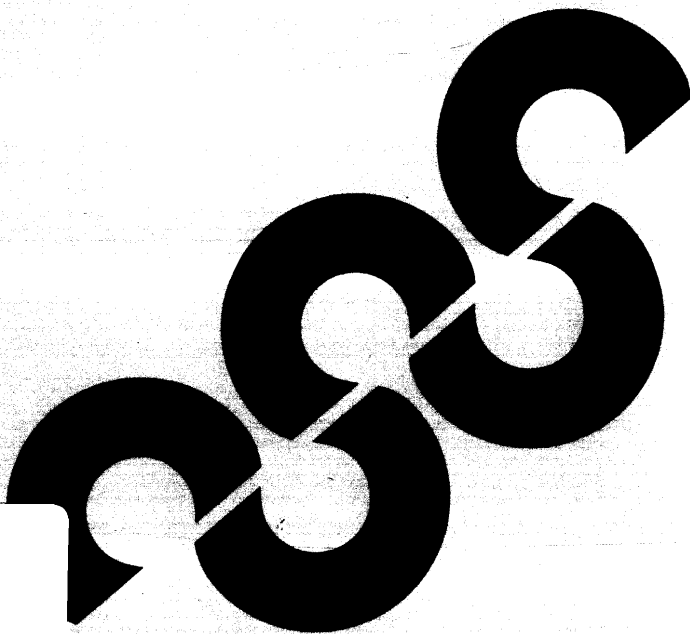


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Background Study
No. 32

Technology Transfer
in Construction

by A. D. Boyd and A. H. Wilson

January 1975



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Technology Transfer in Construction

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Technology Transfer in Construction

by A. D. Boyd and A. H. Wilson

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Archibald D. Boyd

Dr. Boyd was born in Nova Scotia. He received his BA degree in 1949 from St. Francis Xavier University, Nova Scotia, and a Diploma in Education in 1950. In 1952, he received an MA in Economics from the University of Toronto and a PhD in economics from the University of Ottawa in 1967.

Between 1952 and 1955, he lectured in economics at St. Francis Xavier University. In 1955, he was appointed to the Nova Scotia Department of Trade and Industry as an economic adviser on regional industrial development. In 1958, he joined the Federal Department of Labour (later the Department of Manpower and Immigration) and became Head of the Highly Qualified Manpower Research Section. During this time, Dr. Boyd also worked on the staff of the Royal Commission on Health Services, and was associated with the OECD Committee on Educational Investment and Planning. Later, he was a member of the Canadian Delegation to the Intergovernmental Conference on the Utilization of Highly Qualified Manpower in 1971. In 1968, he became a senior economist in the Program Division of the Department of Regional Economic Expansion with responsibilities for electric power and water programs. From 1969 to 1973 he was a Science Adviser with the Science Council. He is now with the Social Development and Manpower Policy Division of the Department of Finance.

Dr. Boyd is author or co-author of a number of monographs dealing with the linkage between scientific and technical education and employment, including Background Study No. 28, *Education and Jobs*.



Andrew H. Wilson

Mr. Wilson was born in Scotland in 1928 and has lived in Canada since 1957. He received early education at George Watson's College, Edinburgh, graduated in mechanical engineering at the University of Glasgow in 1949 and, in 1954, received an MA for studies which included political economy and social economics.

After serving a cooperative – or “sandwich”-type – apprenticeship in marine engineering between 1946 and 1949, he was commissioned in the Technical Branch of the Royal Air Force in 1950, served for the next 18 months as a staff officer at Headquarters, Coastal Command, and was an active member of the RAF Reserve of Officers until 1954.

He gained technical experience in the design of hydraulic equipment (1949-50); technical and business experience in the ball and roller bearing industry (1954-57); further mechanical design experience, principally in nuclear physics instrumentation (1958-60); and experience in the administration of basic and applied research (1960-64).

He was employed by Atomic Energy of Canada Limited at its Chalk River Nuclear Laboratories from 1958 until 1964, subsequently joined the staff of the Economic Council of Canada and was, for four years, Secretary and Chief Research Officer of its Advisory Committee on Industrial Research and Technology.

Mr. Wilson joined the staff of the Science Council of Canada in 1968 and continued to specialize in the study of government and industry problems in the field of science policy. He served first as Project Officer for the group studying aeronautical research and development activities in Canada, then as a member of the research team associated with the Council's Committee on Industrial Research and Innovation, then as Co-Project Officer for the study of technology transfer in the construction industry, and, most recently, as Project Officer for the Council's examination of further processing opportunities in the resource industries.

He currently holds membership in the Engineering Institute of Canada and its constituent Canadian Society for Mechanical Engineering, the Association of Professional Engineers of Ontario, the American Society of Mechanical Engineers, the (UK) Institution of Mechanical Engineers, and the Industrial Developers Association of Canada.

Mr. Wilson is the author of several background and research reports for both the Science and Economic Councils and of numerous articles and papers on aspects of science policy and on other topics published elsewhere.

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Foreword

This background study was initially researched and written by Dr. A.D. Boyd and Mr. A.H. Wilson as a contribution to the more comprehensive, recently published, study of the construction industry undertaken at the request of the federal government by the Economic Council of Canada. The authors were guided in their work by a Committee of the Science Council chaired by Mr. W.G. Leithead with Members Dr. J. Kates and Mr. R.F. Shaw.

Subsequently, with the kind permission of Dr. André Raynauld, the Chairman of the Economic Council, the authors revised their material in accordance with the Science Council's publication and review procedures in order to bring it to the standard required for contributions to the background study series.

The material contained in this study is both descriptive and analytical, and it has a number of special features. For example, an assessment has been made of the total value of construction-related research and development activities carried out by the different sectors of Canadian industry, by government laboratories and by the universities, and not solely by the construction sector itself. An examination has also been made of the institutions in Canada that have roles to play in transferring technology into, and within, the construction industry. The study contains a good deal of information of a general nature that is pertinent to the problems being faced by the industry at the present time. It is worth noting, however, that the authors carried out their research work under a tight schedule in order that the material provided for use by the Economic Council should be available by the date required. However, in spite of this limitation, I believe that the authors have made a useful contribution to our understanding of the technical activities of the construction industry in this country.

Dr. Boyd is a widely experienced economist who spent four years as a staff member of the Science Council and is currently on the staff of the Department of Finance in Ottawa. Mr. Wilson is an engineer/economist who has done science policy research for both the Science Council and the Economic Council, specializing in the study of government and industrial problems.

As with all background studies published by the Science Council, this present study presents the views developed by the authors on the basis of their analysis and does not necessarily reflect the views of the Council itself or of the Department of Finance.

P.D. McTaggart-Cowan,
Executive Director,
Science Council of Canada.

Acknowledgements

During the research work, of which this study is a visible result, we received assistance and advice from a good many people. Our thanks go, in particular, to the officers of the government departments and agencies, the industry associations, the institutions, the universities, and the companies who took time to see us or who prepared special background material for us.

We acknowledge with thanks the encouragement and advice given by Mr. Leithead, Dr. Kates, and Mr. Shaw of the Science Council Committee established to guide our work. We wish especially to thank those who kindly agreed to review our study, as part of the Council's pre-publication procedure, for their most helpful comments and advice. We also wish to acknowledge with thanks the work done by Miss F.R. Wark and by the other members of the Science Council support staff who participated in the preparation of this study in its various stages. Finally, we wish to thank Mr. B.A. Keys and Mr. D.M. Caskie of the staff of the Economic Council of Canada and Mr. J.A. Dawson of the Department of Industry, Trade and Commerce for their cooperation and assistance.

A.D. Boyd

A.H. Wilson

Introduction

This background study should perhaps have a much longer title to describe its contents, coverage and conclusions more accurately, for example: *Some Observations Concerning Technology Transfer Mechanisms in the Construction Industry in Canada, with Some Additional Comments on the Innovation Process*.

As a source of information, this study is less than exhaustive in its contents and in its coverage of the industry across the country. Its examinations of past experience with regard to the innovation and technology transfer processes are broadly based, but selective. Nevertheless, it has been judged sufficiently comprehensive and original from the descriptive and analytical points of view to be regarded as a worthwhile contribution to the understanding of the way in which the construction industry in Canada actually “works”.

This study had its origins at a meeting between the Chairmen of the Economic and Science Councils, early in 1972, when it was decided that the Science Council should explore the possibility of undertaking a supplementary, technology-oriented study in support of the Economic Council’s Reference Study on the causes and effects of, and remedies for, the instability problem in the construction industry in Canada.¹

With this purpose in mind, contact between the two Councils was established at the staff level and a series of discussions was held to identify an area for study which would make use of the Science Council’s special expertise and interests. It was agreed that the broad Terms of Reference of the Science Council’s work should include an examination of modes of technology transfer into and within the construction industry in Canada, including the part played by R & D activities, and an examination of some of the impediments and incentives to technology transfer and innovation in this industry.² This proposal was subsequently approved, in October 1972, by the Science Council. The Council appointed a small Committee from among its Members to act as advisers to it and to the staff assigned to prepare a study. The staff members, the present authors, then obtained the agreement of the Committee for a plan for action, and research work began early in December.

Both the October proposal and the subsequent plan for action took into account two limitations on the potential Science Council contribution to the study of the construction industry. The first of these was the fact that the Economic Council would itself be looking into *economic* aspects of recent technology changes within the construction industry. The second was the Economic Council’s wish that the report be available to it by early April 1973.

1. This reference Study has already appeared in published form, *Toward More Stable Growth in Construction*, Report of the Economic Council of Canada, Information Canada, 1974.

2. The Terms of Reference have been given in full in Chapter I.

After ten weeks of research and interviews, followed by three weeks of written preparation, a draft report was considered by the Science Council Committee. An amended version was subsequently submitted to the Economic Council in accordance with its scheduled requirements.

In February 1974, after the text of the Economic Council's own report had been finalized, the Chairman agreed that the Science Council could consider the material it had submitted for separate publication. The normal review and approval procedures were set in motion and changes were made to convert this material to the form and standard required for a Science Council background study.

The material in this study has been presented in two principal parts. The eight Chapters contain the various analyses and discussions. The nine Appendices contain material designed to support or illustrate the earlier analyses. Sandwiched between the two principal parts is a short set of Conclusions drawn directly and without elaboration from the preceding Chapters.

I. The Framework

The purpose of this Chapter is to “set the scene” for the other Chapters and for the conclusions reached at the end of the study. It reviews the definitions of *the construction industry*, *technology transfer* and other terms used. It then provides additional information about the scope of the study and its principal source materials. And, finally, it establishes the place of the industry in the Canadian economy. But first, for the record, the *Terms of Reference* for the study in their finally agreed form should be noted. They were as follows:

- to identify specific technology transfer modes and mechanisms;
- to identify specific incentives and impediments to technology transfer and innnovation;
- to examine the implications of these incentives and impediments;
- to trace causes and effects of technology transfer; and
- to take into account in the above work:
 - i) new and improved materials and equipment used in construction;
 - ii) new and improved processes for making these materials and equipment;
 - iii) new and improved methods of assembly at the construction site; and
 - iv) new and higher standards and objectives in user requirements and satisfactions.

What is “The Construction Industry”?

The term, *the construction industry*, has been applied in this study to building and engineering construction activities. These activities, in turn, can either be narrowly or broadly defined. In the narrow sense, they include only the operation of construction contractors and sub-contractors in assembling buildings and engineering projects and the work of architects and engineers in designing them. However, *for the purposes of this study, the broad definition of the industry has been used. It includes not only the assembly and design activities, but also the manufacture and supply of the components and materials that go into building and engineering construction projects and the manufacture and supply of the equipment used on these projects.*

Put another way, the industry, in the broad sense, includes those firms which share in the receipts and expenditures for all construction-related activities. Because of this, it is perhaps the most complex industry in the whole economy. In addition, these construction-related activities include research and development done for, as well as by, all of the firms included under the broad definition, and the technical information, testing, inspection and other services available within, and to, the industry from both public and private sources. It includes the application of regulations by the three levels of government in Canada to the business of construction.

The construction industry should therefore be viewed as a *system* which includes, in addition to contractors and others engaged in assembly, engineers and design professionals, manufacturers of components,

materials and equipment, developers, and those who regulate the industry, as well as the people or the corporations that own or use the final product. In Canada, it is a large, heterogeneous and fragmented industry. Indeed, there is some doubt about the usefulness of applying the term “industry” at all when trying to describe or understand it. The concept of a “galaxy” could be used with reference to it.

The boundaries of the construction industry are not clear-cut and, in fact, change with time. Nor can the industry be considered simply as a set of companies which share similar production methods and products, but, as suggested above, only as a *system* of companies interconnected as suppliers and markets, which handle diverse products in a variety of production processes, and which may overlap in their contributions to the end-use product or function.¹

Other definitions

As used in this study, the term *technology* includes the body of technical knowledge and experience – or “know-how” – that can be applied to building and engineering construction. The term *technology transfer* refers to the diffusion of new or existing technical “know-how” into, and throughout, the construction industry. In any one instance, the transfer of technology involves either or both of two kinds of operations. The first of these is the reduction of a technical principle to practice, and the second is the transfer of the same piece of technology from use in one context to use in another.

The term *technology change* has been used in this study to identify situations with different “know-how” content. The term *innovation* may be applied to those instances in which technology change associated with a product or technique has resulted in that product or technique being widely accepted by architects, engineers and others involved in the business of construction.

Throughout the history of building and engineering construction, technology change and innovation have taken place, for the most part, in an evolutionary fashion in response to a variety of economic, social, political and technical stimuli. Sometimes luck has played an important role. This evolution has also been unevenly paced in the various sub-sectors of building and engineering, and in the different scientific and technical disciplines which the sub-sectors embrace. Revolutionary changes have been fewer and farther between and, until the last hundred years or so, have perhaps been more difficult to distinguish from those of the evolutionary kind.

One example of *revolution* in the post-World War II years might be the tower crane, which came to North America after initial development and use in bomb-damaged Europe. Another might be the use of plastic materials, thanks largely to the chemical and not to the construc-

1. See, for example D.A. Schon, *Technology and Change: The New Heraclitus*, New York, Delacorte Press, 1967, p. 164.

tion industry. An earlier example might be the highrise building of the 1880s and, going back to around 3000 BC, the development of the stone arch. The discovery of hydraulic cement by the early Romans may be considered as an example of perceptive good fortune in a evolutionary-revolutionary context. *Evolution* in the use of cement, concrete, iron and steel in construction since about 1800 has been uneven, but changes have been clearly visible from time to time. Also, developments in high tensile steel stimulated the development of pre-stressed concrete. Highrise building construction played a part in the engineering of elevators and in the control of their operations. On the other hand, the efficiency of the railroads in North America in the early 1900s discouraged the concurrent development of highway systems and the associated construction technology.

The speed of evolution has been faster in building construction than in engineering in the post-World War II years, although some changes have been applied simultaneously in both sectors of the industry. Equipment for construction has generally become larger and more efficient or smaller and more efficient, depending on the application. Building materials have proliferated enormously. New methods of construction have been developed, although these have often been less successful commercially than technically.

Additional Comments on the Scope of the Study

For the purposes of the study, the term "the construction industry" does not include the construction of chemical, petrochemical, and other similar plants. While this third sector of the construction industry is just as important economically and technically as building and engineering sectors, the time and resources available for the study made the omission of the chemical sector inevitable.

An analysis of the influence of labour unions on the introduction of new and improved technology within the construction industry is not included in this study because the study of union activities in the industry has been one of the Economic Council's own fields of special concern. For a similar reason, this study has only touched upon the question of the economic impact of the introduction of new and improved construction technology and on the role of contractors, in particular, in the technology transfer process.

This study does not attempt to define precisely the future technology needs of the construction industry in Canada nor to deal with the problems of future supply and demand affecting construction equipment and materials. The recent fuel and materials supply problems have made forecasting in such areas – at this particular point in time – even more hazardous than usual. With regard to construction-related research in the years ahead, the study has made general comments rather than specific recommendations and has not attempted to assess the needs in

the different fields in a comprehensive way.² The Economic Council of Canada has examined in some detail the economic aspects of the industry in this country in its own report, *Toward More Stable Growth in Construction*.

Source Materials

The information analysed for the purposes of this study was gathered from three principal sources: published articles, reports and papers; unpublished papers and material supplied privately on request; and a representative series of interviews. The time limitation ruled out the use of questionnaires for gathering data and encouraged the use of case studies. The geographical distribution of the interviews could not include all of the provinces, and required that the authors conduct them separately, for the most part, rather than together. Special attention was given to national and regional associations with responsibilities in the construction field. A low priority was given to interviews with individual contractors and sub-contractors in view of the extensive program that was carried out in this area by the staff of the Economic Council of Canada.

Numerically and geographically, the pattern of the interviews was as follows:

Federal government departments and agencies (Ontario)	25
Provincial government departments and agencies (Ontario and Manitoba)	13
Local government departments (Ontario and Manitoba)	4
National and Regional associations (Quebec, Ontario and Manitoba)	21
Equipment manufacturers and suppliers, materials manufacturers and suppliers, fabricators, etc. (Quebec and Ontario)	6
Consulting engineers and architects (Quebec, Ontario and British Columbia)	7
Universities and other educational institutions (Nova Scotia, Quebec and Ontario)	13
Contractors and other private institutions (Ontario and Manitoba)	9
Total	98

The Size and Economic Outlines of the Industry

The Canadian construction industry, as it has been defined for the purposes of this study, is very large by almost any measure used. In 1973, the estimated capital and repair expenditures on construction amounted to \$18.1 billion, or 15.2 per cent of gross national expenditure. In the same year, employment in construction contracting firms, alone, represented 6.3 per cent of total employment in Canada. About

2. A much more detailed report on future construction research requirements in this country has been prepared by Dr. N.B. Hutcheon: *Research for Construction*, National Research Council of Canada, Report 14005, Ottawa, July 1974. (Dr. Hutcheon recently retired as the Director of the NRC Division of Building Research.)

58 per cent of construction activities were in the building sector and the remaining 42 per cent in the engineering sector. These latter figures have been broken down in more detail in Table I.

Table I – Value of Construction Work Performed, by Type of Structure, in 1973

Type of Structure	Value \$ Millions	Per Cent of Total
Building Construction:		
Residential	5 853	32.4
Industrial	881	4.9
Commercial	1 897	10.5
Institutional	1 188	6.6
Other	579	3.2
<i>Total, Building</i>	<i>10 398</i>	<i>57.6</i>
Engineering Construction:		
Marine	184	1.0
Road, Highway, Aerodrome	1 692	9.4
Waterworks, Sewerage	778	4.3
Dams and Irrigation	67	0.4
Electric Power	1 605	8.9
Railway, Telephone	784	4.3
Gas and oil	1 502	8.3
Other	1 048	5.8
<i>Total, Engineering</i>	<i>7 660</i>	<i>42.4</i>
Total, All Construction	18 058	100.0

Source: Construction in Canada, 1971-73, Statistics Canada, Ottawa, 1974.

In addition, the construction industry is not only large, but diffused, and consists of a loose collection of units, many of them small. For example, the \$10 billion annual volume of *building* construction was performed by more than 7 200 contractors and sub-contractors employing some 150 000 people. These contractors were supplied by firms whose employees worked in sawmills, metal fabrication plants, and many other areas. On the design side alone, there were some 3 000 architects and more than 5 000 civil engineers involved; more people still were associated with the financial side of the business and in servicing the real estate market.

An outline of the elements that comprise the *housing* part of the building construction sector will help to illustrate the structural complexity and size of the industry. These elements include the preparation phase (land acquisition, planning, and zoning amendment); the production phase (site preparation, actual construction, and initial financing); the distribution phase (sale, and subsequent resale or financing); and the service phase (maintenance and management, repairs, improvements, and additions).³

Another view of the size and economic outlines of the construction industry can be obtained by reference to the appropriate listings for the industry in Statistics Canada's *Standard Industrial Classification Manual*⁴

3. Edgar F. Kaiser, and others, *A Decent Home: The Report of the President's Committee on Urban Housing*, Washington, D.C., 1968.

4. Statistics Canada, *Standard Industrial Classification Manual*, Information Canada, Ottawa. (The current Manual was first published in 1960 by the Dominion Bureau of Statistics, through the Queen's Printer.)

in the sections covering building construction, highway, bridge and street construction (including airports), other construction, and special trade contractors. On the other hand, activities related to the industrialization of construction, as exemplified in mobile home construction, have been listed in this Manual in the manufacturing industry sections.

The size of the construction industry has two major implications for technology transfer in the context of the economic efficiency of the industry. First, the size and sales potential of the construction market also provides considerable incentives for manufacturers to introduce new products into it. This means that small, incremental rates of changes in efficiency may represent large total dollar changes. Second, for many of the products of the construction industry, the research and development work associated with them must take into account the physical and social environments in which they will be placed and the ways in which they will be used in practice. One writer commented as follows:

The promise of space-age technology as an antidote to our rotting and burgeoning cities has fascinated many of those concerned with urban environment. . . . It has not been recognized that technology and design of space for the human community must respond to infinitely more complex and pluralistic human needs and choices than are involved in the production of vehicles. The demands for creative citizen, professional, and user participation in shaping the community and its individual dwelling spaces are enormously more persistent than ever encountered in the auto or aerospace industries.⁵

Two further economic factors influence the role of technology in the construction industry: the *product* of the industry, and the *demand* for the product. In the first place, consider the product. It generally consists of a building or an engineering structure in a fixed location. In manufacturing mass production, materials go to where the tools and men are. In contrast, in construction, the tools and men go to where the product needs to be built. Frequently the product is of a unique nature. It is usually heavy, often composed of bulky, local materials, and consequently cannot be moved long distances. The production process itself is complex and needs forward planning. Capital requirements are large, which results in the fact that financial charges may be more important than technology, with respect to costs. The introduction of mass production techniques requires very large investments and markets in order to succeed. These prerequisites reflect some of the problems facing the industrialization of construction. Moreover, the product, reflecting clients' tastes, is often very diverse, adding to the problem of standardization and mass production. These factors in various ways tend to

5. David A. Crane, Keyes, Lethbridge and Condon, Architects, and Associated Architects and Planners for Fort Lincoln New Town, *Developing New Communities*, U.S. Department of Housing and Urban Development, Washington, D.C., 1968. p. 3.

increase the conservatism of the construction industry. In addition, construction is an assembly-type industry, responding to society's needs.

These factors have implications for technology transfer in the construction industry. In common with industries such as food and clothing that provide man's basic necessities, the rate of growth of the "shelter" sector of the industry tends to parallel that of society in general. Technological efforts at the contractor or assembly level tend to be aimed at the improvement of the operation and process of production, rather than the materials used or the products themselves. Because of the regional orientation of construction, it will tend to reflect local attitudes and requirements, legal, social and political, including national and local requirements expressed through fiscal policy, building codes and zoning regulations.

The Links Between Construction and the Rest of the Economy

The construction "industry" in a narrow statistical sense involves the fabrication and assembly of many different materials and types of equipment from many different parts of the economy. These range from sand, cement and raw lumber to elaborate electrical and mechanical equipment such as air conditioning systems. Besides material goods, the construction industry involves inputs of services such as transportation, finance, architectural and engineering design, land assembly and development.

A convenient way to visualize the complicated network of inter-relationships is by using an "input-output" type of analysis. Table II shows the contribution of these various material inputs as a percentage of the value of all inputs. It is clear that metal fabricated products, iron and steel, cement and concrete products, lumber and plywood, other wood products, petroleum, coal, other minerals and non-metallic products, and electrical equipment are the chief material inputs to the construction industry as a whole. The figures reflect the larger proportion of iron, steel, metal fabricated and wood products in the building sector of the construction industry compared with road construction, for example, in the engineering sector. Conversely, the Table shows the importance of concrete, cement, and other minerals, plus petroleum and coal products in the latter sector. It also indicates the relatively larger proportion of metal fabricated products and electrical equipment used in the non-residential part of the building sector.

Table II – Material Input Shares by Type of Construction, 1961

Inputs	Type of Construction							
	Resi- dential	Other Buildings	High- ways	Gas and Oil	Dams and Irrigation	Railways and Telecom- munications	Engi- neering	Repairs
	(Per cent)							
Metal fabricated products	21	25	18	11	28	14	11	11
Iron and steel products	4	7	1	39	1	4	20	3
Cement and concrete products	5	5	10	3	9	0	14	7
Lumber and plywood	9	4	2	0	2	7	4	9
Other wood products								
Petroleum, coal, other minerals and non-metallic products	11	3	0	0	1	3	2	7
Electrical equipment	11	8	29	13	3	6	6	10
Wholesale Services	2	8	1	0	21	33	2	7
All other	10	8	11	7	7	9	7	10
Total	27	32	28	27	28	24	34	36
	100	100	100	100	100	100	100	100

Source: Economic Council of Canada, *Toward More Stable Growth in Construction*, Information Canada, Ottawa, 1974, Table 5-7, p. 123.

II. Governments and Construction

All three levels of government in Canada have at their disposal a number of policies, programs, regulations, "in-house" activities, and other measures through which they may influence the transfer of technology into and within the different sectors and parts of the construction industry in this country. The purposes of this present Chapter are to illustrate briefly the activities of the different governments and their departments and agencies that are related to the business of construction and to indicate how the government sector as a whole can influence construction technology transfer. *Additional information on the activities of some of the departments and agencies can be found in Appendices A,B,D,E,F and H. More detailed discussion of specific policies, programs, and so on, has been included in Chapters IV, V and VII.*

The *Federal Government*, for example:

- performs construction-related research and development work, principally in the Division of Building Research of the National Research Council, but also in the Department of Public Works, the Ministry of Transport, and the Forest Products Laboratory of the Department of the Environment. The government may also contract-out R & D work to private companies and institutions through these and other federal agencies;
- performs design work associated with federal public buildings and engineering facilities, principally in the Department of Public Works and the Ministry of Transport, but also in the National Capital Commission, Atomic Energy of Canada Limited, and the Department of Indian and Northern Affairs, and may contract out and approve design work to private companies and institutions;
- performs design work associated with private housing in the Central Mortgage and Housing Corporation;
- contracts for building and engineering construction work to be performed by private contractors, principally through those departments and agencies that also have design responsibilities, and may also act as its own contractor;
- performs maintenance and repair work on its own building and civil engineering facilities, and may also contract out some of this work;
- establishes standards for the purchase of building materials through the Canadian Government Specifications Board;
- prepares and publishes, on a regular basis, the National Building Code and the National Fire Code, the implementation of both of which are under the jurisdiction of local or provincial governments;
- publishes research reports and other technical information relating to construction, principally through the National Research Council and the Central Mortgage and Housing Corporation;
- organizes seminars and courses on aspects of construction, principally through the National Research Council and the Department of Man-power and Immigration;
- provides technical information services for the construction industry,

principally through the Department of Industry, Trade and Commerce, the National Research Council, and the new Canadian Construction Information Corporation;

- operates, through the Department of Industry, Trade and Commerce, programs of financial assistance for research, development and design activities and for the purchase of equipment for all of which companies in the construction industry may apply;

- shares with the provinces, principally through the Department of the Environment, control of the physical environment;

- performs, principally through the Department of the Environment, the Ministry of State for Urban Affairs, the Department of Regional Economic Expansion, and the National Design Council, social and physical environmental impact studies that can influence construction activities;

- sponsors, again through the Department of Industry, Trade and Commerce, the advisory activities of the Construction Industry Development Council; and

- controls fire prevention activities and equipment in federal buildings, through the Office of the Dominion Fire Commissioner.

The following other federal departments and agencies also play some part in technical activities related to the construction industry: the Standards Council of Canada; the Metric Commission; the Emergency Measures Organization; the Departments of Consumer and Corporate Affairs, Supply and Services, National Health and Welfare, and Labour; the Post Office; the Canadian International Development Agency; the Ministry of State for Science and Technology; and Canadian Patents and Developments Limited.

The federal government has legislation in force which governs the negotiation of adjustments to technological change, but which may only be applied to federal employees. It is possible under this legislation to cause certain changes to be temporarily halted and subjected to collective bargaining.¹

The *Provincial Governments*, for example:

- in most cases, perform some research and development work related to the building and engineering sectors of the construction industry, either in the Research Councils or in particular line departments, or in both;

- perform design work associated with construction, or approve the work performed by outside consultants on their behalf;

- provide financial and other support for certain types of private and public housing;

- perform building, highway, power supply, and other engineering construction work, or contract out this work;

1. This legislation has been discussed in some detail in *Governments and Innovation* by Andrew H. Wilson, Science Council of Canada Background Study No. 26, Information Canada, Ottawa, April 1973. pp. 212–220.

- perform maintenance work associated with their own buildings and engineering facilities;
- influence the methods through which local governments establish and administer building by-laws and, through these, the National Building and Fire Codes;
- administer laws relating to construction safety, the use of electricity, gas, and oil, the control of fire hazards in certain public buildings, and boilers, pressure vessels and elevators;
- provide, where the facilities exist in the Research Councils, for the performance of research, development, and testing work under contract to construction-related associations and companies;
- provide, again through the Research Councils, for technical information and industrial engineering services;
- play the principal public role in the control of health hazards related to construction and share, with the federal government, responsibility for the study of health hazards; and
- in some cases, provide, direct encouragement for the local manufacture of materials and components used by both the building and engineering sectors of the construction industry.

The Provinces of Manitoba, Saskatchewan and British Columbia, like the federal government, have legislation in force which may be applied in the process of adjustment to technology change.

The Local Governments, for example:

- where the capability exists, perform design work related to both building and engineering construction and, where it does not, approve the work performed by outside consultants on their behalf;
- where the capacity exists, perform building, street, power supply, waterworks, and other engineering construction and, where it does not, contract-out this work;
- perform all or most of the maintenance work required for their own buildings and engineering facilities;
- devise and administer, under the authority of their provinces, planning, zoning, building and fire protection by-laws applicable to construction within their individual jurisdictions; and
- share, with their provinces, the administration of health, utility and other regulations applicable to construction.

Some Comments on Government Sector Activities

From the illustrations above, it should be clear that the three levels of government have, among them, a wide variety of construction-related activities of their own and, at the same time, exert considerable influence on the private sector of the industry and on individual companies within it. But government influence may frustrate as well as encourage technology transfer into and within the industry and the companies, and it may have limited as well as general application. For example, while government laboratories do a lot of construction research, this work may

only have relevance for certain parts of the industry. While government departments and agencies publish a steady stream of new construction-related technical information, it may only be intelligible to the design professionals and to the more technically sophisticated contracting companies. While governments take proper steps to protect the physical environment, they may be doing so in a jurisdictionally competitive way.

Among the most difficult problems encountered by the construction industry in its dealings with governments are those associated with concurrent and conflicting jurisdictions and with their implications for political decision making. For example, in some matters relating to construction, such as taxation, all three levels of government are involved. In those parts of the country that have regional government at the local level, the jurisdiction may be shared between the participating municipalities and the regional or metro government – as is the case in Winnipeg, Toronto and Ottawa. Building by-laws are the business of municipalities, their Councils and their Planning Boards, but the provinces must normally approve original by-laws and changes to them. Zoning, the issuing of building permits, and building construction inspections are normally in municipal hands, but there may be jurisdictional problems between adjacent municipalities with regard to their impact. Highway pavement and bridge construction are provincial matters, except in areas under federal jurisdiction. Streets, on the other hand, are the responsibility of the municipalities and are under the technical authority of the City or Town Engineer. The provincial Hydro Electric Commissions have design, construction and inspection authority over their own power installations. Construction safety is principally under provincial jurisdiction, but the municipalities also have duties under the law.

In the National Capital Region, the federal government, two provinces, and the regional and municipal jurisdictions are all involved. Even at the departmental level, the authority of the federal government in the Region is divided, with no one department having clear overall responsibility for the federal posture. Outside of the Region, the federal Department of Public Works has the responsibility for all federal buildings but, as matter of courtesy, the Department will normally apply for local building permits and will allow inspections to be made by the local inspectors. In the same way, the Office of the Dominion Fire Commissioner will cooperate with local fire authorities. The provinces and municipalities have jurisdiction over their own public buildings.

Within the construction industry, owners, developers, architects, engineers, suppliers and contractors must concern themselves about laws, by-laws and regulations. Technical as well as non-technical matters are subject to them. The Canadian Institute of Steel Construction, for example, has stated that the first stage in the design process is to determine the owner's requirements. The second stage is to determine applicable laws and regulations, including zoning by-laws, fire safety and protection requirements, and building by-laws – notably the use and occupancy

requirements of the National Building Code. The third stage is to take account of the broad engineering and economic considerations.²

During the interviews conducted to gather data for this study, it became clear that zoning by-laws are seldom impediments to innovation in building construction except, perhaps, when they include restrictions on the appearance of structures or give rise to problems affecting adjacent jurisdictions. The issue of building permits, on the other hand, can be a matter of some concern depending on the numbers of approvals that are necessary and the time that may elapse before issue is effected. In the larger municipalities, where it is the practice to examine the submitted designs with some care, critics contend that this rigour encourages engineers and architects to be less than thorough and to let "city hall" finish off their design work. In the smaller cities and towns, the stamp of a registered professional on construction drawings is often enough to secure the issue of a permit. This situation, too, has been criticized on the grounds that professionals can sometimes make mistakes which an under-qualified issuing authority may miss.

