantitatively. When one has several programs to choose from and all have more or less the same capabilities, the decision to use one program over the other can be rationalized by the use of a comprehensive set of evaluation criteria.

4.2 Development of Criteria

The selection of criteria for evaluation is of primary importance as the criteria must truly reflect the requirements and objectives of the decision maker. The objective of the decision maker, in this instance, may be broadly defined as - enhanced productivity - both in quality and in quantity, through the use of computer aids. By identifying all the criteria which have a bearing upon this objective, a straightforward technique for assessing the relative merit of alternative programs is created. Any decision which is then made using the evaluation process, will reflect the importance of fundamental criteria, without neglecting the significance of the less important ones.

In order to avoid a biased evaluation, the following guidelines were used in the selection of criteria:

- 1) **Meaningfulness:** The criteria must be defined clearly so that any individual or group carrying out an evaluation will have a shared image of the intent of each criterion.

- 2) **Practicality:** The criteria must apply directly to the objective of enhanced productivity through the use of computer aids.

3) Independence: The criteria should be mutually exclusive so that one characteristic of the programs is not evaluated several times.

4) Completeness: The criteria should be sufficiently exhaustive as to include all the important, and the less important but significant factors relevant to the objective.

5) Specificity: The criteria must be reducible to a sufficiently specific level so as to permit a clear evaluation on a relative scale.

In order to satisfy this fifth guideline, and to create a semblance of order, within the criteria, it becomes necessary to use a hierarchical structure of criteria and sub-criteria. To define the criteria one starts at the main objective, as previously stated, and moves through the first level criteria, to the second level and third level criteria. The first level criteria are broken down into lower level criteria (2nd and 3rd level) to help clarify the definitions, and to permit a clear rating of programs to be made. In this way the first level criteria are defined through their respective second and third level criteria. The nature of this breakdown is illustrated in figure 4.1. It may be noted

Figure 4.1
Evaluation Criteria

that the graphical representation of the criteria defines the hierarchical structure of the criteria and sub-criteria.

4.3 Definition of Criteria

In this section the criteria, introduced in figure 4.1 are defined. It should be noted that these criteria are intended to be generally applicable to the evaluation of any group of programs which have application in the engineering of building structures. They were developed to aid in the evaluation of programs, all of which have comparable problem solving capabilities. Important factors which will become apparent in this evaluation are ease of use and economy.

There are six key influences on the level of productivity which may be attained by a normal user of the software. These are:

1. Supporting Data Center
2. Documentation
3. Input
4. Solution
5. Output
6. Efficiency and Reliability

Each of these will be defined along with their respective sub-criteria.

4.3.1 Criteria

1. Supporting Data Center

There are many characteristics of data centers which although, in a sense are independant of the program, can have a serious effect upon the usability of the program. The features of the data center which have the most significant effect are the type of service and support they offer. These elements are broken down into the following sub-criteria.

1.1 Operating Support

The operating support is basically the assistance available from the data center in aiding the execution of programs. Since there are various degrees of assistance offered by data centers, it is best to evaluate the support under the following three sub-criteria.

1.1.1 System Support

As was pointed out in chapter 3, the data centers offering application software, are all capable of helping

a novice user structure the Job Control Language (JCL). The JCL consists of instructions to the computer on the management of input, output, internal files, and various steps in the execution of the program. In large programs the JCL is important to the efficient execution of the job. The ease with which a user is aided in writing the JCL, varies a good deal. Some centers, such as Multiple Access, permit the user to generate the JCL and run their program with a very easy to use conversational mode JCL generator. Others, such as SDL may require the potential user to wait days while they try to find the appropriate JCL file to use for a special problem.

1.1.2 Program Support

Good data centers will offer the support services of a structural engineer, familiar with a specific program package. This is a boon to a novice user whose problems may stem from a lack of understanding of the program. This type of support varies from program to program as well as from data center to data center. Centers such as CDC, MA or IST all provide engineers who can talk intelligently about the structure being designed or analysed. This makes it very easy for a user to explain his difficulties.

1.1.3 Seminars

Although not many data centers promote their software through seminars, those that do, should be more attractive to potential users. There is a difference between simply using a program, and using a program economically and effectively. The sort of information which may be learned at seminars can be very useful to both experienced and novice users. In the limited time that the author has been engaged in this study, CDC, MA, and IST have been the most active centers in sponsoring seminars.

1.2 Job Turn-Around

The turn-around time for a job is largely dependent upon the kind of service one is willing to pay for. Every data center will offer fast turn-around for a premium and will permit overnight runs at some savings. There are however, different options at different centers, and a normal run will return faster from some than from others.

1.3 Computer System

There are several facets of the computer system maintained at a data center, which can affect the usage of

a program. An in depth discussion of computer hardware is well beyond the scope of this thesis. Instead, only the aspects which pertain to engineering usage are considered. Certain computers, such as the CDC, feature a larger word length, which means that decimal numbers have more significant digits, and calculations performed on a CDC machine can be done more accurately than if they were carried out on an IBM machine. This is a serious concern to engineers who are involved with very large analysis problems. Certain systems offer powerful and easy to use file editing systems which make the generation of input data files a very simple task. Edit systems vary from data center to data center and evaluation of edit systems is a very personal problem. The author has had more satisfactory experiences with CDC oriented edit systems than with IBM oriented systems. The last characteristic of the computer system which can have an effect upon the use of packaged programs is the nature of the JCL and system diagnostics. For an engineer who does not want to become too involved with how the computer deals with his program run, and yet does want to know some basic information, the experience of the author indicates that CDC machines communicate more intelligently with the user than IBM machines do.

2. Documentation

The effectiveness of the user's manual, and other documentation, in preparing a user to run a problem and to understand the output, is one of the fundamental downfalls of some otherwise very useful programs. This is particularly a problem for some very large programs which one might use only occasionally. Since this is such an important problem, it requires consideration of several sub-criteria.

2.1 Explains Methods

The level at which the documentation outlines the techniques used in the program varies greatly among the commercially available programs. This is particularly true of some design programs which gloss quickly over the assumptions and tolerances implicit in the program. As an example, AMECO will permit over-design of members by up to 20% and yet in none of the documentation made available for this program can this information be found. When little information is available about how a design is produced, an engineer must, of necessity, be wary of the results.

2.2 Data Preparation Aid

As a bare minimum, the documentation for a program should clearly explain how to prepare the input data for a program. Since it has been found time and again that it is in the preparation of data that a great deal of the engineers efforts are expended, it is very important that the documentation be effective in making this task, at the very least, straightforward. This criteria can best be evaluated through the following three sub-criteria.

2.2.1 Instructions

The clarity and organization of the instructions for data preparation is of great importance. Some well thought out explanation can save hours of trial and error in data preparation. This is important for all programs. The problem is often simplified by using input forms which guide the user in a step by step way through the data preparation. The same is also true of conversational programs.

2.2.2 Examples

The presentation of complete example problems in the documentation is extremely useful. Good examples will

illustrate quickly and clearly the proper input form, and can be a very effective part of the documentation, particularly if the examples show the spectrum of problems which may be solved. Most program manuals provide good examples, one notable exception to this is the PCA Preliminary Design program which gives example input, but not the corresponding output.

2.2.3 Command Summary

In every manual there should be a summary of the input requirements, indicating necessary input data, and data which is optional and which may be omitted. This is more difficult to do for large flexible programs but it is also more valuable for such large programs.. Although STRESS 3.0 from Multiple Access is a well documented program it does not include in its documentation a summary of the input requirements. This type of summary makes working with a Problem Oriented Language (POL) program that much easier once one has become familiar with such a program. It saves one having to flip through an entire manual just for the syntax of one command statement. Of course, for small programs the summary of requirements usually takes the form of a preprinted input data sheet, or an interactive conversation.

2.3 Output Interpretation

Once the documentation has helped the user to prepare the input, its next most important task is to assist the user in understanding the output. The manual should help the user understand the output both in the case of successful and unsuccessful runs.

2.3.1 Output Description

The quality of the description of the output which may be expected from a successful execution of the program is one aspect of documentation which is often barely touched upon. In several of the Systems Professional programs, the output description consists of little more than a statement such as: 'Output listings are self explanatory'. This type of approach is totally unsatisfactory since it is rarely completely true, and can lead to much wasted time which would otherwise have been avoided with adequate documentation.

2.3.2 Error Message Explanation

There is little, that is more frustrating than having a run return with an abundance of error messages and no real explanation of the problem.. As an example, STRESS

3.0. offers the following error statements with no explanation: STATEMENT NOT ACCEPTABLE or PROBLEM FAILED DURING EXECUTION or PROBLEM INCORRECTLY SPECIFIED. These type of messages are of little use to a user who is trying to debug his input. Of course, they could be made useful if an adequate description of their meaning were contained in the documentation.

2.3.3 Trouble Shooting Guide

This criterion is used to evaluate the effectiveness of the documentation; in helping the user to identify and correct mistakes in his representation of the problem to the computer. This really comes down to the manual discussing common errors which are easily made. For one reason or another, some developers of programs overlook this as part of the documentation but it is a very useful item and greatly appreciated from time to time.

2.4 Cost Estimating Guide

It is an attractive feature for a computer program manual to permit one to predict, a priori, the cost of running a problem. Many engineers have been scared away from using a program such as ICES STRUDL because they have had unfortunate experiences with it overshooting their budget. If one uses

a program often, it becomes easy to predict the cost for a normal run. There are often however, special cases which get run only as a last resort because, predicting the cost is so difficult. Programs such as the STRU-PAK Library, of analysis programs, which provide the user with a means to predict the run cost tend to give the user an added degree of confidence in the use of the program. One problem in incorporating such information in a manual is the differences in costing between data centers for the same computing resources.

2.5 Honesty

There is often a gap between the claims of the documentation, and the real requirements and capabilities of the program. This difference may occur due to changes made in the program by the data center, or because the original developer exaggerated the abilities of his program, or because somewhere along the line a portion of a program became non-functional. All of these problems become less important once one has become familiar with the realities of the program. This is, however, not the most satisfactory arrangement, for deviations between the program and the manual must be worked out every time a new user makes use of the program. More than a week of the author's time was wasted because SDL had changed the title block requirements for the PCA Frame-Shearwall

Analysis program. A very simple problem, resulting in a significant waste of time. Unfortunately this type of problem can only be identified once the program has been used.

3. Input

The simplicity and ease with which a structural model may be defined and input, to a program can have a serious influence on the time and energy spent running a program. This goes hand in hand with some of the criteria regarding documentation, but there are several aspects of input which deserve consideration on their own. These are discussed in the following five sub-criteria.

3.1 Input Language

The form of the input requirements can have some importance in making the program easy to use, and also in making the record of the input file easy to understand. Of key importance is the ability to use free format numerical input if the engineer is going to code the problem at a terminal. A great deal of attention has been given to conversational input, however, in the author's opinion it is often more effective to be able to use a conversational mode of input during the initial usage of a program, then to be

able to turn off the conversational mode once the user has become familiar with the program requirements. Problem Oriented Language (POL) input of course makes the input file much more readable, and as such is valuable. There is nothing inherently wrong with the application of preprinted input coding forms, but the more sophisticated input modes do take some of the drudgery out of preparing data.

3.2 Errors and Defaults

The ability of a program to correct simple errors in the input data, and to provide optional default values for common data is a boon to the user and a potential time saver. Most programs do offer default values for many variables but few are able to correct simple errors such as reading the letter O as the digit zero.

3.3 Units

As the acceptable system of units in this country is changing from Imperial to Metric, it has become important that programs offer the ability to specify different unit systems. In addition, it is useful if programs permit the user to specify different units for different variables. For instance, SDRC SAGS requires the user to employ a consistent

set of units. This implies that all lengths would have to be specified in inches or in feet, but not both. While member lengths are naturally specified in feet, cross sectional areas are naturally specified in square inches. Having to use one unit or the other could result in making the input data difficult to verify.

3.4 Automatic Data Generation

Much time is often spent on generating input which could otherwise be more efficiently used. The advantages, in terms of time saved, of a program with the ability to abbreviate the input data by having some data generated automatically are substantial. STRESS 3.0 by example, permits the structural topography to be defined by a grid. AMECO is a further example, permitting the user to specify the properties of one floor, and have those properties duplicated for all similar floors.

At a very sophisticated level, some of the data centers such as CDC CYBERNET permit the user to specify a finite element mesh interactively using a graphics terminal. The time-saving advantages of these types of features are of significant importance, even in small programs where it is useful if repetitious data can be avoided.

3.5 Input Stored

The existence of a stored, changeable and re-usable record of the input data is essential. This becomes of key importance when using a conversational input mode. Most programs require an input file or deck of cards, but when the input is generated in a conversational mode, no input file will normally exist. It is redundant for the same data to be repeated in sequential runs. This becomes particularly frustrating at a low speed terminal. If one can build an input file while carrying out an interactive conversation, and be able to change and re-use that input file, then a significant amount of time can be saved. Some of the STRU-PAK programs are deficient in this respect.

4. Solution

It has been assumed throughout this discussion that programs of similar capabilities are being assessed as aids to design office productivity. Given the context of the assessment, it might seem reasonable to omit comparisons of the solution since all the programs, being compared, should be acceptable at least as far as solution is concerned. Nevertheless, there are aspects of the solution which do vary, between similar programs, and may have a bearing on the

usefulness of the output. In this case, it becomes necessary to distinguish between analysis programs and design programs. Further discussion of the solution has been subdivided into these two categories:

4.a Analysis Solution

This criterion is primarily intended for an evaluation of the usefulness of the calculations carried out by the program, as well as to evaluate the validity of the numerical model of the structure which may be created with the program. This is subdivided easily into two sub-criteria.

4.a.1 Level of Sophistication

Although the programs being compared will produce roughly the same results, some may offer a more sophisticated solution and theoretically more accurate results. From the point of view of producing a quality product, this needs be a factor in the selection process. It is to be understood that the specific definition of this criterion must be reassessed for each different category of analysis programs. Some care must be exercised in giving consideration to those aspects of sophistication, which have a bearing upon the type of problem which needs solving. As was discussed in chapter 2, there are

some programs which are very sophisticated, but which are not particularly useful for analysis of either building structures, or of portions thereof. Examples of what one might consider as useful sophistications for frame analysis programs are: shear deformations, finite joint sizes, P- Δ analysis, and elastic supports. AMECO and ICES STRUDL fall into the category of sophisticated analysis programs.

4.a.2 Loadings

The ability of a program to cope with loads in a manner suitable to the design of buildings, can have a significant influence on the usefulness of the program. In general, one wants to be able to apply a variety of load combinations in order to be able to determine maximum member force envelopes. Normally, each load case would consist of different types of loads, such as uniform distributed loads; trapezoidal distributed loads; and point loads. Several such load cases representing dead loads, live loads, wind loads and earthquake forces must be combined either by the computer or the user. A program such as STRU-PAK 2D GENFRAME which does not permit linear combinations of individual load cases, places a serious extra burden upon the user.

4.b Design Solution

In a similar vein, as the Analysis Solution, it is important to assess design programs in terms of the design produced by the programs. The level of confidence which a designer can have, in an automatic design, and the ease with which a designer exercises personal control over the design, are both factors which bear directly on how useful a specific program is to an engineer. (20) This criterion also divides into two important sub-criteria.

4.b.1 Control

A designer does not use computer aids for design to avoid becoming involved in the design. Rather, most engineers would not feel comfortable using an automatic design procedure unless some control could be exercised over the design produced. The designer will at least want to specify such things as the design code to be invoked; member similarities; restrictions on member sizes; and the number of design iterations to be performed. The Systems Professional Footing Design programs offer so little control to the user that it may be difficult to specify what design is in fact desired.

2

4.b.2 Quality

Given that one is evaluating programs which will all produce a design of roughly the same member, the quality of the design need still be assessed. In general terms, one should identify the degree to which the output may be considered as a final design, with consideration given to: reliability of design values, satisfaction of code requirements, conformity to the most up to date design philosophy, economy of design, and the presentation of alternative designs.

5. Output

Once a program has been run, the output embodies the only lasting evidence of its execution. It is the part of the program which should justify the cost of execution. It, definately receives the most attention over an extended period of time. The effectiveness of the program output, in communicating the information, generated by the program, in a manner useful to the structural designer, must receive due consideration. There are three important sub-criteria in this case.

5.1 Control

Every computer program is capable of generating much more output than is really necessary in any specific case. The ease with which a user may request only the output desired, suppressing all the unwanted output, influences the success of the engineer's ability to work from the output. In this way, the onus is placed upon the user to know exactly what he wants from the program. Clearly this is not too much to expect. An additional desirable aspect of output control is the ability to specify the decimal accuracy with which the results are printed. In this subtle way, the engineer can remind himself of the limits of numerical analysis, and automated design. Both STRESS and ICES STRUDL offer a great deal of freedom in selecting the output desired by the user.

5.2 Organization

In selecting a program for use in a production environment, it is worthwhile to scrutinize the output of the program for clarity and organization. One of the most basic considerations is the clarity of tabular data. It is a substantial aid if the tables are divided into properly labelled pages which include the appropriate units. Also, it is beneficial if the output can easily be received, on a

narrow page low speed terminal, with only 80 characters per line, and if the output can be divided into standard page sizes of 8½" x 11", or into the slightly larger metric paper size. In cases where plotted output may be useful, its influence upon the organization of the output must be weighed, and some importance attached to plotting as an asset. Plotted output is particularly valuable in checking the input to very large analysis programs.. STRESS 3.0, SDRC SAGS, STRUDL II and the PCA programs offer well organized output.

5.3 Content

There can be no question that the content of the output is its most important feature. To simplify the discussion of output content, it is natural to discuss this criterion as it applies to both analysis and design programs.

5.3.a Analysis Output Content

Without commenting on all of the elements which could be included in the output of each different category of analysis programs, the following two key considerations are identified. There should be, available to the user, a complete set of computation results from which may be selected the data desired. Again, the onus is placed upon the potential

user to decide what his needs may be and thereby define the extent of a complete set of computation results. There should also be some indication of the numerical accuracy of the solution generated, so that a rational decision may be made by the user concerning the level of confidence which may be placed in the results. The STRU-PAK analysis programs are among the only programs which benefit the user by giving some indication of the numerical accuracy of the solution.

5.3.b Design Output Content

There are several items which need be included in good design program output. One of the primary considerations is, whether the output contains material that can easily be used by a draftsman. The other primary considerations pertain to the engineer who must be able to see what code requirements have been satisfied, how many design iterations have been performed, how over-designed the members are, as well as, quantity take-offs and cost estimates. The draftsman, in turn, needs concise schedules. The complete output of a design program should satisfy both the needs of the engineer and those of the draftsman.

6. Efficiency and Reliability

Two of the main motivations for the use of computer aids in business are, to save time, and money. To determine the true cost effectiveness of computer usage, it is necessary to consider the real cost of using a program. This cost must reflect both successful and unsuccessful executions of the program. Three aspects of programs which affect the cost of their usage are discussed in the following sub-criteria.

6.1 Relative Cost

The relative cost of executing a similar problem, using different programs, is a function of several variables. Every program has a fixed cost resulting from; loading the program, the input output operations, and allocation of storage. For some programs, this can be a significant charge. Then there is the variable cost, resulting from the number of operations carried out, and which is a function of the size of the problem. The third cost aspect pertains to the royalty charge, levied by the data center. Each of the above costs can and do vary greatly from program to program. Based upon comparisons of several frame analysis programs, solving the same problem, there was found to be enormous variations in the cost of a successful run. In several tests, STRESS 3.0 was found to be the least expensive frame analysis program.

6.2 Solution Efficiency

The solution efficiency is a difficult thing for anyone to truly assess. To a certain extent, the solution efficiency is reflected in the relative cost. There is no doubt that for very large problems, the relative cost is primarily a function of the solution efficiency. This has been made a criterion because the relative cost is intended to be an evaluation of several parts of the cost function, while the solution efficiency will give an indication of how fast the cost will grow for larger problems. To evaluate the solution efficiency, correctly, the features of the algorithm must be known. It can also however be judged by running the same program with different size problems and by observing how the cost grows.

6.3 Start-Up Reliability

There are only a few programs available at data centers which have non-functioning parts. The real problem with using most programs lies in the initial stages of the program usage. Most of the money and time, wasted on unsuccessful runs, is done so during execution of the first few problems. This is partly a reflection of the quality of support, the documentation, and the input. It is apparent

that some programs are more difficult to become accustomed to than others. Since money almost invariably will be wasted by the user, executing a new program, it would seem expedient to attempt to assess ~~the~~ ease with which one adapts to a specific program. The simple ratio of the number of successful runs to the number of total runs required for the solution of the first few problems, is a good indicator of start-up reliability. Interestingly, the Systems Professional Library of programs was found to be quite easy to adapt to in spite of its relatively weak documentation. This concludes the definition of the criteria.

4.4 Use of the Criteria

The criteria defined in the preceeding section provide a complete set of guidelines which may be used for the evaluation of commercial software. They may serve as guidelines for program developers in identifying the concerns of the user, with regard to using commercial software as design office tools. Nevertheless, the specific purpose for their definition, as previously stated, is to permit a rational evaluation of programs of relatively equal problem solving capabilities. While they may serve the purpose of acting as simple guidelines, in order to aid the potential user to arrive at a subjective decision, their real significance lies in their ability to be used in a somewhat more structured manner by employing a multi-level system of evaluation matrices. The method of evaluation matrices, employing weighted criteria, is perhaps the most straightforward way to assess the relative merit of alternatives in a pseudo-objective way.

(21) Each program, in a category of similar programs, may be subjected to the exhaustive set of specific criteria, thereby generating a general evaluation of the alternatives. This type of technique has value in that it automatically reflects the importance of fundamental criteria, without neglecting the relevance of some of the less significant ones.

In Appendix B, the procedure for carrying out an evaluation in this manner is presented. The weighting of the criteria, to reflect their importance, and the sensitivity of the evaluation to the criteria weights, is also presented therein. The technique has been used to evaluate a sampling of commercially available programs in various categories of analysis and design. The results of the evaluation are set out in Table 4.1. The evaluation was performed by the author and his assistants who used the programs as made available in the data center environment, to solve a sample of test problems. The evaluation of the programs is based primarily upon the experiences of the author in the use of the programs.

TABLE 4.1

Commercial Program Evaluation: Refer Appendix B

Analysis Programs

Program	Data Center	Rating/100	Rank
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Frame Analysis

AMECO	MA	78	2
SAGS	CDC	62	6
STRESS 3.0	MA	79	1
STRU DL II	SDL	63	5
GENSAP	CDC	68	3
2D GENFRAME	CDC	66	4

Frame-Shearwall

Analysis

PCA/STMFR	SDL	53	2
SP/SHWINT	CDC	60	1

Dynamic Frame

Analysis

DAGS	CDC	73	1
STRU DL	SDL	63	3
2D FMAP	CDC	67	2

TABLE 4.1 Cont'd...

