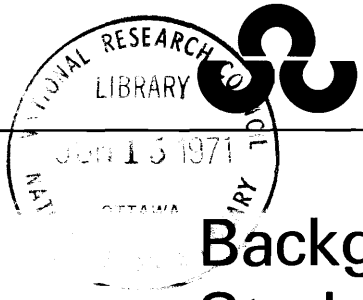

Background Study for the Science Council of Canada

May 1971 Special Study No.17

A Survey of Canadian Activity in Transportation R & D

By C.B. Lewis

A Survey of Canadian Activity in Transportation R & D

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Foreword

In August 1967 the Science Secretariat, on behalf of the Science Council, commenced a study to determine the most effective contributions that science and technology could make in developing transportation systems suited to Canadian requirements between now and the end of the twentieth century and how national resources for research and development could best be harnessed to that development. The first phase of this work was to be a survey of transportation research and development activities in Canada.

A Study Group under Mr. C. Beaumont Lewis tackled this initial task. The group encountered a number of difficulties and finally a report in three volumes was completed and presented to the Science Council in December 1968. This was largely the work of Mr. Lewis personally. This report is entitled *A Survey of Canadian Activity in Transportation Research and Development* and is in three volumes.

Volume I: Summary Report
Volume II: Survey Results by Sectors
Volume III: Appendices

The present publication is the above Volume I. It summarizes the results of this survey and comments on the state of transportation R & D in Canada as of late 1968.

The remaining volumes will not be published but are in the archives of the Science Council of Canada and are accessible to anyone wishing to consult them.

As is the case for all other publications in this series, it is the work of the author and his colleagues and does not necessarily represent the opinions of the Science Council of Canada.

The Council has examined the field of transportation as potentially having the character of a major program (see Science Council of Canada Report No. 4, Section 6) and has reported on this investigation separately (see Science Council of Canada Report No. 11).

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

Table of Contents

Volume I

Summary Report

A survey of Canadian activity in transportation research and development was undertaken by the Science Secretariat of the Privy Council Office at the request of the Science Council of Canada. It has attempted to catalogue as completely as possible those research and development (R & D) activities across Canada which are concerned directly with transportation or which have a significant transportation content. It attempts to relate this activity to the importance of transportation to Canada in such a way as to enable the reader to arrive at his own conclusions concerning the adequacy and relevance of present effort in relation to the present and future needs of Canada.

Since only about 20 man-months of professional effort have been devoted to this somewhat ambitious task, the Study Group cannot claim to have done more than scratch the surface of its subject. Thus any views expressed must be regarded as tentative, often subjective, and occasionally presumptuous, since the author lays no claim to expertise in all of the many disciplines involved in transportation research.

It seemed logical to attempt a working definition of transportation research and development before commencing the survey. It was recognized that we were dealing with R & D which is essentially mission-oriented, and thus much research of a "basic", or "curiosity-directed", nature was excluded, even though it might very conceivably find applications in transportation.

Since engineering is the purposeful application of scientific knowledge towards the satisfaction of human needs, almost all engineering research must be regarded as applied research. Engineering research was excluded from the survey unless it had direct and obvious applications which were mainly or exclusively in the realm of transportation. Thus, for example, research on ball bearings or the mechanisms of lubrication was excluded whereas research on gas turbine powered locomotives was included.

At the other end of the scale, it was often difficult to decide whether certain studies could be classified as transportation research or development. For example, urban traffic studies were included in the survey, even though they used standard techniques for data collection and analysis, on the grounds that they contributed to our knowledge of a particular transportation situation and would, hopefully, be used to improve that situation. On the other hand, the routine accumulation of transport statistics was excluded from the survey.

In borderline cases, classification has erred in the direction of inclusions rather than exclusions.

This study has proceeded on the basis of the following definitions.

Transportation is all movement of people and things for social or economic purposes which involves the use of machines or equipment. Thus walking and the moving of goods by hand are excluded except where these actions are essential to an interchange process and are thus an integral part of the progress from origin to destination.

For the purposes of this study, in-plant, in-house or on-site transportation of people and things (e.g. conveyor and feed systems, elevators, earth-moving, and waste disposal systems) have been excluded from the definition.