Taxation was another aspect of the law about which considerable concern was expressed during the interviews. For example, sales taxes on equipment and materials vary from province to province, real property taxes vary from municipality to municipality, and the federal sales tax has to be added on to the provincial ones. In the industrialized building field, assemblies and sub-assemblies that are built in-plant attract higher levels of sales tax than is the case when their components are delivered un-assembled to the construction site. This tends to impede the industrialization of the building sector. With regard to corporation taxes, the permissible rates of depreciation on equipment and buildings and the allowances for building maintenance have some influence on the resources available to companies and on the attitudes of their officers toward risk taking.

There was less concern among the industry people, however, about profit-reducing and time-consuming safety requirements instituted by the provincial governments. The cost of safety is not measured so much in terms of profit-loss to the company that takes the required precautions, but in the penalties sustained by the company that does not do so. On the other hand, the policing of construction sites can stretch the resources of the provincial agencies concerned, especially in busy times. But even in slack times, when competition for the available work is very strong, special care must be taken by these agencies to guard against corner-cutting by contractors in safety matters.

The influence of individual ministers, politicians and departmental officials in the awarding of design and construction contracts cannot be overlooked in this present discussion. Governments, as a group, are important customers of private sector contractors within the construction

2. See, for example, the *Handbook of Steel Construction*, Canadian Institute of Steel Construction, 1815 Yonge Street, Toronto, Ontario.

industry, but also have their own construction activities. It is not therefore surprising that political decision making may have a profound effect on the business of construction.

Before leaving the public sector, it is important to note that the federal and provincial Winter Works programs of years past have played a part in the development of cold-weather building construction technology in this country. It is also important to note that several government agencies have, themselves, developed considerable construction-related expertise that has been widely recognized:

- the Division of Building Research of the National Research Council is a unique resource in its fields of interest and has special responsibilities for the preparation and promulgation of the Material Building and Fire Codes; the Central Mortgage and Housing Corporation builds housing in all parts of Canada; Atomic Energy of Canada Limited has been among the pioneers in the design of facilities requiring shielding from nuclear radiations; the Ministry of Transport has special expertise in the design of airport runways and harbour facilities;

- at the provincial level of government, in the Province of Ontario, for example, the expertise in design and construction acquired by the Ontario Hydro-Electric Corporation and the former Ontario Department of Highways (now incorporated in the Department of Transport and Communications) have earned them international reputations; also, the annual value of the research and other activities of the Ontario Research Foundation in support of the construction industry, as broadly defined in this report, has recently been in the neighbourhood of \$1 million per year.

To sum up briefly, there are a great many construction-related activities performed by the three levels of government in Canada which are essentially technical and contribute to the application of construction technology as well as to the discovery and development of new information. There are also a great many non-technical roles and responsibilities associated with public agencies across the country which influence the way that the business of construction is carried out under public as well as private sponsorship. Depending on the circumstances, the interpretation of these roles and the execution of these responsibilities may or may not benefit the construction industry as a whole, or sections of it. Governments and their agencies, therefore, take part in the transfer of construction technology in this country and, by their policies and actions, they may either encourage or discourage this particular activity.

III. Construction Industry Associations and Consultants

In this Chapter, those institutions and individuals whose activities are being discussed have been divided into two main categories.

(1) National and regional associations belonging to the construction industry, which have been further divided into four smaller groups:

(a) those that are national in scope and predominantly technology-based or professionally oriented, for example, the Canadian Wood Council,

(b) those that are national in scope and predominantly commercial in outlook, for example, the Canadian Construction Association,

(c) those that are regional in scope and predominantly technical or professional, for example, the Branches and Chapters of the professional engineering societies, and

(d) those that are regional in scope and predominantly commercial in outlook, for example, the Roadbuilders and Heavy Construction Association of Manitoba.

(2) Consulting engineers and architects.

The intent of this Chapter is to illustrate the scope of institutional and individual activities and to indicate how they influence technology transfer in construction. The institutions actually mentioned do not, therefore, exhaust the possible memberships of the various categories or groups. *Additional information on the activities of some of the institutions can be found in Appendices C and H.*

National Technical and Professional Associations

This first group includes associations which have specialized technical interests. One of these is the Canadian Wood Council (CWC), which is actually a national federation of associations. It promotes the use of wood products in construction, and provides technical and other services not otherwise available to its members. The Portland Cement Association (PCA) in Canada is a division of the U.S.-based association of the same name. The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) is also technically-oriented and U.S.-based, with chapters in Canada. The Roads and Transportation Association of Canada (RTAC), formerly the Canadian Good Roads Association, draws its members from governments, industry and the professions. The new Canadian Fire Safety Association, which is currently active in Central Canada, has a strong interest in the education of fire protection professionals. The Associations of Fire Marshals and Fire Chiefs (ACFM and CAFCF) have legislative, technical, and professional practice interests.

Also included in this group are the professional associations. For example, the Engineering and Chemical Institutes of Canada (EIC and CIC) and their constituent societies have as members some professional engineers and chemists who have direct contact or involvement with the construction industry, as well as others who have only indirect affiliations with it. Then there is the Royal Architectural Institute of Canada (RIAC), the Specification Writers Association of Canada (SWAC), and the Canadian Institute of Quantity Surveyors (CIQS), all of which are

exclusively construction oriented. These two associations are concerned with professional practices and with the legislative problems of the industry as well as with technical matters. Moving further away from technology toward professional practices, legislation, and so on, are the Association of Consulting Engineers of Canada (ACEC) and the Canadian Council of Professional Engineers (CCPE). All of these particular associations have provincial memberships or regional Branches and Chapters. Finally, in this first group, is the Canadian Standards Association (CSA). Its special roles and responsibilities for standards-writing and certification distinguish it from the other members.

Generally speaking, the national technical and professional associations have a number of features in common besides their strong technical interest in construction, for example:

- each has its own intelligence network and its own system of technical information dissemination;
- each is available to interface with governments, to assist, through its membership, in the writing of codes and standards, to give guidance to its membership regarding new or proposed legislation, to supplement government-operated information services and, consequently, to influence the effectiveness of the dissemination process;
- each has a strong interest in specialist education and may pursue this interest through the sponsorship of and participation in seminars, courses and conferences;
- each is in a position to advise with regard to professional practices, to bring about improvements in these practices, and to assist in the “marriage” of commercial and technical procedures;
- each has an interest in the latest research work in its fields of interest, although not all of the associations themselves participate in, or sponsor, R & D activities;
- each has contacts within the Canadian universities;
- each is able to exercise some degree of preceptive anticipation in technical matters and may, as circumstances dictate, either consult or advise its membership with regard to up-coming developments, for example, with regard to metrication;
- each has an interest in encouraging the use of its “product”, whether it be wood, steel, concrete, or professional services.

Associations such as the Specifications Writers are relative newcomers and have provided a means through which skills that are new or relatively underdeveloped in this country can be improved and more widely applied. Some, again like SWAC, may take the lead in the processes of standardization, coordination and classification as it applies to the use of technical information within the construction industry. Others, such as the Canadian Standards Association, provide for the actual development of standards, provide a national forum and focus for technical discussions between people from different backgrounds, and provide an international interface for the exchange of technical information.

A number of interesting points were made in connection with technology originating abroad, during the interviews with representatives of national technical and professional associations. For example, on a number of occasions, warnings were given that the applicability of European technology, in particular, *underdeveloped* European technology, to Canadian construction activities can sometimes be seriously overestimated. On the other hand, the direct relevance to Canada of most of the construction technology originating in the United States was often mentioned. Indeed, it became clear that the construction industry in this country has good access to *North American* technical expertise in all the specialized areas of construction technology. However, *access* to this technology and expertise does not, in practice, guarantee its *application*.

Another point made with particular regard to the United States was that the members of construction industry associations in that country are normally in a much more highly competitive situation with regard to one another than is the case in Canada and thus tend to be less communicative and cooperative. Consequently, American associations are less well placed in their dealings with governments. The view was also expressed several times that Canadian technology and technical practices in construction *can* be ahead of those in the United States. The record shows, however, that in instances where the U.S. lags in certain areas, it quickly catches up.

Encouraging though it may be, the current situation with regard to the national technical and professional associations gives rise to a number of concerns. For example, there is the seemingly universal problem of financing. Given larger resources, all of the associations maintained that they could extend their activities significantly and improve the services to their members. Association executives are continuously seeking new avenues for financial support – including increased participation in government programs already available. But, as explained by more than one executive, part of the problem lies in the financial burden imposed on member companies by the total of the annual dues to *all* of the associations to which they feel they must belong.

Other problems that concern this group of associations include the following:

- their staff efforts are too small or too thinly spread and often lack specialist depth;
- there is fragmentation among the associations themselves, from the technical coverage point of view;
- there are wide variations in the technical sophistication and learning abilities of member *companies*;
- association memberships frequently do not include the smallest of the eligible companies; while it is clear that not all small companies would benefit, membership *can* lead to the acquiring of new kinds of expertise that will keep some of them profitably in business.

National Commercial Associations

The headquarters of a significant number of the associations in this group are in Ottawa, indicating the importance attached by them to keeping a watching brief on federal legislation and to keeping in contact with federal politicians and public servants.

One member of the group, the Canadian Construction Association, is a national organization whose membership includes contracting firms and their regional or trade associations, materials manufacturers and suppliers, and individuals from all regions of the country. Other members of the group, for example, the Canadian Association of Equipment Distributors, the Mechanical Contractors Association of Canada, and the Canadian Home Manufacturers Association, represent sectional interests within the industry. The Heating, Refrigerating and Air Conditioning Institute is, in spite of its title, a commercial rather than a technical association. Its membership includes trade associations in these fields, as well as manufacturers, suppliers and others who have joined individually. One of the nine Standing Committees of the Institute during 1972, however, was the Technical Council.¹ The Canadian Manufacturers' Association should be included in the national commercial group, although the CMA plays no particular role with regard to construction-related activities of its members.

Several members of this second group of associations have very strong technical interests and activities in addition to their predominantly commercial ones. One example is the Canadian Institute of Steel Construction (CISC), and another is the Canadian Prestressed Concrete Institute (CPCI). Both have compiled and published manuals and textbooks of considerable value and have made other contributions to the design process. The CISC's membership includes steel and steel plate fabrication companies that have met the Institute's qualification standards and have subscribed to its Code of Standard Practice. The CISC also admits steel-producing mills in Canada, the U.S. and the U.K. to associate membership, but has no individual members from the construction professions. The CPCI, on the other hand, admits applicants from the specialist building and engineering sectors of the industry, from the professions, from among equipment and materials suppliers and fabricators, and from among other contractors.

In the case of the Canadian Home Manufacturers' Association (CHMA), its objectives include commercial, technical, and regulatory elements:

- to make known to the home buying public and the builder the advantage of the manufactured product;
- to represent the industry in dealing with government departments and other agencies on matters affecting the industry as a whole;

1. The HRA, as it is known, is not associated with the technically-based American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) which was mentioned in the previous section of this Chapter.

- to encourage research into improved structural methods and the use of new materials;
- to provide a basis for the exchange of information to assist members to improve their methods of production;
- to develop industry-wide standards and ethics to safeguard the public interest;
- to help achieve uniform building Codes throughout the country; and
- to assist and encourage the industry as a whole in the wider marketing of its product, including export to other countries.²

With regard to the exchange of information, the CHMA has said:

Communication is the keynote to the Association's existence. Without it, there would be little progress for the industry. From an exchange of ideas through such means as regular Bulletins, Conferences, Seminars, and from a pooling of talents through such means as continuing Committee Work and Plant Tours, the Association thus makes possible a greater prosperity for the benefit of the industry.³

The 1972 membership of the CHMA included the home manufacturers themselves, plus component suppliers and six Associate Members, including the National Association of Building Manufacturers in Washington, D.C. (the CHMA counterpart in the United States), the Housing and Urban Development Association of Canada, and two consulting firms.

The members of the national commercial associations group interact with a variety of federal departments and agencies. Of these, by far the most frequent interactions have been with the Department of Industry, Trade and Commerce. Others have been with the Export Development Corporation, the Departments of Labour, Manpower, and National Revenue, the Central Mortgage and Housing Corporation, and the Ministry of State for Urban Affairs. The regional affiliates of the national associations, where these exist, deal with provincial legislation and provincial departments and agencies and keep the National Associations generally informed of developments. All of the Associations have a deep interest in tax matters.

The national commercial associations also interact with standards-writing agencies within government and outside it. Interaction with the Canadian Standards Association is perhaps the most frequent and takes place mainly through individuals from member companies rather than through the associations themselves.

The following additional points, which came to light during the interviews, are relevant to the associations included in this second group: – the interests of some members of the group are not confined to the construction industry;

2. As given on page 1 of *Up Date '73*, the 1972 Annual Report of the CHMA, currently available from Association House, 27 Goulburn Avenue, Ottawa.

3. *Ibid.*, p. 2

- the associations are particularly concerned about the lack of firm forecasting of up-coming construction requirements, especially on the part of governments; without this information, technical as well as commercial planning becomes more difficult;
- some of the associations interact with the trade unions; two particular areas of mutual concern which have a bearing on technology transfer are the systems and conditions of apprenticeship;
- some of the associations have memberships that are underrepresentative of the volume of construction activity in the Province of Quebec;
- the associations, generally, are underrepresented with regard to small company members; on the other hand, the associations themselves may argue that they can do relatively little for the small company. As already noted, the national technical and professional associations have the same problem.

Regional Technical and Professional Associations

Although no interviews were held with associations in this group, their existence and activities must be mentioned. The principal members of the group are the regional and local branches and chapters of the technical and professional associations and societies, but it also includes a small number of regional specialist associations, for example, the Western Canada Water and Sewage Conference.

Like their national counterparts the branches and chapters have varying degrees of interest in technical matters and in licensing, professional practices, education, legislation, and regulations as these affect their memberships. Not all of the associations of this third group give priority to the construction industry. However, in the past, the associations of architects and engineers have influenced the attitudes and actions of provincial governments with regard, for example, to codes, standards and professional practices in the industry.

Regional Commercial Associations

This group includes the Construction Associations and Builders' Exchanges in the towns and cities across the country. It includes the Road-builders and Heavy Equipment, Ready-Mix Concrete, Good Roads, and Construction Associations in the various provinces, and the specialist associations for the plumbing, electrical and mechanical equipment and other trades. Associations in this fourth group can also belong to the corresponding national organizations and to the Canadian Construction Association.

Only a few interviews were held with members of this group and the findings must therefore be considered as indicative of the general thrust of their activities.

One of the most important duties of each association is the promotion of the interests of its membership in the regions over which it has jurisdiction. In Ontario, for example, the Ready Mix Concrete Association has developed and put into operation a program of certifi-

cation of ready mix producing plants. The Hamilton Construction Association, to give another example, is an "umbrella" association whose members include general contractors, manufacturing and supply companies, mechanical and electrical contractors, sheet metal contractors, and a trade section made up of firms of bricklayers, cement masons, glaziers, painters, roofers, structural steel erectors, plasterers and firms with an interest in insulation, sewers and watermains, and refractory materials work. The Association provides a forum for discussion and action affecting the construction industry as a whole in the Hamilton area. It operates a Plans Room where eligible contractors based in the area can prepare tenders for construction work on local projects. It also operates a bid depository for the mechanical and electrical trades.

Provincially-affiliated commercial associations also follow new legislative and regulatory proposals and enactments and are in a position to advise their memberships, and their governments on matters affecting construction operations.

Few of the regional commercial associations have technical committees, although there may be an avenue through which technical matters can be discussed. Technical support for members' activities may also be readily available already. The Ready Mix Concrete Associations, for example, can turn to the Portland Cement Association or to the cement companies themselves for technical help; and the Roadbuilders and Good Roads Associations can turn to the Roads and Transportation Association of Canada. The regional associations, like their national counterparts, may avail themselves of the technical assistance offered by the National Research Council's Division of Building Research.

The associations in this group have a number of other interests that have some bearing on technology transfer, for example, industrial and labour relations, construction methods and safety, education and training. They may collaborate in a variety of areas with the appropriate educational institutions and trade unions, for example, in the development of trade training and qualification courses. These associations also concern themselves with standard practice matters which determine how the business of their members will be carried out. Standard practices may have little direct relevance for technology transfer but, if simple and effective, may have significant *indirect* benefits and provide opportunities for interface discussions between the associations and the architectural, engineering and specifications-writing professions. The members of the regional associations also have serious interests in codes and standards. The activities of their members in these fields provide further opportunities for contact and discussion with government officials and politicians.

Consulting Engineers and Architects

Since the number of interviews held with firms of consulting architects and engineers in the private sector was quite small, the statements made in this section should be considered as indicative of their concerns with regard to the construction industry and to technology transfer rather

than as the results of a statistically significant sampling of the opinions of members of these professions. Also, it should be remembered that these statements do not necessarily reflect the views of construction professionals associated with contractor companies or with organizations such as the national and regional associations. The opinions of consulting engineers and architects were chosen for study – in the context of technology transfer – because of the importance of their professional roles in devising new construction concepts and in the decision making associated with the design and supervision of construction projects.

The opportunities for both engineers and architects to practice their professions in construction or consulting firms vary from region to region across the country. In the same way, the physical, geographical and climatic resources with which engineers and architects must work or contend are different. It would appear that, nowadays, the job opportunities in the largest production and population centres of the country have a special attraction for newly graduated engineers and architects, as also happens in other professional fields.

For example, about one-third of the graduating class of architects at the University of Manitoba leaves the province every year, and many go to Toronto, Montreal and Vancouver. At the same time, it has been found difficult to encourage new graduates to undertake projects in Northern Manitoba in competition with Winnipeg and the southern half of the province.

In engineering, in particular, the entry of new firms into consulting practice has been relatively easy in the past. This has had three unfortunate effects. First, the competence of new firms can be difficult to assess, second, in the view of some members of consulting engineering firms, the consulting business has become fragmented and over-competitive. The cyclical nature of the industry in the past has meant that, in “bad times”, there have been as many as 600 firms competing for work in a market able to support only half that number. Third, since reputations and future prospects have to be protected, there may be little incentive for the introduction of new materials or methods in case they should fail. The application of past practices may therefore be unnecessarily prolonged.

The same kinds of problems have arisen recently with regard to the increasing number of consulting firms that are building up and offering project management services. While this development has been generally welcomed, specially when the larger and longer-established firms have been involved, not every firm offering these services is necessarily capable of providing sufficient competence.

Although some have internationally-rated competence, there are simply not enough consulting firms in Canada currently involved in construction projects abroad. This is, in part, a function of the over-competitive situation at home. But it is also a function of the lack of government “push” behind the international use of Canadian firms. Such

activities can have spin-off effects of benefit to Canadian contractors, materials suppliers, and to owners and users in this country.

Established engineering and architectural firms in the private sector are very conscious of the expertise that they have been able to build up over the years. They have therefore tended to view with dismay examples of government agencies employing particular consultants in areas in which these consultants have little or no expertise. The engineering firms, in particular, emphasized strongly the value of experience, in addition to formal qualifications, in the establishment of professional competence.

During the interviews, the views of architectural and engineering consultants were found to diverge in a number of important ways. For example, while engineers and architects accepted the application of codes and standards as essential in construction design, the architects tended to view them as conflicting factors. The principals of engineering firms seemed to view it as the responsibility of the individual professional to keep himself up to date on technical developments within his field of competence. Architectural principals, on the other hand, showed much more enthusiasm for extending the scope and availability of technical information *systems* and tended to view the effectiveness of these systems as the biggest continuing problem associated to technology transfer. Architects were generally much more enthusiastic about encouraging specialization in fields such as specification writing and quantity surveying than were engineers. Architects were generally less enthusiastic than consulting engineers about the standard of the technical work of the Division of Building Research of the NRC, the Canadian Standards Association, and national associations such as the Canadian Institute of Steel Construction. On the other hand, it was suggested by engineers that the Division of Building Research, in particular, should complete its research projects more expeditiously and should develop more active contacts with more of the problems that are being faced in the field – problems which consultants lack the resources to investigate. At the same time, the view that government-sponsored research grants to the Canadian universities in construction-related fields should lean towards mission orientation seemed to be generally held by the consulting engineers and architects who were interviewed.

There were wide variations in the enthusiasm with which consulting firms appeared to conduct their own research experiments, both during and after construction. Follow-up experiments, in particular, may add significantly to new knowledge of methods and materials and to the optimization of designs. Much of the research work actually done by these firms was not experimental but was directed toward the extraction of pertinent information from the available literature, and toward the integration of technical, environmental, behavioural and other published material.

There was general, but not unanimous, agreement that the level of management and technical skills among the large building and civil engineering contractors in Canada is high, but the view with regard to

the management and technical abilities of smaller contractors was less favourable. From the international point of view, the efficiency of the construction industry in Canada was highly rated. However, two general points of criticism were made. First, the interchange of technical information between contractors and consultants has been inadequate in the past. Second, even in some of the larger contracting companies, the top managements have tended to be long-serving field engineers and financial people whose technical knowledge and innovative capacities are likely to be quite limited.

In summary . . .

The national and regional associations that belong to the construction industry in Canada have important parts to play in the transfer of technology into, and within, the industry. To the degree that their respective mandates permit, the majority of the associations play these parts quite effectively. Indeed, one of the principal roles of all of the associations is communication and, for this purpose, they are active in the collection and dissemination of different kinds of information from many different sources. The national and regional associations are interconnected, along specialist or generalist lines, according to their mandates, across Canada and with the corresponding associations in the United States. To a degree, some of them are in competition with one another, but this can have favourable consequences for the transfer of technology.

The situation with regard to the technology transfer activities of architectural and engineering consulting firms is both encouraging and discouraging. There are wide variations in size and competence, and the field tends sometimes to be overcrowded. Engineers and architects do not always view particular problems and their solutions in the same ways. The contributions of consulting engineering and architectural firms to technology transfer in Canada should be increased.

IV. Research and Development Related to Construction: Current Scope

The purpose of this Chapter is to examine the current R & D work applicable to the construction industry. It will also provide a setting for the discussion in Chapter V of some of the elements associated with research, development and design activities in the construction industry.

As noted in Chapter I, the construction industry may be narrowly defined to include designers and assembly contractors, or more broadly to include all the firms that are linked to construction activities by information flows or through the financial system, namely, materials and equipment manufacturers, suppliers, owners, developers and realtors, as well as contractors, architects, engineers and other designers. This present study therefore takes into account research and development done in support of the assembly part of the industry as well as R & D associated with the materials, equipment and services that are utilized by it. Accordingly, the research and development activities of companies wholly committed to construction were deemed, in this study, to be of interest, as were the R & D activities of companies and institutions having identifiable proportions of their output directed toward the construction market.

Current R & D Work Relevant to the Construction Industry

The essence of R & D is gaining knowledge and putting it to work. In the context of the construction industry, it would be useful to know the amount and distribution of R & D among the industry, government and academic sectors. But given the statistical problems discussed in what follows, it is not surprising that there are a wide variety of measures and opinions concerning construction R & D. Despite these limitations, some useful insights can be gained by attempting to put together the available statistics. They reveal not only the distribution of R & D effort, but also some of the gaps in our knowledge.

The Measurement of Construction R & D

A distinction has to be made between R & D performed *in* the construction industry and R & D performed *for* it. The complex nature of the industry presents a problem when it comes to measuring relevant R & D.

If one considers construction in the narrow sense, the R & D figures are negligible. They might be compared to those of the auto industry, measured in terms of the R & D budgets of the assembly departments of the major producers. An analogy might also be drawn between technology growth in agriculture and in construction. Agriculture, like construction, is characterized by many small producers who are widely dispersed throughout the nation. Individual farmers and individual contractors are seldom able to do their own R & D work. In parallel fashion, the federal government finds it necessary to support research in agriculture in the same way that it has given special support to research in building construction.

In past years, Statistics Canada has narrowed the definition of

construction statistics to manageable limits and has classified industrial establishments by *major* product or service produced.¹ Thus, a firm manufacturing mainly cement products or other building materials has been classified as part of the manufacturing industry and not as part of construction, and the R & D figures on the improvement of such materials have therefore been included in manufacturing and not in construction. This, coupled with the fact that many of the technical advances relating to construction design, and so on, tend to be of a practical, applied type or embodied in equipment purchased from abroad, means that typical R & D figures relating to construction in Canada in the narrow sense provide only a partial indication of technology transfer activities, many of which go unrecorded. In fact, in the past, Statistics Canada R & D figures relating to construction have been negligible and have not been shown separately.

Another point is that engineers, compared with scientists, tend to be more reluctant to write things down and depend more on verbal contacts than on R & D publications. Since construction has few scientists and many engineers, this means that technology transfer is not completely reflected in the yardsticks sometimes used to measure technical effort, i.e., by published articles.

R & D in Construction – An Overview

There are no statistics available which give an holistic picture of construction R & D. Ideally, this would include R & D in private industry, in government, federal, provincial and local, associated agencies at these levels, plus R & D done by universities and other academic or technical bodies. As noted previously, most construction-related R & D done in this country is counted under manufacturing.

From the point of view of the federal government, the principal building research agency is the Division of Building Research of the National Research Council.² Some research is done or sponsored by the Department of Public Works and other departments relating particularly to engineering and heavy construction. Provincial departments and agencies, as well as local governments, support or carry out construction-related research mainly on engineering and heavy construction. University departments also do some, a good deal of it sponsored by grants from the National Research Council. In addition, the federal government

1. If construction is defined to include "the creation of any structure (including the repair of such structure) or the alteration of the natural topography of the ground", then the following agents perform the work: (1) construction contractors; (2) the "own account" performed by the labour force of a large number of firms classified in industries other than construction and government departments; (3) work undertaken under contract by firms not classified as "construction contractors".

Statistics Canada defines (1) as the *Construction Industry*, while (1) plus (2) plus (3) is called *Construction Activity*.

2. For a full description of the role of the Division, see *The First 25 Years: 1947 to 1972*, Division of Building Research, National Research Council of Canada, Ottawa, July 1973. A much shorter description is given in Appendix A of the present study.

sponsors some construction-related R & D through its programs in aid of industrial R & D such as IRAP, administered by the National Research Council, and PAIT, administered by the Department of Industry, Trade and Commerce.³

Industrial R & D

Until recently, no data on construction R & D were collected regularly by Statistics Canada. However, this agency has now begun to report the amount of R & D performed by industry and by the federal government which is applicable to the construction market. Table III shows that, in 1971, out of a total of \$371 million spent on R & D by industry, \$6.3 million (or 1.7 per cent) was for R & D applicable to construction. This is a fairly rough estimate, because the construction market was not closely defined in the questionnaire. It shows, however, that most construction-related R & D going on in industry is done outside the assembly part of it by manufacturers of wood, electrical, and chemical products, with lesser amounts by manufacturers of metals and machinery and equipment.

Table III – Current Intramural R & D Expenditures by Market for which Products and Processes are Developed, by Industry Group, 1971

Industry Group	Construction \$ Million	Total \$ Million	Construction Per Cent of Total
Mines & Wells	—	17.4	—
Chemical-based	1.0	79.7	1.3
Wood-based	1.4	19.9	7.0
Metals	0.8	35.5	2.3
Machinery & Equipment	0.7	66.1	1.1
Electrical	1.4	120.4	1.2
Other Mfg.	0.6	8.3	7.2
Utilities	0.3	23.5	1.3
Total	6.3	370.9	1.7

Source: Statistics Canada, *Industrial Research and Development Expenditures in Canada, 1971*, Information Canada, 1974.

Federal Government R & D

Estimated federal government current intramural science expenditures on R & D and other scientific activities for 1974, whose principal application was to construction, are \$9.8 million (or 1.7 per cent) of all such “in-house” spending, as shown in Table IV. If secondary as well as primary applications are included, the total rises from \$9.8 to \$14.7 million for 1974, as shown in Table V. A breakdown, which is available for 1971, indicates that NRC financed slightly over half of R & D expenditures by federal departments applicable to construction. The Department of Energy, Mines and Resources and the Environment each are responsible for around 15 per cent of the total, the Department of Public Works is responsible for about 8 per cent, and the Central Mortgage and Housing Corporation for just under 1 per cent.

3. For details of these programs, see Appendix D.

Table IV – Principal Application of Estimated Federal Government Current Intramural Expenditures on Scientific Activities, 1974

Principal Application	R & D \$ Million	Per Cent of Total	Other Activities \$ Million	Per Cent of Total	Total \$ Million	Per Cent of Total
Construction	7.4	2.1	2.4	1.1	9.8	1.7
Total	354.8	100.0	219.9	100.0	574.7	100.0

Source: Statistics Canada, *Federal Government Activities in the Natural Sciences, 1972 - 1974*, Information Canada, 1974.

Table V – Current Federal Government Expenditures on R & D whose Principal Plus Secondary Application is Construction, 1972-74, and Application by Department, 1971

Construction (\$ millions)	Intramural	Extramural	Total
1972	11.7	0.5	12.2
1974	13.7	1.0	14.7

Application by Department, 1971

Department	\$ Million	Per Cent of Total
Central Mortgage & Housing	42	0.7
Energy, Mines & Resources	1 151	17.9
Environment	1 188	18.5
National Health & Welfare	53	0.8
National Research Council	3 431	53.5
Public Works	513	8.0
Transport	41	0.6
Total	6 419	100.0

Source: Statistics Canada, *Federal Government Activities in the Natural Sciences, 1972 - 1974*, Information Canada, 1974.

Special Tabulation by Statistics Canada for 1971.

Other Federal Programs

In addition, other federal financial support for construction was provided by university grants and assistance to industry through the PAIT and IRAP programs (see Table VI and Appendix D). Together, these account for another \$3 – \$4 million. However, totals for PAIT and IRAP are reflected in the “industry” totals in Table III.

Table VI – Other Federal R & D Financial Support for Construction

Program	Construction- Related \$ million	Total \$ million	Construction Per Cent of Total
University Grants (1971-72)	2.9	132.9	2.2
PAITA (1972-73) ^b	1.8	36.6	4.9
IRAPA (1972-73) ^{c, d}	0.277	10.9	2.5

^a These figures would be included in the “industry” total shown in Table III.

^b To 31 December 1972.

^c Preliminary.

^d Some additional assistance to construction would be provided under the *Industrial Research and Development Incentives Act*, but no estimates are available.

Sources: The National Research Council and the Department of Industry, Trade and Commerce

The Provinces

In addition, some construction-related R & D is done intramurally by the provincial research councils, and by provincial and local government departments. Data on these expenditures, as well as on other con-

struction-related R & D sponsored by these bodies at universities and other organizations, are not presently provided by Statistics Canada. One recent estimate indicates that about \$1.5 million of construction-related R & D was performed by the provincial research councils in Ontario and Alberta during the fiscal year 1971/72, chiefly on building and on engineering research respectively.⁴

The Universities

The university sector, as indicated above, does some construction-related R & D. A special analysis of the 1971/72 federally-financed grants to universities indicated that between \$1.5 and \$2.9 million can be considered as either definitely or partially related to the construction industry.⁵ In addition, universities do some R & D which is sponsored by grants or contracts from other levels of government, from industry, or from technical industry associations such as the Canadian Institute of Steel Construction. The Systems Building Centre of the University of Toronto, for example, coordinates work done under contract for the construction industry by professors and students in the Faculty of Applied Science and Engineering. At the same time, university professors, particularly in faculties of civil engineering, undertake consulting work for governments or industries on construction-related problems which may lead to R & D. Two examples of university R & D applicable to the construction industry are shown in Appendix E: wind tunnel tests on buildings by the University of Toronto Institute of Aerospace Studies and a study which was coordinated by the Waterloo Research Institute at the University of Waterloo on the pollution effects of sanitary land fills on ground and surface water. However, the largest proportion of construction-oriented R & D tends to be done by those universities with large departments of civil engineering.

The Total R & D Picture

This picture is not complete. By piecing together the available statistics, it would appear that the amount of construction-related R & D in the natural sciences and engineering in Canada currently amounts to \$25 million a year. There is some reason to believe that this figure may be low.