Concrete Design Programs

Program	Data Center	Rating/100	Rank
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Concrete Building

Design

AMECO	MA	74	1
PCA/ESTIM	MA	67	2
STRUDL II RC	SDL	56	3

Concrete Slab

Beam Design

PCA/ADOSS	MA	71	1
SP/CBULT	CDC	67	2
SP/NONPU	CDC	66	3

Concrete Column

Design

PCA/COL	MA	66	2
PCA/LS	MA	77	1

Concrete Wall

Design

SP/RETWAL	CDC	60	1
SP/EQUIER	CDC	54	3
SP/BRGWAL	CDC	59	2

Concrete Foundation

Design

PCA/MAT	MA	62	1
SP/COMFTG	CDC	52	2

Cont'd...

TABLE 4.1 Cont'd...

Steel Design Programs

Program	Data Center	Rating/100	Rank
Steel Frame Design			
AMECO	MA	75	1
STRUDL II CSA S16	SDL	67	2
Steel Floor Beam Design			
CISC/FLOOR	MA	73	1
SP/STLBMA	CDC	60	2
SP/COMPBU	CDC	58	3
Steel Column Design			
CISC/CSP2	MA	61	1
SP/STLCOL	CDC	58	2

The evaluation of the programs produces a rating out of 100, which may be used to rank the programs as has been done in Table 4.1. Strictly speaking, the rating is simply a relative number which applies only to comparisons of programs within a single category. It gives an indication of the program's merit as a design office tool. By following through the matrix evaluation, presented in Appendix B, it becomes immediately apparent that there are always trade-offs. Programs which rate well overall, are not necessarily without serious flaws. It has been shown however, in Appendix B, that the overall ranking of the programs is relatively insensitive to the weighting scheme as applied to the criteria.

CHAPTER 5

SURVEY OF COMPUTER USAGE IN THE BUILDING DESIGN INDUSTRY

5.1 Introduction

In the preceeding chapters of this thesis, the available programs and support services have been discussed, and methods of evaluating these programs and support have been presented. The previous discussions were aimed at providing information to the consulting firms of Canada, involved in the design of building structures. It would seem to be a natural progression to now attempt to study exactly what is being done by consultants, in terms of their computer usage. To this end, a questionnaire survey has been carried out.

During the course of the present computer study, a survey was conducted to determine the number of consultants making use of computer aids, their reason for doing so, and the scope of their computer usage. The study was carried out through the use of a questionnaire, sent to a number of Canadian consulting offices advertising themselves as structural consultants. The sample included both head offices and branch offices.

5.2 Objectives

The survey was undertaken with the following goals:

- 1) To obtain a clear view of the extent to which structural consultants use the computer, in terms of money spent, and programs used;
- 2) To assess the attitude of consultants towards automated procedures for analysis and design;
- 3) To identify what procedures are actually being carried out by consultants on the computer (ie. development and use of in-house programs or application of commercially available programs);
- 4) To gain some insight into the hardware preferences of Canadian consultants;
- 5) To compare the attitudes of Canadian consultants, as revealed by the questionnaire with the attitudes of American civil engineering consultants, as revealed in a survey conducted for Civil Engineering Program Applications (CEPA) by J. Crosier Brown, 1974 (22).

5.3 Previous Studies

There have been some earlier attempts in the United States to survey the civil engineering profession's attitudes regarding the digital computer (22,23). The most general

and significant of these surveys is the "Review of Private Practise Organizations" by J. Crosier Brown, 1974, which was part of a study undertaken by CEPA into the feasibility of establishing a National Institute for Computers in Engineering (12). Brown carried out a questionnaire survey of 4,400 members of the American Consulting Engineers Council, and received only a 6.8% response. Despite the rather low response, Brown has made some observations regarding computer usage in civil engineering consulting practise in the United States.

Among Brown's claims are, that in 1974, 83% of respondent consulting firms used computers, of which 45% used in-house computers, and 78% used outside computer services, while 24% used a combination of both. About 60% of the in-house computers identified in Brown's survey were IBM products. Brown's survey disclosed that, as a general trend, a higher proportion of large firms used computers than smaller firms. Brown further claimed from the results of his survey that, on the average, firms with in-house computers spent \$3,800.00 per month on computing, while firms using outside services spent \$1,300.00 per month on their computing. Firms using both in-house and outside computer services spent \$6,500.00 per month on computing. In addition, the average expenditure for program development by consulting organizations was \$1,967.00 per month.

A careful reading of Brown's report reveals, however, some inconsistencies. His response sample was only 6.8% of the firms surveyed and yet these 6.8% represented only 1.1% of all consulting firms in the United States. On the other hand, they represented 11.8% of all civil engineers, clearly indicating that his response was skewed towards large offices. In addition, he identified 33 non-user firms in his survey sample, implying that, in fact, 88.7% of his respondents were computer users. This figure is consistent with all the graphical data presented in his paper.

For comparison, some of Brown's data is presented herein, alongside the findings of the present survey. If one accepts Brown's survey as substantially valid, some comparisons may be made between Canadian and American attitudes, with respect to the computer. A basic difference between the two surveys must be noted; Brown's figures apply to a wider spectrum of civil engineering consultants, including transportation, municipal, geotechnical, structural, management, environmental, architectural, and others. Comparison between Brown's data, and the results of the present survey must therefore be made with this in mind.

5.4 Questionnaire Development

The questionnaire, presented in Appendix C, was developed in an attempt to fulfill the goals as presented in section 5.2. Fulfillment of these goals would essentially identify the nature and extent of computer usage in Canadian consulting offices which carry out structural design of buildings. The information which was sought is listed below.

- 1 Size of office and type of work carried out
- 2 Nature of computer usage
- 3 Extent of computer education or training of personnel
- 4 Budget breakdown of computing expenditures
- 5 Reasons for the use of the computer
- 6 Hardware preferences
- 7 Nature of the software used
- 8 Overall attitude of consultants towards the computer

5.5 Population Sample

The survey sample was selected from two main sources. Since the intent of the study was to obtain a greater understanding of computer usage by structural consultants engaged in building design, an attempt was made to survey only that type of consulting office. The Association of Consulting Engineers of Canada (ACEC) (24) provided

addresses for all the offices of its member firms, by selecting the firms which listed structural engineering as a field of specialization, an initial population sample was produced. This sample was supplemented with all the offices which advertised as "Structural Consultants" in the 'Yellow Pages' of Victoria, Edmonton, Regina, Toronto, Ottawa, Montreal, and Quebec City. This final sample consisted of 567 offices, all of which advertised as structural consultants. The entire population of structural consulting offices in Canada is estimated at 900.

The questionnaire was mailed to the 567 offices. Responses were received from 106 offices. The Post Office returned 8 unopened. The response sample is 19% of the surveyed population. The responding offices are listed in Appendix C.

Of the 106 respondents, only 79 offices actually engage in the structural design of buildings. This difference is attributed to the fact that some offices design structures other than buildings, such as bridges. Other offices are branch offices that do no structural design at all. In all further discussion in this report, only respondents indicating building structures as one of their specialities will be addressed. Those offices represent a total of 1990 engineers.

5.6 Survey Results

5.6.1 Computer Usage

Of the consulting offices which responded to the questionnaire, computer usage by 78% is indicated. This figure includes 8% of consulting offices which use desk-top programmable calculators only, such as a Hewlett Packard 9830 or Wang 2200.

Of the responding sample, 72% were head offices and the remaining 28% were branch offices. The head office sample indicated that 87% are computer users, while only 54% of the branch offices indicate that they are computer users. Many branch offices responded that all their computing needs were taken care of at head office.

The offices which are in fact computer users have been using computers for an average of 8 years. The variations in computer usage, and length of computer usage as related to the size of the office, are presented in the following figures 5.1 and 5.2. In this report, the size of the office is measured in terms of the number of engineers employed in the office.

Figure 5.1

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COMPUTER UTILIZATION IN STRUCTURAL CONSULTING OFFICES BY SIZE OF OFFICE

Figure 5.2

LENGTH OF COMPUTER USAGE IN STRUCTURAL CONSULTING OFFICES BY SIZE OF OFFICE

P

The responding offices indicate that of those offices which use computers, an average of only 43% of the engineers in the offices are actual computer users.

The questionnaire indicates that 23% of those offices not presently using computers are considering the practical advantages of beginning computer usage. Of the offices which are presently using computers, 43% indicate an intention to increase their usage, while only 1% indicate an intention to decrease their usage.

5.6.2 Computer Education

The respondent offices using computers indicate that only 59% of the engineer computer users have any formal computer training. Those who have had training responded that 66% had taken a programming course, while only 40% had taken a course in computer-aided design. Only 21% of respondent offices which use computers provide any computer training for their employees.

5.6.3 Computer Budget

The breakdown of the computer budget information is summarized in Table 5.1, and figures 5.3, 5.4, 5.5, and 5.6. It should be noted that the number of respondent offices in each category is listed at the top of Table 5.1.

Of the respondent offices using computers, 90% feel that their computer usage is cost effective.

5.6.4 Benefit Ranking

The respondents were asked to rank a set of the potential benefits of computer usage according to the importance that they placed upon them. The resulting ranking of the benefits is as follows:

Most Important	Better Analysis
↑	Better Design
↑	Faster Job Turn-around
Increasing Importance	Relief from Routine Work
↑	Preferred by Employees
↑	Preferred by Clients
Least Important	Prestige

TABLE 5.1

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Computer Budget Data

	ALL OFFICES	1 - 3 ENGINEERS	4 - 10 ENGINEERS	11 - 20 ENGINEERS	20 + ENGINEERS
Number of respondents. in size cat- egory	49	7	15	10	17
Annual computer budget	\$26,637	\$4,428	\$8,816	\$10,740	\$59,656
Percent for:					
Hardware	16	3	17	19	18
Software procurement	2	3	2	0	2
Software development	9	4	3	8	17
Production Work:					
1) analysis	42	23	52	52	37
2) design	28	65	23	19	21
<u>Production Work Breakdown</u>					
Percent for:					
In-house programs	41	37	29	52	45
Purchased programs	9	18	8	0	11
Data center programs	49	43	61	47	42

Figure 5.3

Figure 5.4

PERCENTAGE OF COMPUTER BUDGET FOR PROGRAM DEVELOPMENT BY SIZE OF OFFICE

BREAKDOWN OF COMPUTER BUDGET FOR PRODUCTION WORK BY PROGRAM SOURCE AND SIZE OF OFFICE

Figure 5.6

PERCENTAGE OF COMPUTER BUDGET FOR PRODUCTION WORK BY PROGRAM TYPE AND SIZE OF OFFICE

5.6.5 Hardware Use

The hardware used by respondents is summarized in figures 5.7 and 5.8. These figures indicate hardware used at data centers and hardware used in-house. The abbreviations used in the figures are identified in Table 5.2.

TABLE 5.2

HARDWARE VENDOR ABBREVIATIONS

Vendor	Abbreviations
Control Data Corporation	CDC
Data General Corporation	DGC
Digital Equipment Corporation	DEC
Digital Scientific Limited	DSL
General Automation Incorporated	GAI
Honeywell Limited	HON
Hewlett Packard	HP
International Business Machines	IBM
Systems Approach Limited	SAL
Texas Instruments Incorporated	TI
Univac Division of Sperry Rand Corporation	UNIVAC
Wang Laboratories Limited	WANG

Figure 5.7

DATA CENTER HARDWARE USAGE IN STRUCTURAL CONSULTING OFFICES BY VENDOR

Figure 5.8

IN-HOUSE COMPUTER HARDWARE USAGE IN STRUCTURAL CONSULTING OFFICES BY VENDOR

5.6.6 Software Usage

No meaningful information could be obtained from the responses to questions regarding in-house software development other than what may be inferred from Table 5.1 and figures 5.4 and 5.6

The responses of offices regarding the usage of commercial software provides information on: the number of offices which use a specific program at least once a year (Users); the number of offices which use a specific program more than just once a year (Intense Users); and the average number of runs per year of a specific program by those offices which use the program more than just once a year (Intensity). This information is given in Table 5.3 and figures 5.9, 5.10, and 5.11.

TABLE 5.3

Structural Software Usage

Program Name	Users ¹	Intense Users ²	Intensity ³
AMECO	11	9	10
ANGIR	1	0	0
ANSYS	6	5	11
BEAMANAL	1	1	7
CBA PROGS.	3	1	20
CISC PROGS.	8	3	334
GASPX	2	2	252
ICES STRUDL	16	12	16
MARC	1	1	50
NASTRAN	4	4	5
NISEE SAP IV	2	0	0
OPFRAD FLOBIM	2	2	35
OPFRAD KOLUM	2	2	105
OPFRAD BAPLAF	2	2	20
PCA ADOSS	19	16	200
PCA LOAD STACK	1	0	0
PCA COL USD	7	5	76
PCA OTHERS	15	12	6
SDRC SAGS	1	0	0
STARDYNE	10	7	18
STRESS	37	34	56

¹Program used at least once a year

²Program used more than once a year

³Average runs per year for Intense Users

Figure 5.9

PROGRAMS USED BY RESPONDING OFFICES
USAGE OF COMMERCIAL SOFTWARE IN STRUCTURAL CONSULTING OFFICES BY PROGRAM

Figure 5.10

Figure 5.11

INTENSITY OF COMMERCIAL SOFTWARE USAGE IN STRUCTURAL CONSULTING OFFICES BY PROGRAM

5.7 Representativeness of Sample

In a survey of this type, some consideration must be given to the validity of the results, or, more precisely, the representativeness of the response sample. In the present survey, the response to the questionnaire was 19%. This information does not, however, give any assurance of validity, in itself, since it is possible that the response sample had a very different set of characteristics than that of the entire population.

The best way to get a feeling of the representativeness of the sample is to compare characteristics of the respondents with some known characteristics of the population. (25) In this case, unfortunately, Statistics Canada (26, 27) was unable to offer much information about the population of structural consultants, but some characteristics of these consultants were obtainable from ACEC. (24)

Comparisons of some characteristics of the sample with data obtained from the ACEC have been made. It must, however, be noted that the ACEC does not constitute the entire population, having only approximately 50% of Canadian consulting firms in its membership. Table 5.4 illustrates the regional distribution of structural consulting offices. Table 5.5 illustrates the average number of engineers per office and the proportion of head offices in the sample,

TABLE 5.4

Regional Distribution of Consulting Offices

	ACEC Structural offices (%)	Survey frame (%)	Survey response (%)
Newfoundland	1.0	0.8	0.9
Prince Edward Island	0.4	0.4	0.0
Nova Scotia	3.7	3.0	3.8
New Brunswick	2.6	2.3	4.7
Quebec	27.2	27.6	15.1
Ontario	38.9	40.3	40.6
Manitoba	2.8	2.3	3.8
Saskatchewan	2.2	2.3	3.8
Alberta	7.8	8.9	6.6
British Columbia	11.8	11.0	18.9
Yukon	0.2	0.2	0.0
Northwest Territories	1.0	0.8	1.9

TABLE 5.5

Comparative Consulting Office Characteristics

	ACEC 76 Structural offices	Survey Response
Average number of engineers per office	19.8	20.5
Proportion of head offices (%)	51	57

compared to the same figures for the ACEC structural consulting offices. These three comparisons provide some measure of the relationship between the response sample and the ACEC membership.

The regional distribution of offices compares quite well, with the exception of Quebec and British Columbia. Unfortunately, the questionnaire was a unilingual English document which, no doubt, accounts for the low response rate from Quebec. The other comparisons indicate a clear correlation between the response sample characteristics and those of the ACEC membership. It seems clear that the response sample is not significantly skewed regionally, nor is it far from the ACEC average in terms of office size and proportion of head offices to total offices for structural firms.

To attempt to extrapolate the response data over the entire population, based on these comparisons, is probably not justified, however, trends that appear clearly in the response sample are believed to be fairly representative of the population.

5.8 Discussion of Survey

The results of the survey indicate clearly that a majority of structural consulting offices are making use of computer aids, and, in general, feel that their usage is economically worthwhile. Although large offices apparently make considerably more use of the computer than do small offices, a majority of the small offices which responded are using computer aids, and benefitting from this usage. The length of time that offices have been using computers varies considerably between less than one year and up to 18 years. There appears to be, however, no clear relationship between size of office and the length of time the office has been using computers. This lack of relationship makes sense, of course, since the initial investment required for access to computing power at data centers has been within the resources of even small offices for almost two decades in Canada.

The response of the computer users, that almost half intend to increase their usage, and almost one quarter of the non-users are considering implementing computer aids, indicates a very positive general attitude towards the computer as a design office tool.

The fact that only 59% of the engineers who are using the computer have any formal education in computers is quite interesting. The implications are twofold: first, that using the computer is not something beyond the capabilities of a good many practising engineers who graduated before computer programming became a regular part of the engineering undergraduate curriculum; secondly, that enough computer programs are available from data centers, or other organizations, that advanced programming is not a prerequisite to employing computer aids effectively. These implications have, in fact, been verified in the author's own experience at the university with respect to both foreign and mature graduate students for whom the computer was not a part of undergraduate training.

The breakdown of the computer budget of the respondents is worthy of some consideration. As might be expected, the amount of money spent on computing varies considerably with the size of office; from an average of about \$4,400.00 per year, for offices with less than four engineers, up to an average of almost \$60,000.00 per year, for large offices employing more than 20 engineers. The percentage of computer budget, spent on software development, is also related to size of office, with only the large offices devoting more than a nominal sum to software

development. The figures for the production work budget indicate that, in general, more money is spent on analysis programs than on design programs, however, in small offices, this trend is apparently reversed, with a greater portion of their production budget being spent on design oriented programs. This response points out that when engineering resources are at a premium, the computer can be used effectively to supplement the designer's abilities.

The breakdown between in-house developed programs and data center programs is almost equal among the respondents. The increasing availability of high quality commercial software has clearly been paralleled by increasing usage of commercial software in the private sector. Few offices have the resources available to devote to program development, and it seems clear that consultants are relieving themselves of that burden by using commercial programs. The allocations for the purchase of programs and for the use of purchased programs are low, presumably because most programs that are for sale are also available from, and supported by, one data center or another.

Although Canadian consultants responding to the survey spend less on computing than their American counterparts did in 1974, (according to Brown), it is apparent that the respondents are happy with their level of expenditure,

90% indicating that it was cost effective. This reinforces the overall positive attitude towards computer aids, illustrated previously by the fact that the majority of design offices surveyed, including smaller offices, use computers.

The benefit ranking of respondents contains little surprising information, the highest ranked benefit being Better Analysis, indicating clearly that consultants appreciate the enhanced analytical abilities made feasible through the digital computer. This is followed by Better Design, and Faster Job Turn-around, showing that consultants value the computer for its capabilities, and not as a status symbol.

The hardware preferences of the respondents are in some ways difficult to interpret. The hardware used at data centers, by respondents, is more likely a reflection of the services, and software, offered by the data centers than a conscious decision based upon the merits of one manufacturer's hardware over another's. There is, however, a definite indication that data centers with CDC hardware are doing more business with structural consultants than data centers with other hardware. Data centers providing IBM hardware are not far behind. CDC and IBM clearly dominate the market.

The in-house hardware being used by respondents is greatly diversified. The information presented in figure 5.8 may, however, be somewhat misleading since the hardware represented in the figure ranges from quite large machines such as an IBM 1130, to small programmable desk-top devices such as HP 9830. Bearing in mind that this comparison involves machines of varying processing power, these results must be treated with some caution. Nevertheless, it would seem that Hewlett Packard is the most popular vendor of in-house hardware. Perhaps the most important comment which can be made about this data, is that the in-house processing requirements of consultants differ greatly from office to office, and the experience of one office may be of little value to another.

One of the significant pieces of information gained from the survey is that which pertains to the usage of commercial software by structural consultants. The information presented in figure 5.9, containing the number of offices using a program at least once a year, gives some idea of how widely the programs are used. On the other hand, figure 5.10, shows the number of offices using a program more than just once a year, giving a better indication of how widely the programs are used in a serious vein. From figure 5.10 it may be seen that very few programs

receive wide usage. ICES STRUDL, the PCA programs, and STRESS stand out from the others, and are clearly important. AMECO, ANSYS, NASTRAN, and STARDYNE appear to be used moderately by respondents. This result leads one to conclude that the level of availability and support combined with the age of the program have a significant effect upon the number of users.

Alongside this, the Intensity of Usage (figure 5.11) gives some idea of how much the respondents have grown dependent upon programs. In this figure we find several programs (the CISC programs, GASPX, MARC, and the OPFRAD Programs) which although not widely used, are extensively used by a few offices. Since the number of times a year which one would have need to use a program is highly dependent upon the type of job the program is built to handle, it is difficult to make straightforward comparisons, based solely on this figure. It is useful, therefore, to summarize this discussion of commercial software with a list of programs which appear to be useful to structural consultants. These programs may be called important in the Canadian context. This evaluation is based upon how widely they are used, as well as how extensively they are used, giving full consideration to the nature of the programs. These programs are:

AMECO

ANSYS

CBA programs

CISC programs

GASPX

ICES STRUDL

MARC

NASTRAN

OPFRAD programs

PCA programs

STARDYNE

STRESS

To conclude, it appears that computer aids are being used widely and economically by Canadian structural consultants. The breakdown between in-house developed programs, and commercial programs, is about 50 - 50. Data centers with CDC hardware are used by more offices than data centers with other hardware. There are, in fact, only a handful of commercial programs which are being used in a serious way. Most of those that are, appear to be the well known programs which have been available for many years. It is refreshing to note that not all of the important programs have been imported from the United States.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This thesis has not been a state-of-the-art study, rather, it has been an investigation into the state of an industry. The role of the computer in the building design industry in Canada has been assessed in some depth. In this chapter, some of the questions which have been answered, are summarized, and some new questions are posed.

It has been shown that a substantial library of commercial software exists at data centers. This software places vast computing power within the grasp of engineers who need know almost nothing at all about computer programming. The consulting engineer is provided with broad capabilities for computer-aided design and analysis. In terms of analysis, there exists a broad range of programs, from the most sophisticated to the most rudimentary. Although there are some gaps in the programs specifically developed for building structure analysis, these can be worked around. While in terms of design programs there is not the same spectrum of software available, there is a sampling of very useful

programs. The trade organizations have done the consulting industry a great service by sponsoring the development of useful, good quality, design programs. The most noticeable gap in the design programs generally available, lies in timber member design. It is also interesting that there are really no optimization design packages available from data centers at this time; that is, no programs which develop their designs from a mathematical programming procedure, or some generalized optimality criterion.

The data centers in Canada provide support for the usage of their engineering application software. Although the support provided by data centers is not of consistently high quality right across the board, there are a few which do offer very good service to their engineering clients. The data centers which best serve building designers, employ structural engineers who can help the users solve problems related to either the program, or the structural model. They offer seminars on the effective use of their software. In general, they take an active interest in the needs and problems of their clients.