Research and Development includes all activities by governments, universities, consultants and industry which are concerned with increasing our knowledge of transport systems as they are today, what has caused them to be that way, and what might be done to improve them in the future.

Modus Operandi

The survey was divided into the following sectors:

1. universities
2. consulting industry
3. manufacturing industry
4. operating industry
5. government.

There is, of course, some overlapping between these sectors. For example, much of the extramural work of government at the provincial and municipal levels is done by consultants, and a significant part of the R & D undertaken by the equipment manufacturing industry is funded by the federal government. Every effort was made to cross-check the returns to avoid duplication of reporting.

Survey techniques ranged from formal questionnaires, through simple letter questionnaires and personal interviews, to telephone inquiries.

For a number of reasons, it was not possible to make the survey as comprehensive and complete as was hoped at the onset. One obvious reason was the need to preserve commercial security and to respect other sensitivities. This precluded the detailed listing of projects in some cases, or divulging details of R & D expenditures by individual companies or agencies. In industries such as the rail and air transport industries, where one or two companies dominate, these problems are particularly acute and this factor, coupled with the shortage of time and effort available to the Study Group, led to a decision to omit these important sectors altogether. In the case of provincial and municipal governments, the response to our questionnaires was extremely slow and incomplete in many cases and the data collected could not be presented in any reasonably coherent form. Some idea of the type of work sponsored by these sectors may be gleaned from the survey of transportation consultants (Volume II, Part 2) and the in-house R & D effort is, in most cases, not very significant.

Form of the Report

This volume attempts to present a summary of the collated results of the survey, together with such conclusions as can be drawn from them.

Volume II of the report contains the detailed results of the survey arranged in parts corresponding to each sector referred to in the "Modus Operandi" above.

Volume III of the report contains appendices related to each part of Volume II, such as copies of questionnaires issued, lists of organizations and people interviewed, etc., and also appendices containing background material referred to in Volumes I and II.

This format is intended to facilitate access to the particular sector or sectors of particular interest to the reader and in the depth desired.

Canadian Expenditures on Transportation

It is estimated that Canada is currently spending about $10 billion a year on transportation. This figure represents direct expenditures on transportation by the public, private and corporate sectors, and does not include all manner of indirect expenditures on transportation. Thus, it excludes all transportation of people and goods on construction sites, in mines and factories, etc. It excludes costs of packaging associated with transportation, the policing of our highways, the removal of our garbage, and such other items as might be included under a more general definition of transportation than has been used in this study.

If such expenditures were included, it is likely that our total spending on transportation would amount to almost 20 per cent of Canada's Gross National Product.

About one-quarter of this direct expenditure is from the public purse, about one-quarter from corporate coffers, and about one-half from private pockets. About two-thirds of all direct expenditures are on automotive transport, less than one-fifth on rail transport, about one-fiftieth on pipeline, and the remainder is divided about equally between air transport and water transport. (See Figure 1 for a more precise estimate of the above distributions.)

As a nation we spend more on transportation than we do on food. The private

automobile accounts for almost one-half of this expenditure.

The above is a brief sketch of the background against which we attempted to assess the efforts currently being made in transportation research and development in Canada.

Canadian Expenditures on Transportation R & D

Any precise estimate of nation-wide expenditures on transportation research and development is almost impossible to obtain. Even where data are available, there seems to be a fairly wide variance in the definitions used for research and development.

The following items represent a rough estimate of the current expenditures (i.e. excluding capital expenditures) on transportation R & D by the various sectors considered in this survey.

On the basis of the Dominion Bureau of Statistics (DBS) 1966-67 forecast of federal government expenditures on R & D, and allowing for the fact that meteorological R & D is included by DBS under transportation and that the expenditure of the National Research Council on transportation research might be somewhat underestimated, it is still unlikely that the total federal government expenditure exceeds $5 million for the current year.

Provincial and municipal governments across Canada are estimated to be spending currently about $5 million per annum on transportation R & D, including work done for them by consultants and universities.

The Canadian transportation equipment industry is currently spending about $25 million on transportation R & D, and the aircraft sector at least, has received substantial assistance from federal government sources.