In 1966, the Division of Building Research and Statistics Canada undertook a survey to determine the amount of construction R & D performed by all sectors of industry, and it was estimated that this amounted to about 0.1 per cent of the total spending on construction.⁶ At the same time, the total R & D by all sectors, industry, government and university, related to construction amounted to 0.3 per cent of this

4. See Appendix B.

5. Private communication from the Division of Building Research, National Research Council, Ottawa.

6. N.B. Hutcheon, *Research for Construction*, prepared for the National Research Council of Canada, Ottawa, March 1974.

same figure. Applying these ratios to the \$18.1 billion spent on construction in 1972 would indicate an upper range estimate of current spending of around \$50 million per year on construction-related R & D. Thus, even if "measured" estimates of spending on construction-related R & D were raised by a factor of 2, they would amount to about 0.3 per cent of the total value of construction, compared with all scientific R & D which amounts to about 1.1 per cent of Gross National Expenditure.

The broad picture of R & D applicable to the construction industry may be summarized as follows: in relation to construction output and to high-growth manufacturing industry, the overall amount of R & D seems to be low, even if allowances are made for the hidden R & D that is not statistically measured. The bulk of the R & D is undertaken in industry and in governments, and a relatively small amount by universities, provincial utilities, technical associations and other bodies. In industry, the bulk of the R & D applicable to construction is done by manufacturers of materials used in the industry. In the government sector, the main role is played by the federal government through intramural R & D at the Division of Building Research and through the university grants program.

In spite of the unsatisfactory coverage of recent statistics on construction research and development in this country, steps that are now being taken by Statistics Canada should improve the situation in the future.

V. Institutional Aspects of Research, Development and Design in Construction

Apart from the actual R & D performed by organizations in or on behalf of the construction industry, there is a structure of institutions, programs and relationships in both public and private institutions which affects the nature and extent of activities related to research, development and design. The purpose of this Chapter is to examine some examples of these organizations and programs.

One aspect which needs to be mentioned is the advance of research and new technology. As Dr. N.B. Hutcheon, former Director, Division of Building Research, National Research Council, put it:

The advance of new technology is presenting new products and new situations at a faster rate than they can be evaluated in an industry in which the conversion from a traditional to a scientific base is still far from complete. There are demands for new and better test methods, performance tests, codes and standards, and these can be produced only if the knowledge of the subject involved is adequate. The continuing development of building science is, therefore, essential to the welfare of the building industry.

But the mere existence of building science is not enough. It must be put to use throughout the building industry wherever technical decisions are made about building. It must be introduced appropriately into the education and training of all those who are in a position to use it.¹

The Information Network

The majority of the interviews arranged for the purposes of this study were with people involved in research and design activities associated with construction. The following observations emerged from these discussions:

- It is clear that there is an extensive “network” of people and institutions involved in the transfer of technical information relating to construction.
- This network may operate formally or informally.
- Paradoxically, even though the construction industry can be described as fragmented and localized, there is still a large, free, two-way flow of information across international borders, particularly between the United States and Canada.
- One important factor associated with the network is the multinational corporation; another is the existence of national and international technical societies.
- The government sector, through the sponsorship of research and development, for example, in NRC’s Division of Building Research, and as a prime user of construction output in the form of buildings and engineering works, helps to ensure that such technical information is disseminated, is readily available, and is thus able to improve the operation of the open market for it.

1. N.B. Hutcheon, *The Utility of Building Science*, prepared for Division of Building Research, National Research Council, Ottawa, 1971.

- Despite the extensive information flow, numerous impediments to technology transfer exist within the industry itself, and much attention is being given to how they can be minimized or removed entirely.
- Technical information programs in the construction field, for example, those set up or sponsored by the federal Department of Industry, Trade and Commerce, are attempting to overcome these impediments.²
- It should be remembered, however, that the existence of new research information does not, in itself, ensure that it will be utilized in practice.

Use of Computers in the Construction Industry

A recent study commissioned by the Department of Industry, Trade and Commerce examined the current status and use of computers by the Canadian construction industry with a view to recommending how their use could be made more effective.³

There seems to be some resistance on the part of the industry against accepting the computer as a working tool. The reasons appear to be a lack of awareness by industry members of the computer's potential, and the mystery that surrounds the computer in terms of its language and operation, as well as a lack of user-oriented programs to satisfy specific needs.

Another reason for reluctance relates to the cyclical nature of the industry itself. Firms find it difficult to do long-term planning and development of computer applications. They are understandably hesitant to commit funds to these developments if they are unlikely to be able to make use of them.

The uses of computers are mainly in the area of project planning, budgeting, cost control, and general accounting and payroll. Among engineering firms, however, particularly those doing structural design, the computer has had a greater degree of acceptance than in the case of other sectors. Architects have used the computer mainly for accounting and project control, although some architectural firms have spent a good deal of money developing new programs or modifying existing packages to produce architectural design programs.

In the case of general contractors and developers the computer is used mainly for project control and various accounting activities. In quantity surveying, the principal computer application is as a data bank for pricing information. However, no known developments are under way to use the computer for matching up price information with specifications. This process is still done manually.

Some suggestions were made aimed at increasing the effective utilization of computers in the industry.

- Further work still needs to be done to determine where the computer

2. The programs and the impediments are discussed later in this Chapter, and more details of the programs are given in Appendix F.

3. *A Study of Computer Utilization in the Canadian Construction Industry*, prepared for the Department of Industry, Trade and Commerce by Demers, Gordon, Baby Limited, February, 1972.

can make more significant contributions to increasing the productivity and the efficiency of the industry.

- Governments should improve, generally, the interchange of computer programs.

- An analysis of cost trends should be done to determine what the potential benefits to the industry could be in view of recent developments in computer hardware and software and communications technology.

- Some industry associations have taken the initiative to improve the effectiveness of computer use in construction, but these activities should be extended to all parts of the industry.

- Efforts should be made to develop a problem-oriented language and standardized procedures in order to simplify problem solving using computers.

The use of computers in the information transfer process is also growing. The new systems are being designed in order to make full utilization of their capability.⁴ However, it must also be recognized that, for such new techniques to be cost-effective, particularly in their demand on users' time, they should be designed to "absorb complexity": they should be simple to use and should avoid passing complexity on to the user of the systems. The computer will come into general use when it is as easy to use as a slide rule, a calculator, or a telephone.

Programs Related to R & D

There is an "infrastructure" of programs, practices and relationships in government, industrial and educational institutions which affects the scope and quality of research, development and design. In this section, the focus is on technology transfer, and the aim will be to describe exactly how a particular information channel for construction technology is operating and what impediments, if any, there may be to the information flow. To anticipate somewhat, there is a general feeling within the industry that the channels for the transfer of technical knowledge need to be improved. The chief problem appears to be the need to establish more effective linkages between research, development and practice.

Some of the impediments may be called "lateral discontinuities", for example, between the academic disciplines in educational institutions, as well as in the professions associated with the construction industry itself. Views differ on whether the main emphasis should be put on the need for more research and development to keep up with the rapidly changing requirements of society and technology, rather than on the need to improve the dissemination of the existing information. The differences of opinion seem to be strongest between those who generate the information and those who use it. Those who generate tend to think that more R & D is needed to solve current problems. On the user side, there is the feeling that too much information is available already, or that too much of it is of the wrong kind. The knowledge already avail-

4. See Appendix G for further discussion.

able needs, therefore, to be communicated more effectively and put to work. To deal with the information overload problem, better screening procedures will be required to reduce the amount of information going to users in manageable proportions. In the same way, relevance tests should be applied to new research projects.

Another form of lateral discontinuity arises from the demand from many in society, through governments, building developers, and others, for feedback from users to the industry. This would be particularly helpful to designers, who may feel that the needs of users should be identified more precisely before the attempt is made to search for the appropriate technology to meet them. The emphasis, in short, must shift from “what can be done” to “what should be done”.⁵ This particular problem reflects the fragmented structure of the industry.

In addition, a number of comments were made during the interviews to the effect that a larger role should be played by government in testing and related experimental work. More risk money, for example, should be provided by the government sector to do a greater amount of testing and full scale experimental work that tends to be very costly. There is little incentive at the present time for commercially-oriented firms to do this kind of work on their own, although the social benefits of knowledge gained in this way may be very high. There is also a need for a new “quick reaction” testing body in the government sector. This service is not being provided by the Division of Building Research, for example, since it has neither the facilities nor the budget to do the job.

Federal Government Financial Support

The federal government supports research and development in industry generally – directly, through grants, loans and contracts, and indirectly, through laboratory and information services. Part of this assistance goes to the construction industry. Government support for testing and other similar activities is discussed later in Chapter VII.

The principal federal financial support for industrial research and development is channelled through a number of special programs designed to develop the R & D capacity and capability of Canadian industry as a whole. The programs that apply to the construction industry are IRAP, PAIT and IRDIA.⁶

The *Industrial Research Assistance Program* (IRAP) was begun in 1962. Its major objectives are to create new or expand existing research facilities within industrial companies and to facilitate communications between researchers and government in industrial laboratories. Under this program the National Research Council pays the direct salaries of scientists, engineers and technicians in approved research projects performed by industry, while industry itself pays for equipment and overhead. The financial assistance is concentrated mostly on relatively long-

5. See, for example, R. Ian Clapperton, “Developing a Technology Transfer System”, *Building International*, November/December 1972. p. 338.

6. See Appendix D for additional information on the IRAP and PAIT programs.

term applied research in the sciences and in engineering, and on the development of prototypes and laboratory bench processes. In broad terms, about 2.5 per cent of the funds allocated under IRAP have gone to construction-related projects. In 1972-73, for example, \$277 000 out of a total of \$10.8 million were allocated in this way.

The *Program for the Advancement of Industrial Technology* (PAIT), administered by the Department of Industry, Trade and Commerce, was begun in 1965. The basic purpose of the program is to improve technical capability and to expand innovative activity throughout Canadian industry. It provides financial assistance for projects concerned with the development of new and improved products and processes which incorporate new technology and which offer good prospects for commercial exploitation in domestic and international markets. As a rule, the Department contributes, on a grant basis, up to 50 per cent of the total estimated cost of approved projects. In 1973, for example, an estimated \$36.6 million was committed to the program, of which about \$1.8 million (or 4.9 per cent) could be regarded as related to construction. PAIT, therefore, is directed to the development stage of the innovation process while IRAP is focussed on applied research.

Some assistance may also be granted under another program administered by the Department of Industry, Trade and Commerce, the *Industrial Research and Development Incentives Act* (IRDIA). It has not been possible to make estimates of the part of this program that can be considered relevant to construction.

Indirect Federal Support for the Construction Industry

In addition to the financial support mentioned above, federal government departments and agencies provide scientific support for industry, both through their own intramural scientific activities, and through information services to industry. The outstanding example of this service is the *Division of Building Research* of the National Research Council.⁷ The Division of Building Research (DBR) was established at the National Research Council in 1947 to assist the building sector of the industry. The Division provides centralized research services covering various aspects of the building research, from the fundamental properties of materials to the development of winter construction techniques. These research activities are the core of the Division's work, and they support as well as feed its other activities. The Division also provides technical support to the Central Mortgage and Housing Corporation, assistance to NRC associate committees which have responsibility for the National Building and Fire Codes, and assistance to other standards and technical committees, both national and international. In addition, it provides extensive information and advisory services to the construction industry. Some limited testing for individual firms is carried on, particularly when special facilities are required and are not available elsewhere.

7. See Appendix A for more information on the Division of Building Research.

Those involved in design work within the construction industry see the need to improve the bridge between the research and development performed in government laboratories, including those within DBR, and the application of it in the field. For example, they see the need for a "fast-reaction mechanism" for processing information urgently needed by designers as well as throughout the industry. There are many who feel that DBR has not been able to provide this mechanism. But the critics do not always recognize DBR's current limitations to a manpower complement of only 70 professionals (220 people in all) and an annual budget of around \$4 million. The capability of the Division to perform this particular kind of service is therefore limited.

The National Research Council also operates the *Technical Information Service* (TIS) for the benefit of Canadian manufacturers. The service is divided into three sections: industrial engineering, technical enquiries, and technological developments. Although TIS field officers do not usually call on builders or contractors, the organization will accept enquiries or requests for information from any Canadian firm, organization or individual, including contractors, architects, manufacturers and potential users of materials or services.

In 1972, an estimated 19 firms associated with the construction industry were given assistance by the Industrial Engineering Group, representing about 3.3 per cent of the total of 575 calls for it. In 1972, out of some 3 000 written replies handled by TIS staff, an estimated 121 requests dealing with buildings and structures were handled by the Division of Building Research on behalf of TIS. In addition, a further 400 to 500 enquiries relating to building materials, construction equipment, and so on, were handled by TIS staff. In the Technological Development Section, which provides a literature awareness service to all sections of Canadian industry, about 300 to 400 of the 4 000 to 5 000 firms that have completed an *Interest Registration* card, have indicated an interest in subjects such as paving and the use of plastics as building materials.⁸

In 1967, the Department of Industry, Trade and Commerce launched its *Building Equipment Accessories and Materials* (BEAM) program specifically to assist the construction industry. One of the principal concerns of the program has been the dissemination, storage and retrieval of technical information. This work is still being developed and has now been taken over by the new *Canadian Construction Information Corporation* (CCIC).⁹

The Provinces

A certain amount of research is undertaken by provincial departments and by provincial hydro-electric and other facilities relating, particularly, to engineering and heavy construction. For example, information avail-

8. For additional information on TIS, see Appendix F.

9. For information on CCIC, see Appendix F.

able on road research in Canada for 1972 indicates that there were 282 projects that could be considered directly related to construction. Of these, 31 per cent were *sponsored* by the National Research Council and 36 per cent by provincial departments of highways. On the *performance* side, universities undertook 41 per cent of the projects while provincial highway departments undertook 26 per cent.¹⁰ Both provincial departments and utilities are generally well connected to the world technology sources in their fields of interest. For example, the Department of Transportation and Communications of Ontario maintains close links with bodies involved with research and technical information on highways in the United States, as well as in the U.K. and in Europe. Regular information is exchanged on a two-way basis and it would appear that both utilities and departments are in the forefront of technology in their respective fields, which relate, particularly, to engineering and heavy construction.

Academic Institutions

As indicated above, academic institutions are involved in information and technology transfer in construction through the education of students, through research, through technical publications and seminars, and through contract and consulting work undertaken by professors.

The attitude taken by most of the faculty members interviewed was that the research projects accepted for performance in the universities should be of value in the education of the students since this is the primary mission of these institutions. Some professors, however, undertake routine consulting work in the construction field, and it is now generally accepted that members of engineering and architecture faculties should devote part of their time and attention to industry-related problems. In certain instances, a particular university will be the only repository of some special kind of technical expertise or experimental equipment. In such cases, the role of the professor in contract research is as a "special expert", for example, as a consultant to a firm of consultants.¹¹

A number of universities in Canada offer academic programs related to construction, for example, the Universities of Waterloo, Toronto, Montreal and Sir George Williams. Programs *are* offered by others, but it was not possible in the time available to do an overview of programs in the Atlantic Provinces or Western universities.

One interesting example is the *Construction Management Option* program at Waterloo, which was begun in 1971 with the cooperation of the Canadian construction industry. This is a graduate program that leads to the degree of Master of Applied Science. In order to enter the program, the student must have at least two years' experience in industry,

10. *Road Research in Canada, 1972*, Roads and Transportation Association of Canada, Ottawa, 1972.

11. This is the kind of university-industry relationship which the Science Council has supported and favoured in its reports and studies.

as well as a bachelor's degree in either engineering, science, architecture or economics. Non-degree students may enter on a diploma basis. It consists of a one-year postgraduate course in construction planning, economics and finance with application to construction, law and labour relations, construction methods and equipment, as well as selective offerings and a research project. It has had an enthusiastic response from students, most of whom are sponsored by their previous employers to whom they return once they receive their degree. The program, however, is small – nine or ten students each year. The industry has offered the university full cooperation and provides speakers from industry for seminars and course work. A number of companies have also offered financial support.

With regard to the formal education of architects and engineers, there has been considerable support in recent years for the “cooperative” type of university program which allows for equal amounts of theoretical training and practical experience to be absorbed during alternate periods through four or five undergraduate years.

At the same time, one feature which can be found in universities, generally, is the existence of narrow scientific or professional specialization, along with interdisciplinary barriers, and a focus which is often unrelated to the construction industry or its problems. Against this must be placed the need for more people with a knowledge of project management or with broad interdisciplinary backgrounds – a need recognized by both the universities and industry. More university courses and programs related to construction should therefore attempt to provide a better background for students planning to enter the industry.

As with the universities, the chief role of the relatively new post-secondary institutions such as the Colleges of Applied Arts and Technology (CAATs) in Ontario and *Les Collèges d'enseignement général et professionnel* (CEGEPs) in Quebec is to educate and train good people, some of whom will enter the construction industry. This, in turn, will help solve a problem mentioned by a number of people during the interviews, namely, the inability of the industry to absorb more technology because some of those presently working in it lack the necessary training. Already, a very important contribution has been made by non-university institutions at the postsecondary level. As Table VII indicates, enrolment in construction-related programs in Ontario CAATs in 1970-71

Table VII – Enrolments and Graduations in Construction-Related Programs, Ontario Colleges of Applied Arts and Technology, 1970-71

Programs	Enrolments	Graduations
Technology (3-year) ^a	353	73
Technician (2-year) ^b	541	117
Total	894	190

^a Includes “construction”, “architectural” and “structural” technology.

^b Includes “construction”, “architectural”, “concrete”, “drafting”, and “structural” technicians.

Source: Ontario Ministry of Colleges and Universities, private communication, 16 February 1973.

was 894, while graduations totalled 190. Postsecondary institutions in various parts of the country offer programs and courses related to construction. Institutions such as Algonquin College, in Ottawa, have local committees which advise on construction-related programs and curricula.

A recent study was conducted for the Construction Industry Development Council (CIDC)¹² of the education needs of managerial, professional and technical personnel in the construction industry and the educational resources currently available to meet them.¹³ Although the viewpoint of industry is that more education is required emphasizing management subjects and a cross-discipline approach, construction firms feel little obligation to encourage it. For their part, educators regard the industry as uncomplicated and unstable, and tend not to counsel students toward careers in construction. To overcome the lack of formal contact between the industry and educators, the study recommends the formation of a National Construction Industry Education Institute.

Industry

There was a consensus among the members of the design professions who were interviewed that the cyclical nature of construction activity in the past has been one of the principal impediments to technology transfer in this country. It has lead, for example, to recurring discontinuities in the employment patterns of technical personnel. In one instance specifically mentioned, the number of employees in a consulting firm dropped from 65 to 15 in the course of a single year because of a lack of new projects. In such periods of decline, many firms have laid off – or lost – good people who have not returned to the industry. And, while some of these companies have survived to start again at “square one” when construction volumes recovered, others have gone out of business altogether. Experience of similar discontinuities in relation to the construction cycle was also found during interviews with associations and companies not specifically concerned with design and consulting work.

The available evidence suggests, therefore, that technology transfer activities have in no way contributed to the instabilities that have occurred in construction volumes but, rather, that the *existence* of recurring instabilities discouraged technology transfer. Also, no substantial evidence was uncovered during the study to support the view that any one part of the instability cycle discouraged technology transfer and innovation more than any other part. Even in busy times, it is important to distinguish between those people who are simply busy at their jobs and

12. The CIDC was formed in 1970 as an advisory body to the Minister of Industry, Trade and Commerce on matters concerning the construction industry. Its membership includes senior representatives of industry, labour and government. The Council was a strong supporter of the study of the industry which was subsequently assigned by the federal government to the Economic Council of Canada.

13. Urwick, Currie and Partners Limited, *Construction Industry Management Education Needs: The Construction Industry Education Institute*, a Study Conducted for the Construction Industry Development Council, October 1973.

those who are also involved in the technology transfer process. It is also important to remember that busy people are not necessarily communicative ones.

There was a consensus among the industry people interviewed that the desire to avoid risk in construction tends to foster conservatism in the use of new methods and materials. But this risk-induced conservatism often applies to the use of several new materials *together* for the first time or to the combination of new materials and methods. This may require the assessment of the materials and methods on a scale that would be financially unattractive for the individual firm to undertake. Government departments and agencies that have the capability and financial resources are in the best position to help overcome this problem, and they sometimes do so in their own construction projects. Nevertheless, many in the industry feel that this facet of technology change is not adequately covered by current government programs and requires additional financial, material and professional support.

Another important aspect of the tendency toward conservatism in the industry is the pertinence of the problem of legal responsibility for designs and for the supervision of professionals. Typically, the professional is personally liable and cannot incorporate his personal responsibility, yet he must contend with a "joint-and-several" liability alongside the limited liability of the contractors. In the opinion of some observers, this legal "reality" has killed many innovations. However, the breadth and depth of the examinations that would be required to deal with the relevant parts of the law satisfactorily, when set against the time available, are the principal reasons for the omission of a discussion on liability and responsibility in this present study.

Additional Comments

The general thrust of the views expressed by people performing research, development and design functions in the construction industry, with varying degrees of emphasis, is in support of the thesis that the industry does not need more and more technology but, rather, that existing technology should be more effectively digested and developed and put to work. But it is also clear that if the existing *information* about methods and materials is to be put to better use, better *communications* will be required. The efforts to do this will require the support not only of research institutes but also of government agencies, contractor firms, the design professions, the universities and institutes of technology, and many others.¹⁴ They will require improvements in the mechanisms, institutions, programs, relationships, and people that are *involved* in the process of technology transfer. The most productive relationship between the research laboratories, the industry, and the education sector will, in the future, require greater emphasis on activities, including research,

14. See also, N.B. Hutcheon, *The Utility of Building Science*, op. cit.

which are specially directed toward the more effective *dissemination* of existing knowledge.

One of the key factors in the effectiveness of any construction information system is the quality of the information that is put into the system by manufacturers of building materials, and others. A second important factor, mentioned during the interviews by architects and other design professionals, is the provision of more information related to their own particular needs. However, some design professionals tend to be reluctant to exchange technical information freely. Others feel that technical information alone is not adequate. Data on the economic, sociological, psychological, and regulatory aspects of construction are necessary to meet design needs fully. These kinds of information must therefore be built into the information system effectively in order to bridge the knowledge gap from the designer's point of view.

Because of the difficulties associated with the extent of the available technical information and with its complexity, the individual designer may not always search the information *system* adequately in every case. To help him, the designer may sometimes need a colleague to sift through the system and perhaps act as a technical translator or interpreter. This particular aspect of the operation of an information system is being complicated further by the rising standards of safety, environmental and other constraints on designs that must now be related to users' requirements.

VI. Equipment and Materials for Construction

The purpose of this short Chapter is to discuss the role of technology transfer in relation to the supply of equipment and materials used and consumed by the construction industry in Canada. This information has been drawn from the interview program as a whole and not solely from the manufacturing, fabricating, supply companies, and contractors with whom contact was actually made.

The bulk of the *equipment* currently used by the construction industry in Canada was designed, developed and manufactured abroad, principally in the United States, but also in countries like Britain and Japan. In contrast, the bulk of the construction *materials* consumed in this country were mined or quarried, refined, grown, fabricated, and manufactured into end products somewhere in this country.

Equipment

Canadian manufacturers of construction equipment have not failed completely to capture a share of the available market. For example, the majority of the grader and snow removal equipment and a significant proportion of the paving machinery, air compressors, pumping equipment and tower cranes now in use were built, if not always designed, in this country. Some types of Canadian-designed and -built equipment, notably graders, have also been exported in significant numbers.¹

The problem for Canadian producers in recent years has been to supply the required types of equipment competitively. Prior to the Depression, a significant proportion of Canadian construction equipment requirements was met from domestic sources. During the 1930s, there was little construction activity anywhere in North America. But World War II, with its enormous demands for construction equipment of all sizes and types, gave U.S. manufacturers, fabricators and suppliers the competitive edge in the post war years. With few exceptions, Canadian companies have been unable to regain positions of advantage in the market place. Also working against them have been the twin difficulties of achieving economies of scale in production and of acquiring new kinds of technical sophistication in competition with foreign manufacturers who already have this sophistication and the incentive to use it. Even the rigours of construction in the cold Canadian climate have not been of much advantage to domestic manufacturers, since winters in the inhabited parts of this country are remarkably similar to those in the bordering states of the U.S., where many of the American producers are located.

The manufacture and supply of very large, highly specialized, and technically sophisticated types of construction equipment have posed particularly difficult problems for Canadian firms. Not only has the North American market for them been quite small, but the growth and concentration of technical capability in the United States has left current

1. See, for example, the notes on the Dominion Road Machinery Company Ltd. in Appendix G.

production in the hands of U.S.-based manufacturers, fabricators and suppliers.² The relatively small size of the *Canadian* share of the North American market, and of its size in comparison with the European Community market, has also affected the ability of firms in this country to compete successfully in the production and supply of technically complex sub-assemblies, components, and parts for construction equipment. Notable among the components are power transmissions and prime movers. On occasions, however, some components have been built in Canada and shipped to the U.S. for the assembly of the complete equipment unit, and then returned to Canada. This procedure might involve truck-mounted cranes, for example, where the truck is made in this country and the crane in the United States.

The "normal" lifetime of a piece of construction equipment in Canada is around seven years. During this time, any one piece can have several owners and the circumstances of changing hands can vary considerably. For example, a large contractor may simply leave behind the equipment used in a remote construction project because the costs and inconvenience of removing it for use at another site are financially and physically unattractive. This will be particularly true in the case of equipment designed or modified specially for use at the remote site. In these circumstances, the firm or public agency responsible for the maintenance of the completed project can acquire useful equipment, often at little or no cost. On the other hand, small general contractors in the cities seldom buy new equipment and rely, instead, on a trade-in process or on a leasing arrangement.

For contractors of all sizes and talents, the business of selecting equipment to be bought or leased is usually a lengthy one involving consultations with manufacturers and dealers and the canvassing of experience among other contractor companies.³ Price, or leasing cost, is not always the key element in the acquisition of construction equipment. Factors such as reliability, low maintenance, the availability of spare parts, and operator safety, among others, have to be taken into account. In the process of contractor-dealer-manufacturer consultations, some of the operational experience of the contractor is fed back to the designers of the original equipment, although it is not possible to estimate how effective this feedback mechanism actually is in practice.

In the construction field, new types of equipment tend to evolve from older types. In the case of vehicle-mounted equipment, this

2. On the other hand, the position of Canadian manufacturers of large, specialized and sophisticated types of equipment for the forest industry has been subject to less competition from foreign manufacturers. The difference seems to lie, in part, in the uniqueness of the equipment required in the B.C. forests, compared to the North America-wide applicability of most of the special construction equipment and, in part, on the fact that Canadian firms have been able to stay ahead of their foreign competitors.

3. Construction equipment dealers are normally required to have technical capability and experience before receiving their franchises. But they are supported by the capability and experience of the manufacturers they represent, whether these be located in the United States, in Canada, or elsewhere.

evolution may result from advances in vehicle technology as well as from advances in the technology of the mounted equipment. For any one particular type of equipment, there may be model changes of an evolutionary kind from year to year, bringing with them some spare parts problems near the end of a model's life. But, in view of the relatively short working life of most equipment used in construction, as opposed to its use in maintenance work, the problems of technical obsolescence need not be serious.

More serious, however, may be new government safety requirements in the design and/or operation of construction equipment, particularly when these requirements are applied retroactively to existing as well as to new equipment, within an unduly short time period. This kind of situation may be complicated further if the requirements are not being applied right across Canada and in the bordering states of the U.S. In such circumstances, there is a tendency for the older pieces of equipment to be "dumped" in the "non-requiring" provinces and states, provided that the transportation and other costs of doing so are not unreasonable. One set of restrictions that is being felt increasingly by equipment manufacturers, as they attempt to build larger and more efficient units, is the imposition, by government authorities in the provinces and states, of axle loading limits for vehicles using different classes of highways and bridges. Such restrictions are normally reasonable, unless there are considerable variations between neighbouring jurisdictions.

The needs of Canadian construction contractors for up-to-date and efficient equipment and the relative paucity of domestic manufacturing capability and capacity have not gone unnoticed by the federal government. The Department of Industry, Trade and Commerce is responsible for encouraging both the efficient use and the manufacture of construction and other equipment in this country. Under the terms of the Machinery (MACH) Program, for example, duties payable by importing companies under Tariff Item 42700-1 may be remitted, allowing Canadian machinery users to acquire, at the lowest possible cost, capital equipment not available from Canadian sources.⁴ This particular provision can also be applied in a limited way for leasing arrangements and, for this purpose, a special schedule of tariff payments has been worked out by the Department of National Revenue in consultation with the Canadian Construction Association. At the same time, the program enables Canadian machinery producers to derive incentive and encouragement from the tariff by extending the duty protection to them once they are in a position to supply specific items on demand. The category "Canadian machinery producers" can, of course, include subsidiaries of foreign-based manufacturers who find production in Canada attractive.

4. Tariff Item 42700-1 covers a broad range of machinery, including general purpose machinery, metalworking and woodworking machinery, materials handling equipment, various types of special machinery used in the pulp and paper and plastics industries, as well as construction equipment.

Materials

As noted earlier, the circumstances associated with the manufacture, and supply of construction equipment and the supply of materials are quite different. One part of the reason for the predominantly domestic production of materials is the cost advantage enjoyed by local sources in the supply of bulk materials. For example, quarried aggregates are normally sought from sources near the projects for which they are intended because of the cost of transporting them over longer distances. Another part of the reason is the technical competence and market presence of certain Canadian-based manufacturers of materials, including those that can be used in all parts of the country, for example, plywood from British Columbia, and explosives from Quebec.

The companies that manufacture, fabricate and supply construction materials in Canada come in all shapes and sizes. Some serve local markets, and do so effectively from both technical and commercial points of view. Other larger companies serve regional markets or the country as a whole. Under “normal” circumstances, the larger companies have some advantages:

- They are able to offer pre-bid and post-bid technical advice and back-up services to tendering contractors.
- If they are affiliated with foreign companies, they will usually have access to experience gained abroad. Alternatively, if they are themselves active internationally, their own experts will have been able to gain additional foreign experience.
- They are often able to support larger and more comprehensive R & D and testing activities.
- If they have diversified product lines, they will have other divisions, in chemicals, for example, that can contribute to advancing *construction* technology even though their principal markets are not in this field.
- They will be better able to ride out the cyclical instabilities to which the construction industry has been subject in the past.

On the other hand, and at the other end of the scale, any small company that has profitable returns from the sale of bread-and-butter products should be able to provide a good many of the services available through the larger companies.

In contrast with the situation in construction equipment production, the unit price is often the most important element in the specification and purchasing of construction materials. In practice, those materials manufacturers, fabricators and suppliers who save their customers money and who provide, at the same time, equivalent quality, delivery, and other services will usually win more business. Suppliers who simply market a better product, without its also being less expensive and, on a unit cost basis, more effective, will not be able to keep this product in the market for very long. However, cost savings need not arise solely from the price of the construction material itself. The use of a particular new material may also bring about a reduction in the cost of maintaining the structure in question.

One of the important steps in the achievement of commercial success in the production of Canadian construction materials seems to be their acceptability and acceptance in the United States construction market. To enter this market, a product must of course conform to the requirements of U.S. federal and state standards, codes, and other regulations, and it must be free from transportation penalties. It helps, too, if a Canadian manufacturer can acquire the status of "nominated supplier" to particular American companies or government agencies, although the award of this status may require that some or all of the nominated supply has to be produced in the U.S.

In the building construction sector, one of the unanswered questions at the present time is whether much money can be saved through the use of cheaper materials, when the cost of these materials is increasing less rapidly than the cost of labour and other elements in a house or apartment building. If cost savings are likely to be marginal, the incentive to be innovative will be reduced as far as materials are concerned. But it may also be argued that the production of materials for the *building* sector of the construction industry has now reached the stage at which too many of them are available, that obsolescence is in fact being artificially and prematurely induced, and that the competition between steel and other metals, concrete, wood, and plastics, for "cosmetic" rather than structural purposes, has become rather more wasteful than efficient.

The Department of Industry, Trade and Commerce carries the principal responsibility at the federal level for encouraging the use of Canadian-made construction materials in the domestic and export markets. At the provincial level, the Departments of Industry and Commerce, or their equivalent, usually have responsibility for ensuring the use of basic materials from local sources and for encouraging subsequent production activities where these are likely to be profitable as well as feasible.

All of these departments, and some others, have a vital interest in the effectiveness with which construction materials technology is disseminated throughout the industry. At the federal level, a number of programs have been established to encourage R & D in construction materials and to make the process of transfer more efficient. These have been discussed earlier in Chapters IV and V. In Manitoba, where approximately three-quarters of all construction materials and supplies are currently being "imported", special committees have been assigned to study the situation on behalf of agencies of the provincial government.