The selection, by a designer, from the available programs at various data centers may be rationalized through the use of comprehensive evaluation matrices.

With the investment of a little work, and a few test runs of alternative programs, it is possible to systematically evaluate the programs and data centers in a total and comprehensive way. The procedure outlined, can result in a quite different selection of programs than what might result if the potential user simply selected his programs based on the available documentation. It may be concluded that, undertaking a few test runs, and carrying out a comprehensive evaluation procedure, is the most effective way to select commercial software.

The survey of consultants shows clearly that the computer, as a design office tool, is here to stay. Overall, consultants are using the computer for analysis, more than for automated design. This is without a doubt, a reflection of the comment made previously - that the design software, commercially available, is less well developed, and somewhat more limited in scope than the available analysis packages.

There exists a correlation between the commercial software being used by consultants responding to the survey, and the software which rated well in the evaluation (chapter 4 and Appendix B). Ignoring the programs which were not evaluated in Chapter 4, it may be seen that STRESS which is the top rated program, is also the most widely used program. The PCA slab design program is the top rated slab program and is also very widely used by Canadian consultants. AMECO

which rated very well, as a frame analysis program, and was the top rated concrete and steel frame design program, is quite widely used by respondents. This correlation lends credence to the evaluation procedure showing that it does reflect the objectives and needs of consultants, operating in the private sector.

6.2 Recommendations

There are several recommendations for further work in this field which have become apparent during the course of the present research. The recommendations have been grouped into the following categories.

Mini-computers: The present study has been concerned primarily with the use of data center computers. The alternative to the data center computer, is an in-house mini-computer which is now viable in economic terms. There are two studies which relate to the mini-computer and which would be of great value. They are as follows:

(i) It would be very useful to compile a catalogue of programs, available for sale to Canadians, which could be housed on various mini-computers, and which would be applicable to Canadian building design.

(ii) It would be extremely useful to undertake a study of the state-of-the-art mini-computer hardware. This study would establish bench-mark standards, and, present the capabilities of the mini-computers from a civil engineer's perspective.

User Studies: There are several surveys which would be valuable undertakings. They are as follows:

(i) The study of consultant's use of computers, undertaken in this thesis, should be repeated in several years time, and compared with the present work, noting trends. Such a survey would reasonably be more concerned than the present study both with in-house usage, and with graphics applications.

(ii) In the course of the present survey, several firms were identified as being heavily involved with in-house program development. It would be useful to undertake a series of case studies of these firms. These studies would delve deeply into the true cost benefit ratio for in-house program development. A sample of more than five offices, with experience developing both analysis and design software, would constitute very valuable research.

Data Centers: There are two features of data centers which were not adequately dealt with in this study. They are as follows:

(i) A study and evaluation of the operating and edit systems, available at Canadian data centers, from the perspective of a program developer. If there are substantial differences between data centers, it would be useful to evaluate these, since it has been shown that many consulting firms are involved in program development. The author is, of course, aware of an inherent danger in such a study since the 'best' operating systems and editors are always those that one is currently most familiar with.

(ii) Many data centers offer graphics packages which complement their structural engineering analysis programs. A study and evaluation of these packages would be useful since it is evident that many respondents to the survey actually do use large finite element programs, on a regular basis.

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Appendix A

Guide to Commercially Available
Application Software For Structural
Engineering, 1978

Preface

This guide is one part of a general survey which has been conducted at Carleton University, on the applications of computers in building design and construction in this country.

The main objective of the present work is to provide Canadian structural consultants with a catalogue of available computer programs. Each of the programs mentioned in this guide are available from one or more of the time-sharing data centers in this country.

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Introduction

Since the early 1950's when the electronic digital computer was first used for structural analysis, engineers have increasingly accepted the computer as a design aid. The 1960's saw the advent of computers large enough to handle realistic structures, and progressive consulting firms began to write and use programs for the analysis and design of structures. As the programs grew in size it became apparent that the cost of development of large scale programs was beyond the means of small consultants. To satisfy this market of potential users who possessed neither the expertise nor the time and money to develop their own programs, data centers began to provide packaged programs, that is, more or less fully documented, user oriented programs.

The number of packaged programs available for structural design has increased markedly in the past decade. In the U. S. A. and Canada the number of programs commercially available, and applicable to the design of buildings, number in the thousands. (In Canada the quantity and range of available programs, is somewhat smaller than in the U. S. A.) It presents a formidable task to any consulting firm to survey all of the available data centers, and each data center's available software to find a needed program.

The purpose of this guide is to catalogue all programs applicable to building design, and available at data centers in Canada. The information presented herein was gathered largely in Ottawa, Ontario. The number of data centers in Canada is large, and there are certain to be some omissions. It is felt that the material presented in this guide is largely applicable to major urban centers throughout Canada.

The program abstracts presented herein have been categorized into several classes. Each category contains programs of essentially the same or similar analytical or design capabilities. Some programs fall into more than one category, and as a result there is some unavoidable repetition. The program categories are listed in table A-1. The time sharing data centers referred to in this handbook are listed in table A-2.

Each program abstract contains information about the origin, availability, capabilities, input, and output of the program. Except where noted the programs described are more or less fully documented, that is, a printed guide to the use of the program is available.

The input for many of the programs is described as a "format free data file", which implies that card spacings, or print positions need not be counted (leading to a substantial savings in time and elimination of errors), and that the file

may be changed, and updated. The phrase "Problem Oriented Language" (POL) is used to describe programs which incorporate standard words and phrases in their input requirements. The term 'Conversational' is used to describe programs which receive their input by carrying out an interactive dialogue with the user.

TABLE A-1

Analysis:

Finite Element Analysis
Frame Analysis
Special Structures Analysis
Single Structural Element Analysis

Design:

Concrete Building Frame Design
Concrete Column Design
Concrete Beam and Slab Design
Concrete Foundation Design
Concrete Wall Design
Precast Prestressed Concrete Design

Steel Building Frame Design
Steel Beam and Composite Beam Design
Steel Column Design
Steel Base Plate Design

Masonry Design

Timber Design

Table A-2
Data Centers Providing Structural Engineering
Application Software

Canadian General Electric Company Limited	CGE
Computel Limited	Computel
Computer Sciences Canada Limited	CSC
Comshare Limited	Comshare
Control Data Corporation Cybernet Services	CDC
Dataline Systems Limited	Dataline
Industrial Life-Technical Services	IST
International Business Machines Canada Limited	IBM
I. P. Sharp and Associates	IPS
Multiple Access Computer Group	MA
Systems Dimensions Limited	SDL

Finite Element Analysis:

ANSYS

ASAS

EAC/EASE2

ICES/STRU DL II

MARC

MRI/STARDYNE

NASTRAN

SAP IV

SDRC/SUPERB

Program: ANSYS - Engineering Analysis System

Origin: Swanson Analysis Systems Inc.,
Elizabeth, Pennsylvania

Availability: CDC, Comshare, CGE, CSC, IST, MA

Capabilities: This is a very large, general purpose, finite element program with a wide range of analysis capabilities, including: static, dynamic, elastic, plastic, creep, swelling, and small and large deflections. The program can also solve the following heat transfer problems: steady state and transient, conduction, convection, and radiation. The wave-front direct solution method is used to solve the simultaneous linear equations developed by the matrix displacement method. The program may be applied to any general 2 or 3 dimensional structure, plates, shells, or non-linear problems, including interfaces and cables.

Input: The structure may be input to the program using 2 or 3 dimensional element mesh generators. Boundary conditions may be defined automatically. Data checking, and error analysis are performed.

Output: The output may consist of forces, stresses, strains, displacements, time histories, eigenvalues, eigenvectors. Output may be printed or plotted. Root-mean-square and other operations may be performed. Parts of the output may be suppressed.

Program: ASAS - Atkins Stress Analysis System

Origin: W. S. Atkins and Partners,
Epsom, England.

Availability: Comshare

Capabilities: This is a general purpose, linear elastic finite element program for the stress and deformation analysis of 2 and 3 dimensional structures. The program was designed for ease of usage by engineers. The special features of the program include some unusual elements, suitable for shear walls, general thin shells, and fracture mechanics.

Input: Data is input to the program in a fixed format mode. The use of printed data coding forms is indicated. A partially automatic element mesh generator, and some data checking is available,

Output: The output from the program is printed.
Plotting is available for data checking purposes.

Program: EAC/EASE2 - Elastic Analysis for Structural Engineering 2

Origin: Engineering Analysis Corp.,
Redondo Beach, Calif.

Availability: CDC

Capabilities: This program can perform static linear elastic structural analysis of 3 dimensional systems, subject to mechanical, inertial, and thermal loads. The solution includes: displacements, beam internal forces and stresses, triangular and quadrilateral element stresses, solid element stresses, and reaction forces.

Input: The input may be supplied graphically.
Extensive error checking is performed.

Output: The program will plot the undeformed, finite element model. Various types of output may be specified.

Program: ICES/STRU DL II - Integrated Civil Engineering
Systems / Structural
Design Language II

Origin: Massachusetts Institute of Technology

Availability: Computel, Comshare, IST, SDL

Capabilities: STRUDL is a large scale computer program, capable of performing static and dynamic analysis of 2 or 3 dimensional general structures. The finite element facilities are generally reliable in solving problems in continuum mechanics. The present M.I.T. version provides a variety of elements for the solution of plane stress and plane strain, plate bending, shell analysis, and 3 dimensional solids. Modified and enhanced versions have been developed by Messerschmitt-Blokow-Blohm, McDonnell Douglas Automation, and Pennsylvania State University. The PSU version is available from IST.

Input: STRUDL uses a POL input format. Data checking is performed. No automatic mesh generation capability is available.

Output: The output may consist of forces, displacements, stresses, strains, time histories, eigenvalues and eigenvectors. Printer plotting of geometry for data checking is available.

Program: MARC - CDC P.V. Marcal

Origin: MARC Analysis Research Corp.,
Providence Rhode Island

Availability: CDC

Capabilities: MARC was written specifically for non-linear (plastic and large deflection) analysis. It also has linear static analysis capabilities. The program employs recent advances in finite element techniques, and is suited for state-of-the-art analysis applications. The program can handle material properties based upon a Mohr-Coulomb yield criterion which is suitable for modelling soil or rock behaviour. This is a sophisticated, and powerful program, and as such, demands a knowledgeable user.

Input: The program permits automatic mesh generation in 2 or 3 dimensions, and automatic loading generation. Substantial data checking is performed.

Output: A wide variety of printed output is available. Plotting capabilities include: plots of deformed geometry, and stress contours.

Program: MRI / STARDYNE

Origin: Mechanics Research Incorporated
Los Angeles, California.

Availability: CDC, MA

Capabilities: The program is designed to handle linear elastic structural models for static and dynamic analysis. The capabilities for static analysis include basic computation of member loads and stresses, and structural deformations caused by arbitrary applied loads and displacements. Dynamic response analysis can be performed either by direct integration, or the normal mode technique. Dynamic loading includes shock spectra excitation, and random excitation. The program permits Guyan reduction or kinematic condensation to improve solution efficiency.

Input: Finite element mesh generation capabilities are available. Data may be supplied graphically. Coded input must be supplied in a fixed format mode. Data checking is performed.

Output: The output may consist of internal forces, stresses, displacements, eigenvalues and eigenvectors as well as time histories. Plots of both deformed and undeformed geometry are available.

Program: NASTRAN - NASA Structural Analysis

Origin: MacNeal-Schwendler Corp.,
Los Angeles, California.

Availability: CDC, CGE, Comshare, IST, MA, SDL

Capabilities: NASTRAN is a huge general purpose finite element program which can be used for the static or dynamic analysis of general structures, the elastic stability analysis of structures, or for general matrix manipulations. The program can handle material nonlinearity. The program was developed primarily to solve large (1000 degrees of freedom plus) structural problems in the aerospace industry. It is not efficient for solving small problems, and is not particularly oriented towards the problems encountered in buildings.

Input: NASTRAN uses a uniform input format for all coded data. The program does not use a POL. Data may be created graphically, or with automatic mesh generators. Substantial error checking is carried out.

Output: The output of NASTRAN may be controlled by the user and may consist of: forces, stresses, displacements, eigenvalues, eigenvectors and time histories. The undeformed geometry may be plotted for data checking, deformed geometry plots, and stress contours are also available.

Program: SAP IV - Structural Analysis Program IV

Origin: University of California
Berkeley, California.

Availability: MA, IST

Capabilities: This is a finite element program for the static and dynamic response of linear structural systems in 2 or 3 dimensions. It provides a wide range of analytical capabilities for linear elastic isotropic materials. The program can calculate the eigenvalues, and eigenvectors or, it can perform direct integration of the dynamic response. Matrix condensation is performed to permit efficient solution.

Input: SAP IV requires that data be supplied in a fixed format mode. A limited amount of automatic data generating capability is available.

Output: The output consists of element stresses and strains, forces, displacements, eigenvalues, eigenvectors, and response histories. No plotting capabilities are available within the program.

Program: SDRC/SUPERB - Super Best (Bending Evaluation
of Structures)

Origin: Structural Dynamics Research Corp.,
Cincinnati, Ohio

Availability: CDC, Comshare, CSC

Capabilities: SUPERB carries out linear elastic small deflection static analysis. It can also perform steady-state heat transfer analysis, including an iterative solution for temperature dependent, or orthotropic material properties. The program uses isoparametric elements. The wave-front solution technique is used for the matrix solution.

Input: Data may be supplied in a free format mode, interactively. Automatic mesh generating capabilities are available. Data checking is performed.

Output: The output consists of: stresses, strains, and forces, and may be controlled by the user. Plots of the deformed and undeformed structure, as well as stress contours are available.

Frame Analysis Programs:

AMECO
FRANAL
GASPX
ICES/STRU DL II
OPFRAD/FLOBIM
PCA/STMFR
PLANEFRAME
SDRC/SAGS
SDRC/DAGS
SDRC/LAGS
STRESS
STRU-PAK/'SAP
STRU-PAK/'MAP
SP/DETTRS
SP/REGFRM
SP/RIGFRM
SP/SHWINT
**TRUSSC

Program: SDRC/SAGS - Static Analysis of General
Structures

Origin: Structural Dynamics Research Corporation
Cincinnati, Ohio.

Availability: CDC, CGE, Comshare, CSC

Capabilities: This program performs analysis of elastic statically loaded beam type structures. For example, planar and space frames, trusses, grids, and continuous beams. The program will handle non-prismatic members, elastic supports, semi-rigid connections, shear deformations, temperature loads, and differential member stiffness due to the beam column effect. A conventional stiffness analysis is used. Nominal stresses in members may be calculated. This program is fairly expensive to use.

Input: The data is supplied in a format free data file. The use of preprinted coding forms is indicated. Data checking is performed. Data consists of: member properties, joint coordinates, member connectivities, and loads.

Output: The output may consist of: member forces and nominal stresses, joint displacements, and reactions. Plotting options for both deformed and undeformed geometries are available.

Program: **FRANAL - Frame Analysis

Origin: IBM

Availability: IBM

Capabilities: This frame analysis program will compute the end moments, and shear forces in the members of a 2 dimensional, rectangular, building frame. A maximum of 100 members, and 400 member and joint loads may be entered in the program. The solution is achieved by the slope deflection method, using joint rotations, and sidesway deflections as unknowns. The solution ignores axial shortening of columns, and all shear deformations.

Input: The input mode of FRANAL permits the user to supply data either conversationally, or from a format free data file. The user must specify the lengths, rigidity, and degrees of freedom for each member, and, all loads applied to members.

Output: The program produces the end moments and reaction forces at each end of every member. The program does not output deflections.

Program: GASPX - General Analysis of Structural
Engineering Problems Extended
Version

Origin: Swan Wooster Ltd.
Vancouver, B.C.

Availability: CSC

Capabilities: GASPX is a general frame analysis program, employing the stiffness method. The program also includes limited finite element capabilities permitting enhanced structural models to be analysed. The solution of the linear equations is by the Choleski decomposition technique. The program can handle the normal array of frame elements, plus triangular and rectangular plate and shell elements. Joints may be elastically supported, and, in addition, the program permits degrees of freedom to be equated so that the horizontal translation of a floor may be uniform. The program permits a number of static load types to be applied, either concentrically or eccentrically. Thermal loads can also be applied.

Input: The data may be supplied in either a fixed format, or a free format mode. Preprinted input coding forms are available. Input consists of joint coordinates, member connectivities and properties, and load data.

Output: The program will output member forces, element stresses, and deflections. Load combinations may be performed by a separate program, ADGASP. Undeformed

Program: ICES/STRU DL II - Integrated Civil
Engineering System/
Structural Design
Language II

Origin: Massachusetts Institute of Technology

Availability: Computel, Comshare, IST, SDL

Capabilities: STRU DL II can carry out the static and dynamic analysis of a 2 or 3 dimensional frame. It can perform a stiffness analysis or a statically determinate analysis for preliminary frame design. The dynamic analysis capabilities include eigenvalue extraction, as well as the dynamic response of a structure subject to time function loadings. The program also solves first order buckling.

Input: STRU DL permits data to be supplied in a format free mode, with a POL. Extensive data checking is performed. No automatic topography definition is available. Input consists, in general, of joint coordinates, member connectivities and properties, and load data.

Output: The output may consist of: member forces, displacements, reactions, eigenvalues, eigenvectors and time histories. The user may request only that output which is desired. Printer plotting is available for data checking.

Program: OPFRAD/FLOBIM - Optimum Framing Design
Floor Beams

Origin: Computerized Design Services Ltd., and
Julius Nagy and Associates Engineering Ltd.,
Toronto, Ontario.

Availability: MA

Capabilities: FLOBIM is the first of a series of three programs written for the design of steel frames. The program calculates the shears, moments, and deflections for a frame subjected to vertical and horizontal loads. The program also carries out column load accumulation for the most critical combinations of gravity and wind loads. The program also performs beam selection.

Input: The input to FLOBIM is supplied from a format free data file. The use of preprinted data coding forms is indicated. Some automatic data generation is available. Data checking is performed by a separate program. The input consists primarily of geometry and load data.

Output: The output consists of shear and moment envelopes for beams, column load tables, and deflections. The column load data may be punched onto cards for submission to a column design program - (OPFRAD/KOLUM).

Program: PCA/STMFR - Static Analysis of Plane
Multistorey Frame-Shearwall
Structures Under Lateral and
Gravity Loads

Origin: Portland Cement Association
Skokie, Ill.

Availability: Computel, Comshare, Dataline, IST, SDL

Capabilities: This program performs a static analysis of a linear elastic plane rectangular frame, or series of frames linked together, and subjected to gravity and lateral loads. Axial deformations are considered in columns, but not in beams. The program has the capability of handling finite joint size, shear deformation in columns, partial fixity factors for rotational restraints, and vertical displacements at the foundations. The solution involves the formulation of stiffness equations employing a condensed matrix with only one horizontal degree of freedom per floor. This program was found, by the author, to be overly expensive for some small frames.

Input: This program requires fixed format input, corresponding to preprinted input coding forms. The structural geometry is defined by a grid. The user inputs column spacings, storey heights, member properties, and loads.

Output: The program outputs member forces, displacements, reactions, and an equilibrium check of unbalanced forces at each storey.

Program: PLANEFRAME - Analysis of Plane Rigid
Frames

Origin: I.P. Sharp Associates Ltd.,
Toronto, Ontario.

Availability: IPS

Capabilities: This program was developed to analyse all of the frames and loading conditions in "Rigid Frame Formulas", by A. Kleinlogel. The program performs static analysis of plane rigid frames. The program is written in APL. The documentation is limited.

Input: The input for the program is supplied in an interactive conversational mode. Data supplied consists of: joint coordinates, member connectivities, member properties, and loads.

Output: No example output was available.

Program: SDRC/SAGS - Static Analysis of General
Structures

Origin: Structural Dynamics Research Corporation
Cincinnati, Ohio.

Availability: CDC, CGE, Comshare, CSC

Capabilities: This program performs analysis of elastic statically loaded beam type structures. For example, planar and space frames, trusses, grids, and continuous beams. The program will handle non-prismatic members, elastic supports, semi-rigid connections, shear deformations, temperature loads, and differential member stiffness due to the beam column effect. A conventional stiffness analysis is used. Nominal stresses in members may be calculated. This program is fairly expensive to use.

Input: The data is supplied in a format free data file. The use of preprinted coding forms is indicated. Data checking is performed. Data consists of: member properties, joint coordinates, member connectivities, and loads.

Output: The output may consist of: member forces and nominal stresses, joint displacements, and reactions. Plotting options for both deformed and undeformed geometries are available.

Program: SDRC/DAGS - Dynamic Analysis of General
Structures

Origin: Structural Dynamics Research Corporation
Cincinnati, Ohio.

Availability: CDC, CGE, Comshare, CSC

Capabilities: This is a dynamic analysis program, performing undamped, modal analysis of frame type structures. DAGS uses the stiffness matrix formulated by SDRC/SAGS with either lumped or consistent mass models to extract the natural frequencies and normalized mode shapes. The natural frequencies are found by a combined Determinant Tracking-Sturm Sequence method. The program will use the normalized mode shapes to calculate the normalized member forces, and nominal stresses. The program does not permit the user to condense the stiffness and mass matrices of the structure other than by direct matrix input.

Input: The data is supplied in a format free data file. The use of preprinted coding forms is indicated. Data checking is performed. Data consists of: member properties, joint coordinates, mass data, member connectivities, and frequency range.

Output: The output may consist of: natural frequencies, mode shapes, strain energy, and kinetic energy. Plotting of the deformed and undeformed geometry is available.

Program: SDRC/LAGS - Limit Analysis of General Structures

Origin: Structural Dynamics Research Corporation
Cincinnati, Ohio.

Availability: Comshare

Capabilities: LAGS performs the elastic-plastic analysis of 2 and 3 dimensional framed structures composed of interconnected beam elements. LAGS increments the loads until a plastic hinge forms, then automatically alters the stiffness matrix and continues incrementing the load until enough hinges have formed to create a mechanism. LAGS is capable of determining the ultimate load and deflections of framed structures in 3 dimensions based upon approximate, user defined, yield criteria. The program assumes infinite rotation capacity for plastic hinges, and neglects strain hardening.

Input: The input is supplied in a format free data file. The use of preprinted coding forms is indicated. Data checking is performed. Data consists of: member properties, frame geometry, and load-energy limits.

Output: The output may consist of the: energy, displacement, and force at the end of each phase of the analysis. Both the undeformed, and deformed geometry may be plotted.

Program: STRESS - Structural Engineering System
Solver

Origin: Prof. S.J. Fenves
Massachusetts Institute of Technology

Availability: CDC, Comshare, CGE, CSC, Dataline, IBM
IST, MA

Capabilities: This is probably the most famous structural frame analysis program. It performs linear elastic analysis of statically loaded frame structures in 2 or 3 dimensions. STRESS is an implementation of the stiffness method. There are many different versions of STRESS available commercially, the version maintained by MA (STRESS 3.0) is a greatly enhanced version. STRESS 3.0 permits the user to engage an automatic joint re-sequencing subroutine which optimizes the bandwidth for efficient solutions of poorly banded structures, such as domes. STRESS has proven to be a reliable program.