The data for R & D expenditures by the transportation operating industry were far from complete. However, the upper limit is probably in the neighbourhood of $5 or $6 million, even using the most elastic definition of research and development. Of this total, Canadian Pacific Railways, Canadian National Railways and Air Canada spend by far the largest part; the trucking industries probably spend something less than $400 000 per annum, and the shipping industry even less.

The present contribution of Canadian universities to the sum total of transportation R & D is very small indeed, nor are they training researchers for this field in numbers sufficient for the coming years. Including the universities with other sectors, such as research foundations, major shippers, and the various trade and other associations concerned with transportation, this group probably spends less than $500 000 per annum on transportation research and development.

It follows from the above rough estimates that the total current expenditures on transportation R & D in Canada are about $40 million per annum, and that considerably more than half of this is spent on R & D concerned with transport equipment rather than on economic research, systems analysis or the development of new concepts.

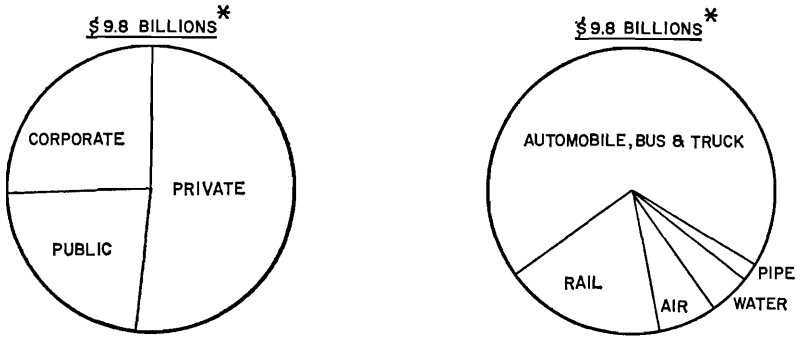
Capital expenditures on transportation R & D have, in general, been insignificant. One exception here is perhaps the aircraft industry. The National Research Council has, in the past decade, spent about $7 million on its wind tunnel equipment which is used both in aircraft development and in the National Aeronautical Establishment's research programs.

As a nation, our spending on transportation R & D is thus somewhat less than 0.5 per cent of our total spending on transportation, and the federal government's contribution to R & D is less than 0.05 per cent of the nation's total transportation expenditures.

Some interesting comparisons arise from perusal of the DBS statistics on current expenditures on R & D by the federal government.

In 1966-67, only 1.2 per cent of the total current expenditures on R & D were in the area of transportation. The only area receiving a lower amount of R & D funds was "construction", with 1.1 per

Figure 1–Direct Expenditures on Transportation in Canada



(A) DISTRIBUTION BY SECTOR

(B) DISTRIBUTION BY MODE

* ESTIMATE FOR 1968

cent. "Military science" received 32.6 per cent, and "agriculture, fishing and forestry" received 20.7 per cent of the total.

In the agricultural, fishing and forestry industries of Canada, which have a total dollar product roughly equal to or less than our national expenditure on transportation, the federal government is currently spending more than $70 million (about 0.9 per cent of total product) on research and development. The provincial governments also make significant contributions to research in these fields.

Our defence spending is about $1.6 billion per annum and the federal government spends more than $90 million per annum (about 0.6 per cent of total spending) on R & D in military science.

Such comparisons may be invidious, or even unfair, but nevertheless, they are interesting.

Professional Manpower Available for Transportation R & D

The survey revealed an impressive number of professionals who are reported to have some experience in transportation R & D projects. However, when this number is divided into the somewhat optimistic estimates given in the previous section for our total expenditures on transportation R & D, it is obvious that this number of professionals is not currently employed full-time on transportation R & D activity.

The survey of 46 Canadian universities revealed a total of only 40 faculty members who described themselves as transportation specialists. Their experience in transportation teaching and (or) research ranged from 2 to 35 years, and most have doctoral degrees.

Among the 62 consulting companies who responded to the survey, a total of 273 professionals were reported to be, or to have been, active in transportation research projects. Their median experience was over 10 years, and about a quarter of them have higher degrees.

The survey of the transportation equipment industry revealed a total of 458 professional personnel who are reported to have had some experience in R & D projects. About 75 per cent of these have bachelors degrees, and about 12 per cent have higher degrees. The number reported constitutes a surprisingly high percentage of the total professional staff of these companies, and it seems unlikely that very many of them are employed in a full-time capacity on R & D activities.