In spite of present government help and in spite of the parts played by cost and functional attractiveness in the commercial success of most new materials, the interviews with manufacturers, fabricators, contractors and associations produced critical comments on the lack of the use of federal and provincial government purchasing powers in the encouragement of technological advances in the manufacture of construction materials and in their application to construction design, methods and

maintenance. A significant part of this criticism was aimed at the lack of government support for the development of industrialized building.⁵

Finally, the following are examples of the kinds of mechanisms through which technology is transferred in the field of construction materials:

- The competition which exists between three of the principal construction materials, steel, concrete and wood, has encouraged technical progress and change throughout the industry. Indeed, such competition is openly welcomed by the national associations and other leading advocates for these materials, as well as by consulting engineers.

- A fourth construction material, plastics, has been growing in importance in non-structural applications during the past two decades. In recent years, however, this growth has been hampered by the lack of a national association to promote research and the better understanding of the potential uses of plastic materials in the business of construction (as the CISC, the PCA and the CWC now do for the other three materials).⁶

- Advances in fields other than construction materials, for example, the chemistry of plastics and adhesives, and the mechanics of fasteners, can significantly increase the options for production open to manufacturers and the options open to owners, architects, and engineers for their application.

- Recent developments in the energy field will, over the coming decades, significantly change the kinds of materials that are used in building construction, as will changes in the life styles and in the quality assurance requirements of people generally.

- Fashion-consciousness is a factor that must be considered in relation to change in building materials, and architects as well as owners and others may influence the trends of fashion. The influence of the United States on building construction fashion in Canada is quite marked.

- A manufacturer, fabricator or supplier anticipating adverse customer reaction to a new construction material is unlikely to put that product on the market.

- The owner of a building or facility, either by himself or under the influence of his principal agent, will usually have the last word with regard to the choice among alternative materials. However, there may be other factors involved, for example, it can be politically risky to put up a concrete structure in a “steel town”.

- Fragmentation among contractors and over-competition between consultants does not help technology change and innovation in construction materials.

- One of the problems faced by a construction contractor operating outside the Quebec City–Windsor Corridor is that he cannot always

5. Industrialized building – or systems building – has been discussed in more detail in Appendix J.

6. In the future, however, the growth of plastics as construction materials may be further hampered by problems of supply and by their past history in fire situations.

obtain qualified technical advice from materials manufacturers, fabricators, or suppliers for the price of a local phone call.

To conclude this Chapter very briefly, the manufacture of construction equipment in Canada is at a low level at the present time and the opportunities for Canadian manufacturers to benefit from production and technology transfer opportunities outside their particular product lines are rather limited. This situation seems unlikely to change for the better in the short-term future. On the other hand, the levels of production and transfer activities in construction materials, components, and so on, are considerably higher and are unlikely to be reduced significantly in the absence of a serious market downturn. At the same time, owners, distributors, architects, contractors, and others not associated with the production of equipment and materials need to have access to relevant technical information regardless of its country of origin.

VII. Technology Transfer Mechanisms: Some Examples

For the most part, this Chapter consists of a series of short notes which illustrate some of the practical ways in which technology is transferred into, and within, the construction industry in Canada. These notes cover a broad range of topics and draw heavily on material gathered during the interview program. They also serve to draw attention to a number of incentives and impediments in the technology transfer process.

The remainder of the Chapter is also illustrative – this time of some of the circumstances and factors that have influenced the development and transfer of construction technology currently in use in Canada. The historical and factual material on which the discussion and analysis of these factors are based appears in Appendix J.

Codes and Standards

Representatives of industries, governments, and universities, as well as private individuals, take part in the compiling of codes, the writing of standards, and the application of both within the construction industry in this country. To the outsider, the whole field is immensely complex historically, technically, jurisdictionally, and in other ways. Indeed, it has all the attributes of a legal-cum-technical jungle. The discussion that follows has therefore been drawn together, in general terms, to reflect current views and problems concerning the present and future of codes applicable to engineering and building construction in Canada. Some additional information on the National Building and Fire Codes and on the history and work of the Canadian Standards Association, the Canadian Government Specifications Board, and the Standards Council of Canada has been given in Appendix H.¹

During the interview program for this present study, a consensus evolved in favour of the application throughout the country of the National Building and Fire Codes, the Electrical Code, the Welding, and other Codes related to construction. This favourable consensus was predicated, however, on the codes being sensitive to climatic, physical, resource, and other variations found in the different regions across the country – a feature that not everyone believes to be the case at the present time. It was also predicated on the need to keep the codes current from the technical point of view and on having control and administration in the hands of the provinces rather than the municipalities, as is the case with the Electrical Code at the present time.

The code detractors' arguments were directed principally toward the National Building Code, which they felt was, among other things, impossible to administer equitably and therefore an important impediment to technology transfer and innovation in the building construction sector. The Building Code was also considered to represent a minimum set of standards that does not generate quality products and that has to

1. The definitive study of codes and standards in this country was undertaken by Robert F. Legget on behalf of the Economic Council of Canada and the Science Council of Canada. Dr. Legget's report was published under the title *Standards in Canada*, Information Canada, Ottawa, 1971.

be up-graded by the authorities having the jurisdiction over implementation according to their individual needs. Some said that the Code as it is being administered by the municipalities at the present time, or would be administered by the provinces at some future date, provides an umbrella for the lazy or incompetent design consultants.

At the present time, the application of the National Building Code across the country is uneven. Since its implementation is voluntary in the eyes of the federal government, the provinces must take the initiative to put it to use. The evident trend at the time of the interviews was for the Code to become mandatory and be applied uniformly across each province. In practice, there could eventually be a series of Provincial Building Codes, with the National Code becoming the principal element in each of them. For the time being, however, the municipalities remain responsible for implementation.

The heart of the code problem with regard to *building* construction lies in the fact that people need some form of protection from structural, fire, electrical, health and other hazards associated with buildings. Nowadays, a lot of people expect that codes will become stricter, will move more and more in the direction of providing quality control and assurance, and will put an end to unnecessary and undesirable environmental damage. At the same time, other people maintain that codes must remain sufficiently flexible to permit the rapid application of new technology. In other words, different people conceive of building codes and standards as serving purposes that can be contradictory.

The *engineering* sector of the construction industry is subject to codes and to standards of safety and design which do not apply to the building sector. Some sets of standards are applied on a province-wide basis, for example, in the case of highway design and construction. Others are national in scope and cover construction projects, such as airports and harbours, for which the federal government is the design authority. In addition, a variety of standards published by the Canadian Standards Association apply to both the engineering and building sectors of the construction industry.

With the establishment in 1970 of the Standards Council of Canada as a federal Crown Corporation, there is now a national forum for the discussion, study, and reorganization of the writing and application of standards in this country. The Council's membership is large and broadly representative, but few of those appointed to it initially were widely experienced in standards work. The staff it has gathered together is expert but still small. The Council does not write standards, but certifies standards-writing agencies, approves national standards written by them, and identifies and evaluates needs for new standards. It promotes co-operation among organizations concerned with voluntary standardization in Canada, as well as with government departments and agencies, and it has international as well as national responsibilities. It has also been charged with coordinating the conversion of Canadian industry to metric

standards.² Since the budget for 1972-73 fiscal year was around \$1½ million, the Standards Council has a key role to play in the technology transfer process in the construction industry in this country. It became clear during the interviews, however, that opinions were divided on whether the Council would play this role effectively in the future, given the resources then at its disposal and the low public profile which it had been adopting.

The interviews also brought to light a list of problems in the field of codes and standards which need detailed study and which have considerable relevance for improving the technology transfer process. The list included the following:

- an evaluation of the economic impact of maintaining the present variety of codes and standards that are applicable to construction designs and methods and to construction equipment and materials;
- the study of methods for speeding up the writing of new standards and the resolution of conflicts between, and within, different codes; and
- the study of effective and practical quality assurance standards, warranties, and other measures related to product performance in construction.

There was general agreement that the construction industry in Canada needs a single publication, to which reference can be made for information on all *codes* and standards applicable to the building and engineering sectors of the industry. The fact that such a publication exists for the building sector did not appear to be widely known.³

Inspection and Testing

Two of the problem areas in *building* construction frequently mentioned during the interviews were the lack of skill and uniformity in inspections required by the various codes and the lack of facilities, in some parts of the country, for the testing and certification of materials to the required standards. Indifferent inspections and absent facilities were blamed, in part, for slowing down technology transfer and innovation in this sector of the industry.

Responsibility for building inspections rests with the municipalities, and could continue to do so even after Provincial Code legislation has been passed and implemented. The magnitude of the uniformity/skill problem is reflected in the number of municipal jurisdictions (over 4000) in the country as a whole. Responsibility for providing testing and certification facilities, on the other hand, rests principally with the private sector. Those who provide and operate the facilities must therefore be persuaded that it is worth their efforts to do so.

2. The Metric Commission is responsible for preparations for metric conversion in Canada. See p. 77.

3. The *Building Standards Index* was first published by the Canadian Government Specifications Board in October 1969 and a second, revised, version is due for issue late in 1974. The work on the first *Index* was done by Mr. Isadore Kalin of the Materials Branch, Department of Industry, Trade and Commerce. The revised *Index* is being prepared under contract to the Department.

In practice, cities and larger towns in the settled parts of the country have been quite adequately served in the past from the points of view of skilled inspectors and uniform inspections on a jurisdiction-by-jurisdiction basis. But increasingly sophisticated construction technology especially in the case of high-rise buildings, has been adding to the responsibilities and skill requirements of the inspectors, particularly in the cities. In practice, the smaller towns and rural areas that have had no building or other relevant by-laws have had no safeguard system at all. In others, the skills of inspectors have sometimes been less than adequate because qualified people have been difficult or impossible to hire. On the other hand, in small towns and rural areas, technology change in the construction business has normally proceeded much more slowly than in the cities, and there have been no high-rise buildings, with the result that the burdens of inspection have usually been less onerous.

Testing laboratories do exist in Canada, for example, at the Underwriters' Laboratories of Canada in Scarborough, Ontario. Some of the members of the Canadian Testing Association⁴ have laboratory facilities suitable for the testing of building and engineering construction materials, and there are other private laboratories across the country that are equipped to do certain types of testing. The laboratories of the Canadian Standards Association are normally concerned with developing test procedures and with certifying manufacturers, not with routine testing. Certain federal and provincial government departments also have laboratories that have the capability, but not necessarily the mandate, to test construction materials. On the other hand, the Research Councils in the Provinces have the mandate, and usually the capability, to perform materials testing under contract.

The decisions involved in the improvement of building inspections across the country will be essentially political ones involving the provinces and the municipalities. Decisions regarding the provision of more testing and certification facilities will also be political to a significant extent, but will involve the federal government as well as the other two levels. However, in the view of some of those interviewed, the twin problems of inspection and testing deserve detailed study by an agency such as the National Research Council, the Central Mortgage and Housing Corporation, or the Standards Council of Canada.

Metric Conversion

Although it has responsibility for the coordination of the conversion to metric standards, the Standards Council of Canada has a limited role to play in the extensive, national preparations for metric conversion in this country. The leading role in these preparations is being taken by the Metric Commission, which was established by the federal government

4. See, for example, the 5th Edition of the *Directory of the Canadian Testing Association*, published by the Association in 1971 at 20 Carlton Street, Toronto, Ontario.

in June 1971 and which began its work about six months later. The Canadian Standards Association and other technical and commercial associations serving the construction industry have, of course, both interests and activities relating to the problems of metric conversion.

The Metric Commission was little known at the time the interviews took place, but a fair number of construction industry people had views on *metrication* that were generally favourable. Some, indeed, saw the coming of the metric system as an opportunity to simplify design and other aspects and procedures in construction. Among the other points made were the following:

- Unique opportunities for dimensional standardization and coordination and for modular construction will be presented.
- The differences between current Canadian and metric standards for safety, quality and so on will be more easily resolved.
- The design process will be simplified.
- Technology transfer between Canada and countries that are already metric will be facilitated.

Conversion to the metric system in Canada is to be speeded up in the next few years and, by 1980, should be well on the way to completion.

Specifications and Contracts

The ways in which specifications and contracts are written will influence significantly the opportunities for technology transfer and innovation in the construction industry as a whole. This much is obvious. The difficulty is to identify techniques through which particular kinds of specifications and contracts can be “worded and conditioned” to encourage the increased flow of technology throughout the industry as well as into it.

Perhaps the problem starts with the fact that there are alternative methods of doing a great many things in the construction business. There are alternative materials that can be used in similar applications, and there are new methods and materials appearing all the time. For those responsible for specification and contract writing, there is the difficulty of knowing when documents should be tightly written, and prescriptive, to reduce the opportunities for conflict and litigation between the parties involved, and when they should be loosely written, with performance principally in mind, to allow the contractor and his associates scope for innovation. At the same time, there is the human tendency among the writers to repeat successful specifications long past the time when they represent the best use of construction methods and materials. And there is the equally human tendency, among contractors, to look askance at new methods and materials with which they are not familiar.

What the writers of these documents actually need is more and better storage, screening, and retrieval of technical and other required information – computerized as soon as possible. They already have standard formats for the different kinds of specifications and contracts. For example, there is now, in published form, a Uniform Construction

Index designed to provide the Canadian and U.S. construction companies "with a coordinated construction communications vehicle".⁵

The acceptance of low contract bids has been criticized on the grounds that low bidders, whether competent or not in the business of construction, may have little or no financial margin with which to support technical experimentation during or prior to undertaking a project. The acceptance of higher bids from contractors of known technical competence was criticized, also, on the grounds that this procedure can be wasteful. Technical sophistication does not necessarily go hand-in-hand with financial well being as far as contractors are concerned.

In matters of specification and contract writing, therefore, a great deal depends on what it is the owner of the new building or facility wants to have, what regulatory and other restrictions apply, what financing is available, what the construction schedule demands happen to be, and so on. However, at the root of the matter is the need for technically better-informed owners, consultants, contractors and specification writers.

During the interviews, it became evident that the art of specification writing is still developing in Canada, partly in response to new technological alternatives, partly under the influence of quantity surveying techniques practiced in Europe, and partly as the result of the activities of the Specification Writers Association. This development will continue. It also became clear that there is no sure method of contract writing that will guarantee the optimum application of the available technical knowledge in any one particular project.

An attempt is currently underway to study the feasibility of preparing and using a "master" building specification throughout the federal government. This work is based on the masters developed by the Departments of Public Works and Transport for their own use. If successful, the next logical step will be to examine how the federal master specifications can be modified and amplified into a *national* master specification, in collaboration with the private sector.

Fire Protection

On the surface, it appears that effective arrangements for the protection of buildings from fire hazards have already been made. The National Building and Fire Codes are available, fire research is continuing at the National Research Council, the Underwriters' Laboratories and, on a smaller scale, in other laboratories in Canada. The federal government and each of the provinces have Fire Marshalls or Commissioners with qualified technical staffs. New technical information should spread quickly among institutions and individuals with fire protection.

But the situation is less satisfactory in practice:

– The design of the fire protection system for a building is usually left to the end, until all the other systems and services have been put in

5. Published by the Construction Specifications Institute, Washington, D.C., 1972.

place – new and improved methods stand little chance of adoption.

- The approval of fire prevention and fire-fighting arrangements under building permits are not always made by officials experienced in the field.

- In the past, insurance companies have been preoccupied with the assessment of fire hazards to property and have been less concerned about the assessment of these hazards for people. The technology involved in people-saving has therefore been slow to evolve.

- Changing construction methods and the rapidly proliferating selection of plastic materials are adding enormously to potential fire hazards, for example, by the generation of toxic or nauseous fumes under conditions of high temperature.

- For the occupants of high-rise buildings, the hazards from fire are usually less than the hazards from the smoke resulting from fire – smoke research has not been done quickly enough.

- Fire research is difficult and expensive because it is often necessary to make full-scale tests rather than tests on less expensive scale models.

- Existing fire research facilities in Canada are fully extended.

- Fire *fighters* have always been in relative abundance in Canada. There have never been enough qualified fire *protection* engineers.

Fire protection engineers in Canada practice, almost exclusively, in Ontario and Quebec. Their connections with colleagues in the United States and with the National Fire Protection Association in Boston are well developed. A recent expression of their concern for the domestic situation was the formation, a few years ago, of the Canadian Fire Safety Association. The immediate purpose of this Association is to improve the education of engineers and others in industry and government concerning fire safety and fire protection by means of meetings and seminars. The Association also intends to encourage the establishment of professional and technical-level courses in universities and colleges. Thus far, the universities in this country have taken little or no interest in fire protection engineering in the construction environment.

People in the Construction Industry in Canada Will Not Write Things Down

In relation to its size, the construction industry publishes relatively little new technical information. Few engineers or architects, whether employed as consultants or by contractors or suppliers, and even fewer members of the sub-professional trades ever put pen to paper. The principal exceptions are those who write for the specialized journals and magazines, those whose job is research, and those who prepare the material published by the technical associations or by individual firms. This lack of “writing down” influences the effectiveness of technology transfer across the functional interfaces within the industry. In addition to proprietary information, a good deal of potentially valuable information and experience is, therefore, retained in people’s heads or in notes that are filed away and are not generally available.

In defence of the industry, however, it should be said that the mobility of people within it can be fairly rapid as compared with manufacturing, where people tend to stay longer with the same firms. It should also be noted that “writing down” is a time-consuming luxury that few companies in the fragmented contractor side of the construction industry, in particular, can really afford. Equipment and materials companies, on the other hand, do write more because, among other things, they need to advertise their products in order to encourage sales and to provide post-sale services. Consultants write the private reports through which they earn their fees.

A number of other practical points associated with the “writing down” problem should be mentioned.

- General contractors in the building construction sector may subcontract as much as 90 per cent in value of any project with which they are involved, but general contractors in the engineering sector will subcontract only 25 per cent. This means that the new technical information needs of the general contractor in the building sector will be somewhat less than those of his counterpart in engineering.

- Only a small part of the annual output of new technology relating to “world wide” construction will be generated each year in Canada. It is therefore necessary to have access to the “writing down” of other countries, especially the United States.

- It is important to distinguish between the transfer of technology and the transfer of expertise. In other words, it is not enough simply to *know* something, it is important to know how to *use* it.

- It is important to recognize that, apart altogether from the time factor, individuals have at least two kinds of limits to their ability to take advantage of additional new published information. In the first place, they may not see any possibilities for using it, and are insufficiently curious to read it anyway. In the second place, they may have limited personal capacities to understand and absorb it.

At the same time, it has to be recognized that sophisticated technical information intended initially for use by research people and consultants usually needs to be rewritten and reduced in complexity before it can be passed on for application by members of the contracting trades. Governments need to share responsibility for performing this kind of work and should bear some of the cost of it. Governments and associations should also arrange that more courses and opportunities are available for the further training of building tradesmen, inspectors and others directly involved with new construction technology and experience.

Lessons from the Case Studies

The dozen case studies developed in Appendix J cover:

Explosives	Particleboard and waferboard
Earthquake engineering	Grader
Airport runway and apron sealants	Concrete transit mixer

Electrical wires and cables
Gypsum drywall
Plywood

Concrete slipforming
Prestressed concrete
Systems building

The different lessons have been set out as a series of numbered statements which include references to one or more of the twelve cases but which omit supporting arguments and discussion. Since the cases are not exhaustive, the lessons have the same shortcoming. Nevertheless, they serve to draw attention to factors that have been important in bringing about technology change and innovation in the past – factors which will presumably continue to be of importance in the future.

1) General Hypotheses

The case studies lend support to the view that most technology changes and innovations in construction are evolutionary in nature, but that, every so often, there will be a significant revolutionary one. They show that the evolutions and the revolutions are all quite different technically, historically, and in other ways. And they show that a variety of factors will influence each revolution and each stage of an evolution.

2) Political, Economic, or Social Discontinuities

During the 20th Century, thus far, the two most important “discontinuities” which encouraged advances in construction technology were the World Wars. Systems building, for example, received a boost as the result of World War I, only to lapse into relative inactivity when the shortages of housing and skilled labour had been made good. But it received even greater boosts during and after World War II. The use of sub-systems such as drywall also increased, at the expense of the lath-and-plaster technique, during and after the Second World War. Post-war demands also brought about rapid changes in construction equipment technology, for example, in concrete transit mixers. The “discontinuity” which discouraged technology change was the Depression. During the 1930s, very little new technology was developed anywhere in North America.

3) General Economic Development

In the United States, construction technology has grown increasingly sophisticated in step with the long-term trend of economic development of that country. This lock-step relationship has also been in evidence in Canada, encouraged in part by the way in which things in this country tend to follow things American. Examples are to be found in the explosives field, prestressed concrete, concrete slipforming, and systems building.

4) Pre-eminence of Europe and the United States

The history of the construction industry in Canada is replete with examples of Canada’s “follower” status in the development and adoption of new construction technology. The case studies of prestressed concrete and heavy concrete systems building show that both originated in Europe and came to Canada some time later. In the development of drywall construction and of truck-mounted equipment, the United States led both Europe and Canada.

Canada's record, particularly in the improvement and modification of construction technology, has not been completely blank. On the equipment side, for example, at least one Canadian company has maintained both its technology and its market for highway graders. Canadian companies have also made contributions to the development of wood-based construction materials and to the techniques of industrialized, or systems, building, again using wood. And Canadian engineers were the first in North America to use a combination of prestressed concrete and slipforming in a nuclear reactor containment building, at Gentilly, Quebec.

5) Technical Advances in Non-Construction Industries

These have been fruitful sources of new construction technology, as well as one of the most significant forms of technology transfer. For example, the development of waterproof glues expanded the use of plywood enormously; the development of high-tensile steel transformed prestressed concrete from theory into practice; the rivalry between steel, concrete and wood for use in particular applications in construction has had the effect of encouraging technical developments in all three fields; systems building has borrowed extensively from manufacturing techniques and technology; and gasoline and diesel engines transformed the concrete transit mixer and the highway grader into self-propelled pieces of construction equipment.⁶

6) Parallel (or Almost Parallel) Technical Advances in the Construction Industry Itself

A technical advance in one field of construction may stimulate developments in other fields. For example, the advent of climbing cranes made possible the use of vertical slipforming techniques in the construction of high vertical towers; new and stronger plywoods encouraged the adoption of this type of material in structural as well as in decorative and other non-load bearing applications; and developments in blasting techniques have reduced "overbreak" and provided stable walls in excavations in slate or rock.

7) Reductions in Production Wastes

The particleboard and waferboard examples show the influence that waste reduction initiatives can have on the development of construction materials technology.

8) Reductions in Overall Construction Costs

To some extent, all of the case studies illustrate ways in which these costs can be cut through the use of better technology. Cost cutting is just as powerful an incentive for technological change and transfer in construction as it is in other industries.

9) Entirely New Applications

In the case of the development of the airport runway sealants, the requirement came directly from the need for surface cleanliness during

6. Although no specific cases involving *plastics* have been considered in this study, the almost revolutionary effect of plastic materials on building construction, in particular, should not be forgotten.

the take-off and landing operations of large aircraft with low-slung jet engines when they began replacing propeller-driven ones. In the case of the concrete aprons, the requirement resulted from sealant tracking and breakage caused by spilled jet fuel.

10) Requirements of Safety

Several examples have been given in the electric wire and cable case study to illustrate how safety requirements, aggravated by poor operating practices and Canadian climatic conditions, can influence technology change. These examples also demonstrate the importance of both the standards-writing bodies and the equipment manufacturers knowing about the problems of safe operation and working together to solve them.

11) Some Additional Points with regard to Technology Transfer

– A conference may help to get a relevant new technology “off the ground” (for example, earthquake engineering).

– A construction disaster or near-disaster may have an adverse effect on a promising new field of technology (for example, the partial collapse of a high-rise system-built apartment house at Ronan Point in England in 1968).

– The need for full-scale experiments, and the cost of them, may hold back the technical development of particular construction applications (for example, in earthquake engineering).

– Because of their disaster potential or their general “visibility”, some sections of a field of construction technology may get adequate, or better than adequate attention, while less visible sections may be poorly served, or not at all (for example, in earthquake engineering, high-rise buildings have been receiving a great deal of attention and low-rise buildings very little).

Some Views on Technological Developments and their Encouragement

Set out in the first of the two lists that follow are the technological developments considered to be the most significant from the point of view of the Canadian construction manager, in the engineering sector, in particular, during the past 50 years. Several of them have been included already in the case studies. The second list identifies the circumstances that, during the same period, encouraged developments in the technology of construction generally and hastened their acceptance.⁷

1) Technological developments:

– the application to construction equipment of steam engines, followed by gasoline and diesel engines and turbines

– the development of powered material handling systems, such as conveyors, forklift trucks, pumps and cranes of all types

– progressive improvement in transportation facilities

7. These lists were prepared by senior engineers of the Ontario Hydro Electric Power Commission (now the Ontario Hydro Corporation) and forwarded in a private communication by David C. Aird, Executive Assistant, Generation Projects, Ontario Hydro, Toronto.

- progressive improvement in communications
- the application of compressed air to rock drills and other construction equipment
- the use of tracks on construction equipment
- the application of rubber-tired wheels to construction equipment
- the development of portable power tools
- the development of central concrete mixing plants
- the development of transit mix delivery equipment
- the development of self-propelled mobile cranes
- the application of hydraulics to cranes
- the development of high-tension bolting for steel construction
- the development of welding and cutting devices and techniques for steel
- the application of industrial building techniques to construction
- the development of pre-stressed concrete
- new management techniques

2) *Circumstances:*

- significant increases in the cost of labour
- the need for special techniques to solve special construction problems
- increases in the cost of money
- increases in construction volumes, providing opportunities for repetitive applications
- tendering systems which generate the drive to develop new methods
- more complex structures, which demand more sophisticated techniques

These significant technological developments, for example, have enabled the construction manager to muster and deploy larger and larger amounts of power quickly and economically whenever and wherever he has required it. More and more off-site fabrication of construction components for delivery to, and assembly on, the construction site has also been possible. Again, the contributions of portable power tools to increases in the efficiency of construction operations throughout North America have been very significant – in comparison with the corresponding operations in Europe. All of the developments listed have contributed to changes in the composition and size of on-site work forces. The availability of new technology has, to a degree that cannot be computed with accuracy, permitted some construction projects to proceed when they would otherwise have been cancelled or deferred due to the high costs of labour or money.

It is difficult to sum up a Chapter such as this one because it has been illustrative rather than complete in its coverage. It does, however, clearly demonstrate that a wide variety of factors, some of which are legal, economic and administrative rather than technical, need to be taken into account when attempts are being made to improve the effectiveness of technology transfer in a particular industry. It shows, also, that past technical experience and trends have some relevance in any search for the next evolutionary steps in a particular technology and

that technology transfer in the construction industry has much to gain by borrowing technology from other industries. It shows that Canada will contribute to new construction technology, but is likely to remain a net importer of this technology from abroad.

VIII. Some Problems and Issues in the Future

The purpose of this brief final Chapter is to focus attention on a number of problems and issues related to construction generally and to technology transfer in particular that will require thought and action in the very near future on the part of governments, the construction industry, and the universities and other training institutions in this country. The problems came to light during the interview program and the other data gathering phases of the study. They also reflect changing world circumstances during the interval between April 1973, when the initial version of this report was sent to the Economic Council, and April 1974.

While there are some suggestions for future research projects in the construction field included in this Chapter and in the "Conclusions" that follow, no attempt has been made to present a comprehensive list of projects that should be undertaken in Canadian laboratories during the next few years. As stated in the Introduction, this task has been left largely in the hands of a more qualified authority. Dr. N.B. Hutcheon, former Director of NRC's Division of Building Research.¹ No guidance will therefore be given with regard to the levels of public and private funds that should be committed to R & D in the years immediately ahead or with regard to some suitable aggregate target figures six or ten years into the future. Such expenditures must inevitably be scrutinized from year-to-year, and in the longer term, alongside the needs of R & D projects in non-construction areas and with due regard to the country's ability to make them in the first place.

Future levels of expenditure on technology transfer activities are difficult to estimate because many of these activities are informal and can neither be counted nor costed. On the other hand, much more should be spent on *formal* technology transfer programs, especially on those that involve planned contacts between resource people and potential users. But, once again, precise figures cannot be given – in this case, because the present study has been limited in its coverage and could not examine all of Canada's future national needs in relation to the effectiveness of the existing programs.

Society and the Economy

The problems and issues facing the Canadian construction industry must be placed in a wider context. As the report by the Secretary General of the United Nations to the Conference on the Human Environment has indicated:

By the year 2000, world population will have risen to close to seven thousand million, three-quarters of them in the less-industrialized countries. Owing to internal migration, urban growth is likely to be at least twice as rapid as total population growth. To house this population will require building in one generation more structures than have been built

1. See, N.B. Hutcheon, *Research for Construction*, prepared for the National Research Council of Canada, Ottawa, March 1974.

in the whole of human history. The provision of shelter for the vast majority of the human race now has a priority only less urgent than the prevention of famine or the elimination of war.²

The construction industry in any country plays a two-way role in defining the quality of the man-made environment. First, it is the major tool for shaping the physical framework of any settlement. Secondly, by creating a physical shape, it has a basic impact on the quality of almost all man-made components of the human environment. The interaction between building and environment has become a complex and increasingly critical phenomenon, characteristic of the modern industrial era.

The Economic Council of Canada has, from its beginnings a decade ago, warned about the implications, for both the building and engineering sectors of the construction industry in this country, of the trend toward the formation of larger and larger urban centres and the depopulation of rural areas. The Science Council, for its part, made a number of broadly-based recommendations in its report on urban problems that are relevant to the future of the construction industry in this country.

The Council recommended, for example:³

- that sophisticated systems techniques and simulation models be incorporated into the planning efforts for all urban regions of all provinces in Canada;
- that the federal and provincial governments embark on a cooperative program to fund experimental programs in demonstration projects in urban transportation;
- that a program of wide-spread experimentation be encouraged to make communities in Canada more livable;
- that governments give urgent attention to the construction industry's fragmentation, under-capitalization, inadequate economies of scale, seasonality, hazardous work conditions, and lack of effective utilization of highly qualified manpower in adequate numbers; and
- that a detailed study of waste recycling and disposal be given the highest possible priority.

In a subsequent report, the Science Council recommended that Canadians, their governments, institutions and industries should soon begin the transition from a consumer-oriented to a conserver-oriented society.⁴

In the same vein, Fred W. Myers discussed in an essay the influence of the changes on the design and planning processes in construction that will occur during the transition from an industrial-type Canadian society to a post-industrial one.

2. *Planning and Management of Human Settlements for Environmental Quality*, United Nations Conference on the Human Environment, Stockholm, June 1972.

3. Science Council of Canada Report No. 14, *Cities for Tomorrow*, Information Canada, Ottawa, September 1971. p. 11.

4. Science Council of Canada Report No. 19, *Natural Resource Policy Issues in Canada*, Information Canada, Ottawa, January 1973.

Probably the most significant impact of these changes for the construction industry is the increased public concern for the environment. . . .

More and more, the designer of structures must be a designer of man-made environments which meet ecological standards and which use minimum resources in terms of energy and material. Urban communities must include waste disposal and garbage re-cycling as well as meeting the functional and psychological needs of society. . . .

At the same time, availability of land and the capital costs of construction are of increasing significance in considering the long-term use of major buildings – efforts must be made to make buildings more flexible in terms of adapting them for other uses. . . .⁵

In the future, programs for the construction of buildings and of industrial and social infrastructures and facilities are likely to be dependent upon the working out of a series of compromises between the life styles, or the quality of life, to which people wish to aspire and the ability of public and private sources to afford them. These programs will also be influenced by the distribution of the population between cities, towns and rural areas, on the location of mines and industrial plants, on the need for slum clearance, and so on. They will likely involve more complex and physically larger systems and require new personal skills and new combinations of old ones in which building and engineering construction interface more effectively. In addition, these programs will have to be flexible in order to respond to gradual, or drastic, changes in social and economic factors and in the attitudes and aspirations of people.

Governments, or their agencies, have always been the owners of much of the output of engineering construction, and will continue to be. They have also owned some of the output of the building sector of the industry and have provided a variety of programs to assist private ownership. Indeed, the continuation of these patterns has been taken for granted for some time, and their extension rather than their existence will provide occasions for future discussions and decisions.

The rates and volumes of the transfer of “conventional” construction technology are likely to be more responsive, in the future, to the search for solutions to social and economic problems and issues than in the past. More important, however, is the need for the more rapid transfer of *economic* and social “know-how” or technology to provide for the more effective underpinning of all of the activities included in building and engineering construction work.