Input: STRESS pioneered the use of POL and format free data input. Data consists of: Frame geometry, member properties, and loads. Some versions of STRESS such as STRESS 3.0 provide automatic geometry generation capabilities.

Output: Output may consist of forces, displacements, and reactions. STRESS 3.0 permits the user to request force envelopes, and undeformed geometry plots.

Program: STRU-PAK/'SAP - Structural Analysis
Programs

Origin: TRW Systems Group
Redondo Beach, California.

Availability: CDC

Capabilities: This is a series of programs for the static analysis of structures, including 2 and 3 dimensional trusses, 2 and 3 dimensional frames, grids, hybrid (truss-frame) structures, and general structures including plates. The analysis is linear elastic small deflection stiffness analysis. GENSAF combines the basic stiffness analysis with finite element analysis using triangular plate elements, having membrane, or bending stiffness. Matrix alterations may be performed by the user. Solution of the simultaneous linear equations is achieved through Choleski decomposition.

Input: Most of the 'SAP series require data to be supplied in a format free data file, however, 2DGENFRAME permits data to be input conversationally. The input consists of: joint coordinates, member properties and connectivities, and load data.

Output: The program output may consist of: joint displacements, member forces, reactions, and an equilibrium check. The user is permitted control of the output. No plotting is available.

Program: STRU-PAK/'MAP - Modal Analysis Programs

Origin: TRW Systems Group
Redondo Beach, California.

Availability: CDC

Capabilities: This is a series of dynamic analysis programs which solve the eigenproblem for grids, 2 and 3 dimensional trusses and frames. The programs permit matrix alterations by the user, to add special structural members. The program will condense any degrees of freedom which are not given mass out of the stiffness matrix. The frequencies and mode shapes are computed using Householder-Strum method, and inverse iteration on the dynamic matrix. The programs will search for up to 20 modes. The lumped mass undamped model is used.

Input: The 'MAP series requires most of the data to be supplied in a format free data file, however, some data may be supplied in a conversational mode. The input consists of: joint coordinates, member connectivities, member properties, and mass data.

Output: The output consists of frequencies and mode shapes, as well as an orthogonality check of the mode shapes with respect to the mass matrix. There is no plotting capability.

Program: SP/DETTRS - Determinate Truss Analysis

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program solves a statically determinate pin connected truss for support reactions and member forces, and stresses. The program also calculates the length of each member. The program uses the method of joints, solving joints sequentially using equilibrium until all the member forces at each joint have been found. The program is restricted to plane trusses with less than 245 members, and 124 joints which are determinate and can be solved using the method of joints. The solution does not produce deflections.

Input: The input is supplied to the program from a format free data file. The use of preprinted input coding forms is indicated. Data checking is performed. Data consists of joint coordinates, member connectivities, and load data.

Output: The output consists of reactions and member forces. The output is brief.

Program: SP/REGFRM - Regular Rigid Frame Analysis

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program will analyse a regular plane frame of up to 24 stories, and 5 bays with fixed or pinned foundations. The frame must be regular with prismatic members. Missing members are permitted only on upper floors in a cake tier fashion. The program does not consider axial or shear deformations in frame members. The program employs the stiffness method and uses an iterative procedure to solve the simultaneous linear equations. The program cannot combine individual load cases.

Input: The program requires data to be supplied in a format free data file. The program input must be in Imperial units (Kips, Feet, Inches). The geometry of the frame is generated with a grid of bay sizes, and storey heights. Other input requirements are the member stiffnesses at each joint, and load data.

Output: The output consists of member forces, and storey deflections. The user has no control over output or choice of units. No plotting is available.

3

Program: SP/RIGFRM - Small Rigid Frame Analysis

Origin: Systems Professional
Los Angeles, California

Availability: CDC

Capabilities: This is a relatively small frame analysis program for plane rectangular frames with up to 60 members, and 60 degrees of freedom. The program considers only flexural deformations. Several load cases may be analysed, but no load combination is performed. Members must be vertical or horizontal. Non-prismatic members may be handled by direct matrix input. The frame is not defined as a grid, so missing members are acceptable. Pin ended members are also acceptable.

Input: The input for the program is supplied in a format free data file. Joint coordinates, member connectivities, and member properties are all input together, one line per member. Load data must be input as fixed end forces and moments.

Output: The output consists of member forces. No deflections or reactions are output. The user has no control over the output.

Program: SP/SHWINT - Shear Wall-Frame Interaction

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program computes deflections, and rotations, as well as axial, shear and flexural forces for a structural model comprised of frames and walls, subjected to lateral loads. The frame may have up to 10 stories, and 5 bays. The wall may be non-prismatic. The frame may be linked to the wall by pin ended rigid links, or framed links of specified stiffness. The frame is solved by slope deflection, and the wall, as a fixed cantilever, an iteration procedure is used to ensure compatibility and equilibrium between the frame and the wall. Axial and shear deformations are ignored.

Input: The input for SHWINT is supplied in a format free data file. Frame geometry is defined by a grid. Member stiffnesses must be input for each joint. The units used must be Imperial (Kips, Feet, Inches).

Output: The output is divided into frame output, and wall output. The output consists of member forces and horizontal deflections. The user has no control over the output. No plotting is available.

Program: **TRUSSC - Truss Analysis Program using
Coordinates

Origin: IBM

Availability: IBM

Capabilities: TRUSSC computes the member axial forces and joint displacements for any planar truss. The solution is based upon the stiffness method. The program is limited to 75 members, 65 degrees of freedom, and 75 joints. The program will produce influence lines.

Input: The input may be supplied either conversationally, or in a format free data file. If the conversational mode is used, all data is lost after execution. Data supplied from a data file may be altered conversationally during execution. Data consists of: joint coordinates, member connectivities, section properties, and load data.

Output: The user has control of the output of member forces, displacements, and geometry data. The output is controlled conversationally.

Special Structures Analysis Programs:

CBA/BRICK1

CBA/BRICK2

CSTRES

MITAS

PCA/FLOOR

PIERANAL

SP/EQKSWL

Program: CBA/BRICK1 - Wind Analysis Program

Origin: Hastings and Aziz Ltd.,
London, Ontario.
and The Clay Brick Association of Canada

Availability: CSC, IBM

Capabilities: BRICK1 is the first of three separate but interrelated programs for design of masonry walls in accordance with the National Building Code of Canada 1970 (NBC-70). The programs are written in BASIC. BRICK1 computes the physical properties of each wall type, and then the distribution of lateral loads, to each wall, based upon the relative stiffness of the walls. It then calculates bending moments and shear forces in each wall caused by the wind loading. Maximum bending stresses at the extreme fibers, and maximum shear stresses in the web at each level are calculated. Wind loads are computed using the detailed procedure of NBC-70.

Input: The input data is supplied to the program in a format free data file. The data requirements consist of wall dimensions and properties, and their location in the building plan as well as wind load parameters.

Output: The output consists of two parts: wall properties, and wind load stresses. Each part of the output may be stored for use in the other CBA programs. The user has control over what data is printed and stored.

Program: CBA/BRICK2 - Earthquake Analysis Program

Origin: Hastings and Aziz Ltd.,
London, Ontario.
and The Clay Brick Association of Canada

Availability: CSC, IBM

Capabilities: This program calculates the bending moments, and shear forces in each wall type specified at each floor level, caused by earthquake loading in accordance with the NBC -70. The physical properties of the walls must be calculated in BRICK1 and stored in a data file. The program calculates extreme fiber stresses caused by bending moments, and the web shear stresses at each level.

Input: The program accesses the wall properties computed by CBA/BRICK1, and the seismic load parameters are supplied by the user in a format free data file. The input consists of mass at storey levels, and the other necessary seismic load parameters specified in the NBC -1970.

Output: The user has control of what data is printed and stored. The output consists of earthquake induced stresses in walls at each storey level. The output data may be stored for use in the third CBA program (BRICK3).

Program: CSTRES - Calculate Stresses

Origin: CSC

Availability: CSC

Capabilities: CSTRES is a package of programs which carry out stress calculations for specific structural forms. There are sixteen general categories of structural analysis which include: (1) Beams-shear moment and deflections, and rigid frames, (2) Beams-combined axial and transverse loadings, (3) Rings and Arches, (4) Plates, (5) Pressure Vessels, (6) Bars and Rings, (7) Spherical Shells, (8) Toroid Shells, (9) Conical Shells, (10) Cylindrical Shells, (11) Barrel Vaults, (12) Hypar Shells, (13) Paraboloid Shells, (14) Cycloid Shells, (15) Ellipsoid Shells, (16) Plates and Shells elastic stability analysis.

Input: The CSTRES programs all operate in an interactive conversational mode. Data requirements vary from program to program consisting of generally, the geometry material properties and the loading data.

Output: No documentation of the output was available, and no sample output could be obtained.

Program: MITAS - Martin Marietta's Thermal Analysis.
System

Origin: Martin Marietta Corp.,
Denver, Colorado.

Availability: CDC

Capabilities: MITAS performs both transient and steady-state analysis of thermal analogue models defined in network format. The program can handle a wide variety of heat transfer problems, and can be used to generate data for the analysis of thermal stresses on structures. MITAS incorporates many special features which permit the user to deal with phenomena such as diffuse radiation within enclosures.

Input: No documentation of the input was available. V

Output: No documentation of the output was available
and no sample output could be obtained. U

Program: PCA/FLOOR - Floor System Supported by
Central Core, and Exterior
Columns.

Origin: Portland Cement Association
Skokie, Ill.,

Availability: Computel, Comshare, Dataline, IBM, IST

Capabilities: This program computes the internal moments, and edge reactions of an L shaped slab with its inner edge supported by a continuous wall, and its outer edge supported by columns. Only a uniform distributed load is considered in the analysis. The spandrel beam between columns at the outer edge of the slab may be specified as having either zero or infinite torsional rigidity. The solution is achieved through a finite difference approximation to the classical plate differential equation.

Input: The input must be supplied in a fixed format mode. The input is brief, consisting of one line of data. Data requirements are: floor geometry, column heights and stiffnesses, and loads.

Output: The output from the program contains the moments and shear forces in the floor slab and the adjoining wall. The user cannot control the output.

Program: PIERANAL - Bridge Pier Analysis Program

Origin: Babcock and Wilcox
Lynchburg, Virginia

Availability: IST

Capabilities: PIERANAL is intended for the analysis of bridge piers but could be used for the analysis of small building frames. The program can handle structures of up to 3 stories, and 9 bays. All members must be prismatic. Base fixity may be varied. The analysis is performed using the moment distribution method. The accuracy of the solution is controlled by the user who may select the number of iterative cycles.

Input: No documentation of the input was available.

Output: No documentation of the output was available and no sample output could be obtained.

Program: SP/EQKSWL - Multistorey Wind or Earthquake
Rotational Analysis Shearwall
or Frame

Origin: Systems Professional
Los Angeles, California

Availability: CDC

Capabilities: This program can analyse a shearwall building for either wind or earthquake, providing all shears, and overturning moments in each wall. The program can handle up to 20 walls in each direction, up to 10 stories in height. Forces are distributed to the walls in proportion to their rigidity, taking into account the torsional increase in shears. The program is based upon "1970 Los Angeles City Code", "1970 Uniform Building Code", and, "Recommended Lateral Force Requirements by Structural Engineers Association of California 1966, amended 1971". The program determines the period of the structure. Direct applied wind forces, or seismic loads from a dynamic analysis may be input.

Input: The program input is supplied in a format free data file. The use of preprinted data coding forms is indicated. The data requirements consist of wall geometries, wall properties, wall weights, and the force parameters (seismic and wind)

Output: The output consists of direct shear per wall, and the overturning moment per wall. The user has no control over the output which is lengthy.

Single Structural Element Analysis Programs:

COLUMN

STRU-PAK/BEAMCOL

STRU-PAK/ELASTCOL

SP/COLLDS

ANGIR

BEAMANAL

BEMANL

**CONBEAM

STRU-PAK/MULTISPAN

STRU-PAK/STANBEAM

SP/SIMPBM

Program: COLUMN - Column Analysis Program

Origin: CSC

Availability: CSC

Capabilities: This program evaluates the maximum allowable working stress for a specific column section. Loads may be concentric or eccentric. Material may be linear elastic or elastic-plastic. The program uses the parabolic Euler formula for concentric linear elastic columns. It uses the secant formula for eccentrically loaded columns, and employs the Engresser equation for concentric elastic-plastic columns. The secant formula is solved by iteration. Solutions are valid for slenderness ratios of less than 300.

Input: The input is supplied to the program in an interactive conversational mode. The input consists of column geometry and properties, as well as the load data.

Output: The output consists of the maximum allowable stresses for the column. The user has no control over the output.

Program: STRU-PAK/BEAMCOL - Bending Analysis of
Variable Cross-Section
Beam Columns

Origin: TRW Systems Group
Redondo Beach, Calif.

Availability: CDC

Capabilities: BEAMCOL performs a bending analysis of single span beam columns. The beam column may be non-prismatic and have various end conditions. The program uses the finite difference method and numerical integration (Newmark's Method) to give internal member forces, stresses, and displacements. The program can be cycled for new load cases or new geometries.

Input: Data may be supplied to the program in an interactive conversational mode, or from a format free data file. The data supplied conversationally, is lost after execution. The input data consists of beam column geometry, cross-section data, and load data.

Output: The user can control the output which may consist of internal forces, displacements, and stresses at as many intervals along the beam column as desired.

Program: STRU-PAK/ELASTCOL - Elastic Stability of
End-Loaded Columns

Origin: TRW Systems Group
Redondo Beach, Calif.

Availability: CDC

Capabilities: This program uses a finite difference technique and inverse iteration to solve for the lowest buckling load, and associated normalized mode shape for an elastic end loaded column. The column may be non-prismatic, and may have any stable combination of end conditions.

Input: The input to ELASTCOL may be supplied in an interactive conversational mode, or in a format free data file. If the conversational mode is used, all data is lost after execution. The data requirements of the program are column geometry and section properties.

Output: The output consists of the critical buckling load of the column and the normalized mode shape of the buckled column. The user has control of the output.

Program: SP/COLLDS - Multistorey Column Loads
Take-Off

Origin: Systems Professional
Los Angeles, Calif.

Availability: CDC

Capabilities: This program provides the capability of compiling column loads for an entire building or portion thereof, up to a maximum of 20 stories, and 10 columns. Gravity loads applied at each floor level are computed, identified, stored, and reduced by allowable code reduction ratios. The program will combine the loads, and carry out a load take-off floor by floor, for each column.

Input: The input data is supplied to the program in a format free data file. The use of preprinted data coding forms is indicated. The data requirements are the loads applied at each storey level and the number of times the loads are repeated on other columns or other storey levels.

Output: The output consists of the column load accumulation at each storey level with the combined loads conforming to the requirements of ACI -63. The user has no control over the output.

Program: ANGIR - Analysis of Continuous Girders

Origin: Babcock and Wilcox
 Lynchburg, Virginia.

Availability: IST

Capabilities: No substantial information could be
obtained for this program in spite of repeated efforts.
The data center claims that the program is available on
their system.

Input: No documentation of the input was available.

Output: No documentation of the output was available,
and no sample output could be obtained.

Program: BEAMANAL - Continuous Beam Analysis
Program

Origin: J.F. Gibbons
Control Data Corp.

Availability: MA

Capabilities: This program is intended for the analysis of bridge girders. The slope deflection method is used to calculate moments, shears, and reactions as specified by AASHO -1965. The program can handle up to 10 spans with 2 intermediate expansion joints. The program considers impact and load distribution in the analysis. The program can handle various sections including wide flanges and non-prismatic plate girders, which may act compositely with either a void slab or regular slab, with or without haunches.

Input: The input data is supplied to the program in a format free data file. The input requirements are the beam geometry, section properties, and loading data.

Output: The user may control what data is printed. The output may consist of: moments, shears, stresses, deflections, and influence lines.

Program: BEMANL - Continuous Beam Analysis Program

Origin: CSC

Availability: CSC

Capabilities: BEMANL is capable of the analysis of a continuous beam with up to 12 spans, with or without columns above and below. The program uses the moment distribution method with sidesway prevented. Members may be non-prismatic. Beam characteristics are determined by numerical integration of the shear, moment, slope, and deflection diagrams. The program accepts various load cases and combinations. The solution is terminated at 1% accuracy.

Input: Data is supplied to BEMANL in an interactive conversational mode. The input consists of frame geometry, member stiffnesses, and load data.

Output: The user may control the output which can consist of maximum beam and column moments, as well as maximum beam shear forces. No deflections are output.

Program: **CONBEAM - Continuous Beam Analysis

Origin: IBM

Availability: IBM

Capabilities: This is a continuous beam program in which the beam may be non-prismatic and have up to 8 spans with columns above and below with their far ends fixed. The program cannot handle cantilevers. The moment distribution method, with sidesway prevented is used for the solution. The accuracy and the number of cycles are at the discretion of the user. Frame constants are derived by numerical integration of the shear, moment, slope, and deflection curves. The program can handle various live and dead loads.

Input: Data must be supplied to the program in a format free data file. Input requirements consist of frame geometry, member stiffnesses, and load data.

Output: The user cannot control the output which consists of maximum beam and column moments, and maximum beam shear forces. Deflections are not output.

Program: STRU-PAK/MULTISPAN - Multispan Beam Analysis

Origin: TRW Systems Group
Redondo Beach, Calif.

Availability: CDC

Capabilities: This program performs a static Euler-Bernoulli analysis of multiple span beams with up to 10 continuous spans. The end support condition may be free pinned or fixed, but internal supports must be pinned. A numerical integration scheme is used to solve the equations of motion. Members may be non-prismatic. The program may be recycled for various load cases.

Input: Data may be supplied to the program in an interactive conversational mode, or in a format free data file. If the interactive mode is used, all data is lost after execution. The input requirements consist of beam geometry, support conditions, member properties, and load data.

Output: The user may control the output which can consist of: reactions, internal forces, stresses, and displacements. Data may be requested for individual spans or for the entire beam.

Output: The user may control the output which can consist of shear forces, moments, internal stresses, and displacements.

Program: SP/SIMPBM - Simple Beam Analysis

Origin: Systems Professional
Los Angeles, California

Availability: CDC

Capabilities: This program determines the maximum dead and live load moments and deflections for a simple beam with an optional cantilever. Moment envelopes are computed at the 1/12th points for the various load conditions.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input data coding forms is indicated. The input data requirements include beam geometry, section properties, and load data. Imperial units must be used.

Output: The user may not control the printout which consists of moment and shear force envelopes, deflections, and reactions.

Concrete Building Frame Design:

AMECO

ICES/STRU DL II RC

PCA/ESTIM

Program: AMECO - Automated Design in Metals
and Concrete

Origin: Andre A. Palejs and I.F. Freibergs
Montreal, Quebec.

Availability: MA

Capabilities: AMECO can perform both analysis and member design for a complete 3 dimensional concrete frame or its elements. The provisions of several building codes are incorporated including ACI 318-71 and CSA A23.3 1973. The design may be based upon either Working Stress, or Ultimate Strength. Rectangular, T, and L shaped beams can be handled, as well as, one way, two way, and flat slabs. Columns may be rectangular, square, or circular with tied or spiral reinforcement. The program considers slenderness of columns, and live load reductions. A multitude of load combinations are generated automatically to obtain envelopes of critical loads, for both shear and moment, which are used to proportion and locate reinforcement.

Input: The data is supplied to AMECO with a POL in a format free data file. Floor plan geometry may be duplicated for sequential floors premitting abbreviated input. Input requirements consist of frame geometry, building code and design method (USD or WSD) and load data. Data checking is performed.

Output: The user may control the output which may consist of frame analysis data, design data and reinforcing schedules for slabs, beams, and columns, material quantity estimates, and costs.

Program: ICES/STRU DL II RC - Integrated Civil Engineering
Systems/Structural Design
Language II Reinforced
Concrete

Origin: Massachusetts Institute of Technology

Availability: Computel, Comshare, IST, SDL

Capabilities: STRUDL RC is a design program capable of carrying out the design of reinforced concrete frame members. Designs are performed in accordance with ACI-318-63 USD. The program investigates beams for shear, flexure, bond and deflection; flat slabs for flexure, shear and deflection; columns for uni or bi-axial bending plus axial loads. The program can proportion beams, flat slabs, columns, one way slabs, and joist slabs. The program employs a modified Hogenstad stress strain curve for concrete. Unfortunately, the reinforced concrete features of STRUDL have fallen into some disrepair, and the enhanced versions of STRUDL do not incorporate the reinforced concrete design capabilities.

Input: The input must be supplied to the program using a POL and a format free mode. Frame topography may be specified with a 3 dimension grid. The input requirements are frame geometry, member dimensions and properties, design restrictions, and load data. Data checking is performed.

Output: The user may control the output which can consist of frame analysis data, beam slab and column design data, reinforcing schedules, and estimated quantity data. Printer plotting of undeformed geometry is available for data checking.

Program: OPFRAD/BAPLAF - Optimum Framing Design
Base Plate and Footing
Design

Origin: Computerized Design Services Limited
and, Julius Nagy and Associates Engineering
Ltd.
Toronto, Ontario.

Availability: MA

Capabilities: This is one program in the OPFRAD design series. The user may request the design of spread footings to accommodate rectangular concrete columns, or steel columns with base plates. The design is performed according to user specified restrictions on dimensions. The program calculates the reinforcement required, and will compute quantities of steel and concrete.

Input: The input must be supplied to the program in a format free data file. Column load data may be supplied by the FLOBIM program. The input requirements consist of column loads and design restrictions.

Output: The user can control the output which may consist of footing dimensions, reinforcement schedule, base plate schedule, and quantity estimates.

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Concrete Column Design:

PCA/COL

PCA/LS

SP/CONCOL

Program: PCA/COL - Strength Design of Reinforced
Concrete Column Sections

Origin: Portland Cement Association
Skokie, Ill.

Availability: Computel, Comshare, CSC, Dataline, IST,
MA, SDL

Capabilities: This program can investigate the adequacy of a given column cross-section to resist a given combination of loads, or design a reinforced concrete compression member to resist a given set of loads. Columns may be round or rectangular, with a tied or spiral reinforcing. Each loading case consists of an axial compressive load, combined with uni or bi-axial bending. The solution is based upon the Ultimate Strength Design method of ACI 318-71 and CSA A23.3 1973. The program uses a modified Hogenstad stress strain distribution for concrete. The design consists of determining the reinforcement which results in a minimum amount of steel, and the lowest ratio of ultimate capacity to factored loads.

Input: The input data must be supplied to the program in a fixed format mode. The use of preprinted input data coding forms is indicated. Input requirements are column cross-section, and loading.