Financial Factors

The incidence of, and rewards for, financial speculation associated with the business of construction has been the subject of debate for some

5. Fred W. Myers, *Some Thoughts on Evolutionary Trends in Construction Design/Planning*, prepared for the National Design Council Secretariat, Ottawa, 1973. (Mr. Myers wrote this essay as a special contribution for use in this study.)

time. The recent inflationary trends have led to the introduction of anti-speculation measures in the Province of Ontario, for example. Speculation has been more in evidence in the building construction sector than in engineering construction where governments, or their agencies, are most frequently the owners. However, the combination of continued speculation and inflation, if these are accompanied by shortages of capital for construction in Canada, could have a depressing effect on the levels of certain types of construction in this country. However, shortages of energy and of certain raw materials could divert capital funds from the building to the engineering sector. If such a diversion occurs, it will influence the types of construction research and development programs that will be pursued and will govern the kinds of technology transferred into, and within, the industry as a whole. This much is obvious.

On the other hand, with the exception of public and special facilities, priority has usually been given in the past to the acceptance of the lowest tender for a construction project or to the use of the least expensive methods and the materials compatible with the basic safety requirements and with the purpose of a building or engineering facility. Little thought has gone into the problems of maintenance, reliability in service and so on, of the facility itself, or into its impact on people and on the physical environment around it. Dealing only with the *first* costs of construction rather than with the combination of first and *downstream* costs has been the more attractive way to proceed. But recent pressures for environmental impact studies and for energy economies, for example, have already changed the attitudes of some owners and others toward the inclusion of downstream costs in the total financial package. This trend should continue in the future and, as a consequence, more, rather than less, technology will be needed during the design, specification and subsequent stages of a construction project in order to bring it up to the new environmental quality and other standards.

Technology

Given continuing economic and social opportunities and the removal of instability disincentives, there should be no lack of ingenious people to make significant contributions to the application of technology in the business of construction in this country in the years ahead. While there may be no technological revolutions, the evolutionary style of innovation should continue to be effective. And with 90 per cent of a contractor's or an engineer's technical problems amenable to solution, he should be able to live more comfortably with the 10 per cent for which solutions have still to be found. All of these things are encouraging.

There are, nevertheless, a number of problems involving new construction technology that deserve attention, with the future in mind. For example, it is important that priority be given to those research projects that will result in the most significant cost savings. A project of considerable technical interest has its place (in the universities, for

example) but is of doubtful value from the industry's point of view if it will save only \$25 while a potential saving of \$1 000 remains uninvestigated. In the same vein, but in the opposite direction, the temptation to employ sophisticated construction technology should be resisted when a hammer or other simple tool is all that need be used. It is also important to encourage contractors and others to specialize and to "make perfect through practice", but even experienced practitioners need to be taught new tricks occasionally. And it is important that contractors understand fully how a new method, material or piece of equipment "works". Otherwise, they are unlikely to use it.

In his essay, Fred Myers commented as follows:

Industrialized building techniques and [the] standardization of components are . . . placing new demands on the designer/planner. It is increasingly important for the designer to come up with the correct solution the first time and for him to fully understand the advantages and limitations of industrial processes. . . .⁶

Design and specification writing play key roles in the technology transfer process to a degree not particularly appreciated in the past. More emphasis on these roles will be needed in the future. More emphasis must also be given to extending the contributions and increasing the collective competence of the multi-discipline teams that will have important roles to play in technology transfers. More attention will need to be given to the dissemination of new technical information in forms that accommodate the different levels of training found throughout the construction industry. And more attention will need to be paid to devising methods to feed new technical experience back and forward from its point of origin in the construction process.

The place of codes and standards in relation to technology transfer is now quite well understood, as is the importance of the forthcoming moves toward metrication in Canada. Nevertheless, more study – with a view to simplification and, where possible, consolidation – will be needed. The move toward very much longer construction warranties, which has now begun in earnest, will require a re-evaluation of the existing performance and safety measurement procedures and facilities.

The effectiveness of technology transfer in any country in the future will be influenced as much by the choice of *what* to build as by the choice of *how* to build it. The "Conclusions" that follow are intended to improve this effectiveness.

6. *Ibid.*

Conclusions

As it has been defined for the purposes of this study, *the construction industry* represents a very large and heterogeneous part of the Canadian economy. It is also an industry that has a significant degree of interdependence with other industries in the economy.

A study such as this one – which does not cover all of the activities and problems of the construction industry – could only examine those related to technology transfer in a fairly modest way. Nevertheless, enough has been learned in the time available for a number of general conclusions to be drawn.

1. The processes of technology change and innovation in construction in Canada, and in other countries, are for the most part evolutionary. Revolutionary changes or innovations are relatively rare.

2. The application of “new” technology is basically dependent on the existence of opportunities for application and on the availability of people competent to perform the work required. The same may be said for a great deal of “old” technology. Advances in construction technology – and the need for transfer activities – depend just as much upon what is to be built as on how the construction is to proceed.

3. There is a loosely connected technology transfer network of private and public institutions, associations and companies within, or associated with, the construction industry in Canada. The activities of the members of the network may include the performance or encouragement of research, development, design, testing, and inspection as well as actual construction. This network functions quite effectively when the mutual interests of its members are involved. It is also well connected to sources of technology abroad, especially in the United States. Any steps that are taken to strengthen the network from the institutional point of view should therefore recognize the network’s existence and build upon its current strengths.

4. Some companies within the construction industry whose activities include the fabrication and manufacture of equipment and materials or the assembly of building and engineering projects, are members of the technology transfer network. Others are linked to it through association memberships, through suppliers, or through other contractors. The ability of the latter group of companies to take advantage of their membership depends to a significant extent on their technical skills and on the kinds of projects they undertake.

5. In the past, the federal government has made significant contributions to the solution of technical problems, to the upgrading of technical skills, and to the transfer of technology in the *building* sector of the construction industry through the National Research Council’s Division of Building Research (DBR). But, in theory at least, the Division shares its technology transfer responsibilities with other NRC Divisions. Whatever changes are made within the National Research Council in the future, the interests of the construction industry will not be well served if the level and effectiveness of DBR’s contributions to it are diminished.

6. The federal government has provided research and technical support for the *engineering* sector of the construction industry in years past, but this has not been the responsibility of a single agency. Consideration should now be given to the possibility of assigning a single agency to this task or to defining more specifically the roles of the different agencies concerned. Consideration should also be given, from the technology transfer point of view, to the establishment of closer collaboration between the agencies serving the building and engineering sectors of the industry.

7. A variety of levels of construction activity and competence exist in the provinces and in the municipalities across the country. On the whole, technology transfer activities involving the provinces and municipalities have not always been satisfactory, due principally to the fragmentation of effort among the agencies and to problems of jurisdiction. These activities need to be made more effective. In so doing, however, the strengths of the existing provincial and local agencies and associations in both the government and private sectors should be used as the starting points.

8. In the past, the universities have played limited roles in research and technology transfer activities in support of the construction industry in this country. In recent years, some universities have expanded their interests and activities – sometimes significantly. However, the principal problem in many schools of engineering has been narrow specialization unrelated to the needs of the industry and, in the schools of architecture, insufficient science training. For both, a sense of relationship with the industry has been lacking, due to their tradition of professionalism. It should be recognized that the contributions of the universities to construction generally need to be carefully integrated with their primary mission, education.

9. There is a widely shared view within the industry that the factor which most discourages the transfer of technology within, and through, the network is the lack of communication at the interfaces between the various parts of it, for example, between the construction-related disciplines, between the universities and the “outside world”, between consultants and contractors, and between developers, designers, and users. The industry also shares the view that people play the principal parts in the actual transfers of technology and that the solution to the interface problems will require the encouragement of interpersonal contacts. For these to be successful, however, both government and private financial support will be required.

10. There is also a widely-held view in the industry that another important factor inhibiting technology transfer is the general failure to place sufficient emphasis on the design function, on experience gained through design work, and on the role of specifications. Too much weight has been given to publishing research results and to the development of systems of technology transfer relative to overall information needs. In

the future, design and specification activities must be given their proper place in the scheme of things.

11. The relatively large size of the construction industry in Canada, its complexity, and the fragmentation within it, all influence the process of technology transfer. It includes companies that are enterprising, efficient, and technically sophisticated, in addition to those that are less well endowed. In attempting to upgrade the general level of enterprise, efficiency and technical sophistication by means of more effective technology transfers, it must be remembered that some companies have neither the resources nor the incentives to respond to these attempts.

12. Construction projects have their unique features and problems, requiring special considerations and special solutions. At the same time, there has been a tendency among owners, developers, consultants, contractors, and others in Canada to follow experience and past practice too closely. This reluctance to experiment is, to a degree, understandable. It is rooted in financial and cost considerations, in the need for speed and reliability in the process of construction, in legal liability considerations, and in the need for reputations to be maintained. It may also be the result of a lack of technical expertise or a lack of confidence to carry the work through. In order to change its ways, the construction industry in this country must be challenged by public and private owners, developers and others. To respond to this challenge, it will require good leadership from institutions and individuals as well as good and relevant research and design support.

13. The transfer of new technology originating in contractor and consultant companies in this country has not been sufficiently effective. A large part of the blame for this rests on the unwillingness or inability of individuals to write down their experience for publication directly or for dissemination to a wider audience through other means. At the same time, there are companies and individuals that have neither the skills nor the resources to devote to the luxury of increased technical communications, and there are companies that will make little or no contribution to new knowledge regardless of the work they undertake. In view of its pervasiveness and the cost and the time involved, the solving of this particular problem on a national basis is probably beyond the ability of a single institution to tackle. None the less, and for the same reasons, this problem deserves further serious study.

14. The size of the construction market in the United States has influenced technology change and innovation in the industry in Canada in the past. The influence of size has been reinforced by the fact that the northern states of the U.S. share the same kinds of climate with the inhabited parts of Canada. Construction technology has also come to Canada from the universities and from government laboratories in the United States, the United Kingdom and other countries. The U.S. and Europe have both been sources of certain radically new construction techniques, adopted in this country but often with improvements of Canadian origin. In some cases, this technology has first crossed the

Atlantic to the U.S. before entering Canada. The cross-fertilization of Canadian technology with technology from other sources should not be discouraged. At the same time, Canadian competence must be upgraded to take advantage of it, as well as to make contributions that can be used for national purposes or in exchange for foreign technology.

15. While the use of materials that have been mined or manufactured in this country has been increasing, much of the construction equipment used in Canada is of U.S. origin. There seem, at the moment, to be relatively few opportunities available to increase domestic production of this equipment significantly.

16. For the most part, construction research and development work done in Canada in recent years has been of high quality. Nevertheless, there is a consensus of concern within the industry that more effective links are required between the performance of R & D in laboratories and the application of the results in the field. Work on industry's technical problems has to be speeded up, so that solutions are more timely in relation to the need for application. At the same time, contractors, in particular, must bring their needs to the attention of the laboratories more quickly. An effective response to this R & D application problem will require more generous government and private support for research and development. But it has to be remembered that solving industry's technical problems does not always require the performance of *more* R & D. In some cases, the application or "repackaging" of the available technology will suffice.

17. One of the most important techniques that should be used in the upgrading of non-professionals and in the training of professionals for the construction industry is the more effective "marriage" of theory with practice. The adoption of techniques in education which provide alternate periods of study and work experience should therefore be encouraged. The training and education of better people at all levels of technical effort is a key requirement for improved technology transfer, since people are the principal agents through which this transfer takes place. Both universities and other postsecondary institutions can play important roles in developing professional and technical personnel who will be valuable in the work of construction.

18. Research professionals in construction science and technology normally communicate most effectively with one another and less effectively with those trained to less sophisticated levels of expertise. Nevertheless, the work of the research professionals should eventually be used in the field and therefore needs "translation" into the vocabulary of the less expert person. Training courses can, of course, be useful for this purpose; and they have been available in this country in recent years. But much greater efforts are needed to bring about these translations through the printed word and other means. The responsibility for sponsoring these would seem to lie, especially, with public agencies and with the technically-based industry associations.

19. The PAIT and BEAM programs of the federal Department of Industry, Trade and Commerce, and the IRAP and TIS programs of the National Research Council, plus the work of the Division of Building Research, have made useful contributions to research and technical information transfer activities for the construction industry. The new Canadian Construction Information Corporation is also concerned directly with technology transfer questions. All of these programs merit continued support from the federal government and the private sector. A certain amount of contract research, materials testing and technology transfer work is being done by the Research Councils in the provinces and this also merits continued government and private support.

20. There is, however, room for improvement in government-sponsored technical information *systems* designed for the construction industry, and some steps have been taken in this direction. A key factor in the effectiveness of such a system is the quality of the information that is processed through it. There is also a need to incorporate an effective screening mechanism which will reduce the quantity of irrelevant material reaching the user.

21. The use of computers in the construction industry as a whole has been increasing, principally in the areas of project planning, budgeting, cost control, and general and payroll accounting. In the case of engineering firms, particularly those doing structural design work, the computer has been readily accepted. In the case of architectural firms, the computer has been used mainly for non-technical applications, although, in some cases, the firms have developed new programs to produce their designs. However, a large amount of research has been, and is being, done in less "quantifiable" areas of architecture, design, and computer drafting. Although significant savings of time can be effected in design work, every design project does not require the services of a computer.

22. One large and very important element in the technology transfer network that has far reaching effects is the work of writing and revising codes and standards for safety and other purposes. The associations and agencies in the private and public sectors which are responsible for this work involve several thousand people, with both technical and non-technical backgrounds, in the actual writing process. Although codes and standards have their opponents and detractors, no more effective alternative system has so far been suggested. There is, however, a consensus in the construction industry in favour of streamlining the writing and application processes for all codes and standards in operation in this country. The initiatives now being taken by the provinces to reduce the jurisdictional complications of code application are also welcomed. But there is still some concern that the physical and other differences between the regions of the country have not been given adequate consideration in the compiling of the National Codes. While past experience shows that codes and standards evolve slowly, the pressures of the future will require that additional resources be allocated

by governments to the technical work on codes and standards and to the mechanics of publishing fewer and more comprehensive volumes containing them.

23. Canada should continue to expand its involvement in work on international standards. New opportunities for standardization, dimensional coordination, trade in building materials, and so on, will come with the fuller adoption of metrication and metric standards throughout the construction industry in North America. The use of the metric system will also help to simplify and speed the design process and to extend the application of the computer to more construction-related activities.

24. It is important that the resources available to the Standards Council of Canada with regard to codes, standards, metrication and other areas for which it is currently responsible should keep pace with the growing technical complexities that the construction industry in this country must face. It is equally important that this Council be given the power to commission studies of matters related to codes and standards that are economic and social rather than purely technical. The same may be said about the resources allocated to the Metric Commission for the carrying out of its particular responsibilities.

25. There is a consensus of concern in the building sector of the industry that the procedures for issuing building permits and for inspections are unduly cumbersome. This matter should obviously be considered by the provinces and the municipalities in their discussions of the administration of the National Building and Fire Codes. However, in a country as large as Canada, where the majority of contractors and sub-contractors have local affiliations, the need for compatibility of procedures between one region of the country and another is less important than the resolution of problems between adjacent jurisdictions.

26. There is a further consensus of concern in the construction industry as a whole in regard to the adequacy of materials testing facilities across the country and particularly, outside Central Canada. Most of the existing government and private agencies that have testing facilities either lack the mandate or the capability, or both, to meet present needs. In the future, as consumer procedures that favour extended warranty coverage and performance assurance are introduced, the pressures on the existing facilities will become intolerable. This problem deserves study as a matter of priority.

27. This study has been able to identify two general areas of socio-economic research that will require work in the very near future:

- interdisciplinary research into the behavioural and social factors associated with the use of living space, the urban and rural environment, and building user requirements;
- economic studies of standards, and especially of quality assurance procedures, warranties, etc.

In addition, there are other future-oriented areas of research that are under study at the moment, for example, the energy consumption of

buildings, the problems of smoke and personal safety in high rise buildings, and the implications of the conserver society. Work in these areas must be continued.

28. There are rising standards of technical quality and sophistication which the construction industry will be required to meet in future. These relate to environmental and energy concerns and to special areas such as nuclear-power generation and rapid-transit systems as well as to the more conventional aspects of construction. The industry will be faced with the rising expectations of its "customers" and it must, therefore, give serious attention to the general upgrading of its technological capacity. In addition, if Canadians decide to accept the conserver society concept, as suggested by the Science Council, new constructive endeavours and new challenges to the construction industry will appear. It is probable that this new emphasis on energy and environmental considerations will have special significance for the building sector of the construction industry in the years ahead. The industry in Canada must therefore be prepared to respond to the challenges and opportunities presented.

29. Certain companies, corporations and government departments are the custodians of advanced technology which they have developed in the course of project construction. Every effort should be made to bring this expertise more fully into the private sector.

30. It has not been possible, in this study, to establish cause-and-effect or correlative relationships between the different phases of the aggregate construction activity cycles in this country in recent years and different rates of technology change or innovation in the industry. On the basis of the findings in the study, no such relationships seem to have existed in the past. However, it is clear that the *existence* of the cyclical phenomenon has continuously discouraged technology transfer to some degree. Its existence has also tended to discourage the accumulation of larger and more talented reservoirs of technical people in, or associated with, the industry. Therefore, measures that successfully eliminate the cycles – or reduce their intensity significantly – are to be welcomed and should provide encouragement for more technology change and innovation.

Appendices

Appendix A – Federal Agencies and Construction

This Appendix contains notes on the activities of three federal agencies that have considerable impact on building construction throughout Canada: the National Research Council's Division of Building Research, the Central Mortgage and Housing Corporation, and the Department of Public Works. These agencies by no means exhaust the federal government's involvement in the business of construction. Some additional information has been given in Appendices D, F and H.

NRC's Division of Building Research

The Division of Building Research of the National Research Council of Canada* was established in 1947. Its main objective is the provision of research and research services in support of the building sector of the construction industry. The Division is also responsible for providing technical support to the Central Mortgage and Housing Corporation and the necessary secretarial and support services for the writing and review of the National Building Fire Codes. In addition, members of the Division take part in a large number of standards-writing and technical committees, both national and international, and provide information and advisory services to the construction industry generally. Commercial testing is carried out on a limited scale. Over the years, the Division has endeavoured to develop and maintain close links with other agencies whose work has some relevance for building.

The range of functions of the Division is reflected in its organization. There are six research sections with laboratory facilities, administered in two groups. The interests of these sections are outlined below. A third group is responsible for the Division's work on the National Codes. A fourth group, concerned with building practices, is again made up of a number of sections. It is responsible for the collection and dissemination of technical information. The Building Research Library is operated by the Division as a branch of the National Science Library. Finally, the Division maintains five small regional stations, one for permafrost research at Thompson, Manitoba, and four which serve as information and regional offices in Halifax, Toronto, Saskatoon and Vancouver.

The following are brief descriptions of the interests of the different sections of the Division, beginning with the six laboratory sections.

Building Materials Research The purpose of the work of this section is to provide basic information about the properties and behaviour of building materials, to assist in formulating standards and specifications for the performance of these materials, and to assist industry and other government agencies in the solution of problems of national importance associated with building materials.

*The principal source of the information included in this section was *Activities of the Laboratories*, (NRCL-72) published by the National Research Council, Ottawa.

Building Physics This section is concerned with vibration and acoustic problems related to buildings and their occupants. The vibration work is primarily associated with the response of buildings and other engineering structures to dynamic forces. The research in acoustics is focussed on the sound absorption and transmission properties of buildings and building elements, on the study of major noises in various environments, and on vibration and noise originating from internal and external sources.

Building Structures This section is involved mainly with providing information on the structural design of buildings and factors that affect the safety of structures, and with field studies of wind and snow loads. A good deal of the work is aimed at the improvement of the structural requirements of the National Building Code.

Fire Research The work of this section is directed toward reducing the losses to life and property by fire in Canada. The emphasis is on problems associated with the National Building Code requirements including, for example, the fire resistance of materials, the surface flammability of materials, and the products resulting after materials are burned. The section has large furnaces for undertaking standard fire resistance tests, and a tunnel furnace for flame spread tests.

Geotechnical Research This section studies and provides information on problems associated with soils, permafrost, peat, ice, and snow with the aim of developing, for the construction industry, both the knowledge and techniques required for good geotechnical practice. The section has a soil mechanics laboratory in Ottawa and two cold rooms for studies of ice and frozen ground. Support for field studies in permafrost areas is available at the station at Thompson, Manitoba. An avalanche research program has been undertaken in the mountains of Western Canada. Of all the research sections within DBR, this one is of special importance to the engineering sector of the construction industry.

Building Services Research This section is concerned with the environment inside buildings and with those aspects of the performance of building enclosures and building equipment that influence this environment. A considerable part of this work has to do with the development of methods and facilities for determining the air, water, and heat transfer characteristics of walls and windows. But emphasis is also given to the development of better methods of predicting the hygrothermal conditions in buildings and the energy needed to power environmental control equipment. Computer simulations have been used to develop information on the behaviour of smoke and gases in highrise buildings.

The Codes and Standards Group* coordinates the Division's services in support of the National Building and Fire Codes and the corresponding Associate Committees, and performs studies related to the special needs

*See Appendix H for more information on the National Building and Fire Codes.

of these Codes. It also has special responsibility for providing technical assistance to the Central Mortgage and Housing Corporation and for maintaining liaison with the Housing and Urban Development Association of Canada.

The principal aim of the *Building Practices Group* is to acquire, communicate and utilize scientific and technical information on building for the construction industry. It manages the output of information from the Division and provides a direct link to those segments of the industry having concern for the use, design and construction of buildings.

Within this Group, the *Design Section* is concerned with the development of building science information for application by the design professions, so that they may improve their ability to predict building and building component performance. *The Building Use Section* is responsible for developing information which will help to define more precisely the human requirements in buildings, and particularly those that relate to the safety of occupants. Its work includes the study of the movement of people during building evacuations, building use by disabled people, and activity space definition and classification. This kind of information is needed for the Building Code and for improved building design and management, generally. *The Construction Section* provides the industry with information that will improve the assembly of buildings, explain performance deficiencies, increase the efficiency of on-site operations, and improve standard building practices. This section also provides technical information in response to inquiries from industry and advises the laboratory sections on the research needs of the industry. *The Publications Section* is responsible for the editing, processing, and distribution of all reports on the work and activities of the Division. The publications themselves, are basic means of communication with the construction industry. Since this particular audience is made up of many elements with varying interests, the main objective of this Section is to ensure that information published by the Division of Building Research is in the appropriate form for the intended audience and that it reaches this audience. Many thousands of people receive monthly listings of the most recent DBR papers or copies of a regular monthly publication, *Canadian Building Digest*.

The *Building Research Library* within the Division of Building Research serves not only the needs of the research staff of the Division but the needs of engineering consultants, architects, contractors, university professors and students across Canada. It has links with other building information sources throughout the world. As a branch of the National Science Library, its resources also extend into all areas of science and applied science that may be relevant to building construction. Lists of acquisitions and books received are sent out regularly by the Library.

The Division of Building Research also sponsors seminars and conferences, from time to time, on aspects of building science and technology designed to meet the needs of particular professional and technical personnel within the building sector of the construction industry.

Central Mortgage and Housing Corporation

The Act of Parliament establishing CMHC* as a federal Crown Corporation was passed in 1945. The main responsibility of the Corporation is the implementation of federal housing legislation. The Corporation's business is carried out in Ottawa and through regional and field offices. The Minister of State for Housing and Urban Development is authorized to advance money to CMHC out of the Consolidated Revenue Fund for purposes specified in the National Housing Act (NHA), and the CMHC Act. It is from these advances that the Corporation makes direct loans. In turn, CMHC gives the Minister debentures undertaking to repay such advances with interest. The Corporation's income is derived from interest earned on direct loans, on agreements for sale, and on mortgages, as well as from property rentals, application fees for insured loans, fees earned for services to government agencies, and profits from real estate sales. The Corporation turns over all its profits to the federal Treasury, but is required to pay income tax. The present National Housing Act was introduced in 1954 and has been amended several times since then.

Under Part V of the National Housing Act, CMHC provides assistance in the form of grants to individuals and organizations for the performance of economic, social, planning, technical research, and advanced studies aimed at improving housing and other urban environments in Canada. In 1971, for example, the Corporation committed several million dollars for these purposes. Under the NHA provisions, also, a Canadian Housing Design Council has been established.

The house construction research sponsored by CMHC is concerned principally with the development of new materials and building techniques which may be employed to improve the quality and reduce the cost of housing in this country. CMHC has no laboratories of its own and the Division of Building Research at NRC carries out the testing and evaluation of materials and systems for it. In collaboration with the National House Builders Association, a series of experimental houses has been built by CMHC, incorporating technical innovations in the use of materials and in other areas. CMHC also employs staff to provide consulting services in house design and building techniques. Special attention has been given by the Corporation to the development, by private architects, of improved designs for small single-family houses.

The Corporation has participated over the years in the preparation and review of the National Building Code. A Canadian Code for Residential Construction was published in 1971 and went into effect in 1972 for construction financed under the National Housing Act. Corporation representatives have also participated in the work of the Canadian Standards Association, for example, on the Advisory Committee for Systems Building. The trend towards factory-built housing and the extension of

*The source material was the *Annual Report 1971*, published by CMHC and a brochure prepared recently by the Corporation and called *CMHC and the National Housing Act*, (CMHC, Montreal Road, Ottawa, K1A 0P7).

the National Housing Act to the financing of mobile homes have involved CMHC in plant as well as in site inspections.

Department of Public Works

According to the source material*:

The Department of Public Works exists, essentially, to do two things: to act as the agent of federal program departments and agencies in ensuring that they have the land, buildings and other improvements to land they require to carry out their program responsibilities effectively, and to act as the agent of the government, to the extent that our current authority allows, in seeking to ensure that the literally billions of dollars that have been invested in federal real property over the years, added to currently at the rate of half a billion dollars annually, bring the best return. We speak of these two responsibilities, respectively, as our service and realty management roles. (page 3)

The service role, for example, may be broken down as follows:

- the provision of general office and other general purpose accommodation to departments and agencies;
- the provision of engineering, architectural and construction management services to meet clients' needs for special purpose accommodation;
- the provision of acquisition, development, disposal and other property services related to real property held by client departments and agencies;
- the provision, on request, of operating and maintenance services related to special purpose properties.

The source material also identified a third, more recently defined, role for the Department:

the responsibility for undertaking a sound technological research and development program. This program will service all our operating branches, and will be very strongly concerned with the research which will flow naturally from the position we occupy as the largest builder and owner of structures in the country. It will be research, we hope, which eventually will be of great assistance to design, construction and general realty activities.

This program will recognize the impact our size and the complexity of our operations has on the Canadian construction and real estate industries and, therefore, our responsibility to play a role in their technological development. Research and development will thus be a key concern of DPW in its new role. (page 5)

During the past year or more, the federal Department of Public Works has been in the process of extensive reorganization and change in

*The source material for this Appendix was the brochure, *Public Works Canada*, published by the Department of Public Works in November 1972, together with material gathered during an interview with senior officials of the Department. (Department of Public Works, Sir Charles Tupper Building, Confederation Heights, Riverside Drive, Ottawa, K1A 0M2).

its management practices and philosophy. Prior to the reorganization, the Department had a construction design capability and it also had a testing laboratory. The strong emphasis on “technological research and development” activities as part of the overall departmental mission is new. The activities have now been organized under an Assistant Deputy Minister. The existing laboratory, for example, will play an increasing role in R & D activities, but its responsibilities and activities have not yet been fully worked out. As the source material noted:

It is already clear that our disposition as a large owner, designer, constructor and operator of buildings and structures provides a laboratory unequalled in Canada for vital feedback of information; a feedback lacking today in the Department and not existing elsewhere to the extent desired, and yet essential if we are to learn from our accumulated experience. (page 11)

The Department intends to perform applied research and development relating to its real property management responsibilities in order to encourage Canadian construction, design, and realty activities. The Department also expects to be involved with the wider R & D community through the universities, the National Research Council, and other institutions. There will, however, be little change in the Department’s design and construction activities except in the area of management. The recruiting of effective project managers will receive particular attention, as will the quality of human resource use within the Headquarters in Ottawa and in the various regional offices.

Appendix B – Construction-Related Activities of the Research Councils in the Provinces

There were no Councils in Newfoundland or Prince Edward Island at the time of writing. The information given in this Appendix for the other provinces refers, unless otherwise noted, to the most recently completed "Council Year" prior to April 1973.* This information is more detailed than the material provided for NRC's Division of Building Research in Appendix A because the construction-related activities of the Research Councils are being recorded for the first time.

A. Nova Scotia Research Foundation

(1) *Assistance provided for:* raw material source and location surveys; building foundation studies; building materials and components studies; application of operations research techniques to land use; noise abatement studies; geology; technical information and industrial engineering services; literature searches.

(2) *Project areas involved:* job scheduling for contractors; plant lay-outs for construction materials manufacturers; optimization studies of the location of solid waste disposal areas; surficial geology for highway location and gravel deposits; geophysical studies and equipment development related to foundation problems, depth of overburden, and quality of bed-rock; geophysical studies related to the location of materials for building construction; chemical analyses of corrosion by-products; uses and application of insulation materials; and consultations with regard to noise level standards for construction machinery.

(3) *Financial support for construction-related activities:*

<i>Activity</i>	<i>Sponsor</i>	<i>Amount</i>
Applied Research	Government	\$ 5 000
Development	Government	33 000
Engineering	Government	10 000
Engineering	Industry	17 500
Total		\$65 500

(4) *Technical information assistance:* supply of technical information on request and on referral to the Division of Building Research at NRC; literature searches on specific problems of interest to consultants and contractors.

(5) *Contacts with federal, provincial and other agencies on construction matters:* the Standards Council of Canada; the Canadian Standards Association; the Provincial Metrification Committee; the (Nova Scotia) Voluntary Economic Planning Metrification Committee; the Nova Scotia Water

This Appendix has been based on data provided by the Chief Executives, or their designates, in the eight Councils and Foundations.

*For additional information on the Research Councils, see *The Research Councils in the Provinces: A Canadian Resource* by Andrew H. Wilson, Science Council of Canada, Background Study No. 19, Information Canada, Ottawa, 1971.

Resources Commission; and the Eastern Passage Committee on Drilling operations.

(6) *Contacts with universities and foreign institutions:*

None relating to construction.

B. New Brunswick Research and Productivity Council

(1) *Assistance provided on:* building systems; building design mathematics; building materials; plastics; building components; technical information; design; industrial engineering; marketing.

(2) *Project areas involved:* the processing of light-weight aggregates; hydraulic cements and cement additives; an inventory of industrial and non-metallic minerals in the province; weathering and durability of building stone; mineral properties of fly-ash as a cement additive; ceramic properties of brick clays; ceramic/glass terrazzos; the causes of spontaneous combustion in glass-fibre insulation; the physical testing of plastic pipes; the redesign of moulds for plastic pipes; paints; performance tests for built-in humidifiers; a manufacturing system for factory-built houses; feasibility study of forms of modular construction of schools; component designs for factory-built houses; stress calculations for monocoque building design; the welding of magnetized piles; noise level measurements for construction equipment; and a market survey for wood/plastic composite siding material.

(3) *Financial support for construction-related activities:*

<i>Activity</i>	<i>Sponsor</i>	<i>Amount</i>
Development and engineering	Industry	\$ 2 700
	Government	6 800
Trouble-shooting	Industry	2 500
	Government	200
Quality Control	Industry	4 400
	Government	2 000
Total		\$18 600

(4) *Technical information assistance:* to contractors and others in the construction and associated trades, in 25 cases.

(5) *Contacts with Federal, provincial and other agencies on construction matters:* the Standards Council of Canada; and the Standards Policy Board of the Canadian Standards Association.

(6) *Contacts with universities and foreign institutions:* the American Society for Testing and Materials; American Society of Metals; and others.

C. Le Centre de recherche industrielle du Québec

CRIQ is a relatively new organization and its most recent activities with regard to the construction industry cannot be described under the six headings used for the other seven Research Councils. Nevertheless, the following points may be noted in relation to the potential of the Centre in support of the construction industry.

- (a) During 1972 and 1973, CRIQ did feasibility studies for a number of building construction projects in order to assess their innovative and economic viability and their place in the overall work-plan for the Centre.
- (b) CRIQ, in its constituent divisions, is equipped to do work on systems building, the selection of materials, structural optimization, concept evaluation, and model testing. However, activities in these areas can only be maintained as long as there are contacts between CRIQ staff and interested groups outside.
- (c) The main CRIQ R & D activities are in mechanical engineering, systems engineering, and materials. But CRIQ also has, in-house, a technical information analysis section, a technical laboratory section, a market research section, a management/coordination section, and an administrative section.
- (d) For specific construction-related work, CRIQ can put together multi-discipline teams drawn from its three principal areas of R & D specialization.
- (e) In pursuing its construction-related feasibility studies further, CRIQ may well collaborate with interested university groups.

D. Ontario Research Foundation

- (1) *Assistance provided to:* all segments of the construction industry; this assistance ranges from long-term R & D projects, through short-term development projects (including design and consultation, prototype development, technical evaluation, structural analysis, and materials development), to specialized testing, technical information and industrial engineering services.
- (2) *Project areas involved:* in three main categories – inorganic building materials, organic building materials and engineering: broken down further into – concrete, portland cement, gypsum, lime and other cementitious materials; bricks, blocks, panels, glass and structural clay products; corrosion engineering; protective coatings, paints, adhesives, asphalt and bituminous materials; plastics, including insulating foams; fireproofing and flammability of plastics, wood, and other materials; composites; textiles, including carpets and wall coverings; water purification and sewage treatment; stress analysis and structural design engineering.
- (3) *Financial support for construction-related activities:* about \$1 million annually, of which about 70 per cent is provided by industry for contract work and about 30 per cent by governments; about three-quarters of this support is for applied research and development.
- (4) *Technical information assistance:* free TIS and limited field engineering service sponsored by the Ontario Government and the National Research Council; in addition, personal-level consultations and general liaison with construction industry people assists in the transfer of technical information.
- (5) *Contacts with federal, provincial and other agencies:* take place through research contracts and the membership of committees.
- (6) *Contacts with universities and foreign institutions:* take place principally on a personal contact basis and through committee memberships.

E. Manitoba Research Council*

- (1) *Assistance available for:* the organization of R & D projects related to construction materials and equipment; shared-cost R & D projects to be carried out by industry; technical information search and application.
- (2) *Project areas involved:* new materials development and testing; equipment development; and techno/economic evaluation of modular housing systems.
- (3) *Financial support for construction-related activities:* during the last two years, about \$100 000 has been committed to projects in this field, with industry committing a similar amount.
- (4) *Technical information assistance:* information obtained, on request, for local firms through MRC staff or in cooperation with university people, consultants, or the Manitoba Office of the NRC; a new technology analysis and evaluation service is also being provided.
- (5) *Contacts with federal, provincial and other agencies on construction matters:* the Standards Council of Canada; the National Research Council.
- (6) *Contacts with universities and foreign institutions:* the University of Manitoba and other educational institutions in the province.

F. Saskatchewan Research Council†

- (1) *Assistance available for:* geological site studies; soil studies; foundation work; ceramic materials; and construction materials generally.
- (2) *Project areas involved:* soil moisture instrumentation; insulation and heating of underground water lines; location of structural materials such as clay products, sand and gravel; studies of cement manufacturing, the production of lightweight aggregates, and the utilization of marl; studies of the foundations for masonry structures and single-storey frame buildings; physical environment studies; storm drainage; sewage studies; technical information and industrial engineering services.
- (3) *Financial support for construction-related activities:* no breakdown figures available.
- (4) *Technical information assistance:* in areas such as lightweight aggregate and concrete block manufacture; construction tools; concrete; foundation settlement; roofing; insulation; and condensation.
- (5) *Contacts with federal, provincial and other agencies:* the satellite laboratory of NRC's Division of Building Research on the University of Saskatchewan campus; the NRC in Ottawa.
- (6) *Contacts with universities and foreign institutions:* the University of Saskatchewan.

G. Research Council of Alberta

- (1) *Assistance provided for:* research, design, development, testing and field studies in the general area of building materials; highways research; noise surveys; technical information and industrial engineering services.

*The MRC is the only one of the Research Councils that has no laboratories of its own. It is also the only one that is part of a provincial government department.

†The information given for the SRC covers several recent "Council Years".

- (2) *Project areas involved*: plastic tanks for mobile homes; fibreglass reinforced plastic beams; elliptical septic tanks; acoustical enclosures for noisy areas; heating systems; roofing systems; heat loss studies; lighting systems; studies of greenhouses and vegetable storage buildings; window temperature gradients; fume exhaust system studies; fan speed controls; roof failures; window evaluations; paint thickness; dirt collection cyclones; quality control of housing components; colour-fastness of artificial bricks; failures in underground plastic piping; geological studies related to buildings and civil engineering works; noise studies of gas plants, office areas, etc.; highways and bridge research studies; and the certification and calibration of acoustical equipment used by police in noise law enforcement.
- (3) *Financial support for construction-related activities*: no firm figures available except for highways research, which has recently been funded at \$300 000 for the year by the province; however, approximately one-third of the total cost of short-term studies has been covered by industrial clients and the remainder through programs jointly funded by the NRC and the Alberta Government.
- (4) *Technical information assistance*: enquiries received on every conceivable subject, involving construction materials and methods, and handled through the Council's own resources or by NRC and its Division of Building Research.
- (5) *Contacts with federal, provincial and other agencies*: the Divisions of Building Research and Mechanical Engineering at NRC; Central Mortgage and Housing Corporation; Canadian Standards Association; Alberta Housing Corporation; Alberta Departments of Public Works, Highways and Agriculture; the Canadian Committee on Acoustics; the Transportation Planning Committee of the City of Edmonton.
- (6) *Contacts with universities and foreign institutions*: the University of Alberta participates in the highways and bridge research program; use is also made of other University of Alberta facilities.

H. British Columbia Research

- (1) *Assistance provided*: to contractors, for the application of industrial engineering and productivity improvement in the plumbing and mechanical trades; to equipment and material manufacturers, for product, process and equipment development, productivity improvement, product evaluation, and market research.
- (2) *Project areas involved*: (for example) the development of new paint coatings; deflection tests on wall sections; dust infiltration tests; cedar shingle fire-retardant coating tests; the application of industrial engineering practices in the lumber and plywood industries; the testing of wood preservatives; waste treatment studies; short courses in work study and marketing.
- (3) *Financial support for construction-related activities*: no firm figures available; most of the R & D work is done under contract with industry but, in the early stages, high-risk research work may be done using grant

funds from the BC Government; technical information and industrial engineering activities financed largely by NRC.

(4) *Technical information assistance:* both TIS enquiry and industrial engineering services provided; emphasis placed on visits of BCR staff to companies.

(5) *Contacts with federal, provincial and local government agencies:* principally with the Division of Building Research at NRC, which has two staff people located at BCR Laboratories.

(6) *Contacts with universities and foreign institutions:* none specifically relating to the construction industry.

Appendix C – Construction Associations in Canada

There are large numbers of national and regional associations linked to the construction industry in Canada, as well as hundreds of Builder's Exchanges and other organizations. The purpose of this Appendix is to say something about the activities of a handful of *national* associations and to identify their respective roles with regard to the encouragement of technology transfer. The following have been included: the Canadian Construction Association and the National Construction Industry Development Foundation which it sponsors; the Canadian Institute of Steel Construction; the Portland Cement Association; and the Canadian Wood Council.

Canadian Construction Association

Established in 1918, and incorporated by Dominion Charter in 1919, the objects of the Canadian Construction Association (CCA) as stated in its Constitution are as follows*:

- (a) to act as the voice of the construction industry in Canada on matters of national concern and interest;
- (b) to promote better relations between its members and owners, architects and engineers;
- (c) to establish and maintain methods of practice between members within the industry;
- (d) to acquire and disseminate useful information concerning the industry;
- (e) to expand the construction market and improve conditions in the combined industries;
- (f) to coordinate the units of the industry in its producing, manufacturing, distributing, professional and constructive activities, thereby increasing its efficiency and extending its usefulness;
- (g) to provide the medium whereby affiliates may exchange opinions and coordinate their efforts.

Under conditions set out in the Constitution, membership of the Association may be granted to individuals, firms or corporations engaged in any branch of the construction industry in Canada; and organized groups of individuals, firms, corporations or associations engaged in, or interested in, the industry may be eligible for affiliate or "collective" membership of the CCA. The membership is organized into sections as follows: General Contractors; Road Builders and Heavy Construction; Trade Contractors; and Manufacturers and Suppliers (of materials, equipment and services). Currently, the CCA has a membership of over 2 000 individual firms and some 95 associations, for a combined membership of over 12 000. Each of the sections and each of the provinces is represented on the CCA Board of Directors and each member association is represented on the CCA National Council and may appoint a member to each of the CCA Standing Committees. The CCA provides the means whereby local, city, regional and provincial construction-related associa-

*The source material was supplied by the Association.

tions can belong to a single organization under a common constitution and work toward agreed ends.

The CCA provides services to members in the following way: the publication of bulletins and other materials; representation in Ottawa where the CCA Head Office is located; clearinghouse facilities for construction industry information; tender reports on federal projects; the services of CCA staff specialists in fields such as engineering, labour relations, law, public relations, taxation and architectural liaison. These services are reflected in the Committee activities of the Association.

The CCA has an interest in education and training. It is the sponsor for the National Construction Industry Development Foundation. It has, on its staff, technically-qualified professionals but its interest in, and activities associated with, technology transfer and innovation is relatively passive. The CCA leaves technical matters very largely to the Foundation and other construction-related associations that have the express mandate to look into them.

National Construction Industry Development Foundation (NCIDF)

This Foundation* was established in 1971 under the sponsorship of the Canadian Construction Association. Initially, the Foundation received a \$50 000 grant from the federal Department of Industry, Trade and Commerce to help it through the formative period. Eventually, the Foundation should become self-supporting on the basis of funds supplied by the construction industry itself.

The general objective of NCIDF is to promote and finance industrial research and testing by industry itself or by research institutions, including education establishments, in order to promote greater efficiency in the construction industry. The following are included among the specific objectives of the Foundation:

- to encourage a practical interest in technical and scientific obstacles to maximum efficiency in the construction industry and, to this end, to promote and finance industrial research and testing whether undertaken by the industry or by way of grants-in-aid to recognized research institutions, including educational establishments;
- to promote education within the industry by providing improved facilities for academic, scientific and technical training by way of grants-in-aid to universities and other approved educational institutions;
- to sponsor independently or in collaboration with the provincial departments of education and approved educational institutions, training courses for management, foremen and other personnel;
- to keep the skilled labour force informed of changing construction methods and techniques in the industry; to provide instruction and training by way of refresher or retraining courses; to facilitate the adaptation of skills to such changing requirements and, where necessary, to extend facilities within the framework of this object to other groups constituting the labour force;

*The source material was supplied by the Foundation.

- to promote safety measures in the industry and to collaborate with bodies already engaged in the promotion of accident prevention;
- to sponsor an advisory service for the construction industry aimed at promoting managerial and administrative efficiency, the improvement of human relations within the industry, and at minimizing the effect of technical and scientific problems encountered in the course of construction;
- to promote detailed studies of the development of statistics measuring construction volume, costs, employment and productivity;
- to sponsor prototype projects using modular dimensioning;
- to promote economic studies designed to stabilize the growth rate of the national construction program.

Canadian Institute of Steel Construction

This Institute*, CISC, for short, is a national trade association representing the structural steel, open-web steel joist, and steel platework fabricators in Canada. The member companies, between them, produce over 500 000 tons of fabricated steel each year and employ around 15 000 people. The Institute also has, as associate members, Canada's leading steel-producing mills and representative British and American steel producers.

Cisc was formed in 1930 and was granted a federal charter as a non-profit trade association in 1942. Beginning as a one-man operation, the Institute now employs upwards of 30 people in its headquarters in Toronto and in its regional offices in Halifax, Montreal, Toronto, Winnipeg, Edmonton and Vancouver. Members of cisc must subscribe to the Institute's Code of Standard Practice. The Institute is governed by a 24-person Board of Directors.

Cisc is both a technical and marketing organization which promotes good design together with efficient and economic use of steel. The Institute serves contractors, owners, developers, architects, engineers, educational institutions and the three levels of government. Its activities include:

- engineering and research;
- the development of design aids, including computer programs;
- project cost analyses;
- the collection of statistics and market information;
- advisory and technical services on structural design, codes, standards, by-laws, fire safety, specifications, etc.;
- the provision of speaker services, films and slides; and
- the sponsoring of training courses, seminars and conferences.

Included among the Institute's publications are *The CISC Handbook of Steel Construction*, users' manuals for various computer programs, steel building design workshop notes, and the proceedings of structural engineering conferences. The Institute also publishes a series of case studies of the successful use of steel in construction, and a number of general information brochures.

*The Institute's published brochure, *Symbol of Progress – An Introduction to the CISC*, was the principal information source. (Canadian Institute of Steel Construction, 1815 Yonge St., Toronto, Ontario.)

The CISC has participated in the work of the National Building Code since this work began. It has taken part in fire protection studies and, since 1964, has financed a Research Fellow at the Fire Research Section of the Division of Building Research at NRC, Ottawa. The CISC is currently involved in the work of the Canadian Standards Association, the American Society for Testing and Materials, the Specification Writers Association of Canada, and in international organizations involved with codes and standards.

In cooperation with the Canadian Steel Industries Construction Council, to which it belongs, the CISC has sponsored research in Canadian universities for several years. The amount spent during 1972 was of the order of \$80 000. The results of CSICC/CISC-sponsored work are usually reported in technical journals, at conferences, and in CISC publications. It may also be used in the writing of new or revised Codes and standards. Through its Standing Committees on Research and Development, Plate-work, Joists, etc., the CISC studies matters of technical interest to the construction industry.

The Institute's interests from the legislative point of view include taxation, contracting procedures and requirements, workmen's compensation, safety, and other matters in addition to Codes, standards and by-laws.

In its Brief to the Special Senate Committee on Science Policy, dated April 1969, the CISC made a number of interesting observations.

- The cyclical nature of the (construction) industry seriously affects CISC members' financial resources in periods of low activity, thus limiting their ability to assure the provision of research funds on a continuing basis.
- The most significant structural steel research, on which basic design rules are based, is done outside Canada, particularly at Lehigh University, University of Illinois, and Cambridge, among others. Canadian structural steel research has been directed mainly toward special problems.*
- Structural steel design usually complies with Canadian Standards Association specifications, although American specifications are used for some projects.
- For platemwork design, we are almost completely dependent on American research, and American specifications are used for major work.
- Welding technology depends mainly on American research and development plus important British, Russian, and Japanese contributions, with rather limited work in Canada.
- Many member companies do work of an "applied research" or "development" nature resulting from particular contract or production requirements, using regular staff and facilities.
- The National Building Code, supported by the Division of Building Research at NRC is of inestimable value to construction in Canada. Departures from this Code by certain major cities are a continuing problem for our industry.

*It should be noted, however, that professors in the Faculty of Engineering at McMaster University, in one of Canada's steel towns, also have good relations with, and do work for, the steel companies.

Portland Cement Association

The Portland Cement Association (PCA)* is a non-profit organization that has been in operation in the United States since 1916, with its main offices in Chicago and its laboratories, built between 1948 and 1968, at Skokie, Illinois. The U.S. parent PCA maintains a headquarters and laboratory staff of more than 200 engineers, architects, scientists and writers and a field organization of nearly 400 engineers, architects and other specialists at offices in the United States and Canada.

The Association's activities cover scientific research, the development of new and improved products and methods, the provision of technical services, promotion and education, and construction safety and are primarily intended to improve and extend the uses of portland cement and concrete. These activities are financed by member companies in the United States and Canada. These member companies represent the majority of the manufacturing and sales effort for portland cement in the two countries.

The PCA's R & D interests in broad terms are: basic research in construction materials and techniques; concrete research; fire research; construction methods; structural development studies; transportation development studies; and technical information services. The Association also has a particular interest in earthquake engineering. Specific research projects are solicited by PCA Laboratory management each year from field staff and members, including those in Canada. The work is performed principally at the Skokie Laboratories and the results are disseminated widely to Association members and to other interested companies, agencies and individuals.

PCA staff members, both in the U.S. and Canada, are very active in work associated with Codes and standards, for example, through the American Concrete Institute, the Canadian Standards Association, and the National Building and Fire Codes in Canada. PCA staff members in this country work closely with the NRC Division of Building Research engineers in Ottawa. The Association has also awarded fellowships for work in DBR laboratories. On manpower and education/training questions, the Association's representatives in Ottawa work closely with the federal Department of Manpower and Immigration.

In addition to distributing trade and technical information, the PCA organizes seminars and conferences on both sides of the Canada/U.S. border. The PCA Laboratories have also been developing and promoting the use of computers in structural design. While the PCA, on both sides of the border, helps to *promote* the use of concrete in its various forms, the Association does not actually *sell* it. This is the task of its member companies.

*The source material was included in two brochures published by the Portland Cement Association in the United States, the one called *Today's Portland Cement Association*, and the other describing the activities of the PCA's Research and Development Laboratories. The material on the Canadian operations was obtained during an interview. (Portland Cement Association, 116 Albert Street, Ottawa, Ontario.)

Canadian Wood Council

Incorporated in 1960, the Canadian Wood Council (cwc)* is a national federation of 18 associations representing Canada's wood industry whose products include lumber, plywood, shingles and laminates.† The associations are commercially-based for the most part, leaving the cwc with significant technical responsibilities. It therefore complements, rather than duplicates, the work of its members.

The Council has four main objectives:

- to represent the wood industry in the complex field of building Codes and standards;
- to coordinate research and technical activities for the benefit of both the industry and the public, particularly with respect to timber engineering and fire performance;
- to undertake educational activities aimed at extending knowledge of wood subjects to both present and future users of wood; and
- to communicate industry developments to wood users, and to encourage effective communication within the wood industry.

The Council's 18-person Board of Directors has an Advisory Committee whose principal task is to advise the Board of industry plans and proposals as they relate to the interests of the member associations. The cwc staff, under the direction of the Executive Director, provides technical, educational, information, and other support services.

The technical services are concerned with three main areas: building Codes and standards; fire research; and wood engineering. Cwc staff maintain close touch with the National Research Council and the Canadian Standards Association. In the education field, the cwc works with educational institutions, but also organizes and conducts technical seminars of its own. The Council's communication task includes the dissemination, to architects and engineers, in particular, of information on the wood industry and its products and on forest products research. Some of this material is written or compiled by Council's staff. The staff maintains close touch with the federal Forest Products Laboratory. Cwc staff also keep in touch with developments in the application of international standards and metrication in North America and with the work of the Standards Council of Canada.

The cwc, in association with the Wood Council in the United States, occasionally sponsors research projects in universities or in federal agencies in the U.S. However, since the U.S. companies are in a highly competitive situation, their willingness to finance or participate in common-interest R & D projects is limited. A few of the companies belonging to cwc Associations have their own R & D laboratories.

*The source material was taken from a brochure on its activities published recently by the cwc, supplemented by information received during an interview. (Canadian Wood Council, 170 Laurier Avenue West, Ottawa, Ontario.)

†For example, the Canadian Lumbermen's Association, the Maritime Lumber Bureau, and the Alberta Forest Products Association.

Appendix D – Research and Industrial Assistance Programs Relating to Construction

Industrial Research Assistance Program (IRAP)

Through activities undertaken in its own laboratories, through its Industrial Research Assistance Program (IRAP)*, and also through a number of its grants to university researchers, the National Research Council supports research and the use of research results for the benefit of Canadian industry.

The National Research Council, under the Industrial Research Assistance Program, provides grants to companies submitting acceptable research project proposals. The grants cover the salary costs of the projects, which usually amount to about half of the total costs. In this way, for projects accepted under this program, a partnership between the federal government, through NRC, and the company is established, with each partner sharing the cost and the risk on a roughly equal basis.

The number of new applications received under this program has risen rapidly in recent years, from 44 in 1969-70, to 76 in 1970-71 and 110 in 1971-72, the year under review. A rapidly increasing demand is coming from small (less than 200 employees) Canadian-owned companies. As of March 1972, 229 projects located in 152 companies were being supported under IRAP, 51 of which were new projects approved during the last year.

In 1972-73, of an estimated \$10.8 million spent in support of IRAP, only 2.5 per cent, or \$277 000, was construction related, chiefly for companies which manufactured materials and supplies for the construction industry.

Program for the Advancement of Industrial Technology (PAIT)

Another program to help Canadian industry grow and become more efficient is the Program for the Advancement of Industrial Technology† of the federal *Department of Industry, Trade and Commerce*. The basic purpose of PAIT, which was established in 1965, is to promote the growth and efficiency of industry in Canada by providing financial assistance for selected projects concerned with the development of new or improved products and processes which incorporate new technology and offer good prospects for commercial exploitation in domestic and international markets. Companies are required, within a reasonable time, to exploit the results of the development project in the domestic and export markets from a manufacturing base in Canada to the extent that it is not uneconomic to do so.

Financial assistance under the program is available to companies incorporated in Canada for development projects to be carried out and

*The source material was *Report of the President 1971-72*, published by the National Research Council, Ottawa, supplemented by interviews with NRC officials.

†The source material was the brochure *Program for the Advancement of Industrial Technology*, published by the Department of Industry, Trade and Commerce, Ottawa, plus correspondence and interviews with the PAIT Office of the Department.

exploited in Canada. Costs of an approved project are shared by the Department and the company concerned. Originally a PAIT grant covered half of the estimated cost of a project, but this grant was repayable if the project was successful. In effect, the grant became a loan. PAIT was revised in 1970 to provide assistance in the form of cash grants instead of repayable loans. Generally, such grants equal 50 per cent of the current costs of development projects, including certain pre-production costs of a non-recurring nature and costs incurred for pilot plants and special purpose equipment. Capital costs incurred for the acquisition of general purpose facilities and equipment, and expenses related to production and marketing activities are not eligible for support under the program.

In fiscal year 1970-71, the PAIT Program supported 141 projects with a contribution committed of \$50.7 million, a 400 per cent increase from the previous year.

Appendix E – Examples of University Contract Research and Development Related to Construction

University of Toronto Institute of Aerospace Studies*

The magnitude and distribution of wind loads on buildings or on industrial designs exposed to atmospheric conditions, depends on the shape of the structure, and on the velocity and characteristics of the wind. As designs tend to become more unorthodox with advances in technical know-how, the questions of wind loads and fluctuating (vortex induced) forces often become so complex that only wind tunnel tests of scale models of the actual structures can supply reliable wind design data.

The attached list gives some examples of architectural and industrial aerodynamics, which were tackled at the Institute in supplying architects and industrial firms with wind force design information. The Toronto City Hall is a typical example of a bold architectural design. Neither the architect nor the structural engineers realized that the existing building code design rules were inadequate. Wind tunnel tests conducted on a City Hall model verified strong torsional forces, for which the original City Hall design did not account. As a result, the City Hall had to be redesigned for torsional stiffness, the extent and importance of which was reflected in the \$5 million total cost increase.

As a typical example of the benefits which can be deduced in industrial aerodynamics, the Welland Canal ventilation study could be used. In the course of searching for an effective and economic tunnel ventilation system, the Institute suggested the application of Coanda surfaces for changing the direction of the forced air ventilating tunnel flow. Wind tunnel tests established the potential of this new system and at present, shorter subway tunnels are to be designed and built using this principle.

Architectural Aerodynamics

Wind Tunnel Testing to

1. Toronto City Hall, original and revised design.
2. Global Centre, Niagara Falls
3. Balloon Launch Shelter
4. Welland Canal
(ventilation study)
5. Ontario Government Pavilion
(Expo 67)
6. African Complex
(Expo 67)

Leading to or Resulting in

redesign, to cure lack of torsional stiffness
strengthening of shaft for globe
wind force determination for structural design data
new (Coanda effect)
ventilation system suggested and successfully tested
wind forces determined for structural design of roof
orientation of open roof scoops for optimal ventilation of buildings

*The source material was supplied by the Institute.

7. St. Louis Arch	confirmation of wind force design data used
8. Welland Canal (traffic study)	studying critical conditions of wind and traffic interaction
9. Air Canada Pavilion (Expo 67)	wind forces and aeroelastic behaviour
10. USAF Museum (Wright-Patterson)	study of wind forces and aeroelastic instability
11. Highway Signs	wind stability in strong winds
12. York University Plaza	gust velocities within plaza and along approaches, human comfort
13. Roof of Kansas City Sports Complex	wind force design data on arc-shaped roof
14. University of Guelph Quadrangle	gust velocities in quadrangle and surrounding, human comfort
15. IDS-Center Office Tower	vortex shedding, no problem to windows, but higher wind loads than expected
16. Skylon, Niagara Falls	bending and torsion force determination
17. Harvard University "School of Design" Building	wind forces, ventilation and human comfort
18. Harvard University Public Health Building	as above
19. Ingersoll-Rand Comp. new Codling Tower Concept	wind forces, vortex shedding, aeroelastic behaviour
20. Spadina Expressway Tunnel ventilation	consulting and checking on ventilation system design
21. Air Turbine Design	design and testing of blading
22. New Flush Valve Designs	selection of best concept

Industrial Aerodynamics

Wind Tunnel Testing to

1. Rotating Beam Vibrations
2. Anemometer Calibration (AEC, Douglas Point)
3. Roof of Kansas City Sports Complex
4. Rain Protection by Jet Sheets
5. Snow Tunnel (NRC)

Leading to or Resulting in

study and review of subject
conversion of electrical into pressure signal
unfeasibility of moving roof by air flotation, hydrostatic lift suggested instead
potential of jet sheets in replacing rigid roofs
for study of drifting and blowing snow

- | | |
|--|--|
| 6. Air Curtain Walls and Roofs (NRC) | inverted annular jet (patent applied for), dome shaped sheltered region against rain |
| 7. Air Curtains for Hydro Installations (Ontario Hydro) | protection from wind-born salt spray from expressway traffic |
| 8. Annular Air Curtain (NRC) | its protective potential against rain, snow, wind |
| 9. Rain Drop Trajectories Through Air Curtain (NRC) | computation and two-dimensional test comparison |
| 10. Rain Drop Trajectories Through Annular Air Curtain (NRC) | computation and test comparison |
| 11. Precipitation Wind Tunnel (NRC) | interaction studies of rain (snow) with structures and jet sheets |

University of Waterloo: A Sample Project*

The work was done by Professors Hill and Farquhar of the Department of Civil Engineering and Professor Farvolden of the Department of Earth Sciences at the University to determine the pollution effects of sanitary landfills on ground and surface water. It began in a highly pragmatic fashion when the University sought to assist several Ontario jurisdictions to develop a valid basis for approval of applications for new sanitary landfill sites. The initial funding of the research was rationalized by sponsors solely on the basis of the work's generating useful decision rules. University acceptance of this highly pragmatic, problem-motivated objective was clearly an essential starting point. The major field measurement program which followed over the next four years has produced not only the decision criteria sought by the initial sponsors, it has also employed students, provided their thesis subject matter and led to the development of field and laboratory measurement and analysis techniques which offer greatly widened potential for future work.

The proposed future work is now pointing both in the more basic and in the more applied directions. For example, the attenuation of contaminants in water as it migrates through soils has been widely known to occur and often utilized, but it has been understood very incompletely in a scientific sense. The University is now in a position to make a useful contribution to this body of basic knowledge and expects funding to enable the work to proceed. On the other hand, the work on sanitary landfills has led to the possibility of making a major contribution to the application of scientific and engineering knowledge. This possibility exists in relation to methane generation in sanitary landfills which is a serious and largely mysterious problem to solid waste managers. Investigators are now able to organize and offer valuable information in a readily usable fashion to the industry.

*Source material supplied by Waterloo Research Institute.

Both the problem-motivated basic research and the applied work resulting from this project required help that only the University could give. The delineation of the problems, the appreciation of their importance, the value and nature of the available solutions and the means of obtaining them stem solely from the University researchers who carried out the earlier work. Neither the basic nor the applied work could have been done as well and as economically by others less capable in basic engineering research and with less comprehensive and valid understanding of the subject matter. Both aspects are needed by society and now both are timely because of society's awareness, as never before, of the need.

Generally speaking, universities need to know and understand the contributions they alone can make in providing unique services to society. On the other hand, the universities need to be flexible in their responses to the needs of society. The performance of those roles which the universities can best provide seems more important than the rigid adherence to conventional tasks.

Appendix F – Government-Sponsored Information Services

Technical Information Service (TIS)

In addition to the National Science Library, the *National Research Council's* formal information dissemination operations include its Technical Information Service*, and the publication of the Canadian Journals of Research. The function of the TIS is to aid Canadian industry, with emphasis on the small- and medium-sized manufacturing companies. However, enquiries or requests are accepted from any Canadian firm, organization or individual including builders, architects, contractors, and potential users of materials or services.

TIS, which is divided into three sections, Technical Enquiries, Technological Developments and Industrial Engineering, works in close co-operation with the National Science Library and the National Research Council Laboratories. In addition to its Ottawa-based staff, TIS has field offices across the country, most of which are operated in collaboration with provincial research councils.

The *Technical Enquiries Section* of TIS responds to specific requests from companies for information and advice on technical matters. If possible, these are handled on a local basis through the field offices, but it is often necessary for the requests to be directed to the Ottawa office, frequently for referral to the expertise available in the the laboratories of NRC or other government departments. During 1972, 121 requests for information dealing with buildings or structures were handled for TIS by the Division of Building Research. In addition, between 400 and 500 of the 3 000 written replies handled by TIS were related to building materials, structures, etc.

The *Technological Developments Section* addresses itself to the more general needs of industry by selecting from the current literature items considered to be of practical value to various industrial groups. These items are then forwarded to registered clients on the basis of the client's expressed interest.

The industrial engineers who make up the *Industrial Engineering Section* provide advice to companies in such areas as production engineering, production planning and control, plant layout, materials handling, management, accounting and personnel. While this Section provides for the transfer of information in areas which are often not considered to fall under the title of scientific and technical information *per se*, its services have nevertheless proved to be extremely effective and beneficial.

*The source material for this section was the National Research Council's *Report of the President, 1971-72*, and supplementary correspondence with TIS.

The Canadian BEAM Program: Development of the Construction Information System

The BEAM (Building Equipment Accessories and Materials) Program* of the Materials Branch of the *Department of Industry, Trade and Commerce* is designed to improve the construction industry in Canada by increasing the productivity and efficiency of the manufacture and use of building equipment, accessories and materials. The program, which was developed in 1967, comprises several related objectives:

- establishment of a comprehensive national construction information system to provide the industry with a means of storing, retrieving, and disseminating information vital to the effective conduct of its business;
- encouragement of modular dimensional standardization and co-ordination;
- encouragement of accelerated industrialization of the building process through an understanding and application of the systems approach to building;
- development and expansion of export markets for Canadian buildings, building components and expertise;
- promotion of nation-wide acceptance and use of the National Building Code, more adequate standards and improved means of assessing new products and systems;
- encouragement of building design excellence through awards programs, research, development, and innovation.

The Construction Information System

The *Construction Information System* (CIS) was developed in 1967 as an arm of the BEAM program. To date, it has received a total capital outlay of about \$1.7 million and it is planned that it will begin operation in 1973 as a computer-supported microfiche data system. The rationale for the system can be briefly outlined. The traditional information system for the Canadian construction industry is large, costly, and of uncertain quality and efficiency. Twenty to thirty million pages of product literature are disseminated annually, and this amount is growing at 8 per cent per year. About 65 per cent of this is discarded either on receipt or after first reading. Four hundred million pages of literature on product and building technology is stored on users' premises throughout Canada. It is estimated that 80 000 queries per day flow from users to all information sources enquiring about prices, new products, technical information, building codes, standard specifications, zoning regulations, etc. This operation probably costs the construction industry between \$400 million and \$800 million per year or up to 8 per cent of the total annual value of construction work in the year 1968. Even a marginal improvement in such a system could result in huge savings.

*For additional information, see the paper by John A. Dawson, *The Canadian BEAM Program: Construction Information System Development*, Department of Industry, Trade and Commerce, Ottawa, August 1972. See also, the Department of Industry, Trade and Commerce Report, *Building Equipment, Accessories and Materials Program*, 1972.

The services consist of a computer store of information, retrievable on command, a microfiche library of manufacturers' catalogues, as well as indexes, terminals and other equipment for operating the system.

The Department of Industry, Trade and Commerce which conducted the development of the Construction Information System up until recently has transferred management of the system to the private sector. A private non-profit corporation known as the *Canadian Construction Information Corporation* has been chartered and had its first Board of Directors meeting in June 1972. These directors represent all sections of the construction industry across Canada. Projections have suggested that the costs to subscriber-users may vary from between \$40 or \$50 per month to a maximum of approximately \$200, depending on the kind of service desired. It is estimated that the potential market for the system includes all sectors of the construction industry, including those who design or purchase building materials or those who sell them. On the basis of a minimum information cost of \$400 million per year, a gain in informational efficiency of only 5 per cent would return aggregate gains of \$20 million annually. It is estimated that the CIS has approximately 10 000 potential users, but needs only 2 000 to succeed.

Modular Coordination

Modular or dimensional coordination refers to the process of standardizing the dimensions of building components in order to reduce the variety of sizes in which components are manufactured and thus facilitate the assembly of components on the building site with a minimum of alteration. Dimensional standardization is based on the standard four-inch building module as a prerequisite to coordination. It provides a way to reduce cost and is a necessary prerequisite to the industrialization of the building process.