Output: The user cannot control the output which includes reinforcement data, ultimate load capacities, and an evaluation of column efficiency.

Program: PCA/LS - Load Accumulation and Concrete
Column Stack Design

Origin: Portland Cement Association
Skokie, Ill.

Availability: Computel, Comshare, MA, SDL

Capabilities: This program performs the Ultimate Strength Design of concrete columns subject to the run-down accumulation of loads. It will design up to 200 columns in one pass, with no more than 6 stacks, or 99 stories in any one stack. Columns may be round or rectangular, with tied or spiral reinforcement. Columns are designed for axial loads and uni or bi-axial bending. Live load reductions in the load accumulation may be included using any of several building codes including the NBC. Slenderness effects may be incorporated using the moment magnification method of ACI 318-71 or the R-factor method of ACI 318-63.

Input: The input must be supplied to the program in a fixed format mode. The use of preprinted input data coding forms is indicated. Input requirements consist of: number of stories, tributary areas, bracing data, building code, reinforcement parameters, column dimensions, and load data including, dead, live, wind, and earthquake.

Output: The user cannot control the output which consists of column schedules, load analysis, load combinations, quantities and cost estimate .

Program: SP/CONCOL - Concrete Column Ultimate
Strength Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program will investigate the strength of a given column, or design a new column based upon the Ultimate Strength Design approach specified in ACI 318-63. It is based upon the original PCA/COL program, and has essentially the same capabilities; to design round or rectangular columns with tied or spiral reinforcing to resist axial compression and uni-axial or bi-axial bending.

Input: The input data must be supplied to the program in a format free data file. The use of preprinted input data coding forms is indicated. The input requirements consist of column cross-section and loading data.

Output: The user cannot control the output which includes reinforcement data, ultimate load capacities, and an evaluation of column efficiency.

Concrete Beam and Slab Design:

**BEAM

PCA/ADOSS

SP/CB

SP/FLPL63

SP/NONP

Program: **BEAM - Reinforced Concrete Beam Design

Origin: IBM

Availability: IBM

Capabilities: This is an investigation program rather than an automatic design program. The user supplies the program with the applied bending moment, beam width, depth, area of steel and modular ratio. The program uses basic stress equations obtained from 'American Civil Engineering Practice', Vol III, 1957. The program can handle rectangular or T sections with tension and compression steel. The Working Stress approach produces stresses in the concrete and steel.

Input: The data must be supplied to the program in an interactive conversational mode. All data is lost following execution. The input consists of beam geometry, and properties, and the applied bending moment.

Output: The user cannot control the output which consists of concrete and steel stresses and the beam self weight.

Program: PCA/ADOSS - Analysis and Design of Slab
Systems

Origin: Portland Cement Association
Skokie, Ill.

Availability: *Computel, Comshare, CSC, Dateline, IST,
IBM, MA, SDL

Capabilities: ADOSS can analyse and design an interior or exterior 2 dimensional equivalent frame in accordance with ACI 318-71. Flat plates, flat slabs, waffle slabs, flat plates with beams, and continuous beams can all be dealt with. The frame may consist of up to 12 spans with 2 cantilevers. All combinations of gravity and lateral loads are performed. The program will use either the Working Stress or Ultimate Strength Design method for the selection of steel, and the calculation of deflections.

Input: The input must be supplied to the program in a fixed format mode. The use of preprinted data coding forms is indicated. The input requirements consist of slab system and geometry, design method, and load parameters.

Output: The output may be controlled by the user, and may contain centerline moments and shears, critical moments and shears, negative and positive reinforcement, reinforcement schedule, deflections, and quantity estimates.

* Some of these data centers may offer an earlier version of ADOSS.

Program: SP/CB - Prismatic Continuous Beam Design
CBULT1 - Ultimate Strength Design (ACI 318-71, 63)
CBWKG1 - Working Stress Design (ACI 318-63)

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This series of two programs includes, Ultimate Strength Design, and Working Stress Design programs. These will perform all load combinations to obtain shears and moments for reinforced concrete beam design. The prismatic beam may have up to 12 spans with columns above and below. The program accepts both gravity and lateral loads. The beam is sized and steel is selected for the ends, and midspan. Compressive steel is selected if necessary, as well as stirrups. The programs calculate beam perimeters for formwork calculations.

Input: Data must be supplied to the program in a format free data file. The use of preprinted input data coding forms is indicated. The input requirements consist of: the beam geometry, the load data, design code, member restrictions, and material parameters.

Output: The output cannot be controlled by the user and includes: moments and shear forces for all load combinations, beam size and reinforcement, and deflections.

Program: SP/FLPL63 - Flat Plate and Frame Analysis
and Design -Working Stress or
Ultimate Strength 1963 ACI Code

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program, in accordance with the 1963 ACI code, will determine all of the necessary analysis and design information for a continuous frame or flat plate of up to 12 spans with or without cantilevers or spandrel beams. It follows directly, the original PCA version of the program. Lateral loads cannot be dealt with by the program. Either light weight or normal weight concrete may be specified. Reinforcement may be designed using either WSD or USD.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input requirements include, equivalent frame geometry, column sizes, slab loading, design method, and design restrictions.

Output: The user can control the printout of data which may consist of: analysis data (moments and shears), shear design data, flexure design data, reinforcement details, deflections, and quantities.

Program: SP/NONP- Non-Prismatic Continuous Beam
NONPU1 - Ultimate Strength Design (ACI 318-71)
NONPR1 - Working Stress Design (ACI 318-63)

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: These programs will design almost any shape of continuous reinforced concrete beam of up to 12 spans with columns above and below. The programs calculate the moments and shears for all combinations of dead load and patterned live load. Positive and Negative moment envelopes are generated and used to design top and bottom steel. Stirrups are calculated. The reinforcement ratios may be controlled by the designer.

Input: Data must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input data consists of: beam geometry data, column stiffnesses, design code, design restrictions, and load data.

Output: The user cannot control the output which consists of moments and shears for all the load combinations, beam size, and reinforcement details.

Concrete Foundations Design:

OPFRAD/BAPLAF

PCA/MATS

SP/COFTG

Program: OPFRAD/BAPLAF - Optimum Framing Design
Base Plate and Footing
Design

Origin: Computerized Design Services Limited
and, Julius Nagy and Associates Engineering
Ltd.
Toronto, Ontario.

Availability: MA

Capabilities: This is one program in the OPFRAD design series. The user may request the design of spread footings to accommodate rectangular concrete columns, or steel columns with base plates. The design is performed according to user specified restrictions on dimensions. The program calculates the reinforcement required, and will compute quantities of steel and concrete.

Input: The input must be supplied to the program in a format free data file. Column load data may be supplied by the FLOBIM program. The input requirements consist of column loads and design restrictions.

Output: The user can control the output which may consist of footing dimensions, reinforcement schedule, base plate schedule, and quantity estimates.

Program: PCA/MATS - Analysis and Design of Foundation
Mats and Combined Footings

Origin: Portland Cement Association
Skokie, Ill.

Availability: Computel, Comshare, Dataline, IST, MA

Capabilities: MATS carries out a finite element analysis of a mat or combined footing, assuming thin plate bending theory, and elastic soil behaviour. Deflections and contact pressures at service load levels, are computed, and the reinforcement for each element in the grid is calculated for ultimate load levels. The program evaluates critical combinations of dead, live and wind loads.

Input: The input data must be supplied in a fixed format mode. The geometry of the finite element mesh is defined automatically with a grid. The data requirements include material properties, external loads, and the geometry of the foundation.

Output: The output may not be controlled by the user and consists of: deflections and contact pressure under service loads, the ultimate bending moments, and the reinforcement at each column.

Program: SP/COFTG - Footing Design Series
COMFTG - Combined or Rectangular Footing Design
COLFTG - Square Column Footing Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: These programs will design footings for square or rectangular columns, and a combined footing for two columns. Both programs follow ACI 318-63 Working Stress Design. The programs consider punching shear, and will design top and bottom steel, but do not check bearing stress of columns on the footings. The allowable soil pressure may be specified between 1000 psf and 12000 psf.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input data includes soil bearing capacity, surcharge and column loads, and the footing geometry for combined footings.

Output: The output cannot be controlled by the user. Printout data includes: footing dimensions, moments and shears and reinforcing details.

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Concrete Wall Design

PCA/FRAME

SP/BRGWAL

SP/EQPIER

SP/RETWAL

Program: PCA/FRAME - Analysis and Design of Concrete
Wall-Beam Frames

Origin: Portland Cement Association
Skokie, Ill.

Availability: Computel, Comshare, IST

Capabilities: This program performs an elastic analysis for a staggered wall-beam frame structure, subjected to vertical and horizontal loads. Web openings in the wall-beams, and the interaction of adjacent frames may be taken into account. The program computes the wall-beam shear and moments, and the required reinforcing steel in the walls for both flexure, and shear.

Input: Input data must be supplied to the program in a fixed format mode. The use of preprinted input data coding forms is indicated. Input requirements consist of the general dimensions of the frame, member properties, and loads.

Output: The output may be controlled by the user, and may consist of member-end forces and joint displacements, as well as the reinforcement for the wall-beams and their midspan deflections.

Program: SP/BRGWAL - Masonry, Block, or Reinforced
Concrete Bearing Wall Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program will design a reinforced concrete, brick masonry, or block masonry bearing wall subjected to end moments, and axial load, together with earth, wind, or earthquake load. The design incorporates wall self weight, and permits either a single or double curtain of reinforcement. No wall openings are permitted. The design complies with UBC - 1970. The program produces bar sizes and spacings.

Input: The data must be supplied to the program in a format free data file. The use of preprinted input data coding forms is indicated. The input data consists of external forces, wall geometry and properties, design restrictions, and type of construction.

Output: The user may not control the output. Output consists of: moments, shears, vertical and horizontal reinforcement, and deflections.

Program: SP/EQUIER - Masonry, Block or Reinforced
Concrete Shear Wall or Pier
Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program is based upon a Working Stress Design approach but incorporates Ultimate Strength Design criteria from the UBC -70, and Los Angeles City Code 1970. It will investigate a shear wall, and select appropriate reinforcement to resist moment, shear, and gravity loads. The program distributes minimum temperature reinforcement horizontally and vertically, and will select concentrated reinforcement at the ends if required. The program does not design additional stirrups for excessive shear, and does not check the wall for bearing capacity.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input data coding forms is indicated. The input data requirements are wall geometry and properties, applied loads, and design restrictions.

Output: The output may not be controlled by the user. Printout data includes: design moments, vertical and horizontal reinforcement, and a check of shear stresses.

Program: SP/RETWAL - Retaining Wall Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program is based upon ACI 318-63 Working Stress Design. It will determine the required concrete thickness, reinforcing, and footing requirements for a retaining wall. The load on the wall may consist of moment, axial load, and horizontal forces which may be an equivalent fluid soil pressure. The user may specify minimum dimensions and footing configuration.

Input: The input data must be supplied to the program in a ~~format~~ free data file. The use of preprinted input coding forms is indicated. Input requirements are wall and footing geometry, material properties, soil and surcharge loads.

Output: The output cannot be controlled by the user. Printout data consists of wall thickness, soil pressure, footing key requirements, and reinforcement for the wall and footing.

Precast Prestressed Concrete Design:

PCA/BRIDGE

SP/PRSTR

**TEES

Program: PCA/BRIDGE - Analysis and Design of Simple
Span Precast-Prestressed
Highway or Railway Bridges

Origin: Portland Cement Association
Skokie, Ill.

Availability: Computel, Comshare, CSC, IST, MA

Capabilities: This program will analyse and design a composite or non-composite simple span precast-prestressed bridge beam. It is based upon standard AASHTO procedures. It handles all standard sections as well as non-standard sections, and calculates shears and moments. The program computes the required number of tendons with locations, and the maximum stirrup spacing.

Input: The input data must be supplied to the program in a fixed format mode. The use of preprinted input data coding forms is indicated. The input requirements include the beam geometry, material properties, and load parameters.

Output: The output may not be controlled by the user. Printout data includes: moments, shear forces, stress distributions for various load combinations, prestressing strands (number and location), shear reinforcement, and midspan elastic deflections.

Program: SP/PRSTR - Prestressed Concrete Beam Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This is a series of two programs, for the analysis and design of precast-prestressed concrete beams, for composite or non-composite, shored or un-shored construction. The program deals with simple span beams of either rectangular, single T, double T, or box sections. The design conforms to the ACI 318-1971 code requirements. The tendon profiles and number of strands and pretensioning are determined. Shear reinforcement is selected.

Input: The input data must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input requirements include beam geometry, section properties, material properties, and loads.

Output: The user cannot control the output. Printout data includes the number and location of prestressing strands, the shear reinforcement, moments, shears, stresses, camber, and deflection.

Program: **TEES - Precast Prestressed Concrete TEES
Design

Origin: IBM

Availability: IBM

Capabilities: This program will design precast-prestressed single or double T beams. The program determines the number of strands, their eccentricity at the midpoint, at the 1/3 points, and at the ends. The stresses for various loadings, and the ultimate capacity are computed. Stirrups are designed. The web reinforcement is designed according to CSA A135-62. No composite action is considered, and all loads must be full span UDL's.

Input: The input is supplied to the program in an interactive conversational mode. All data is lost following execution. The input requirements include beam geometry, section properties, cable tension, and loads.

Output: The user may control the output which can include the number and location of prestressing strands, the required strength of concrete, the ultimate capacity of the section, and the shear reinforcement.

Steel Building Frame Design:

AMECO

CISC/GALE-STRIF

CISC/RESST

ICES/STRU DL II

Program: AMECO - Automated Design in Metals and
Concrete

Origin: Andre A. Palejs and I.F. Freibergs
Montreal, Quebec.

Availability: MA

Capabilities: The latest version of AMECO can carry out the analysis and member selection for a 2 or 3 dimensional steel frame consisting of beams, columns, shearwalls, and braced bays. Steel members are designed according to CSA - S16 - 1969. The frame may have rigid, semi-rigid, or pinned joints, and may be loaded by gravity, wind and earthquake. The program carries out load combinations, and will select beams and columns from prestored tables of shapes. Estimated cost is computed as a total value and on a square foot basis. Bracing members are not designed.

Input: Data is supplied to AMECO using a POL in a format free mode. Floor plan geometry may be duplicated for sequential floors permitting abbreviated input. The input requirements consist of: frame geometry, building code, design restrictions, and load data.

Output: The user may control the output which may contain frame analysis data, member selections for beams and columns, quantities and cost summary.

Program: CISC/GALE-STRIF - Steel Rigid Frame Design

Origin: Canadian Institute of Steel Construction
Toronto, Ontario.

Availability: MA

Capabilities: This program provides design capabilities for the preliminary investigation of multistorey steel plane frames. GALE is essentially a preprocessor for STRIF computing frame geometry, wind, and earthquake loads according to NBC-70. GALE can generate a plot of the frame, input data for STRUDL, or input data for STRIF. STRIF performs a portal or cantilever analysis for lateral loads, and after an approximate design cycle carries out one storey moment distribution for gravity loads. The program carries out many load combinations, and considers live load reductions, and the P- Δ effect. The program selects all columns and girders from standard sections. Quantity estimates are computed including fire proofing.

Input: The data must be supplied to the program in a fixed format mode. The use of preprinted input coding forms is indicated. The input requirements consist of frame geometry and load data.

Output: The user cannot control the output which consists of critical moments and shears, column interaction data, member selections for girders and columns, lateral drift, and quantity estimates.

Program: CISC/RESST - Rapid Evaluation of Steel Structures

Origin: Canadian Institute of Steel Construction
Toronto, Ontario.

Availability: CISC

Capabilities: This program is intended to be a preliminary design tool for 3 dimensional steel structures. The program performs a gravity load analysis, and selects beams, girders, and columns according to either CSA S16 1969, or CSA S16.1 1974 (Limit States Design). Live load reductions are carried out according to NBC 1975. No torsional effects, or cantilevers are permitted. RESST will select beams and girders for interior and exterior bays of a floor plan. It will select columns, and for low rise structures, it sizes base plates and footings. The program computes costs, using user supplied unit costs and the CISC/CSICC costing method.

Input: The input must be supplied to the program in a fixed format mode. The use of preprinted input coding forms is indicated. The input requirements consist of: frame geometry, design code, material properties, and loads.

Output: The output may not be controlled by the user. Printout data includes gravity load analysis results, member selections for columns, girders, joists, footings, quantities and costs, including fire protection. R

Program: ICES/STRU DL II - Integrated Civil Engineering
Systems/Structural Design
Language II

Origin: Massachusetts Institute of Technology and
Canadian Institute of Steel Construction

Availability: Computel, Comshare, IST, SDL

Capabilities: M.I.T. STRU DL II has a built in capability for member selection and checking based upon AISC 1969. Of more interest to Canadians however, is the enhancement carried out by CISC for member selection and checking based upon CSA S16 1969. The program requires initial member sizes in order to carry out an analysis and generate member forces. Members are selected to resist bending, tension, or compression - or a combination, but not torsion. Selections are made from standard structural shapes.

Input: The input to STRU DL may be supplied using a POL in a format free mode. The input requirements consist of frame geometry, member properties, loads and design restrictions.

Output: The output may be controlled by the user, and may consist of: frame analysis data, member selections for columns and girders and, comparisons of actual and allowable stresses for either the initial user supplied sections, or those selected by the program.

Steel Beams and Composite Beam Design:

BEMDES

CISC/FSSP2

OPFRAD/FLOBIM

SP/COMBP

SP/STLBM

SP/WELDBM

Program: BEMDES - Steel Beam Design Program

Origin: CSC

Availability: CSC

Capabilities: This program selects the lightest beam section that satisfies the loading and support conditions specified. Selection is made from standard structural beam shapes. The user must supply loads, span, support conditions, and maximum-allowable stress.

Input: The input data must be supplied to the program in an interactive conversational mode. The data is lost following execution. Input requirements include beam geometry, material properties, and loads.

Output: The user cannot control the output which includes the maximum moment, and the section selected.

Program: CISC/FSSP2 - Floor System Selection
Program 2

Origin: The Canadian Institute of Steel Construction
Toronto, Ontario.

Availability: Computel, CSC, IST, MA

Capabilities: This program is the predecessor of CISC/RESST. It assists the designer in selecting the most economical steel floor or roof system to use in the design of multistorey buildings. The analysis is based upon gravity loads only. Torsion and cantilevers are not considered. All beams and girders for interior and exterior bays are selected based upon stress and deflection according to CSA S16 1969. Construction may be simple, continuous, composite, or non-composite. The program will carry out load combinations including live load reductions, select a set of alternative sections, compute column loads, and estimate quantities including fire protection. Members are costed using the CSICC costing method.

Input: Data must be supplied to the program in a fixed format mode. The use of preprinted input coding forms is indicated. The input requirements consist of floor plan geometry, material specification, design restrictions, and loads.

Output: The output may not be controlled by the user. Printout data includes sets of alternative member selections for beams and girders, cost estimates, and column loads.

Program: OPFRAD/FLOBIM - Optimum Framing Design/
Floor Beam Design

Origin: Computerized Design Services Ltd., and
Julius Nagy and Associates Engineering Ltd.,
Toronto, Ontario.

Availability: MA

Capabilities: This is the key program of the OPFRAD series. It performs the initial calculations for shear forces, and bending moments in a plane frame. It selects all the beams of the frame from available Canadian or U.S. shapes, subjected to the critical combinations of loads (dead, live and lateral) and CSA S16 1969 requirements. The program will identify the beams which require special connection details. Quantity estimates for the beams are prepared, and column loads are calculated.

Input: The input data must be supplied to FLOBIM in a format free data file. The use of preprinted input coding forms is indicated. Input requirements include the general structural specifications, loadings, and column orientations.

Output: The user may not control the output. Printout data includes beam schedules, and column load tables for each storey. The entire column load accumulation table may be punched on cards for submission to the other OPFRAD programs.

Program: SP/COMPB - Composite Steel Beam Investigation
and Design Series

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program series will analyse and design a single, simple supported composite beam according to 1969 AISC specifications. The beam may be shored or unshored, and subject to dead and live loads. The program will investigate a given section, design a coverplate if necessary, select the most economical larger section without a coverplate, and select a section with coverplate such that a user supplied ratio of coverplate area to beam area is satisfied, and the section is fully stressed.

Input: Data must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. Input requirements include span geometry, loads, material properties, and design restrictions.

Output: The user may control the output which can include moments, shear forces, stresses, and deflections for four alternative designs. The printout may also include weld details, and shear connectors.

Program: SP/STLBM - Steel Beam Investigation
and Design Series

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This series of programs can perform the design of steel beams in accordance with AISC 1969. The beam may have a cantilever and be loaded with frame loads (axial forces and moments). The program will investigate a pre-selected section, and will determine alternative sections with stress ratios between .7 and 1.05. Compact and non-compact sections are used. The K (column effective length) value is supplied by the user.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. Data requirements include beam geometry and loads, design parameters for buckling considerations, and design restrictions.

Output: The user cannot control the output. Printout data includes moments for various loads, a check of the initial section and tabulation of alternative sections with the stress ratio and midspan deflection for each.

Program: SP/WELDBM - Welded Steel Girder Investigation
and Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program investigates and designs a tapered welded steel girder in accordance with AISC 1969. The design is based upon plate buckling, compression buckling of the top flange, the tension L/r of the bottom flange, and the forces and moments at the 1/12 th points. Web bearing capacity at supports is verified, and flange weld shears are computed but welds are not designed. Stiffeners are not designed but their requirement is noted. The program can design either parallel or tapered flange beams.

Input: The input is supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input requirements include, beam geometry, material properties, bracing data, load data, and design restrictions.

Output: The output cannot be controlled by the user. Printout data includes the moments, the selected section dimensions, the stresses, weld requirements, maximum deflection, and stiffener requirements.

Steel Column Design:

CISC/CSP2

**COLUMN

OPFRAD/KOLUM

SP/STLCOL

Program: CISC/CSP2 - Column Selection Program 2

Origin: The Canadian Institute of Steel Construction
Toronto, Ontario.

Availability: Computel, CSC, Dateline, IST, MA

Capabilities: This program designs suitable steel columns for axial load and bi-axial bending caused by gravity and lateral loads. Sections are chosen according to CSA S16 1969 requirements. The program selects a group of alternative suitable sections based upon stress and optional lateral drift. Column end restraints may be input directly or computed by the program. Compactness, yield stress, and moment amplification factor parameters are all computed directly by the program.

Input: Data must be supplied to the program in a fixed format mode. The use of preprinted data coding forms is indicated. The input requirements include column length, loads, end conditions, material specification and design limitations.

Output: The output cannot be controlled by the user. Printout data includes design checks for a set of alternative sections all satisfying code requirements.