This aspect of the BEAM program has received considerable support from industry, as well as from federal and provincial departments and agencies concerned with building. The Department of Public Works now requires that all buildings commissioned by it be designed to modular standards. Central Mortgage and Housing Corporation also endorses the concept as well as the Division of Building Research of the National Research Council. The DBR has given much assistance in support of BEAM program initiatives. Other government departments such as National Defence, Indian Affairs and Northern Development, and the Ministry of Transport, as well as several provincial governments, have supported the modular concept.

The Department of Industry, Trade and Commerce has organized clinics of modular practice in various parts of Canada and has prepared a Directory of Modular Building Components.

*Industrialized Building Techniques and Systems**

Traditionally, components and materials for building have been brought to the site in an unfinished state to be cut, fitted and assembled by craftsmen. Changes have been developing in the industry which point to the

*Additional information on industrialized building has been included in Appendix J.

development of a strong capital-intensive, and even factory-based industry which will be less affected by weather conditions. More and more components are being delivered to the site in a finished or nearly finished condition. This evolution is generally referred to as the industrialization of building.

It implies continuity of production, standardization, integration of the different stages of the whole production process, systematic organization of work, and mechanization where possible. It also requires new methods of coordinating the building requirements of customers and to new working relationships between clients, architects, builders, manufacturers and labour.

In order to realize these objectives, the BEAM program initiated a series of studies of building systems development, technical study missions, the publication of reports, and the use of pre-fabricated building materials in Europe, and a series of national conferences.

*Building Codes and Standards**

The National Building Code is being promoted in cooperation with the National Research Council Division of Building Research. The principal method of promotion is through appropriate provincial government departments and agencies such as municipal affairs, housing corporations, public works.

Industry-designed Promotion

A Design Canada Awards Program has been initiated. It will continue the earlier awards programs relating to the creative use of materials, buildings, and bridges and will also recognize design excellence in the development and application of new building equipment, accessories and materials, and in the improvement of existing components. This new program recognizes especially those designs which incorporate the principles of modular coordination, prefabrication, pre-assembly, and standardization of components. The purpose of the program is to encourage Canadian designers and manufacturers of building materials and products to take advantage of design as a means of increasing productivity and efficiency.

*The principal discussion on the National Building Code is in Chapter VII, and additional information has been included in Appendix H.

Appendix G – Companies and Construction

This Appendix contains some notes on the growth and development of two Canadian companies that have contributed to domestic technology in the construction industry. One of them, ATCO Industries Limited, is now well known in the mobile home and systems building fields, and the other, the Dominion Road Machinery Company Limited, has long been active in the design, development and manufacturing of graders for highway construction in Canada and throughout the world.

ATCO Industries Limited

The following paragraphs began a recent article in the *Reader's Digest*:

"We talk a lot these days about how everything is getting too big and regimented – no opportunity any more for the little guy. But consider the enterprising Southerns of Calgary. Twenty-six years ago, a frustrated fireman, Donald Southern started moonlighting to help his boy, Ronald, through college. Today, they run ATCO Industries Limited, the world's biggest industrial housing business. They employ 1800 people and sell or rent \$45 million worth of buildings a year –literally from pole to pole!

"Thanks to this pioneering company, the lights of ATCO-housed schools, hospitals, construction camps, homes, even motels and churches, twinkle across the Canadian North, in Antarctica, and in 40 countries around the world. The secret: versatile, factory-built housing modules; put together like a child's building blocks. . . ."*

Starting as a luggage and house-trailer rental agency, ATCO's first manufacturing ventures began with the oil boom in Alberta in the early 1950s, spurred on by the need for much more rugged, heavy-duty camp trailers. By 1957 ATCO employed over sixty people, was building 400-person mining and other camps and was housing oil workers abroad as well as in Canada. Another sales and production breakthrough came when ATCO landed a \$12 million contract from the Boeing Company, of Seattle, for housing for technicians and construction crews building the "Minuteman" missile sites in the United States. The ATCO workforce grew by 500 people. In 1961, the Company opened a plant in Australia to serve that country, Asia and the Middle East. In 1968, ATCO "went public". By then, it also had a Research and Development Centre associated with its main plant at Calgary.

Operationally, the ATCO group of companies, almost a score of them, are now diversified and decentralized. The Group is still in the rental business as well as in manufacturing. Its main activities in the latter are concerned with industrial housing, mobile homes, residential housing, metal fabrication, and components and interiors. ATCO is also active in finance and is heavily research oriented. In its 1972 fiscal year, the ATCO Group had total revenues of just over \$50 million, an 18 per cent increase over the previous year.

*Paul Friggens, "They Build Houses from Pole to Pole", *Reader's Digest*, January 1972. (The comment on ATCO's size may be disputed.)

The Dominion Road Machinery Co. Ltd.

The material used here has been taken, with light editing, from a submission by the Company in response to a request for information on its grader production. The names of individuals mentioned in the original text have been omitted.

“In many countries on five continents traffic moves on roads built with graders manufactured in Goderich, Ontario, by The Dominion Road Machinery Company Limited (DRMC). Exports account for more than half of the production of the town’s largest industry. This is a factor which, from year to year, assists Canada in achieving a favourable balance in world trade. Accordingly, the federal government lends encouragement and assistance through its embassies around the world. The Government of Ontario has presented DRMC with an “A for Achievement” award in recognition of its contribution to the economy of the province.

“Dominion Road Machinery was established in Canada in 1886. Owned and operated by Canadians, the Company specializes in the design and manufacture of motor graders sold under the trade name “Champion”.

“DRMC employs over 500 people, and visitors to Goderich are likely to see long lines of flatcars loaded with Champion graders destined for the ports of Montreal, Saint John, or Halifax for shipment abroad.

“Champion graders are shipped to Australia, New Zealand, Thailand, Turkey, Spain, Nigeria, Zambia, Venezuela, Colombia, Portugal, France, the United Kingdom, the United States and many other countries. This year, the Canadian Manufacturers’ Trade Fair at Peking saw the first Champion motor graders delivered to the People’s Republic of China. These machines are used both in heavy construction and the maintenance and expansion of road systems. In most areas, these machines are used in a similar manner as in Canada.

“For 86 years, DRMC has been a pioneer designer and manufacturer of quality road machinery. It has been designing and manufacturing, not merely assembling, motor graders, and the Champion dominates this field in Canada. About 80 per cent of the grader is manufactured in Goderich, including hydraulic equipment, transmissions, cabs, frames and many other components. Steel, which is a major component, comes from Dofasco or Stelco at Hamilton or Algoma at Sault Ste. Marie.

“The Company designed the first of a series of post-war grader models with full hydraulic controls and an improved all-weather streamlined cab.

“In 1963 a major plant expansion took place, including a new assembly plant. That year the Company completed a consignment of 100 Champions for the Province of Santa Fe in Argentina.

“Since 1968, the Company has continued to grow steadily. Expanded market areas such as the United States, Africa and the Far East provide a firm base for the future.

“On 18 April 1970, in Ankara, Turkey, the Company signed an agreement for the purchase of 300 Champion motor graders by the Turkish Government. This was one of the largest international sales of

motor graders that has ever taken place, and it was the culmination of nearly four years of negotiation. The first shipment left Goderich in June 1970. The contract was completed in the late summer of 1971.

“The field of international sales is a specialized area. Success in this field requires expert knowledge and government cooperation. The Canadian Manufacturers’ Trade Fair in Peking is a good example of how companies like DRMC in cooperation with the Canadian government meet the challenge of international trade.

“Grader parts and fast, experienced service are available to Champion owners through leading equipment dealers both in North America and abroad.

“Manufacturing operations in Goderich cover a wide field. Steel in all its varied forms of sheets, rods, tubes, angles and channels is sawed or flame-cut to size by magnetically and electronically guided torches. Pieces are assembled and welded in special fixtures to ensure a perfect fit. Parts are machined on lathes, boring mills, drills, milling machines and other types of machine tools to exacting tolerances, many to less than one-thousandth of an inch. Hundreds of parts are then assembled to build a grader, and the final product is then fully tested and adjusted before it leaves the plant. This continuous care ensures the reputation of the product both at home and abroad!”

Appendix H – Codes, Standards and Specifications for Construction

This Appendix contains notes on the National Building and Fire Codes, on the activities of two of the standards-writing bodies in this country (the Canadian Standards Association and the Canadian Government Specifications Board), and on the activities of the Standards Council of Canada.

National Building and Fire Codes

The definitive report on Codes and Standards in Canada was prepared by Robert F. Legget for the Economic Council of Canada and the Science Council of Canada and published three years ago.* It is not the intention in this Appendix to include material more comprehensively described in Dr. Legget's report, but simply to take note of a number of facts relating to the Building and Fire Codes and to their contents.

The first edition of the *National Building Code* was issued in 1941. Subsequent re-issues were made in 1953, 1960, 1965, and 1970, with supplementary documents published in the intervening years. Work is currently underway in the preparation of the 1975 edition. Since 1948, the Code has been the prime responsibility of NRC's Associate Committee on the National Building Code.

At any one time, there are more than 250 people involved in revising and improving the Building Code. The NRC's Division of Building Research provides the secretariat for work on the Code and undertakes research work for it. The Associate Committee has the assistance of a number of expert Standing Committees, each responsible for a principal part of the Code. These latter Committees may be assisted by Task Groups or Sub-Committees when dealing with specific technical areas or problems.

Originally, the Canadian provinces delegated to their municipalities the authority and the responsibility for administering local building regulations. These regulations have to be met in the design and construction of buildings in the interests of public safety and with regard to structural, fire and health hazards. The National Building Code is written in the form of a local by-law so that it can become mandatory building regulations through the passage of an enabling motion by the city or town councils. It is now in use in most of the cities and towns across Canada and is the guide used in the construction of all federal and provincial government buildings.

The following are the principal parts of the Building Code:

Part 1: *Administration* – contains regulations that pertain to the efficient and effective application of the Code

Part 2: *Definitions*

Part 3: *Use and Occupancy* – contains all those requirements that depend upon the use to which a building is put and its type of occupancy and requirements with respect to health hazards and fire safety

*Robert F. Legget, *Standards in Canada*, Information Canada, Ottawa, 1971.

Part 4: *Design* – is made up of eight sections dealing with structural loads and procedures; foundations; wood construction; plain and reinforced masonry; plain, reinforced and prestressed concrete; steel construction; aluminum construction; and cladding

Part 5: *Materials* – contains, among other things, a listing of all standards for materials to which reference is made in other Parts of the Code, standards developed by the Canadian Standards Association, the Canadian Government Specifications Board, the Underwriters' Laboratories of Canada, and a number of American and British standards-writing bodies

Part 6: *Building Services* – includes the regulations, mainly in the form of installation requirements, for designing heating, ventilation, elevator and other service equipment so that it may function efficiently without creating hazards

Part 7: *Plumbing* – is also called the Canadian Plumbing Code, and is the equivalent for plumbing of the other building services included in Part 6

Part 8: *Construction Safety Measures* – deals only with precautions in construction work that must be taken to protect the safety of the public in the vicinity of construction sites since construction safety, generally, is a provincial responsibility

Part 9: *Housing and Small Buildings* – is a detailed set of requirements for the construction of houses and small buildings up to 6 000 square feet per floor and three storeys in height.

The first edition of the *National Fire Code* was issued in 1963 by the Associate Committee on National Fire Codes of the National Research Council. A second edition is currently in preparation.

An Associate Committee to deal with the National Fire Code was established by NRC in 1956 at the request of the Canadian Federation of Mayors and Municipalities, the Association of Fire Marshals, and the Canadian Association of Fire Chiefs. The Committee is generally representative of all the major fire prevention and protection interests in Canada. Again, the staff of NRC's Division of Building Research are responsible for secretariat and research work in connection with the Code in association with a series of special expert committees. Provincial authorities have jurisdiction over the Fire Code through their Fire Marshals or Commissioners, but the Dominion Fire Commissioner is responsible for federal government buildings and facilities. This Code has also been drafted in by-law form.

The National Fire Code sets out the requirements for the safe maintenance of buildings. It makes use of Codes and Standards developed elsewhere, for example, by the National Fire Protection Association in the United States.

The following are the three major Parts of the Code:

Part 1: *Administration* – contains those regulations that pertain to the efficient and effective application of the Code; it defines the duties and

responsibilities of those concerned, and it defines the terminology used throughout the Code

Part 2: *Requirements Based on Occupancy* – includes regulations intended to reduce the incidence of fire and protect the public from the effects of fire in general and also to regulate selected occupancies whose existence presents a potential fire hazard

Part 3: *Extreme Hazards* – includes regulations on the storage and handling of materials which are likely to burn with extreme rapidity or which may produce poisonous fumes or gases.

Canadian Standards Association

Early in 1919, Letters Patent were issued authorizing the formation of the Canadian Engineering Standards Association as a non-profit, independent, voluntary organization providing a service to Canadians. In 1944, by Supplementary Letters Patent, the name of the Association was changed to its present form (CSA) and its activities were extended to a broader field of standardization.*

In 1940, the Association's Testing Laboratories were established to provide for an examination and certification service.

In 1946, CSA accepted membership on behalf of Canada in the International Organization for Standardization (ISO) and in the International Electrotechnical Commission (IEC), both of which it subsequently relinquished to the Standards Council of Canada.

In 1947, the Canadian Welding Bureau was formed as a Division of CSA to provide a service organization devoted to sound and safe practice in welding through the development and application of codes and standards in the welding field. The Bureau is located in Toronto.

In 1960, another Division of CSA, Canadian Lumber Standards, was established to provide a medium for the study and approval of grade-marking qualifications for lumber manufacturing associations and independent grading agencies in Canada. The CLS operation is located in New Westminster, B.C.

In 1962, the Structural Glued-Laminated Timber Division was formed to provide, through CSA, a medium of responsibility for the qualification of manufacturers of structural glued-laminated timber. The Division is located in Coquitlam, B.C.

The present CSA headquarters and major testing facilities are located at Rexdale, Ontario. They comprise over 100 000 square feet of floor area and provide employment for a staff of over 400, including professional engineers and laboratory technicians. Regional offices and test facilities are also located at Montreal, Winnipeg and Vancouver, and there is a Branch Office in Edmonton. The Executive Office is in Ottawa.

Sustaining memberships in CSA are available to individuals, partnerships, companies, government departments and agencies, public utilities,

*The Association's publications, *The ABC's of CSA* and the *CSA News Bulletin* for January 1969, were the principal source materials. (Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario.)

and industrial and technical associations, for an annual fee. There are at present over 1 500 sustaining members. CSA also receives an annual federal government grant for its work in the field of international standardization.

The Association's Board of Directors is elected from the membership. The Board appoints an Executive Committee; a Standards Policy Board which, in turn, appoints Sectional Committees, Standards Committees and Sub-Committees; a Certification Policy Board; Standing Committees; Industrial Advisory Councils; and any other special committees that are necessary. The officers of CSA are elected every two years. Standards and certification activities are conducted by the various divisions under the authority of the Managing Director.

The Association's work is divided into ten fields of standardization:

Construction & Building Industry	Chemical & Petrochemical Industry
Mechanical Engineering	Packaging Industry
Electrical Engineering	Data Processing Industry
Automotive Engineering	Industrial Safety Codes, Products & Equipment
Metallurgy	General Standards

CSA Committees include 34 Sectional, over 300 Standards Committees, and many more Sub-Committees which involve over 3 000 people from industry, government, consumer and safety associations, and scientific and educational institutions who donate their time and skills to the business of standards writing.

The development and revision of a CSA Standard is the responsibility of the Standards Committee in question, but must also be acceptable to the appropriate Sectional Committee and the Standards Policy Board. Over 1 200 Standards have been published.

CSA Standards are voluntary and become mandatory only when adopted by a municipal, provincial or federal authority having the appropriate jurisdiction. All Standards are subject to periodic review and revision. They are established on the basis of minimum requirements and are not intended to restrict design or development.

CSA provides testing, examination and certification services covering a wide range of electrical equipment and components, fuel-burning equipment, and products such as plumbing brass and, plastic pipe, to minimum standards of quality and performance. CSA is the testing authority for safety with respect to life, fire, and shock hazards. Over 10 000 companies are served by the certification program. Over 9 000 new products are submitted for CSA certification each year and over 16 000 factory inspections in 25 countries throughout the world are carried out. The Canadian Mobile Home and Travel Trailer Association now requires its members to obtain CSA certification to cover a number of features in their products.

CSA has close working relationships with the corresponding agencies in Britain, Continental Europe, Japan, India, Australia, and other countries. The Association provides exchange facilities for Canadian standards

with over 50 countries. It still participates actively in the technical committee work of the ISO and the IEC, as well as in the American/British/Canadian (ABC) Joint Committee on Standardization. It has on-going affiliations with the National Research Council, Central Mortgage and Housing Corporation, the Canadian Government Specifications Board, and the Standards Divisions of the provincial governments and public utility companies.

The current CSA Advisory Councils include the Advisory Council (Electrical), the Council on Fire Safety, the Plumbing Advisory Council, and the Canadian Building Officials Advisory Council. CSA has also recently had an Advisory Committee on Systems Building. The Association is also active in the field of metrication.

Canadian Government Specifications Board

The Board's origins go back to 1934 when the Canadian Government Purchasing Standards Committee was formed under the National Research Council to prepare federal purchasing standards for items not already covered by the Canadian Engineering Standards Association (the forerunner of the Canadian Standards Association). By the end of the 1940s, the Board had issued almost 400 standards in areas such as paints, textiles, refractories, and leather. It acquired its present name in 1948. During the 1950s new work was undertaken in areas such as building construction materials and hand and power tools.*

During the 1960s, the operations and staff of the CGSB were transferred first to the Department of Defence Production, and later to the Department of Supply and Services. The Board's composition was also changed. Its present members are the President of the National Research Council and seven federal Deputy Ministers. The Deputy Minister of Supply is the Chairman. The Board has now issued over 1 600 standards.

With regard to the long-time philosophy of CGSB operations, the source material noted:

"The Board has a long and well established tradition in the field of providing voluntary standards in support of federal government requirements. The need for balanced participation in standards writing was recognized as early as 1935 when the advisability of consultation with industry in the preparation of standards was first raised. This developed into the Committee Consensus Method which the CGSB employs today and which is the foundation of its reputation. This requires that standards are developed and maintained with the participation and agreement of all legitimate interests, including users, producers, research and testing organizations, etc. Adherence to these standards is not mandatory except where they are called up in regulations." (page 2)

The CGSB is in the process of introducing a "full cost recovery" system through which the costs of writing standards will be met by the Departments or agencies calling for them. In this way, the Board hopes

*The material included in this section was taken from a report, *The Work of the Canadian Government Specifications Board*, prepared by the Board and issued on 8 July 1971, supplemented by information gathered during an interview. (Canadian Government Specifications Board, 88 Metcalfe Street, Ottawa, Ont. K1A 0S5.)

to become more responsive to user demands. The Board will take account of the views of the new Standards Council as these become known. The Board also makes optimum use in its work of standards already available, irrespective of their source. The introduction of metrication is expected to extend the application of existing foreign standards.

Among the areas in which the CGSB has *not* been active are electrical equipment and appliances, timber and wood products, and metallurgical products, areas covered by the CSA and other bodies, plus heating, ventilating and air conditioning equipment, which is covered by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). CGSB standards include test procedures. The writing of standards for procurement remains the principal area of CGSB activity, but these standards should not be equated with procurement specifications. It is the responsibility of the purchasing authorities to make CGSB's voluntary standards into mandatory ones.

The CGSB has also been involved in:

- international standards work;
- the preparation and publication of standards indexes;
- the preparation of standards intended for the protection of private consumers; and
- preparatory metrication work.

The technical work of developing and revising standards is carried out by over 300 committees with more than 3 000 members. The Board has no funds with which to carry out testing and evaluation associated with new or revised standards. However, members of the technical committees having the required resources at their disposal may arrange for the necessary work to be done at no cost to the Board.

At the request of the Specification Writers Association of Canada, the Board has been preparing a comprehensive index of CGSB standards relevant to the construction industry. It has already published, in 1969, a Building Standards Index, jointly with the Materials Branch of the Federal Department of Industry, Trade and Commerce.

Standards Council of Canada

The Act establishing the Standards Council received Royal Assent on 7 October 1970. The Council met for the first time on 12 July 1971. Its current membership of 56 is drawn from the federal and provincial governments and from the private sector. Its staff is headed by the Executive Director.

The following are among the main objectives and powers of the Council included in Section 4 of the Act:

“The objects of the Council are to foster and promote voluntary standardization in fields relating to the construction, manufacture, production, quality, performance and safety of buildings, structures, manufactured articles and products and other goods, including components thereof, not expressly provided for by law, as a means of advancing the national economy, benefiting the health, safety and welfare of the public,

assisting and protecting consumers, facilitating domestic and international trade and furthering international cooperation in the field of standards.

“The Council, in carrying out its objects in the fields referred to in [the above] subsection, may

- promote cooperation among organizations concerned with voluntary standardization in Canada in those fields to coordinate standardization activities and develop common standards and codes;
 - promote cooperation between organizations concerned with voluntary standardization in Canada in those fields and departments and agencies of government at all levels in Canada with a view to achieving compatibility and maximum common usage of standards and codes in those fields;
 - recommend criteria and procedures relating to the preparation, approval, acceptance and designation of voluntary standards in Canada in those fields;
 - accredit, in accordance with criteria and procedures adopted by the Council, organizations in Canada engaged in standards formulation, testing and certification in those fields, and maintain a register of such organizations and of their standards marks;
 - approve standards in those fields submitted by organizations accredited by the Council as national standards where appropriate, and maintain an index of approved standards;
 - provide for the identification and evaluation of the need for new standards, revisions to existing standards and additional testing and certification services in those fields, and arrange for that need to be satisfied;
 - unless otherwise provided for by any other Act of the Parliament of Canada or by treaty:
- (i) represent Canada as the Canadian member of the International Organization for Standardization, the International Electrotechnical Commission and any other similar international organization engaged in the formulation of voluntary standards, and
 - (ii) ensure effective Canadian participation in the activities of such organizations;
- promote, in cooperation with Canadian organizations engaged in voluntary standards formulation, testing and certification in those fields, arrangements with organizations similarly engaged in other countries for the exchange of information and for cooperation in such activities;
 - provide financial assistance to Canadian organizations concerned with voluntary standardization in those fields to assist them in meeting national and international requirements;
 - collect, translate and distribute information on standards and standardization activities in those fields in and outside Canada;
 - promote the use of Standards approved by the Council;
 - review the need for and make recommendations with respect to the use of, or conversion to, the international system of units, known as the metric system, in Canadian industry, trade and commerce; and
 - make recommendations to the Minister, such recommendations to be included in the annual report of the Council, in respect of standards which, in the opinion of the Council, should be made compulsory.”

Appendix J – Case Studies of Technical Developments in Construction

This Appendix contains a dozen case studies designed to show how some of the technology currently in use was originally developed and subsequently transferred into, and within, the construction industry in Canada. These studies are neither exhaustive, lengthy, nor necessarily complete. The lessons to be learned from them have been included in the latter part of Chapter VII.

Explosives*

Explosives have been used in every major construction project in Canada, from the first transcontinental railway to the St. Lawrence Seaway and the Churchill Falls hydro-electric power project. They have been used extensively in mining and quarrying, in logging and seismic operations, and in other applications.

Canada's explosives industry began in 1855 when the first black powder mill was opened in Southern Ontario. In 1862, Alfred Nobel developed nitro-glycerin as a commercial high explosive, three times more powerful than black powder and safer to handle. Dynamite first became available in Canada in 1873. As E. J. Mullins noted in one of his papers:

“Developments in the manufacture and use of high explosives followed rapidly upon one another after Alfred Nobel's invention of dynamite. Ammonium nitrate, itself a powerful explosive when properly sensitized, was introduced in formulations and many grades and types of explosives were quickly developed to handle the numerous new applications that were now available to them. As a result of the demand for raw materials in the First World War and, later, the continued expansion of the Canadian economy, the range of high explosives was widened to comprise the granular dynamites through the semi-gelatins and ammonia gelatins to the straight gelatins, to suit the requirements of industry. Ethylene glycol, or anti-freeze, was added to dynamite compositions to effect a lowering of the freezing point of nitro-glycerin so that explosives would not freeze at any temperature found on this continent. Special explosives were also designed for coal mining which greatly increased the safety of blasting under the gassy or dusty conditions frequently encountered in these mines

“Many advances were made meanwhile in the development of initiating devices. . . . Developments similarly proceeded to improve several means available to initiate a number of changes simultaneously. . . .”†

Until World War II, the principal uses of explosives were in railway construction, mining, land clearing and quarrying. Since the War, significant advances have been made in the development of blasting agents and improved means of initiation. The new explosives technology has been

*The source material in this case originated with Canadian Industries Limited, Montreal, and included general historical material on explosives prepared for C-I-L publications by E. J. Mullins, of the Explosives Division.

†*The History of C-I-L Explosives*, Canadian Industries Limited, Montreal, January 1968.

complemented by equally significant advances in rock-moving equipment and operations. The needs of the mining industry set the pace.

A significant C-I-L development was the marketing, in 1958, of a powerful new blasting agent called HYDROMEX, a slurry-type mixture of TNT, ammonium nitrate, water and other ingredients that was itself water-compatible and did not depend on its outer container for protection. Further developments on the original HYDROMEX provided a range of blasting slurries which produced increasing amounts of energy. These slurries were used extensively, for example, for excavation work.

The following notes appear in one of the source material papers:

“Outstanding progress has been made in Canada in recent years in devising blasting techniques which reduce overbreak and provide stable walls on practically every excavation. The three most widely used methods, cushion blasting, preshearing, and perimeter blasting, all resulted from C-I-L research and field service.

“Cushion blasting was developed by C-I-L and first used during the construction of the Sir Adam Beck No. 2 (power) development at Niagara Falls, Ontario, for Ontario Hydro in 1953. It involves the final row in a bench blast or the removal of a narrow beam to trim the face or walls of the excavation. The holes are lightly loaded and fired last in a delay sequence in a bench blast or as a separate blast after the main excavation has been removed.

“Pre-shearing employs the same principle as cushion blasting except the row of holes on the perimeter of the excavation is fired first in a delay sequence or ahead of it in a separate blast. It was first used in March 1954, by C-I-L, again during the construction of the Sir Adam Beck No. 2 development at Niagara Falls, Ontario. Perimeter blasting originated in Sweden and was introduced into Canada by C-I-L in 1959 after it had been refined to suit Canadian conditions. It uses a similar principle to that of cushion blasting to control overbreak and to reduce the problem of “loose” in underground operations. The semi-gelatin high explosive XACTEX was developed (by C-I-L) for use with this technique.

“Another interesting and important technique introduced by C-I-L during the construction of the Sir Adam Beck No. 2 development was the “Air Curtain” which uses a barrier of air bubbles to reduce the intensity of hydraulic shock waves produced by submarine blasting. The “air curtain” is placed between the blast and the area to be protected. The technique has been used in several locations in Canada in recent years with considerable success.”*

The pre-shearing blasting technique was also used to excavate all the foundation trenches for Place Ville Marie in Montreal, for example. Cushion blasting was used in the deepening of the Welland Ship Canal to meet St. Lawrence Seaway specifications. It was used in the Côte-St-Catherine section of the Seaway and, in a modified form, in the Soulanges section. The early applications of perimeter blasting were in the mining field. It was later used in various phases of Hydro-Québec’s Manicouagan-

**Explosives Development*, Canadian Industries Limited, Montreal, June 1969.

Outardes project. The pre-shearing and air cushion techniques were both used in the work of extending the Manicouagan Power Company's generating facilities near Baie Comeau, Quebec.

There have, of course, been many other developments in the explosives field in recent years and the examples above have simply served to illustrate them.

Earthquake Engineering

Concern in Canada about the incidence of earthquakes is most evident in British Columbia, although other parts of the country are not immune from the possibility of seismic disturbances.

Most of the experience and scientific data with regard to earthquake design in North America has originated, in the past, in California. Nevertheless, in Canada there has been growing interest and activity in this field. For example, under the sponsorship of the National Research Council there is now a Canadian National Committee on Earthquake Engineering (CANCEE). This Committee, in cooperation with the University of British Columbia, sponsored the first Canadian Conference on Earthquake Engineering Research, which was held in Vancouver in May 1971. CANCEE has also taken part in international earthquake engineering conferences. The latest edition of the National Building Code includes a section in Part 4 on "effects of earthquakes". And, in the nuclear power plant field, Atomic Energy of Canada Limited has acquired expertise in earthquake engineering design.

Not enough is known on a world scale about anti-seismic design. One of the main drawbacks is the cost of the full-scale experiments required to yield new data. Another is the random behavior of earthquakes with regard to magnitude, location, and time which make it particularly difficult to assess the degrees of seismic risk to which a building will be subject during its lifetime.

Part of the earthquake engineering problem lies in the design regulations and Codes. One authority had this to say about the situation in California:

"Building Codes in Los Angeles and San Francisco are among the most stringent in the world and serve as models for other quake-prone areas. But their aim is primarily to minimize the danger of death-dealing collapse, not to insure against lesser damage. Well-funded builders of larger office buildings and apartment houses may retain earthquake engineering specialists to make soil analyses; determine proper siting; and see that the most modern techniques go into foundations, steel frames, and reinforced concrete. Safety specialists maintain, however, that speculative developers cut corners and barely meet the building codes. As a result of the San Fernando quake (in February 1971), California officials are urging federal enforcement of earthquake safety standards and higher criteria to assure structural integrity of vital buildings, such as hospitals, power plants, and fire departments."*

*David Perlman, "The Trembling Earth", *Britannica Yearbook of Science and the Future*, Encyclopedia Britannica Inc., Chicago, 1972, p. 40.

Another commentator, David Dowrick, wrote recently that taller buildings of steel and concrete are probably safer than low buildings in earthquakes, not because they are inherently safer, but because their bigger problems attract more attention from better engineers and because more money is available for better materials.* Dowrick went on to say in the same article that, while tall buildings are supplied with the most aseismic know-how, 90 per cent of the world's population live in low-rise buildings with the least research knowledge and the poorest standards of practice. In the more advanced countries, low-rise buildings are often constructed of materials that are difficult to tie together. In the poorer countries, the vernacular architecture may employ only one heavy, brittle material for the whole building, which results in heavy loss of life during earthquakes.

In Dowrick's view, the problems of earthquake research are so complex that highly simplified situations must be studied in the laboratory. The results of this work are more readily applicable to tall buildings than to most low-rise construction. Dowrick concluded his article as follows:

"Accepting the fact that there are still many unknowns in the anti-seismic design book, there are often other situations preventing the best use of the available knowledge. In some countries, such as the United States, the structural engineer is simply not paid enough to do the job. He either has to hide behind inadequate local regulations or do his best within his fees and hope like everyone else that no strong earthquake will test his buildings. And electrical, mechanical and drainage engineers have made no concerted effort to protect their own designs against earthquakes. Even the well-informed engineer frequently has clients who believe they cannot afford a safe enough standard.

"More seriously, architects often opt for aesthetics over seismic stability. The basic rules of good aseismic structural configuration are symmetry, simplicity, cuboidal form, and no sudden changes in structural members from floor to floor. . . .

"Thus, the earthquake safety problem is not only one for seismologists and structural engineering research; structural and civil engineers should be educating architects, service engineers and politicians in the great need for their full participation."

Airport Runway & Apron Sealants†

The advent of jet aircraft has made changes in the composition and performance of concrete runway and apron sealants necessary.

Sealant materials are used to seal the exposed surfaces of expansion and contraction joints in concrete runways to prevent the entry of water, grit and other foreign matter. The operation of large aircraft, with power-

*David Dowrick, "Must Earthquakes Always Win?", *New Scientist*, 28 December 1972, p. 736.

†The source material in this case was supplied by the Construction Engineering and Architectural Branch of the federal Ministry of Transport, Tower C, Place de Ville, Ottawa. (The title "Ministry of Transport" came into use in 1970.)

ful low-slung jet engines, has increased considerably the use of power brooms and snow-clearing equipment to maintain runways free from matter which could seriously damage these engines. But these additional maintenance activities have resulted in faster deterioration and disintegration of the joint sealants.

After repeatedly poor field performance by existing sealants, and after many unsuccessful laboratory tests to find solutions to the reliability problem, the federal Department of Transport began, in 1968, to study methods of upgrading sealants and to investigate problems related to the sources of supply used by its runway contractors. With regard to supply problems, the Department found that the quality of the available sealants had become downgraded as a result of the strong competition between the manufacturers and because the contractors were buying on price without regard for quality. The Department subsequently decided to purchase sealant materials itself, by means of public tender, through the Department of Supply and Services. Performance specifications and testing procedures were also established by the Transport Department. Manufacturers responded by developing acceptable products.

In the case of the concrete aprons, problems have been encountered with sealants on those on which aircraft refueling operations are carried out. Spillage of jet fuel has softened the sealant, causing tracking and breakage of the bond between the sealant and the pavement. It is now the policy of the Ministry of Transport to have jet-fuel-resistant joint sealants used in refueling areas. There are four sealants of this type available commercially which meet the Ministry's requirements. These four types, plus eight others which are not fuel-resistant, also have properties that were lacking in the older types; for example, they remain flexible and will extrude any foreign matter that may become implanted in them.

Electrical Wire and Cable*

The object in giving examples in this instance is to illustrate the interaction between:

- the need for safe operation under the Electrical Code;
- the role of the Canadian Standards Association in improving the Code;
- and
- the results of cooperation between the CSA and the wire and cable industry in Canada.

Example 1: A number of years ago, electrical inspection authorities in the provinces were of the opinion that the interlocking armoured cable used in residential, commercial and industrial applications was the cause of fires. The problem was reviewed by several Electrical Code Committees and, as a result, it was recommended that CSA invite the wire and cable industry to redesign the cable construction in such a way that the hazard would be reduced. The industry agreed, and changes were made in the design. The results have been successful.

*The source material was provided by Mr. H. L. Freeman, former Manager, Wire and Cable Section, Canadian Standards Association, Rexdale, Ontario.

Example 2: Certain types of insulated wiring used as conductors in building service entrances were found to be unsuitable when installed during low temperature periods in wintertime all across the country. The wire and cable industry, in collaboration with CSA, designed an insulation that would be satisfactory at 40 degrees below zero. In consequence, all of the relevant low temperature restrictions in the Electrical Code were withdrawn, permitting installation to be made during the winter months.

Example 3: For several years, certain types of ceiling fixtures had caused fires in ceilings. The wire and cable manufacturers were asked to study the problem and came up with a cable that would withstand the somewhat higher temperatures encountered in these fixtures. The fixture manufacturers also made a number of design changes which contributed to safer installation. The new cable was found to be acceptable for electrical base-board heating applications as well as for ceiling fixtures.

Example 4: Some years ago, cables used in the wiring of poorly kept barns were often found to have rotted over time and were therefore unsatisfactory and unsafe. The Electrical Code Committee concerned asked CSA and the industry to make improvements. This was done, and Code amendments were subsequently made to accommodate the improved cable type.

Example 5: The wiring of silos had, for years, been the concern of electrical inspectors because personnel accidents involving the wiring were occurring too frequently. Many of the accidents occurred when the silo unloader broke down and the operator attempted to correct the situation. After consultations between electrical inspectors, silo equipment manufacturers, cable manufacturers, and the CSA a new type of wiring was developed and introduced for silo applications. The accident frequency dropped.

Example 6: Until a short time ago, electric stoves and driers in residences could be connected directly to permanent cables. The final hook-up was often made by the owner without being seen by a qualified inspector. The responsible Code Committee considered this practice unsafe and asked the cable manufacturers and the CSA to improve the connection procedure. A flexible cord set was designed. The cord itself was connected permanently to the appliance at one end but could be plugged into a wall outlet at the other by means of a plug cap. The new design was acceptable to the Committee.

Gypsum Drywall*

The early technology of the manufacture and use of interior drywall goes back to the 1890s to the development, in the United States, of Sackett Wallboard. The inventor and first manufacturer, Augustine Sackett, is reported to have said this of his wallboard:

“My improved boards or plates take the place of the lathing, plaster and hard finish commonly employed, and have the advantage thereover of being conveniently and quickly applied, of being perfectly dry so that

*The material in this case was supplied by Domtar Construction Materials Ltd., Montreal.

the room is ready for immediate occupancy, and of freedom from cracking which is so objectionable in plaster walls.”*

Between the appearance of Sackett’s wallboard and the present time, the technology of gypsum drywall has advanced by means of a series of significant developments. For example, in 1909 the U. S. Gypsum Company acquired Sackett’s plants. In 1910, Clarence Utzman, one of this Company’s engineers, discovered a method of making wallboard to an exact width using folded paper edges. Ten years later, Utzman was granted a patent for a machine to do this folding operation. In 1933, E. B. Hummer first used laminated gypsum wallboards in construction. In 1938, Robert Ames invented the first drywall taping tool. In 1950, the patent was issued in the United States for the first fire-rated gypsum wallboard, invented some years earlier by Michael Croce.

Although the technology and production capability has existed in Canada since the 1930s, the gypsum drywall interior finish was for many years considered inferior to lath and plaster. The first significant factor that changed this situation was the great wartime demand for temporary housing and shelter of all kinds. The speed with which the buildings were required, and reduced concern for the quality of interior wall finishes, gave drywall a foothold in the market. The second significant factor was the demand for housing in the immediate post-war years. Lath and plaster interior finishes were still the rule at this time but, as a result of the pressure for speed in erection, plus a number of other factors, the quality of plasterwork deteriorated. Many builders experienced cracking problems which were costly and time-consuming to correct. Some of them switched to drywall on a trial basis and began, at the same time, to make use of recent improvements in the drywall system, particularly the Ames tools for applying, embedding and finishing the jointing compounds. As the Domtar source material noted:

“These developments improved the speed of erection of drywall. Builders began to find that they could complete their interior wall surfacing and their houses two weeks earlier when using drywall as opposed to lath and plaster. Since most builders were using the maximum financial leverage possible, the resultant earlier cash flow added more impetus to switch to the drywall system.”

Tradesmen also took considerable interest in the system. The drywall trade became more attractive because a tradesman required a minimum of equipment whereas the plasterer had to have costly mechanical mixers, scaffolding and special tools. The drywall system was also easier to learn and required a smaller outlay on the part of a sub-contractor to get into the business.

The next set of significant factors broadened the scope of the drywall system. These involved the use of steel studs, the self-tapping screw, and the development of more fire-resistant cores in gypsum drywall. Industrial, institutional and commercial building applications became feasible as the fire-resistance ratings improved and city Code requirements could

**Gypsum Drywall Industry Newsmagazine*, October/November 1971, p. 26.

be met. These fire resistance properties and the savings in weight and installation costs that were possible through the use of drywall encouraged the use of the system in high-rise buildings. So did the development of a variety of pre-finished gypsum boards and improvements in sound resistance. The drywall system has also been adapted to incorporate plumbing and electric wiring components.

Plywood*

The art of veneering was known to the early Egyptians, but it was not until the beginning of the 20th Century that plywood was developed. The first plywood mill in British Columbia began operations in 1913. This plant produced Douglas fir panels suitable for interior use in panelling, furniture, and cabinets.

The single most significant technical change in plywood manufacturing came with the discovery, in the late 1930s, of a waterproof glue. Hot press bonding with the new glue, a synthetic resin of phenol, formaldehyde and alkali, sparked a significant increase in the manufacture and use of plywood. The glue was also unaffected by extremes of temperature and was stronger than the wood which it bonded. Its development was largely the result of work done in the United States. Within a very few years, all plywood manufacturers in British Columbia agreed to use only waterproof glue in all grades of plywood. As a result, B.C. Douglas fir plywood was used for exterior as well as interior applications and for new applications such as boatbuilding.

In Canada, more than in any other country, plywood has had an enormous impact on the building sector of the construction industry. In residential construction, for example, concrete forms, together with sub-flooring, roof and wall sheathing, are most frequently made of plywood. In commercial, industrial and high-rise projects built using site-cast concrete, plywood is extensively used in formwork, either as oiled or as specially coated or overlaid panels.

In the early years, all softwood plywood was made from Douglas fir. It was one of the strongest Canadian softwood species and was available in large, high quality, knot-free logs. During the 1950s, the Plywood Manufacturers' Association of British Columbia initiated a testing and development program which led to the use of veneers of other more abundant species such as hemlock, spruce, and pine in the inner plies of Douglas fir plywood. In 1961, Standard 0151, *Western Softwood Plywood*, was published by the Canadian Standards Association. This standard recognized the value of the other softwoods for use in plywood for non-engineered applications.

During the 1950s, the plywood industry in British Columbia, again through its Plywood Manufacturers' Association, developed the "Rigid

*For this case study, the main source material was provided by MacMillan Bloedel Limited of Vancouver. Additional material was obtained from *Plywood Pictorial* and *British Columbia Plywood*, both published by the Council of the Forest Industries of British Columbia, 1055 West Hastings Street, Vancouver.

Frame Construction” building system for clear-span frame buildings up to 40 feet in width. Applied mainly to farm buildings and light industrial structures, the use of this system spread rapidly across Canada and the United States and is currently creating interest in Europe.

The application of plywood in another building construction development of Canadian origin is at present gaining momentum in this country. Starting in 1961, the use of preserved wood foundations (PWF) in residential construction has also been adopted and proven satisfactory in the United States. PWFs are wood-framed basement or crawl space walls in which all plywood sheathing, studs, and footing plates are pressure-treated with suitable wood preservatives. Not only can PWFs be erected in a very short time, but it is claimed that they may also provide warmer and more comfortable below-grade living than the conventional concrete or masonry foundations.

Individual companies have also played a part in the development of plywood technology. For example, all B.C. producers supply a number of specialty products, such as staintec sheathing. Stained in the factory, this sheathing-grade plywood can be used without further finishing in barns, equipment sheds, construction offices and utility buildings, saving the builder both time and money. MacMillan Bloedel has marketed, since 1967, its trademarked “plygard” and “uraply” panels. These two products were the first Canadian factory-coated self-releasing concrete form panels available to builders and were developed specifically to reduce maintenance time and costs on high-rise projects. MacMillan Bloedel has also published a comprehensive load-span reference manual for plywood stressed skin panels for floor and roof construction.

Particleboard*

The following are some brief notes on particleboard and waferboard, two associated building materials that are becoming more important as the trend to use forest product wastes grows. The source material included this historical comment:

“Particleboards were first developed in Europe to supplement the short supply of building boards available. [The Boards] were manufactured from fine machine-made particles specially reduced from small whole logs. In the USA and Canada the product was developed as a way to make economical use of substantial volumes of waste fibre developed at lumber and shingle mills. At MacMillan Bloedel’s k3 Particleboard Plant, western red cedar sawdust and shingle waste are refined, formed and bonded under heat and pressure to form a dense precision-made building and furniture panel.”

The major use of k3 Particleboard in the building industry is for floor underlays. Other uses have been found for it in kitchen cabinets, furniture, countertops, shelving, partitions and screens.

“Aspenite” (a MacMillan Bloedel trademark) wood wafer panels are manufactured from aspen flakes coated with phenolic resin, interleaved

*The source material was provided, on request, by MacMillan Bloedel Limited, Vancouver.

into mats and cured in a hot press. Its principal uses are for subflooring and for roof and wall sheathing for farm, residential and recreational construction. It is also used for exterior siding, privacy screens, fences and garden buildings. Aspenite was the first *structural* particleboard to be made in North America.

The Grader*

The earliest road graders were simply squared timbers drawn by teams of horses. They became “mechanized” in the 1880s. In 1885, for example, the J. D. Adams Company of Indianapolis, Indiana, first made and marketed the “leaning wheel” horse-drawn grader which was later sold in Canada through a sales subsidiary company.† In 1886, the Dominion Road Machinery Company (DRMC) of Goderich, Ontario, introduced the first of its “Champion” line of graders, again a horse-drawn piece of equipment.

Around the turn of the century, the first elevator graders made their appearance. By 1914, graders of all kinds had become generally larger and more complicated and could be drawn either by horses or tractors, the use of the latter having made increasing size feasible.

The J. D. Adams catalogue for 1928 illustrates the development technique pursued by his company. For example, it said (on page 3):

“Considering the marked popularity of Adams Leaning Wheel Graders for many years, the only logical reason they have not been imitated until the last few years is because Adams patents have made it impossible to duplicate the simplicity and workability of Adams graders. True, the basic leaning wheel patent expired some time ago, but various later patents cover the most simple and functional mechanical application of the leaning wheel principle. . . .”

This particular catalogue claimed that the Adams company was the first to design and manufacture 10- and 12-foot blade graders, the first to introduce a steerable engine tongue, and was the inventor, in 1919, of the backsloper. It went on to say that recent improvements in Adams graders had set a new pace in grader construction. These improvements included machine-cut, enclosed gears and machined bearings, and ball and socket joints throughout the blade control on all models.

The manufacture of the Adams line of graders began in Canada in 1929, at Paris, Ontario. By this time, both Adams and the Dominion Road Machinery Company had self-propelled motor graders with solid tires, blade lengths up to 16 feet, and leaning front wheels in production –

*The material in this case was supplied by the Canadian-owned and operated Dominion Road Machinery Company Ltd., of Goderich, Ontario, and by WABCO Equipment of Canada, of Paris, Ontario, which is associated with the WABCO Construction Equipment Division of American Standard Inc., located at Peoria, Illinois. The DRMC material was accompanied by a brief description of the company's growth since its establishment in 1886. This description is of considerable interest and has been included in an edited form, in Appendix F.

†The J. D. Adams Company in the United States subsequently became associated with the Westinghouse Air Brake Company (WABCO), as did its Canadian subsidiary.

in addition to the tractor-drawn varieties. The Adams Company still recommended that the new machines be used for maintenance work, leaving new construction work to be done by the leaning wheel, tractor-drawn combination.

By the late 1930s, motor graders had either gasoline or diesel engines, rubber tires, 4-wheel drives, and powered hydraulic controls. Tractor-drawn types were rapidly disappearing. The tasks graders could do had also increased in number. For example, an Adams advertising catalogue published in 1938 had this to say:

"The powerful engines built into Adams Motor Graders Nos. 50 and 51 plus the excellent traction afforded by the Adams tandem drive with low pressure tires makes it possible for these machines to do heavy grading and ditch work never deemed possible with motor graders prior to the advent of these graders. In addition to this work, however, the wide range of blade adjustments possible with Nos. 50 and 51 make it thoroughly practicable to use them for cutting down and finishing banks or widening roads or for trimming established backslopes – work which is still impossible with most motor graders. In fact, many highway officials and contractors are building roads complete from bank to bank with these machines."

The technical development of graders continued throughout the post-war period. Heavy-duty, medium-duty and small all-purpose machines were made. Their uses continued to multiply – from highway and street construction and maintenance, ditching, scarifying, bulldozing and dirt work to snow removal, logging, oil field construction, and soil conservation work. This development was also encouraged by the demand for more labour- and cost-saving machinery, increased reliability, flexibility and ease of operation. New and higher-duty steels and alloys, improved tire design, new and improved hydraulic system and component design, engine power capacity, steering, and so on, have been incorporated into the latest machines. For example, the DRMC's "Champion" D-686 grader weighs 32 000 pounds and carries a 200 horsepower motor. Its catalogue description includes these features:

- axle frame sturdily constructed of welded steel bars; heavy, drop forged, alloy steel knuckles with tapered roller wheel bearings sealed against dust and moisture;
- wheel-leaning controlled by a simple hydraulic cylinder, instead of by a mechanical drive mechanism subject to wear and costly replacement;
- effortless booster power steering with completely separate circuit with replaceable filter and independent pump for safety; in an emergency, the grader can be steered with the engine stopped;
- patented 90 degree, 2-way cab-operated Hi-Lift blade control, enabling the operator to place the blade in any working position – right up to the vertical – at either side for grading or extreme bank sloping and ditching;
- two independent brake systems provided; large, internal expanding, self-adjusting hydraulic brakes on the wheels and a heavy-duty, disc brake for parking and emergency use located on the final drive input;

– eight-speed constant-mesh DRMC-built grader transmission; 2-lever control or exclusive single lever control with power range shift; anti-friction roller bearings throughout; . . . transmission cushion-mounted to the frame.

Concrete Transit Mixer*

As was the case with graders, transit mixers carrying ready-mix concrete were horse-drawn before they became self-propelled. The horse-drawn variety appeared in the United States around the turn of the century. In the early mixers, called “Dromedary Mixers”, the drum was suspended between two cart wheels and revolved when the wheels turned. In the two-horse version of 1909, the mixer was the shape of a cube, about 2½ feet square, and had two geared wheels. The wheels turned paddles that mixed the concrete in the cube. A small water tank was attached.

In 1916, Stephan Stepanian applied unsuccessfully for a U.S. patent on the first workable, truck-mounted, self-discharging transit mixer. During actual transit, the mixer itself remained horizontal but was tilted by hydraulic power during the discharge cycle. Around this same time, however, some developments were made in the production of centrally-mixed concrete which was then delivered to the construction site in wagons and dump trucks. This central mixing practice became fairly common in the U.S. during the 1920s.

The development of the revolving drum transit mixers began in earnest around 1927 when trucks, such as Model T Ford Trucks, of the required size and carrying capacity became available. The mixers and trucks have not usually been developed and made up by the same companies.

Up until the mid-1930s, the maximum mixer capacity was 1½ cubic yards of concrete batched at a central plant. With the development of the tandem-axle truck around this time, the maximum mixer capacity rose to around 4 cubic yards. The mixers themselves were, at this stage, of the horizontal drum type and were driven from a power take-off at the truck transmission. The inclined-axis, high discharge transit mixer was developed during the Second World War.

The post-war building boom brought the transit mixer into general use in Canada. Large central batching plants were set up in the cities and provided opportunities for the initial growth of the mixer fleets that became commonplace in the 1960s. Throughout the post-war years, the construction industry has demanded, and has got, larger and larger loads on trucks which could work under variable and difficult operating conditions, with mixers able to give the variations in the concrete specifications required by structural engineers. The incentive to achieve the maximum payload, under pressure from wages and other costs, has

*The material for this case was supplied by the Canadian Division of the Portland Cement Association, Ottawa; the London Concrete Machinery Company, of London, Ontario; Mack Trucks Canada Limited, Toronto; and Jaeger Machine Company of Canada Limited, St. Thomas, Ontario.

always been present. Changes have also been required, particularly in truck design, in order that the increased loads carried could remain within the highway regulations set by the provinces. Around 1962, for example, the first trailer-mounted mixers were developed. By 1967, the average capacity of mixers had been increased to 7 cubic yards.

The majority of the mixers built and sold between 1965 and 1969 employed a mechanical power take-off from the truck engine. But around 1967, attempts were made to develop hydraulic take-off systems. These were not at first successful but, in time, a satisfactory pump and motor combination was found to give the variable mixer speed required by the operators. Revolution counters, hydraulically operated chutes, improved air pressure water systems, and remote control systems have since been developed, adding to the safer operation of the equipment and to the quality control of the product. The standard load is currently around 10 cubic yards. Mixer manufacturers are now working on units with 15 cubic yard capacities, again in an endeavour to keep up with contractors' requirements for cost improvements. Some of these new units will also be required to handle special aggregates with constituent materials not previously used in concrete mixes.

Concrete Slipforming*

Slipforming is one of a number of techniques used in both building and engineering construction to provide for the containment of concrete in its plastic form and during the initial hardening process. One expert in its use described the technique as follows:

"Essentially, concrete slipforming is the vertical extrusion of walls, the plan-section of which may be of any conceivable geometry: rectangular or circular tubes, intersecting straight walls, curvilinear walls of irregular patterns. The resulting towers are usually prismatic but many have diminishing dimensions from bottom to top if so required. More frequently used in buildings is the rectangular tube, housing elevator-shafts, stairwells and service rooms.

"Slipforms are assembled once per building and generally consist of quality and precision-fabricated materials. Slipforming is efficient and economical since it represents an advanced degree of mechanization. It comes remarkably close to a factory procedure. The slipform is an enormous die which travels upwards at a uniform rate and moulds the stationary plastic concrete into it. The concrete is fed by a mechanized handling system. . . .

"Slipforming may be used for entire structures such as nuclear reactor buildings, tall chimney-stacks, observation towers, mining head-frames, batteries of silos and bridge piers."†

*The material used in this case came from interviews and from a variety of published sources, two of which have been quoted directly.

†Norman N. Aylon, "Slipforming for Tall Buildings", *Engineering and Construction*, January 1971.

In practice, slipforming is normally applied to one of the structural sub-systems of a complete building. It may, for example, be used to provide the interior concrete core of the building while the remainder of it, surrounding the core, is a frame sub-system made of structural steel. The interactions and interconnections between the sub-systems can be quite complicated and must be designed to produce a highly efficient integrated structure. In practice, the existence of the concrete core will influence the method of construction of the surrounding frame and the type of connections used will modify the design of the frame members.

The slipforming technique is not really new, and it can be used in horizontal as well as vertical applications. The following is a brief chronological account of the development of the technique in the United States:*

1904: The first United States slipform concrete grain elevator erected.
1908: A slipform sidewalk paving machine introduced.
1915: The United States Bureau of Reclamation slipformed a concrete canal liner for the first time.
1935: The first rail-mounted, slipform concrete canal liner is employed.
1954: The Iowa State Highway Department developed a new type of concrete screening and finishing machine, the slipform paver.
1955: A commercially-produced slipform paving machine appeared.

The advantage of slipforming lies principally in its saving of time. When in operation, the pouring of concrete into the form must proceed without interruption. In an average residential building, the form may rise about one storey per working day. Jacks are used to index the form upwards, usually in one-inch strokes. The use of a tower crane is essential, and it may be raised simultaneously with the slipform. The same slipform may also be used on several buildings. The cost of the slipformed portion of a structure may not always be competitive with alternative methods of construction until the time-saving factor is taken into account.

Slipforming in Canada is at an early stage in its application. Some major ones have been used in engineering construction, for example, the vacuum building of Ontario Hydro's Pickering Nuclear Power Plant, the reactor containment building of Hydro-Québec's Gentilly Nuclear Power Plant, the 380 foot Niagara Skylon Tower, and the 1250 foot chimney at International Nickel's Copper Cliff smelter†, but commercial, institutional and residential buildings using slipforming have also been put up, or are being put up, in major Canadian cities such as Vancouver, Montreal, Toronto and Ottawa. The reactor building at Gentilly was actually North America's first prestressed concrete nuclear containment building to be slipformed. The wall of the circular 120 foot diameter, 140 foot high, and 4 foot thick silo-type structure took only 17 days' work around-the-clock. It would have taken an estimated five months to erect using more conventional techniques, providing the weather remained favourable.

*"Landmarks in Concrete Technology", *Concrete Construction*, February 1967.

†To these should now (April 1974) be added Canadian National's spectacular Communications Tower on Toronto's Waterfront.

Prestressed Concrete*

“The development of prestressed concrete for use in concrete beams and girders should not be looked upon as a complicated, involved structural method but rather (when its use is economically justified) as conventional reinforced construction to which another step in fabrication has been added.”†

These words are from a paper describing the use of prestressed concrete girders for the first time in concrete bridge construction in the United States, at Philadelphia, in 1949.

The theory of prestressed concrete was first proposed in the late 19th century, but its application in practice had to wait for the development of high tensile steel. And, as happened in so many other cases, prestressing theory and practice began in Europe and did not reach North America for some time afterwards.

The Freyssinet system for prestressed concrete, for example, was developed in France in the 1930s. In order to secure adoption, it had to show cost savings over the simpler reinforcing techniques. As was noted in one technical paper describing this system:

“Ordinary reinforcement with an elastic limit of 34 000 lb. per square inch costs about 1½d. a lb. in position, so that a reinforcing bar weighing 3.5 lb. per foot costs about 5d. per foot. This can be replaced with the same factor of safety by steel with an elastic limit of 120 000 lb. per square inch, weighing only 1 lb. per foot and costing about 1½d. before treatment, but it must be subjected to a tension of about 12 tons. From the saving of 3½d. must be deducted the cost of the following operations: (1) Cutting the bar and preparing the permanent anchorings on the concrete: (2) Creating toward the ends of the bar, at two points inside the mould, temporary anchorages able to withstand the pull of 12 tons: (3) Setting up this pull of 12 tons between these anchorages and maintaining it while the concrete is being placed in the mould and hardening: (4) Dismounting the temporary anchors embedded in the concrete and transferring the tensile stresses which they withstand to permanent anchors bearing on the concrete: and (5) Filling the holes left in the concrete for this operation.”‡

The Walnut Lane Bridge at Philadelphia used the Magnel system, which originated in Belgium. While this bridge firmly established prestressing as a viable and acceptable technique in the United States, a number of modifications had to be developed subsequently in order to take account of differences between European and American practices and between the costs of labour and materials on the two continents. In the United States, for example, labour costs were higher and the use of

*The material for this case came from a variety of sources and, again, two of these have been quoted directly.

†S. S. Baxter and M. Barofsky, “Construction of the Walnut Lane Bridge”, *First United States Conference on Prestressed Concrete*, Massachusetts Institute of Technology, August 1951.

‡M. E. Freyssinet, “Developments in Concrete Making”, *Concrete and Construction Engineering*, April 1936.

steel and cement much more generous than in Belgium. American contractors therefore adopted different methods of placing the prestressed wires, to offset the time-consuming Belgium method, and used wetter concrete in order that it could be placed more quickly.

With time, the use of prestressed concrete has become more sophisticated. As noted in the previous case study, prestressing was used for the first time in North America in association with slipforming in the nuclear power reactor containment building at Gentilly, Quebec, in 1971.

Systems Building*

Systems building is sometimes called "industrialized" building, but the connotation of either of these terms varies with the connoter. To some, it means taking a "systems approach" to the business of building houses, to others it means "prefabricating" parts of houses in a factory and trucking them to the construction site for erection. To some it has to do with "modular" coordination in house and building construction, to others it is associated with the trend towards the "standardization" of building components on a regional, national or industry-wide basis. To some, systems building is a management technique, and to others it is the basis of what is now known as "project management". In actual practice, systems building has something to do with all of these things.

One way to describe systems building in general terms is to say that it represents a productive operation based on mechanized processes and procedures which can easily be repeated. It also integrates plant and site operations, and it is a commercially competitive activity from the planning, design and programming phases, through manufacturing, to the distribution of the products.

Systems building is having a profound effect on the business of building construction.†

In practice, systems building developed, like so many branches of construction technology, in an evolutionary fashion. But while systems building and "industrial" techniques, generally, have been centred on the building sector of the industry, it should be remembered that the engineering sector has also used them; for example, in the steel fabrication and precast concrete work involved in bridge construction.

*The material for this case study was gathered during the program of interviews and from publications of which the following were the most immediately useful:

"Systems Building", a Special Report reprinted from the *Engineering News-Record*, New York, 30 October 1969.

John A. Dawson, "A Survey of the 'State of the Art' 1969", *Specifier*, August 1969.

Roderick G. Robbie (of Robbie, Vaughan & Williams, Toronto), "Systems Building and Architecture", a paper presented to the American Institute of Architects, Houston, Texas, 11 August 1969.

Standards Canada, Vol. 2, No. 2, March-April 1971. (Published by the Canadian Standards Association, Toronto.)

S. A. Gitterman, "Industrialized Building", Central Mortgage and Housing Corporation, Ottawa, 1967.

†The growth of one of the Canadian companies active in the field, ATCO Industries Limited, has been described in Appendix G.

According to the Special Report in the *Engineering News-Record*:

"Industrialized or systems building had a spectacular beginning in Europe in 1851 with [the] construction of London's Crystal Palace. But the designer, Joseph Paxton, employed a method now commonly recognized as prefabrication. The 800 000 square foot structure, built in six months, used mass-produced parts installed in a structural frame of cast and wrought iron columns and girders bolted together at the site. . . . (p. 3)

Systems building in the United States got off to a shaky start over sixty years ago. Again, according to the *News-Record*:

"In 1910, a system consisting of large precast hollow-core concrete panels for floors, walls and roofs was developed by a U.S. architect, Grosvenor Atterbury. About 1915, backed by a philanthropic organization, the Russell Sage Foundation, several hundred dwelling units using the system were built in New York City's Borough of Queens. The panels were manufactured off-site, trucked to the job and there erected by derricks. The system proved uneconomic." (p. 1)

Reverting to the European story in the *News-Record*:

"It took two world wars to accelerate the evolution of industrialized building. England's post-World War I shortage of housing and skilled building labour was the prime motivation for development of more mechanized building methods. The country's first industrialized building system was introduced in 1919 by John Laing & Son Limited, of London. Known as "Easiform", and designed for housing of up to four stories, it is a cast-in-place concrete cavity wall system using factory-made steel forms. . . . John Laing Construction Ltd. still uses the system . . . but when the housing shortage was overcome by about 1926, systems languished and conventional building crowded out the fledgling." (p. 3)

The British Government applied the "systems concept" during World War II to the re-housing of bombed-out families. This program of building "Prefabs" was accelerated in the four years following the end of the War when 200 000 single-family flat-roofed houses, designed for easy handling and for a 10-year life, were erected.

Standards Canada in March-April 1971 noted:

"In Europe after the Second World War, governments were the driving force in introducing systems building. Reduced on-site construction time is now reported to vary from 17 to 50 per cent in Britain, to average 50 per cent in Russia where concrete box systems are common, 65 per cent in Denmark and 75 per cent in Czechoslovakia and Switzerland. Cost savings are not as remarkable. Early efforts often cost more than traditional building but small savings are reported with growing experience." (p. 1)

The building systems originating in Europe have proliferated at a great rate since 1950. In England, for example, there has been the development of the "Clasp" system of school construction. In Denmark there has been the Jespersen system; in France, the Coignet, the Spectra and the Tracoba No. 4; in Sweden, the Skarne S66; and in Holland, the

Bejlmereer. The Special Report in *Engineering News-Report* estimated that, in England alone, there were around 300 different systems available for use in 1969. However, on 16 May 1968, high-rise systems building in England suffered a setback with the partial collapse of a 24-storey apartment building at Ronan Point. In connection with this event, *News-Report* commented:

“The disaster . . . greatly accelerated a trend that had started previously, a move away from high-rise apartments to low-rise. This trend has sociological roots, based on the belief that high-rise buildings for families with children result in family stress. . . . It has not, however, cooled official enthusiasm for further refinement and use of systems building in low-rise building.” (p. 4)

Commenting on the contemporary situation in the United States in 1969, the *Engineering News-Record* said:

“Systems building has taken about 20 years to gain a foothold in this country. The U.S., envied by many nations for its ability to spew goods from automated assembly lines, a nation that made computerized planning and production scheduling an everyday management tool, only now fully realizes that buildings can be factory-produced.

“Corporations of many types are looking closely at the present piecemeal process of building. They are intrigued by the profit that could accrue to a company that successfully reduces the number of a building’s pieces and puts together under one corporate roof the functions performed by the many professional, mercantile and labor entities that now make up the building industry.

“With the exception of mobile homes, a variation of the box system, buildings cannot be produced by a factory like refrigerators or autos. But Europe has shown that a building’s components and subsystems can be prefabricated in massive quantities in a factory on or off the building site, delivered to where the building will rise and there assembled with machinery on a time schedule established weeks or months in advance.” (p. 1)

The first Canadian attempts at systems building were made in the late 1950s and early 1960s. In 1964, in the education field, a consulting firm in Montreal, Institut de Recherches et Normalisation Économique et Science Inc. (IRNES), started the *Research in School Facilities* (RAS) study for the Montreal Catholic School Commission. In 1966 the Ontario Government and Metro Toronto School Board obtained a Ford Foundation-sponsored grant to get their *Study of Educational Facilities* (SEF) project under way. Both of these projects were patterned on California’s *School Construction Systems Development* (SCSD).

The first “highly visible” example of Canadian systems building was at Expo ’67. The spectacular, but costly, *Habitat* was manufactured using a very sophisticated mechanized on-site building operation. Also, the Russian Pavilion at Expo was built using the VAR M3 system, which originated in Italy.

In Canada, systems building entered the medical education field with the construction of the Medical Health Centre at McMaster Uni-

versity in Hamilton. The Centre uses the Servo-System developed by the Toronto and Peterborough firm of architects, Craig, Zeidler and Strong. Private housing developers have also recognized the potential of systems building and a number of contractors have entered this field as licencees of European systems. The federal Department of Industry, Trade and Commerce has put its considerable weight behind the use of systems building because the building construction sector of the industry is fragmented and because the climate makes in-plant component construction particularly suitable when combined with the ability to quickly close a building under construction. A major goal of the Department's BEAM Program* is the encouragement of systems building in Canada.

In the single family dwelling field, the recent growth in the activities of the membership of the Canadian Home Manufacturers' Association has been one indication of the seriousness with which systems building is now being regarded throughout the building construction sector as a whole. Another has been the establishment by the Canadian Standards Association of an Advisory Committee on Systems Building. But the arguments that still go back and forth between the supporters and detractors of systems building revolve around the cost of systems in relation to the cost of conventional building for a similar product.

*This program has been discussed in Chapter VI and in Appendix D.

Publications of the Science Council of Canada

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- Third Annual Report, 1968-69 (SS1-1969)**
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- Seventh Annual Report, 1972-73 (SS1-1973)**
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