Program: **COLUMN - Steel Column Design

Origin: IBM

Availability: IBM

Capabilities: This column analysis and design program was developed to compute the allowable working stress for columns. The program will handle concentric and eccentric loads, and linear elastic or elastic-plastic material properties. The program uses the parabolic Euler equation for concentric loaded linear elastic columns, and the Engresser equation for concentric loaded elastic-plastic columns. The Secant formula is used for both cases of eccentric loading. The program will calculate the safety factor for a given column based upon the AISC design formula. This program, is not a true design program since it only carries out investigation of given sections. The analysis is valid for slenderness ratios of less than 300.

Input: The data is supplied to the program in an interactive conversational mode. All data is lost after execution. The input requirements include column length and end conditions, material properties, and the required factor of safety.

Output: The output is brief, including the allowable stress and slenderness ratio.

Program: OPFRAD/KOLUM - Optimum Framing Design
Column Selection Program

Origin: Computerized Design Services Ltd., and
Julius Nagy and Associates Engineering Ltd.,
Toronto, Ontario.

Availability: MA

Capabilities: The program designs columns for frame loading in accordance with CSA S16 1969. Sections are selected from standard structural shapes. Both gravity and wind loads are used by the program and may be supplied by the FLOBIM program. The program selects a group of suitable columns for each design and computes the actual, and allowable stress at top and bottom for gravity loading and gravity plus wind loading. The program will produce a schedule of the most economical columns showing the maximum stress ratio for each.

Input: The input may be supplied in a format free data file. The use of preprinted input coding forms is indicated. Input requirements consist of material specifications, and design restrictions, column data may be supplied by the FLOBIM program.

Output: The user can control the output. Printout data may include column selection table with stress at top and bottom for all load cases, and strength and stability checks, and a summary schedule of the most economical columns.

Program: SP/STLCOL - Steel Column Investigation
and Design Series

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: Based on AISC 1969 specifications, this program investigates a preselected steel column for a combination of axial load, gravity moments in two directions, and lateral load induced axial forces and moments. The program can calculate the column end conditions based upon the intersecting beam stiffnesses. The program selects a group of alternative sections from standard column shapes.

Input: Data must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input requirements include column length and end fixity, gravity loads, material specification, and optionally earthquake or wind loads.

Output: The output may not be controlled by the user. Printout data includes, stresses, in an initial user selected column, and stress data for a set of alternative columns selected by the program.

Steel Base Plate Design:

OPFRAD/BAPLAF

SP/BASPLT

Program: OPFRAD/BAPLAF - Optimum Framing Design
Base Plate and Footing
Design

Origin: Computerized Design Services Ltd., and
Julius Nagy and Associates Engineering Ltd.,
Toronto, Ontario.

Availability: MA

Capabilities: This program designs base plates and footings for column loads. The design is performed in accordance with user specified restrictions such as base plate dimensions. The column loads may be supplied from the results of the FLOBIM program. The program produces either a base plate schedule or a base plate and foundation schedule, including quantities for cost estimating.

Input: The input data must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. Input requirements include material specifications and base plate dimension limits. Column loads may be supplied by the FLOBIM program.

Output: The output may be controlled by the user and may consist of a base plate schedule, footing schedule, detailed quantities and steel tonnage.

Program: SP/BASPLT - Column Base Plate Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program designs the thickness and size of a rectangular or square column base plate in accordance with AISC 1969. The plate may be loaded with axial force and moments in both directions caused by gravity and lateral loads. No torsional effects are taken into account.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. The input requirements include column size and loads, concrete strength and steel strength.

Output: The output cannot be controlled by the user. Printout data includes the base plate dimensions and thickness.

Masonry Design:

CBA/BRICK3

SP/BRGWAL

SP/EQPIER

Program: CBA/BRICK3 - Masonry Shearwall Design
Program

Origin: Hastings and Aziz Ltd., and
The Clay Brick Association
London, Ontario.

Availability: CSC, IBM

Capabilities: In accordance with the NBC 1970, this program designs masonry load bearing shear wall members. The program uses load data generated in BRICK1 and BRICK2. Several load combinations are computed for each wall at each storey level. Live load reductions are performed. The unit strength, nominal thickness, mortar type, and % mortar to % solid area required to satisfy the governing load cases are computed. The program can deal with plain or reinforced, solid unit or hollow unit brick masonry construction.

Input: Data must be supplied to the program in a format free data file. The input requirements include, physical properties of the walls, wind loads supplied by BRICK1, the seismic loads supplied by BRICK2, the gravity loads, design restrictions regarding mortar and masonry types for consideration, and wind loads on external walls.

Output: The output may be controlled by the user. Printout data includes loads on walls, wall thickness, required masonry strength, axial and shear stresses, nominal masonry thickness, unit strength, % solid area, and % mortar.

Program: SP/BRGWAL - Masonry, Block or Reinforced
Concrete Bearing Wall Design
Program

For description see Concrete Wall Design.

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Program: . (SP/EQPIER - Masonry, Block or Reinforced
Concrete Shear Wall or Pier
Design

For description see Concrete Wall Design.

A-112

Timber Design:

SP/GLULAM

SP/SAWN

Program: SP/GLULAM - Glue-Laminated Beam Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program analyzes and selects sizes for a simple span glu-lam beam from either the 1970 edition of the UBC Standard 25-1 or The American Softwood Lumber Standard PS 20-70. Members may have cantilevered ends, and are subjected to vertical loading. Selection of members is based upon moment, shear, and deflection limitation.

Input: The input must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. Input requirements include beam geometry, loads, material properties, and minimum width.

Output: The output cannot be controlled by the user. Printout data includes moments, shears and a set of selected beams for various deflection limitations. The camber requirements are also noted.

Program: SP/SAWN - Sawn Timber Beam Design

Origin: Systems Professional
Los Angeles, California.

Availability: CDC

Capabilities: This program analyzes and designs simple span beams with or without cantilevers subject to vertical loads. The program will select sawn timber or joist sizes based upon moment, shear, and deflection limitation. The user specifies allowable stresses and modulus of elasticity.

Input: The input data must be supplied to the program in a format free data file. The use of preprinted input coding forms is indicated. Input requirements include beam geometry, loads, material properties, and design limitations.

Output: The output may not be controlled by the user. Printout data includes, moments, shears and a selection of members for various deflection criteria.

APPENDIX B

MATRIX EVALUATION OF COMMERCIAL SOFTWARE

B - 1 Criteria Weighting System

In order to use the criteria, defined in chapter 4, in a matrix evaluation system, each criterion must be assigned a weight. Once the criteria have been weighted, the programs may be evaluated under each criterion and the ratings may then be modified by the weights and combined into a single, overall evaluation. The selection of weights for the criteria has a potentially significant effect upon the evaluation and is therefore very important. The criterion weights must reflect the needs of the designer, and be consistent with the overall objective of enhanced productivity through the use of computer aids. A set of weights is proposed herein; these are felt to be rational and justified in their distribution of importance. Naturally, individuals may differ in their views of what is important. For this reason, the sensitivity of the evaluation to variations, in some of the criterion weights is discussed in section B - 4 of this Appendix.

The weights proposed here are structured so that all weights lie between 0 and 100, and in any set of criteria all the weights sum to 100. The weights are presented in Table

TABLE B-1

CRITERIA WEIGHTING SCHEME

First Level Criteria	Weight
1. Supporting Data Center	5
2. Documentation	20
3. Input	25
4. Solution	15
5. Output	15
6. Efficiency and Reliability	<u>20</u>
	100

Second Level Criteria

1. Supporting Data Center	
1.1 Operating Support	75
1.2 Job Turn-Around	15
1.3 Computer System	<u>10</u>
	100

TABLE B-1 Cont'd...

2. Documentation	
2.1 Explains Methods	20
2.2 Data Preparation Aid	30
2.3 Output Interpretation	30
2.4 Cost Estimating Guide	5
2.5 Honesty	<u>15</u>
	100
3. Input	
3.1 Input Language	25
3.2 Errors and Defaults	20
3.3 Units	5
3.4 Automatic Data Generation	30
3.5 Input Stored	<u>20</u>
	100
4.a Analysis Solution	
4.a.1 Level of Sophistication	70
4.a.2 Loadings	<u>30</u>
	100
4.b Design Solution	
4.b.1 Quality	70
4.b.2 Control	<u>30</u>
	100

cont'd...

TABLE B-1 Cont'd...

5. Output	
5.1 Control	20
5.2 Organization	30
5.3 Content	<u>50</u>
	100
6. Efficiency and Reliability	
6.1 Relative Cost Run	40
6.2 Solution Efficiency	30
6.3 Start Up Reliability	<u>30</u>
	100

cont'd...

TABLE B-1 Cont'd...

Third Level Criteria

1.1 Operating Support

1.1.1 System Support	30
----------------------	----

1.1.2 Program Support	60
-----------------------	----

1.1.3 Seminars	<u>10</u>
	100

2.2 Data Preparation Aid

2.2.1 Instructions	60
--------------------	----

2.2.2 Examples	30
----------------	----

2.2.3 Command Summary	<u>10</u>
	100

2.3 Output Interpretation

2.3.1 Output Description	50
--------------------------	----

2.3.2 Error Message Explanation	30
---------------------------------	----

2.3.3 Trouble Shooting Aid	<u>20</u>
	100

B - 2 Matrix Evaluation Procedure

Using the weighting scheme, criteria, and criteria hierarchy, previously defined; the evaluation of a group of alternative programs may be carried out in a systematic fashion. The following steps define the process.

Step 1 Begin the evaluation at the lowest level of criteria ie. level 3. Subject each program to the criteria giving a relative rating to each alternative between 0 and 1.0. The rating may be objective, (ie. converting quantifiable data to a relative value between 0 and 1.0) or, subjective.

Step 2 Multiply the ratings from Step 1 by the appropriate criterion weights. These products should be summed for each alternative to give a total rating out of 100 in each sub-criteria category. These total ratings should then be divided by 100 and carried forward to be the program rating for the appropriate level 2 criteria.

As an example, a group of programs would be evaluated under the third level criteria; Output Description, Error Message Explanation, and Trouble Shooting Aid; each program being given a rating between 0 and 1.0 under each criterion. These ratings would then be multiplied by the appropriate criterion weight, in this case, 50, 30, and 20 respectively. Then for each program these weighted ratings

would be added together and the sum divided by 100 to produce the rating for the second level criterion, Output Interpretation.

Step 3 In cases where the second level criterion needed no sub-criteria, a program rating must be carried out as in step 1.

Step 4 The second level criteria ratings must be multiplied by the appropriate weights, as in step 2, and the products summed to give a total rating in each sub-criteria category.

Step 5 The total ratings, generated in step 4, should be divided by 100 and carried forward to be the appropriate level one criterion rating.

Step 6 The level one ratings, obtained from step 5 should then be multiplied by their respective criterion weights and the products summed to produce a final program rating.

Step 7 The final program ratings should be compared, to determine the relative quality of the evaluated programs subject to the original objective. The programs can be ranked first, second, third, etc.

B-8

B - 3 Program Evaluation

1. SUPPORTING DATA CENTER

Criteria Wt.	75	15	10		100		
Program	Criteria 11 OPERATING SUPPORT	12 JOB TURN- AROUND	13 COMPUTER SYSTEM		1. SUPPORTING DATA CENTER		
Frame Analysis							
AMECO MA	.9 68	.5 8	.8 8		84		
SAGS CDC	.8 60	1. 15	.9 9		84		
STRESS 3.0 MA	1. 75	.5 8	.8 8		91		
STRUDL II SDL	.5 38	.5 8	.2 2		48		
GENSAP CDC	.8 60	1. 15	.9 9		84		
2DGENFRAME CDC	.8 60	1. 15	.9 9		84		
Frame-Shearwall Analysis							
PCA/STMFRC SDL	.3 23	.5 8	.2 2		38		
SP/SHWINT CDC	.8 60	1. 15	.9 9		84		
Dynamic Frame Analysis							
DAGS CDC	.8 60	1. 15	.9 9		84		
STRUDL II SDL	.5 38	.5 8	.2 2		48		
2DFMAP CDC	.8 60	1. 15	.9 9		84		

1.1 OPERATING SUPPORT

Criteria Wt.	3	5	10		100		
Program	Criteria 1.1.1 SYSTEM SUPPORT	1.1.2 PROGRAM SUPPORT	1.1.3 SEMINARS		1.1 OPERATING SUPPORT		
Frame Analysis							
AMECO MA	.9 27	.9 54	1.0 10		91		
SAGS CDC	.8 24	.9 54	1.0 0		78		
STRESS 3.0 MA	1.0 30	1.0 60	1.0 10		100		
STRUDL II SDL	.7 21	.4 24	1.0 0		45		
GENSAP CDC	.8 24	.9 54	1.0 0		78		
2DGENFRAME CDC	.8 24	.9 54	1.0 0		78		
Frame-Shearwall Analysis							
PCA/STMFR SDL	.5 15	.3 18	1.0 0		22		
SP/SHWINT CDC	.8 24	.9 54	1.0 0		78		
Dynamic Frame Analysis							
DAGS CDC	.8 24	.9 54	1.0 0		78		
STRUDL II SDL	.7 21	.4 24	1.0 0		15		
2DFMAP CDC	.8 24	.9 54	1.0 0		78		

2. DOCUMENTATION

Criteria Wt.	20	30	30	5	15		100
Program	Criteria 2.1 EXPLAINS METHODS	2.2 DATA PREPARATION	2.3 OUTPUT INTERPRETATION	2.4 COST ESTIMATING GUIDE	2.5 HONESTY		
Frame Analysis							
AMECO MA	.5 10	.5 24	.5 15	1. 5	1. 15		69
SAGS CDC	1. 20	.9 27	.9 27	.0 0	1. 15		89
STRESS 3.0 MA	.5 10	.8 24	.7 21	.0 0	1. 15		70
STRUDL II SDL	1. 20	.9 27	.9 27	.0 0	.0 0		74
GENSAP CDC	1. 20	.9 27	.6 18	1. 5	1. 15		55
2DGENFRAME CDC	1. 20	.9 27	.6 18	1. 5	1. 15		85
Frame-Shearwall Analysis							
PCA/STMFR SDL	.8 16	.9 27	.4 12	.0 0	.0 0		55
SP/SHWINT CDC	.7 14	.8 24	.4 12	.0 0	1. 15		65
Dynamic Frame Analysis							
DAGS CDC	1. 20	.9 27	.9 27	.0 0	1. 15		89
STRUDL II SDL	1. 20	.9 27	.9 27	.0 0	.0 0		74
2DFMAP GDC	1. 20	.9 27	.6 18	1. 5	1. 15		85

2-2 DATA PREPARATION AID

Criteria Wt.	60	30	10	400		
Program	Criteria 2.2.1	INSTRUCTIONS 2.2.2	EXAMPLES 2.2.3	COMMAND SUMMARY	2-2 DATA PREPARATION AID	
Frame Analysis						
AMECO MA	.6 36	1. 30	1. 10		76	
SAGS CDC	.9 54	1. 30	1. 10		94	
STRESS 3.0 MA	.9 54	1. 30	.0 0		84	
STRUDL II SDL	.9 54	1. 30	1. 10		94	
GENSAP CDC	.9 54	1. 30	1. 10		94	
2DGENFRAME CDC	.9 54	.9 27	1. 10		91	
Frame-Shearwall Analysis						
PCA/STMFR SDL	.9 54	.7 21	1. 10		85	
SP/SHWINT CDC	.9 54	.7 21	.0 0		75	
Dynamic Frame Analysis						
DAGS CDC	.9 54	1. 30	1. 10		94	
STRUDL II SDL	.9 54	1. 30	1. 10		94	
2DFMAP CDC	.9 54	.8 24	1. 10		88	

2.3 OUTPUT INTERPRETATION

Program	Criteria Wt.	50	30	20		100		
	Criteria 2.3.1 OUTPUT DESCRIPTION	2.3.2 ERROR MESSAGE EXPLANATION	2.3.3 TROUBLE SHOOTING AID		2.3 OUTPUT INTERPRETATION			
Frame Analysis								
AMECO MA	.8 40	.4 12	.0 0		52			
SAGS CDC	.9 45	.8 24	.9 18		87			
STRESS 3.0 MA	.7 35	.5 15	.1 20		70			
STRUDL II SDL	.7 35	1. 30	1. 20		85			
GENSAP CDC	.9 45	.0 0	.7 14		59			
2DGENFRAME CDC	.9 45	.0 0	.7 14		59			
Frame-Shearwall Analysis								
PCA/STMFR SDL	.7 35	.0 0	.0 0		35			
SP/SHWINT CDC	.7 35	.0 0	.0 0		35			
Dynamic Frame Analysis								
DAGS CDC	.9 45	.8 24	.8 16		85			
STRUDL II SDL	.7 35	1. 30	1. 20		85			
2DFMAP CDC	.9 45	.0 0	.7 14		59			

Criteria Wt.	25	20	5	30	20		100
Program	Criteria 3.1 INPUT LANGUAGE	3.2 EXERCISES DEFAULTS	3.3 UNITS	3.4 AUTOMATIC DATA GENERATION	3.5 INPUT STORED	3.6 INPUT	
Frame Analysis							
AMECO MA	.8 20	.6 12	.0 0	1. 30	1. 20		82
SAGS CDC	.5 13	.8 16	.0 0	.0 0	1. 20		49
STRESS 3.0 MA	.8 20	.5 10	.1 5	1. 30	1. 20		85
STRU DL II SDL	.8 20	.5 10	.1 5	.0 0	1. 20		55
GENSAP CDC	.4 10	.8 16	.2 1	.0 0	1. 20		47
2DGENFRAME CDC	.6 15	.8 16	.2 1	.0 0	.5 10		42
Frame-Shearwall Analysis							
PCA/STMFR SDL	.0 0	.5 10	.0 0	1. 30	1. 20		60
SP/SHWINT CDC	.4 10	.4 8	.0 0	.0 0	1. 20		38
Dynamic Frame Analysis							
DAGS CDC	.5 13	.8 16	.0 0	.0 0	1. 20		49
STRU DL II SDL	.8 20	.5 10	.1 5	.0 0	1. 20		55
2DFMAP CDC	.4 10	.8 16	.2 1	.0 0	1. 20		47

4 SOLUTION

Criteria Wt.	70	30	100				
Program	Criteria 4.1 LEVEL OF COMPLICATION	4.2 LOADINGS	4.3 SOLUTION				
Frame Analysis							
AMECO MA	.6 42	.1 30	.72				
SAGS CDC	.5 35	.4 12	.47				
STRESS 3.0 MA	.4 28	.8 24	.52				
STRU DL II SDL	.7 49	.8 24	.73				
GENSAP CDC	.6 42	.6 18	.60				
2DGENFRAME CDC	.3 21	.2 6	.27				
Frame-Shearwall Analysis							
PCA/STMFR SDL	.8 56	.6 18	.74				
SP/SHWINT CDC	.6 42	.2 6	.48				
Dynamic Frame Analysis							
DAGS CDC	.8 56	.1 30	.86				
STRU DL II SDL	.7 49	.8 24	.73				
2DFMAP CDC	.6 42	.0 0	.42				

5. OUTPUT

Criteria Wt.	20	30	50	100			
Program	Criteria 5.1 CONTROL	5.2 ORGANIZATION	5.3 CONTENT	5. OUTPUT			
Frame Analysis							
AMECO MA	.8 16	.7 21	.8 40	77			
SAGS CDC	.8 16	.8 24	.8 40	80			
STRESS 3.0 MA	1. 20	1. 30	.8 40	90			
STRUDL II SDL	1. 20	.8 24	.8 40	84			
GENSAP CDC	.8 16	.8 24	1. 50	90			
2DGENFRAME CDC	.8 16	.8 24	1. 50	90			
Frame-Shearwall Analysis							
PCA/STMFR SDL	.0 0	.8 24	1. 50	74			
SP/SHWINT CDC	.0 0	.8 24	.8 40	64			
Dynamic Frame Analysis							
DAGS CDC	.8 16	.8 24	1. 50	90			
STRUDL II SDL	1. 20	.8 24	.8 40	84			
2DFMAP CDC	.8 16	.8 24	1. 50	90			

C. EFFICIENCY & RELIABILITY

Criteria Wt.	10	35	25		100		
Program	Criteria 5.1 RELATIVE COST	5.2 SOLUTION EFFICIENCY	5.3 START-UP RELIABILITY		6. EFFICIENCY & RELIABILITY		
Frame Analysis							
AMECO MA	.8 32	.9 32	.6 15		79		
SAGS CDC	.2 8	.5 18	.7 18		44		
STRESS 3.0 MA	1. 40	.9 32	.5 13		85		
STRU DL II SDL	.1 4	.6 21	.5 13		38		
GENSAP CDC	.7 28	.7 25	.3 8		61		
2DGENFRAME CDC	.7 28	.7 25	1. 25		78		
Frame-Shearwall Analysis							
PCA/STMFR SDL	.0 0	.3 11	.5 5		16		
SP/SHWINT CDC	.7 28	.7 25	1. 25		78		
Dynamic Frame Analysis							
DAGS CDC	.2 8	.7 25	1. 25		58		
STRU DL II SDL	.1 4	.6 21	.5 13		38		
2DFMAP CDC	.8 32	.7 25	.5 13		70		

TOTAL EVALUATION

Criteria Wt.	5	20	25	15	15	20	
Program	Criteria 1. SUPPORTING DATA CENTER	2. DOCUMENTATION	3. INPUT	4. SOLUTION	5. OUTPUT	6. EFFICIENCY RELIABILITY	TOTAL EVALUATION
Frame Analysis							
AMECO MA	.84 4	.69 14	.82 21	.72 11	.77 12	.74 16	78
SAGS CDC	.84 4	.89 18	.47 12	.47 7	.82 12	.44 9	62
STRESS 3.0 MA	.91 5	.70 14	.85 21	.52 8	.90 14	.85 17	79
STRU DL II SDL	.48 2	.74 15	.54 14	.73 11	.84 13	.38 8	63
GENSAP CDC	.84 4	.85 17	.47 12	.60 9	.90 14	.61 12	68
2DGENFRAME CDC	.84 4	.85 17	.42 11	.27 4	.90 14	.78 16	66
Frame-Shearwall Analysis							
PCA/STMFR SDL	.53 2	.55 11	.60 15	.74 11	.74 11	.16 3	53
SP/SHWINT CDC	.84 4	.65 13	.38 10	.48 7	.64 10	.72 16	60
Dynamic Frame Analysis							
DAGS CDC	.84 4	.89 18	.49 12	.86 13	.90 14	.58 12	73
STRU DL II SDL	.48 2	.74 15	.55 14	.73 11	.84 13	.38 8	63
2DFMAP CDC	.84 4	.85 17	.47 12	.42 6	.90 14	.70 14	67

1. SUPPORTING DATA CENTER

Criteria Wt.	15	15	10		100		
Program	Criteria 1.1 OPERATING SUPPORT	1.2 JOB TURN- AROUND	1.3 COMPUTER SYSTEM		1. SUPPORTING DATA CENTER		
Concrete Bldg. Design							
AMECO MA	.9 68	.5 2	.8 3		84		
PCA/ESTIM MA	.8 60	.8 12	.8 8		80		
STRU DL II SDL	.1 8	.5 8	.2 2		18		
Concrete Slab- Beam Design							
PCA/ADOSS MA	.8 60	.8 12	.8 8		80		
SP/CBULT CDC	.8 60	1. 15	.9 9		84		
SP/NONPU CDC	.8 60	1. 15	.9 9		84		
Concrete Col. Design							
PCA/COL MA	.8 60	.8 12	.8 8		80		
PCA/LS MA	.8 60	.8 12	.8 8		80		
Concrete Wall Design							
SP/RETWAL CDC	.8 60	1. 15	.9 9		84		
SP/EQUIER CDC	.8 60	1. 15	.9 9		84		
SP/BRGWAL CDC	.8 60	1. 15	.9 9		84		
Concrete Fnd. Design							
PCA/MAT MA	.8 60	.8 12	.8 8		80		
SP/COMFTG CDC	.8 60	1. 15	.9 9		84		

1.1 OPERATING SUPPORT

Criteria Wt.	30	40	70	100		
Program	Criteria 1.1.1 SYSTEM SUPPORT	1.1.2 PROGRAM SUPPORT	1.1.3 SEMINARS	1.1 OPERATING SUPPORT		
Concrete Bldg. Design						
AMECO MA	.9 27	.9 54	1. 10	91		
PCA/ESTIM MA	.9 27	.9 54	.0 0	81		
STRUDL II SDL	.2 6	.0 0	.0 0	6		
Concrete Slab- Beam Design						
PCA/ADOSS MA	.8 24	.9 54	.0 0	78		
SP/CBULT CDC	.8 24	.9 54	.0 0	78		
SP/NONPU CDC	.8 24	.9 54	.0 0	78		
Concrete Col. Design						
PCA/COL MA	.9 27	.9 54	.0 0	81		
PCA/LS MA	.9 27	.9 54	.0 0	81		
Concrete Wall Design						
SP/RETWAL CDC	.8 24	.9 54	.0 0	78		
SP/EQUIER CDC	.8 24	.9 54	.0 0	78		
SP/BRGWAL CDC	.8 24	.9 54	.0 0	78		
Concrete Fnd. Design						
PCA/MAT MA	.8 24	.9 54	.0 0	78		
SP/CONFTG CDC	.8 24	.9 54	.0 0	78		

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2. DOCUMENTATION

Criteria Wt.	20	5	20	5	15		
Program	Criteria 2.1 EXPLAINS METHODS	2.2 DATA INTERPRETATION	2.3 OUTPUT INTERPRETATION	2.4 COST ESTIMATING	2.5 HONESTY		
Concrete Bldg. Design							
AMECO MA	.6 12	.8 24	.5 15	.0 0	.0 0		51
PCA/ESTIM MA	1. 20	.6 18	.5 15	.0 0	1. 15		65
STRUDEL II SDL	1. 20	.8 24	.8 24	.0 0	.0 0		68
Concrete Slab- Beam Design							
PCA/ADOSS MA	1. 20	.9 27	1. 30	.0 0	.0 0		77
SP/CBULT CDC	.5 10	.8 24	.5 15	.0 0	1. 15		64
SP/NONPU CDC	.5 10	.8 24	.5 15	.0 0	1. 15		64
Concrete Col. Design							
PCA/COL MA	1. 20	.9 27	.5 15	.0 0	1. 15		77
PCA/LS MA	1. 20	.9 27	1. 30	.0 0	1. 15		92
Concrete Wall Design							
SP/RETWAL CDC	.3 6	.6 18	.4 12	.0 0	1. 15		51
SP/EQUIER CDC	.5 10	.4 12	.2 6	.0 0	1. 15		43
SP/BRGWAL CDC	.5 10	.6 18	.2 6	.0 0	1. 15		49
Concrete Fnd. Design							
PCA/MAT MA	1. 20	.8 24	.8 24	.0 0	1. 15		83
SP/COMFTG CDC	.3 6	.4 12	.2 6	.0 0	1. 15		39

2.2 DATA PREPARATION

Program	Criteria Wt.	1	2	10	100	1000	10000
	Criteria	1	2	10	100	1000	10000
Concrete Bldg. Design							
AMECO MA	.6	36	1.30	1.10	76		
PCA/ESTIM MA	.7	54	.39	.00	33		
STRU DL II SDL	.8	48	1.30	.00	78		
Concrete Slab-Beam Design							
PCA/ADOSS MA	.9	54	1.20	1.10	94		
SP/CBULT CDC	.9	54	.90	.00	91		
SP/NONPU CDC	.9	54	.90	.00	91		
Concrete Col. Design							
PCA/COL MA	.9	54	1.30	1.10	94		
PCA/LS MA	.9	54	1.30	1.10	94		
Concrete Wall Design							
SP/RETWAL CDC	.6	36	.824	.00	60		
SP/EQUIER CDC	.2	12	.824	.00	36		
SP/BRGWAL CDC	.6	36	.721	.00	57		
Concrete Fnd. Design							
PCA/MAT MA	.9	54	.618	1.10	82		
SP/COMFTG CDC	.3	18	.721	.00	39		

2.4. OUTPUT INTERPRETATION

Program	Criteria Wt.	2.3.1 OUTPUT DESCRIPTION	2.3.2 EFF. NPU/MA	2.3.3 FRACT. SHOOTING MID	2.3.4 FRACT. INTERPRETATION			
Concrete Bldg. Design								
AMECO MA	.8	.4	.0	.0	.52			
PCA/ESTIM MA	1.	.0	.0	.0	.50			
STRU DL II SDL	.5	1.	.0	.0	.75			
Concrete Slab-Beam Design								
PCA/ADOSS MA	1.	1.	.0	.0	1.00			
SP/CBULT CDC	.9	.0	.0	.0	.45			
SP/NONPU CDC	.9	.0	.0	.0	.45			
Concrete Col. Design								
PCA/COL MA	.8	.0	.5	.10	.50			
PCA/LS MA	.9	1.	.0	.20	.95			
Concrete Wall Design								
SP/RETWAL CDC	.7	.0	.0	.0	.35			
SP/EQPIER CDC	.3	.0	.0	.0	.15			
SP/BRGWAL CDC	.4	.0	.0	.0	.20			
Concrete Fnd. Design								
PCA/MAT MA	.7	.8	.8	.16	.75			
SP/COMFTG CDC	.3	.0	.2	.4	.19			

Program	Criteria Wt.	25	20	5	30	20	100
	Criteria 3.1 INPUT LANGUAGE 3.2 ERRORS & DEFAULTS 3.3 UNITS 3.4 AUTOMATIC DATA GENERATION 3.5 INPUT STORED 3.6 INPUT						
Concrete Bldg. Design							
AMECO MA	.8 20	.6 12	.0 0	1. 30	1. 20		52
PCA/ESTIM MA	.0 0	.5 10	.0 0	1. 30	1. 20		60
STRU DL II SDL	.8 20	.5 10	1. 5	1. 30	1. 20		85
Concrete Slab- Beam Design							
PCA/ADOSS MA	.0 0	.5 10	.0 0	1. 30	1. 20		60
SP/CBULT CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55
SP/NONPU CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55
Concrete Col. Design							
PCA/COL MA	.0 0	.5 10	.0 0	.5 15	1. 20		45
PCA/LS MA	.0 0	.5 10	.0 0	1. 30	1. 20		60
Concrete Wall Design							
SP/RETWAL CDC	.4 10	.5 10	.0 0	1. 30	1. 20		70
SP/EQUIER CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55
SP/BRGWAL CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55
Concrete Fnd. Design							
PCA/MAT MA	.0 0	.4 8	.0 0	1. 30	1. 20		58
SP/COMFTG CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55

4. SOLUTION

Criteria Wt.	30	70	100				
Program	Criteria #1	CONTROL	#2 QUALITY	#3 SOLUTION			
Concrete Bldg. Design							
AMECO MA	1.00	.7	49	79			
PCA/ESTIM MA	.5	.15	.5	35	50		
STRUDL II SDL	1.0	.30	.2	14	44		
Concrete Slab- Beam Design							
PCA/ADOSS MA	.8	.24	.9	63	37		
SP/CBULT CDC	.8	.24	.9	56	80		
SP/NONPU CDC	.8	.24	.6	56	80		
Concrete Col. Design							
PCA/COL MA	.9	.27	.9	63	90		
PCA/LS MA	.8	.24	.9	63	87		
Concrete Wall Design							
SP/RETWAL CDC	.4	.12	.5	35	47		
SP/EQPIER CDC	.6	.18	.5	35	53		
SP/BRGWAL CDC	.6	.18	.6	42	60		
Concrete Fnd. Design							
PCA/MAT MA	.5	.15	.7	49	64		
SP/COMFTG CDC	.4	.12	.5	35	47		

5. OUTPUT

Program	Criteria Wt.	20	30	50	100		
	Criteria 5.1 CONTROL 5.2 ORGANIZATION 5.3 CONTENT 5 OUTPUT						
Concrete Bldg. Design							
AMECO MA	.8 16	.7 21	.7 35		72		
PCA/ESTIM MA	.8 16	.8 24	.6 30		70		
STRU DL II SDL	.8 16	.3 9	.3 15		40		
Concrete Slab- Beam Design							
PCA/ADOSS MA	.0 0	.8 24	.6 30		54		
SP/CBULT CDC	.0 0	.7 21	.7 35		56		
SP/NONPU CDC	.0 0	.7 21	.7 35		56		
Concrete Col. Design							
PCA/COL MA	.0 0	.7 21	.5 25		46		
PCA/LS MA	.8 16	.8 24	.8 40		80		
Concrete Wall Design							
SP/RETWAL CDC	.0 0	.8 24	.5 25		29		
SP/EQUIER CDC	.0 0	.7 21	.7 35		56		
SP/BRGWAL CDC	.0 0	.7 21	.7 35		56		
Concrete Fnd. Design							
PCA/MAT MA	.0 0	.8 24	.6 30		54		
SP/COMFTG CDC	.0 0	.4 12	.4 20		32		

6. EFFICIENCY & RELIABILITY

Program	Criteria Wt.	40	30	30	100		
	Criteria	6-1 RELATIVE COST	6-2 SOLUTION EFFICIENCY	6-3 START UP RELIABILITY	6-4 EFFICIENCY RELIABILITY		
Concrete Bldg. Design							
AMECO MA	.8 32	.9 27	.7 21		80		
PCA/ESTIM MA	.8 32	1. 30	.4 12		74		
STRU DL II SDL	.4 16	.5 15	.2 6		37		
Concrete Slab-Beam Design							
PCA/ADOSS MA	.8 32	.9 27	.7 21		80		
SP/CBULT CDC	.6 24	.8 24	1. 30		78		
SP/NONPU CDC	.5 20	.8 24	1. 30		74		
Concrete Col. Design							
PCA/COL MA	.7 28	.8 24	.7 21		73		
PCA/LS MA	.8 32	.9 27	.6 18		77		
Concrete Wall Design							
SP/RETWAL CDC	.6 24	.6 18	1. 30		72		
SP/EQUIER CDC	.6 24	.6 18	.5 15		57		
SP/BRGWAL CDC	.5 20	.6 18	1. 30		68		
Concrete Fnd. Design							
PCA/MAT MA	.3 12	.5 15	.5 15		42		
SP/COMFTG CDC	.5 20	.6 18	1. 30		68		

TOTAL EVALUATION

Criteria Wt.	3	20	25	15	15	20	100
Program	Criteria 1. SUPPORTING DATA CENTER	2. DOCUMENTATION	3. INPUT	4. SOLUTION	5. OUTPUT	6. EFFICIENCY LEVEL ABILITY	TOTAL EVALUATION
Concrete Bldg. Design							
AMECO MA	.84 / 4	.51 / 10	.82 / 21	.79 / 12	.72 / 11	.80 / 16	74
PCA/ESTIM MA	.80 / 4	.68 / 14	.60 / 15	.50 / 8	.70 / 11	.74 / 15	67
STRU DL II SDL	.18 / 1	.68 / 14	.85 / 21	.44 / 7	.40 / 6	.37 / 7	56
Concrete Slab- Beam Design							
PCA/ADOSS MA	.80 / 4	.77 / 15	.60 / 15	.87 / 13	.54 / 8	.80 / 16	71
SP/CBULT CDC	.84 / 4	.64 / 13	.55 / 14	.80 / 12	.56 / 8	.78 / 16	67
SP/NONPU CDC	.84 / 4	.64 / 13	.55 / 14	.80 / 12	.56 / 8	.74 / 15	66
Concrete Col. Design							
PCA/COL MA	.80 / 4	.77 / 15	.45 / 11	.90 / 14	.46 / 7	.73 / 15	66
PCA/LS MA	.80 / 4	.92 / 18	.60 / 15	.87 / 13	.80 / 12	.77 / 15	77
Concrete Wall Design							
SP/RETWAL CDC	.84 / 4	.51 / 10	.70 / 18	.47 / 7	.49 / 7	.72 / 14	60
SP/EQUIER CDC	.84 / 4	.43 / 9	.55 / 14	.53 / 8	.56 / 8	.57 / 11	54
SP/BRGWAL CDC	.84 / 4	.49 / 10	.55 / 14	.60 / 9	.56 / 8	.68 / 14	59
Concrete Fnd. Design							
PCA/MAT MA	.80 / 4	.83 / 17	.58 / 15	.64 / 10	.54 / 8	.42 / 8	62
SP/COMFTG CDC	.84 / 4	.39 / 8	.55 / 14	.47 / 7	.32 / 5	.69 / 14	52

1. SUPPORTING DATA CENTER

Criteria Wt.	75	15	10		100		
Program	Criteria 1. OPERATING SUPPORT	2. JOB TURN- AROUND	3. COMPUTER SYSTEM		1. SUPPORTING DATA CENTER		
Steel Bldg. Design							
AMECO MA	.9 68	.5 8	.8 8		84		
STRU DL II SDL ¹	.3 23	.5 8	.2 2		33		
Steel Floor & Beam Design							
CISC/FLOOR MA	.8 60	.8 12	.8 8		80		
SP/STLBMA CDC	.8 60	1. 15	.9 9		84		
SP/COMPBU CDC	.8 60	1. 15	.9 9		84		
Steel Column Design							
CISC/COL MA	.8 60	.8 12	.8 8		80		
SP/STLCOL CDC	.8 60	1. 15	.9 9		84		

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II OPERATING SUPPORT

Criteria Wt.	50	60	70	80	90	100		
Program	Criteria II-4 SYSTEM SUPPORT	II-5 SYSTEM SUPPORT	II-6 SYSTEM SUPPORT	II-7 SEMINARS	II-8 OPERATING SUPPORT			
Steel Bldg. Design								
AMECO MA	.9 27	.9 54	1. 10		91			
STRU DL II SDL ¹	.5 15	.2 12	.0 0		27			
Steel Floor & Beam Design								
CISC/FLOOR MA	.9 27	.9 54	.0 0		81			
SP/STLBMA CDC	.9 24	.9 54	.0 0		78			
SP/COMPBU CDC	.8 24	.9 54	.0 0		78			
Steel Column Design								
CISC/COL MA	.9 27	.9 54	.0 0		81			
SP/STLCOL CDC	.8 24	.9 54	.0 0		78			

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2. DOCUMENTATION

Criteria Wt.	20	30	30	5	15		100
Program	Criteria 2.1 EXPLAINS METHODS	2.2 DATA PRESENTATION AID	2.3 OUTPUT INTERPRETATION	2.4 COST ESTIMATING GUIDE	2.5 HUMANITY		2.6 DOCUMENTATION
Steel Bldg. Design							
AMECO MA	.6 12	.8 24	.4 12	1. 5	.0 0		53
STRUDL II SDL ¹	.8 16	.8 24	.8 24	.0 0	1. 15		79
Steel Floor & Beam Design							
CISC/FLOOR MA	.8 16	.8 24	.8 24	.0 0	1. 15		79
SP/STLBMA CDC	.3 6	.6 18	.2 6	.0 0	1. 15		45
SP/COMPBU CDC	.5 10	.4 12	.2 6	.0 0	1. 15		43
Steel Column Design							
CISC/COL MA	.8 16	.9 27	.8 24	.0 0	1. 15		82
SP/STLCOL CDC	.3 6	.6 18	.4 12	.0 0	1. 15		51

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2.2 DATA PREPARATION AID

Criteria Wt.	60	30	10		100		
Program	Criteria 2.2.1	INSTRUCTIONS 2.2.2	EXAMPLES 2.2.3	COMMAND SUMMARY	2.2 DATA PREPARATION AID		
Steel Bldg. Design							
AMECO MA	.6 36	1. 30	1. 10		76		
STRUDL II SDL ¹	.8 48	1. 30	.0 0		78		
Steel Floor & Beam Design							
CISC/FLOOR MA	.9 54	1. 30	.0 0		84		
SP/STLBMA CDC	.6 36	.8 24	.0 0		60		
SP/COMPBU CDC	.2 12	.8 24	.0 0		36		
Steel Column Design							
CISC/COL MA	.9 54	1. 30	1. 10		92		
SP/STLCOL CDC	.6 36	.8 24	.0 0		60		

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2.3 OUTPUT INTERPRETATION

Criteria Wt.	50	30	20		100		
Program	Criteria 2.3.1 OUTPUT DESCRIPTION	2.3.2 ERROR MESSAGE EXPLANATION	2.3.5 TROUBLE SHOOTING AID		2.3 OUTPUT INTERPRETATION		
Steel Bldg. Design							
AMECO MA	.7 35	.3 9	.0 0		44		
STRU DL II SDL ¹	.5 25	1. 30	1. 20		75		
Steel Floor & Beam Design							
CISC/FLOOR MA	.5 25	1. 30	1. 20		75		
SP/STLBMA CDC	.3 15	.0 0	.0 0		15		
SP/COMPBU CDC	.3 15	.0 0	.0 0		15		
Steel Column Design							
CISC/COL MA	.5 25	1. 30	1. 20		75		
SP/STLCOL CDC	.7 35	.0 0	.2 4		39		

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3. INPUT

Criteria Wt.	25	20	5	30	20		100
Program	Criteria 3.1 INPUT LANGUAGE	3.2 ERRORS & DEFAULTS	3.3 JOINTS	3.4 AUTOMATIC DATA GENERATION	3.5 INPUT STORED		3. INPUT
Steel Bldg. Design							
AMECO MA	.8 20	.6 12	.0 0	1. 30	1. 20		82
STRU DL II SDL ¹	.8 20	.5 10	1. 5	.5 15	1. 20		70
Steel Floor & Beam Design							
CISC/FLOOR MA	.0 0	.5 10	.0 0	1. 30	1. 20		60
SP/STLBMA CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55
SP/COMPBU CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55
Steel Column Design							
CISC/COL MA	.0 0	.5 10	.0 0	.5 15	1. 20		55
SP/STLCOL CDC	.4 10	.5 10	.0 0	.5 15	1. 20		55

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4. SOLUTION

Program	Criteria Wt.	30	70	100			
	Criteria 4.1 CONTROL 4.2 S.I.P. 77 4.3 SOLUTION						
Steel Bldg. Design							
AMECO MA	.30 1	.7 47		.71			
STRUDL II SDL ¹	.30 1	.8 56		.86			
Steel Floor & Beam Design							
CISC/FLOOR MA	.15 .5	.56 .8		.71			
SP/STLBMA CDC	.24 .8	.5 .8		.56			
SP/COMPBU CDC	.24 .8	.56 .8		.56			
Steel Column Design							
CISC/COL MA	.15 .5	.56 .8		.71			
SP/STLCOL CDC	.24 .8	.56 .8		.56			

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5 OUTPUT

Program	Criteria Wt.	20	30	50		100		
	Criteria	51 CONTROL	52 PL-RWZP-COL	53 CONTROL				
Steel Bldg. Design								
AMECO MA	.8 .6	.6 15	.7 35		77			
STRU DL II SDL ¹	.8 16	.5 15	.7 35		76			
Steel Floor & Beam Design								
CISC/FLOOR MA	.5 .0	.8 24	.6 30		54			
SP/STLBMA CDC	.0 0	.7 21	.7 35		56			
SP/COMPBU CDC	.0 0	.7 21	.7 35		56			
Steel Column Design								
CISC/COL MA	.0 0	.5 15	.5 25		40			
SP/STLCOL CDC	.0 0	.6 18	.5 25		43			

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6 EFFICIENCY & RELIABILITY

Criteria Wt.	40	30	30		100		
Program	Criteria G1 RELATIVE COST	G2 SOLUTION EFFICIENCY	G3 START-UP RELIABILITY		G4 EFFICIENCY & RELIABILITY		
Steel Bldg. Design							
AMECO MA	.8 32	.9 27	.5 15		74		
STRU DL II SDL ¹	.4 16	.5 15	.2 6		37		
Steel Floor & Beam Design							
CISC/FLOOR MA	.9 36	.9 27	1. 30		93		
SP/STLBMA CDC	.4 16	.6 18	1. 30		64		
SP/COMPBU CDC	.8 12	.4 12	1. 30		54		
Steel Column Design							
CISC/COL MA	.7 28	.9 27	.4 12		67		
SP/STLCOL CDC	.3 12	.6 18	1. 30		60		

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TOTAL EVALUATION

Criteria Wt.	5	20	25	15	15	20	100
Program	Criteria 1. SUPPORTING DATA CENTER	2. DOCUMENTATION	3. INPUT	4. SOLUTION	5. OUTPUT	6. EFFICIENCY IN TIME	7. TOTAL EVALUATION
Steel Bldg. Design							
AMECO MA	.84 / 4	.53 / 11	.82 / 21	.79 / 12	.79 / 12	.74 / 15	75
STRU DL II SDL ¹	.33 / 2	.79 / 16	.70 / 18	.86 / 13	.76 / 11	.37 / 7	67
Steel Floor & Beam Design							
CISC/FLOOR MA	.50 / 4	.79 / 16	.60 / 15	.71 / 11	.54 / 8	.93 / 19	73
SP/STLBMA CDC	.84 / 4	.45 / 9	.55 / 14	.80 / 12	.56 / 8	.64 / 13	60
SP/COMPBU CDC	.84 / 4	.45 / 9	.55 / 14	.80 / 12	.56 / 8	.54 / 11	58
Steel Column Design							
CISC/COL MA	.80 / 4	.82 / 16	.45 / 11	.71 / 11	.40 / 6	.67 / 13	61
SP/STLCOL CDC	.84 / 4	.51 / 10	.55 / 14	.80 / 12	.43 / 6	.60 / 12	58

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B - 4 Evaluation Sensitivity to Criterion Weights

The weighting scheme, proposed in section B-1 and used in the evaluation presented in section B-3 is felt to be rational and justified, however, not all potential users of software would naturally place the same importance on the criteria. Since it may be seen from the evaluation presented in section B-3, that programs do not necessarily receive consistent ratings, it is necessary to investigate the effects of variations in the weighting scheme. To this end, the first level criteria weights have been varied between what are believed to be the maximum and minimum acceptable values. These are presented in Table B-2.

For each of the variations listed in Table B-2, the final total evaluation of the programs was recalculated. In each case, one criterion weight was varied while the others were held constant. As well, the final evaluation was calculated for the case of equal weights for all the first level criteria. The results of this investigation are presented in Table B-3 which summarizes the test by simply indicating the variations in the ranking of programs as the criteria weights are varied.

TABLE B-2

FIRST LEVEL CRITERIA WEIGHT VARIATIONS FOR SENSITIVITY TEST

Criteria	Weights		
	Low	Base Value	High
1. Supporting Data Center	2	5	15
2. Documentation	5	20	35
3. Input	10	25	40
4. Solution	5	15	30
5. Output	5	15	30
6. Efficiency and Reliability	5	20	35

Table B-3

SENSITIVITY OF RANK

Varied Criterion															
	BASE	SUPPORTING DATA CENTER				DOCUMENTATION		INPUT		SOLUTION		OUTPUT		EFFICIENCY & RELIABILITY	
Programs	X	2	15	5	35	10	40	5	30	5	30	5	35	X	
Frame Analysis															
AMECO MA	2	2	2	2	2	2	2	2	1	2	2	2	2	2	
SAGS CDC	6	6	5	6	5	6	6	5	6	6	6	5	6	5	
STRESS 3.0 MA	1	2	1	1	1	1	1	1	2	2	1	2	1	1	
STRU DL II SDL	5	5	6	5	6	6	5	6	4	1	5	4	6	6	
GENSAP CDC	3	3	3	3	3	3	3	4	3	3	3	3	4	3	
2DGENFRAME CDC	4	4	4	4	4	4	4	3	5	4	4	6	4	4	
Frame-Shearwall Analysis															
PCA/STMFR SDL	2	2	2	2	2	2	2	2	2	2	2	1	2	2	
SP/SHWINT CDC	1	1	1	1	1	1	1	1	1	1	1	2	1	1	
Dynamic Frame Analysis															
DAGS CDC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
STRU DL II SDL	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
2DFMAP CDC	2	2	2	2	2	2	2	2	3	2	2	3	2	2	

Table B-3 Cont'd...

SENSITIVITY OF RANK

[illegible]

Table B-3 Cont'd...

SENSITIVITY OF RANK

Varied Criterion		BASE SUPPORTING DATA CENTER DOCUMENTATION INPUT SOLUTION OUTPUT EFFICIENCY RELIABILITY EVEN WTS.													
		X	2	15	5	35	10	40	5	30	5	30	5	35	X
Programs															
Steel Bldg. Design															
AMECO MA		/	/	/	/	/	/	/	/	/	/	/	/	/	
STRU DL II SDL ¹		2	2	2	2	2	2	2	2	2	2	2	2	2	
Steel Floor & Beam Design															
CISC/FLOOR MA		/	/	/	/	/	/	/	/	/	/	/	/	/	
SP/STLBMA CDC		2	2	2	2	2	2	2	2	2	2	3	2	2	
SP/COMPBU CDC		3	3	3	3	3	3	3	3	3	3	3	3	3	
Steel Column Design															
CISC/COL MA		/	/	/	2	/	/	/	/	/	/	/	/	/	
SP/STLCOL CDC		2	2	2	1	2	2	2	2	2	2	2	2	2	

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Clearly, the evaluation of these programs is only slightly sensitive to variations in the weighting of the criteria. Within the range of reasonable weights, there are only a few instances where the final ranking of the programs is affected. The most notable case of sensitivity among the programs evaluated, is in the category of Frame Analysis programs. In this instance, there occurs some oscillation between AMECO, and STRESS 3.0 as the most highly rated program; when the criterion Solution is given a heavy weight. The result is interesting but not surprising, since both programs are meritorious. AMECO's main strength lies in the fact that its solution is oriented towards the problems associated with building structures. Another case of sensitivity is in the category of Concrete Wall Design programs. Here SP/RETWAL and SP/BRGWAL switch ranking in several instances. These two programs are rated almost evenly throughout the evaluation, both exhibiting some strong points and, some weak ones. In fact, the comparative evaluation of the programs in the Concrete Wall Design category is probably not justified since the programs compared, are not really intended for the same problems. In this circumstance, it is fair to ignore this occurrence of sensitivity.

There are two other categories of programs which exhibit sensitivity to the criteria weights. In the category of Frame-Shearwall Analysis programs, the PCA/STMFR

becomes the best rated program if Efficiency and Reliability is weighted very low. In this case, the PCA program was found to be very expensive to use, but somewhat more general than the equivalent SP program, and had better developed input and output. In the category of Steel Column Design programs, the SP program surpassed the CISC program only when the documentation was weighted very low.

The significant observation which may be made at this point, is that the program evaluations which were carried out are not particularly sensitive to the weighting scheme applied to the first level criteria. Therefore, if the reader feels that the criteria weights proposed, are not to his taste, he may at least be assured that the final ranking of the programs evaluated, is not seriously affected by reasonable changes of the first level criteria weights.

C-1

APPENDIX C - 1

SAMPLE QUESTIONNAIRE

Carleton University
Ottawa, Canada K1S 5B6

C-2

October 11, 1977

Attn: Head of Engineering

Dear Sir,

At Carleton University we are presently engaged in a research project which is attempting to identify the role of the computer in the building design industry in Canada. More specifically, we are interested in the use of computers for the analysis and design of building structures.

A major aspect of this research is gathering data from Canadian design offices regarding their computer usage. To this end we request both users, and non-users to lend their assistance in completing, and returning the enclosed questionnaire.

The questionnaire is being sent to both your head office, and branch offices so please restrict your replies to the activities of your own office. The questionnaire may request information which is either unavailable to you, or not for public disclosure, please feel free to skip these questions, indicating the reason why. We hope to have all the questionnaires returned completed, however a partially completed questionnaire will also be of value to us. None of the information on the questionnaire will be attributed to any individual or firm without their prior consent.

We thank you in advance for your time and efforts in completing the questionnaire. The results of the study will help us to evaluate the computer's role in the building design industry in Canada, and help to identify the needs of the industry with respect to the computer. If you are interested in receiving a copy of our results, please indicate this at the end of your questionnaire.

Yours sincerely,

Prof. G.A. Hartley

QUESTIONNAIRE FOR THE EVALUATION OF THE ROLE OF
THE COMPUTER IN THE BUILDING DESIGN INDUSTRY IN
CANADA

Please return all questionnaires by November 20, 1977 to,

Prof. G.A. Hartley
Dept. of Civil Engineering
Carleton University
Ottawa, Ontario
K1S 5B6

1.0 GENERAL CONTACT DATA

1.1 Name of Firm _____

1.2 Your Name _____, Title _____

1.3 Type of work carried out by your firm _____

1.4 Number of employees; Professional _____, Non-professional _____

1.5 Would you object to your name being used in a paper _____

1.6 Would you be willing to provide further information on
your computer usage in a telephone interview _____

2.0 COMPUTER USAGE DATA

2.1 Does your firm use computers _____

If you are not presently using computers please skip to
the last question in this section.

2.2 How long has your firm been using computers _____

2.3 How many engineers are computer users _____

2.4 Is computer training provided by your firm _____

2.5 If yes, please describe the course _____

2.6 What percentage of the engineer computer users have C-4
formal computer training _____ %

2.7 Of those engineers with formal computer training, what
percentage have taken a) Programming Course(s) _____ %

b) Computer-Aided-Design Course(s) _____ %

2.8 Do you feel your computer usage is cost effective _____

2.9 Approximate total annual computer budget \$ _____

Percent for hardware procurement _____ %

Percent for software procurement _____ %

Percent for software development _____ %

Percent for production work; Analysis _____ %

Design _____ %

2.10 Of the computer budget for production work, what
percentage is for using,

Programs developed in-house _____ %

Programs purchased by firm _____ %

Programs available through a data center _____ %

2.11 Please rank the following on a scale of 1 to 7 in
order of the importance you place on them.

Better analysis _____

Better design _____

Faster job turn-around _____

Relief from routine work _____

Preferred by clients _____

Preferred by employees _____

Prestige _____

2.12 Is your firm planning to modify its computer usage _____.

How _____

3.0 HARDWARE DATA

3.1 Please list and describe all computer hardware being used by your firm. C-5

Description (manufacturer, model, core size, peripherals)	In- House	Data Center
1 _____ _____	_____	_____
2 _____ _____	_____	_____
3 _____ _____	_____	_____
4 _____ _____	_____	_____

4.0 IN-HOUSE PRODUCTION SOFTWARE DATA

For each in-house program presently in use please supply the following data.

4.1 Program name _____

4.2 Capabilities _____

4.3 Programming language(s) used _____

4.4 Hardware requirements _____

4.5 Development time in man years _____

4.6 Size in cards _____

4.7 Age of program _____

4.8 Average run costs; Processing \$ _____, Man hours _____

4.9 Estimated man hours to perform the same job manually _____

4.10 On what terms would you be willing to make the program available to other consulting firms, or design offices

5.0 PACKAGED SOFTWARE DATA

C-6

Please complete the following table indicating which of the programs you use and who owns them.

Program Name	Number of Runs Per Year Approx.	Owned by Firm	Owned by Data Center
AMECO			
ANSYS			
ASAS			
Clay Brick Ass. Programs*			

CISC - CSICC Programs*			

EASE2			
GASPX			
GENESYS*			

ICES*			
STRUDL			
COGO			

MARC			
NASTRAN			
NISEE Library*			
SAP IV			

*Specify which of the programs you use please.

Program Name	Number of Runs Per Year Approx.	Owned by Firm	Owned by Data Center
PCA Programs*			

PISCES			
SDRC Library*			
<u>SAGS</u>			
<u>DAGS</u>			
<u>SUPERB</u>			

STARDYNE			
STRESS			
STRU-PAK Library*			

Systems Professional Lib.*			

Others (specify origin)			

*Specify which of the programs you use please.

APPENDIX C - 2

CONSULTING OFFICES PARTICIPATING
IN THE QUESTIONNAIRE SURVEY

Acknowledgement

The following firms responded to the questionnaire survey. Their efforts in doing so are sincerely appreciated.

- 1 GIORGIO GALEOTTI INGENIEUR CONSEIL, 2810 EST BOUL. HENRI-BOURASSA, STE SSI, MONTREAL
- 2 KILBORN LTD. 2 QUEBEC ST. GUELPH, ONTARIO N1H 2Y3
- 3 J.L. RICHARD & ASSOC., 469 BRUCHARD ST., SUDBURY, ONTARIO, P3E 2K8
- 4 N. GANS & ASSOCIES 5000 RUE BUCHAN, SUITE 604, MONTREAL, P.Q. H4P 1T2
- 5 CAMBRIAN ENGINEERING GROUP LIMITED, 1661 PARK ST., REGINA, SASKATCHEWAN, S4N 5A2
- 6 C.C. PARKER & ASS. LTD. 562 WELLINGTON ST., LONDON, ONT. N6A 3R5
- 7 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 8 W.H. CRANDALL & ASSOCIATES LTD., STE 405, 133 PRINCE WILLIAMS ST., SAINT JOHN, N.B.
- 9 PLURITEC LTD, C.P. 668, 585 AVENUE DES CEDRES, SHAWINIGAN, P.Q. G9N 1N6.
- 10 TOTTEN SIMS HUBICKI ASSOCIATES LTD., 49 MANITOBA ST., BOX 1688, BRACEBRIDGE, ONTARIO.
- 11 CANADIAN-BRITISH ENGINEERING CONSULTANTS LTD., 420 KING ST., PORT COLBORNE, ONTARIO
- 12 BESSETTE-CREVIER, PARENT, LANGUAY & ASSOC., 672 BOUL. SAINT-JOSEPH, HULL, J8Y 4A8.

- 13 BRATIS, FRIGON, HANLEY & ASSOCIATES LTD., 100 ARGYLE AVE., OTTAWA, ONTARIO, K2P 1B6
- 14 BRANDZEL CONSULTANTS LTD., 85 THE EAST MALL, TORONTO, ONTARIO, M8Z 5W4,
- 15 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 16 SWAN WOOLTER ENGINEERING CO LTD., 107 YALES ST., BOX 218, ST. CATHARINES, ONTARIO,
- 17 C.D. HOWE CENTRAL LTD., 95N. CUMBERLAND ST., BOX 3225, THUNDERBAY, ONT., P7B 5G6
- 18 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 19 HASTINGS AND AZIZ LIMITED, STE 200, 200 QUEENS AVENUE, LONDON, ONTARIO, N6A 1J3
- 20 B. ALEXANDER & ASSOCIATES LTD., 300, 12120-106 AVENUE, EDMONTON, ALBERTA,
- 21 WYLLIE & UFNAL LIMITED, ONE GREENSBURU DRIVE, REXDALE, ONTARIO, M9W 1C6,
- 22 J.D. LEE ENGINEERING LTD., BOX 1267, KINGSTON, ONTARIO,
- 23 MENARD, MARBAN & ASSOC. INC., 88 QUEST, RUE ST-GERMAIN, RIMOUSKI, P.Q.
- 24 GROUP EIGHT ENGINEERING LTD., 630 MAIN ST. E., HAMILTON, ONTARIO, L8M 1J7
- 25 NORTHLAND ENGINEERING LTD., 528 CASSELLS ST., NORTH BAY, ONTARIO, P1B 3Z7

- 26 KONFORTI & MCCAVUUR LTD., 169 THE WEST MALL, ETOBICOKE, ONTARIO. M9C 1C2
- 27 E.S.C.LIMITED, 105 PROSPECT ST., BOX 365, FREDERICTON, N.B. E3B 4Z9
- 28 CANADIAN BRITISH LTD., BOX 1296N, HALIFAX, NOVA SCOTIA. B3K 5H4
- 29 THE PROCTOR & HEDFERN GROUP, 89 DUNLOP ST.E., STE 301, BARRIE, ONT. L4M 1A7
- 30 BESSETTE, CREVIER, PARENT, LANGUAY & ASSOC., 110 BOUL. CREMAZIE OUEST, MONTREAL.
- 31 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 32 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 33 BANKS SPRONKEN LAMB MCMAHUS LTD., 509 CENTURY ST., WINNIPEG, MANITOBA. R3H 0L8
- 34 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 35 GENDRON LEFEBVRE INC., 1 PLACE LAVAL, STE 200, LAVAL, P.Q. H7N 1A1
- 36 A.F. ESHMADE & ASSOC., 504-272 MAIN ST., WINNIPEG, MANITOBA. R3C 1A9
- 37 BNC/GECO CANADA INC., 100 ADELAIDE ST.W., STE 1300, TORONTO, ONT. M5H 1S3
- 38 V.B. COOK CO. LTD., P.O. BOX 936, THUNDER BAY, ONTARIO. P7C 4X8

- 39 BOILEAU & ASSUCIES, 360 EST; BOUL. MALONEY, GATINEAU, QUEBEC. J8P 1E5
- 40 W.G.CAMPBELL ENGINEERING LTD., STE 1109, 5251 DUKE ST., HALIFAX, N.S. B3J 1P3
- 41 MAKENIZE, SNOWBALL SKALBANTIA & ASSOC, LTD., 1510 ALBERNI ST., VANCOUVER, B.C.
- 42 REBO, CROWTHER & PARTNERS LTD., 1729 SCRATH ST., REGINA, SASKATCHEWAN. S4P 2G2
- 43 W.J.FRANCL & ASSOC. LTD., 13425-146TH STREET, EDMONTON, ALBERTA. T5L 4S8
- 44 KLEINFELDT GROUP, BOX 608, 7665 HURONTARIO ST., BRAMPTON, ONTARIO, L6V 2L6
- 45 M.M.DILLON LTD., BOX 1649, YELLOWKNIFE, N.W.T. X0E 1H0
- 46 TEDSULT INTERNATIONAL LTD., 91E 1500, 85 OUEST, ST.CATHERINE, MONTREAL. H2X 3P4
- 47 YCHA ENGINEERING LTD., 1425 WEST PENDER ST., VANCOUVER, B.C. V6G 2S3
- 48 M.M.DILLON LTD., 6 DONALD ST., WINNIPEG, MANITOBA, R3L 0K6
- 49 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 50 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 51 SANDWELLI & COMPANY LTD., 1155 RUE METCALFE, BUREAU 1717, MONTREAL. H3B 2X3

- 52 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 53 GIFFELS ASSOC. LTD., 30 INTERNATIONAL BLVD., TORONTO, ONTARIO, M9W 5P3
- 54 MCGRIDE, RAGAN, SORENSEN, BOX 4576, EDMONTON, ALBERTA, T6E 5G4
- 55 CRYSLER & LATHEN LTD., 145 SPARKS AVF., WILLOWDALE, ONTARIO, M2H 2S5
- 56 READ JONES CHRISTOFFERSEN LTD., 1216 BROAD ST., VICTORIA, B.C. V8W 2A5
- 57 MARSHALL MASKLIN MONAGHAN LTD., 77 CITY CENTER DR., MISSISSAUGA, ONT. L5B 1M5
- 58 WILLIS GUNLIFFE TAIT & COMPANY LTD., 209-419 YALE RD. W., CHILLIWACK, B.C.
- 59 SANDWELL, 1550 ALBERNI STREET, VANCOUVER, B.C. V6G 1A4
- 60 L'ALONDE, VALOIS, LAMARRE, VALOIS & ASSOC. INC., 1130 RUE SHERBROOKE OUEST, MONTREAL.
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- 64 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***

- 65 SHAWINGAN ENGINEERING WESTERN LTD., 310-1111 W. GEORGIA ST., VANCOUVER, B.C.
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- 67 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 68 CANADIAN-BRITISH CONSULTANTS LTD., BOX 1232, FREDERICTON, N.B. E3B 5C8
- 69 KEITH CONSULTING ENGINEERS LTD., 766 ANGUS ST., REGINA, SASKATCHEWAN.
- 70 WILLIS CUNLIFFE TAIT & COMPANY LTD., 10230, 100TH STREET, FORT ST. JOHN, B.C.
- 71 WILLIS CUNLIFFE TAIT & COMPANY LTD., 321 WALLACE ST., NANAIMO, B.C. V9R 5B6
- 72 ASSOCIATED ENGINEERING SERVICES LTD., 301-1777 3RD AVE., PRINCE GEORGE, B.C.
- 73 GREER GALLUWAY & ASSOC. LTD., BOX 1840, 165 MANITOBA ST., BRACE BRIDGE, ONTARIO.
- 74 MONTREAL ENGINEERING CO. LTD., 593 KING STREET, FREDERICTON, NEW BRUNSWICK.
- 75 DEILLEUM CATHER, CANADA LTD., 1666 DUBLIN AVE., WINNIPEG, MANITOBA, R3H 0H1
- 76 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 77 ROBERT HALSALL AND ASSOC. LTD., 210 GLADSTONE AVE., OTTAWA, ONTARIO, K2P 0Y6

78 STANLEY ASSOCIATES ENGINEERING LTD., 11748 KINGSWAY AVE., EDMONTON, ALBERTA.

79 STANLEY ASSOCIATES ENGINEERING LTD., 206, 3307-32ND AVE., VERNON, B.C.

80 STANLEY ASSOCIATES ENGINEERING LTD., UKANOGAN BRANCH.

81 CROBIE, KILGOUR & PARTNERS LTD., STE 220, 805-5TH ST. S.W., CALGARY, ALBERTA.

82 BEAUCHEMIN-BEATON-LAPUINIE INC., 1134 ST. CATHERINE ST. W., MONTREAL, P.Q. H3B 1M4

83 VERNON ENGINEERING SERVICES LTD., STE 104, 3304-32ND AVE., VERNON, B.C.

84 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***

85 PROJECT PLANNING ASSOC. LTD., 3767 HOWE AVENUE, HALIFAX, NOVA SCOTIA, B3L 4H9

86 SASKMONT ENGINEERING CO. LTD., 201-10408-124TH ST., EDMONTON, ALBERTA, T5N 1R5

87 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***

88 MORRISON, HENSHFIELD, BURGESS & HUGGING LTD., 3089 BATHURST ST., TORONTO, ONTARIO.

89 KAPPLE, RIGHT & MACLEUD LTD., 155 UNIVERSITY AVE., TORONTO, ONTARIO, M5H 3B7

90 JULIUS VAGY & ASSOCIATED LIMITED, 720 CONACHER DR., WILLOWDALE, ONT. M2M 3N6

- 91 JAMES F. MACLAREN LTD., 880 DUELLETTE AVE., WINDSOR, ONTARIO. N9A 1C7
- 92 WRIGHT ENGINEERS LTD., 1444 ALBERNI STREET, VANCOUVER, B.C. V6G 2Z4
- 93 SWAN WOOSTER ENGINEERING CO. LTD., 1525 ROBSON STREET, VANCOUVER, B.C. V6G 1C5
- 94 MCELHANNEY SURVEYING & ENGINEERING LTD., STE 205, 4630 LAZELLE AVE, TERRACE, B.C.
- 95 FENCO CONSULTANTS LTD., 301, PETRO-CHEMICAL BLDG, 805 8 AVE. S.W., CALGARY, ALTA.
- 96 ADJELEIAN & ASSOC. INC., 75 ALBERT STREET, OTTAWA, ONTARIO. K1P 5E7
- 97 GRAEME & MURRAY CONSULTANTS LTD., 1137 YATES STREET, VICTORIA, B.C. V8V 3N1
- 98 C. C. PARKER & ASSOC. LTD., 688 QUEENSDALE AVE. E., HAMILTON, ONTARIO. L8V 1M1
- 99 *** RESPONDING FIRM WHO WANTS HIS NAME TO BE OMITTED ***
- 100 MCKENZIE, SNOWBALL, SKALBANIA & ASSOC. LTD., 147 VICTORIA ST., KAMLOOPS, B.C.
- 101 KER, PRIESTMAN & ASSOC. LTD., 400-800 DOUGLAS ST., VICTORIA, B.C. V8W 2B7
- 102 REED, CROWTHER & PARTNERS LTD., BOX 1259, YELLOWKNIFE, NORTHWEST TERRITORIES.
- 103 J.L. RICHARDS & ASSOC. LTD., 864 LADY ELLEN PLACE, OTTAWA, ONTARIO. K1Z 5M2

- 104 STADLER HURTER LTD., 1600 DORCHESTER BLVD. W., MONTREAL, P.Q. H3H 1P9
- 105 C.D. CARRUTHERS & WALLACE LTD., 34 GREENSBORO DR., REXDALE, ONTARIO, M9W 1E1
- 106 ACRES CONSULTING SERVICES LTD., 5259 DORCHESTER RD., NIAGRA FALLS ONT. L2E 6W1

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