In the course of the federal government survey, we found a total of about 260 professionals who are active in transportation research and development, though not all of these would be employed exclusively in such duties. About 100 of these were in the Department of Transport, or in other agencies reporting to the Minister of Transport, about 100 in the National Research Council, and the rest in a number of other government departments and agencies.

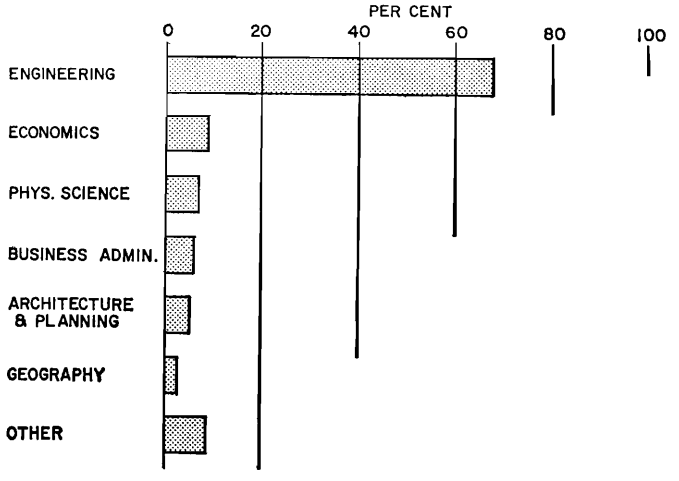
Incomplete returns from provincial and municipal governments indicate that there might be a total of about 100 professionals employed in transportation R & D, including planning activities and the monitoring of extramural R & D.

In the transportation operating industry, a total of about 100 professionals is believed to be engaged on a full or part-time basis in transportation R & D activities.

Thus it is estimated that there is a total of at least 1 000 professionals in Canada who have experience in transportation research and development. This number is not particularly impressive when one notes that the federal government alone employs about 5 000 professionals in research capacities, with almost 1 000 of these in the Department of Agriculture alone.

Most of the professionals engaged in transportation R & D are engineers. The distribution of the sample by discipline, as indicated by last degrees, is shown in Figure 2. This indicates that the engineers outnumber the economists by a factor of 8. However, it is probable that a number of the engineers are in fact working as transportation economists.

Figure 2–Distribution by Disciplines of Professionals with Experience in Transportation Research and Development



Distribution of Transportation R & D Effort

Within the federal government, the problems of the air transport and aircraft manufacturing industries are dealt with by more than 40 per cent of the total number of professionals engaged in transportation R & D; the problems of water transport about 30 per cent; and the problems of rail transport less than 10 per cent. Only about seven professionals (about 3 per cent) are concerned with the problems of automotive transport, and the remainder are engaged in research which is not easily attributed to one mode or another.

The provincial and municipal governments are concerned mainly with highway and urban transport, although the development of integrated regional transportation systems, and of those transportation facilities which are vital to the economic development of the provinces, has been receiving increasing attention in recent years. Ontario has been active in developing improved mass-transit systems for the Toronto area, and Alberta has done pioneering research on commodity pipelines.

Urban transport studies seem to have been the mainstay of the transportation consulting industry in recent years, and about 40 per cent of its income has been attributable to these. Various highway projects have ranked second among domestic projects, with major effort being devoted to studies of improved terminal facilities for both water and air transport during recent years.

Among the transportation equipment manufacturing industries, the aircraft industry has done about 90 per cent of the total research and development reported in this sector. The automotive industry, which produces more than $3 billion of vehicles, parts and accessories each year, does virtually no research and development in Canada.

In the university sector, about 25 per cent of the research projects reported were concerned with urban transport problems. An almost equal number of projects were concerned with multimode regional transport problems. More detailed comments on university research are contained in Volume II, Part I, Section 7.

In the transportation operating industry, about one-third of the R & D funds are devoted to improved equipment, and about one-third to operations research. The remainder is spent on economic analysis of intermodal competition, modal integration, rates and tariffs, possible new equipment, accounting systems, inventory control, etc.

There is very little research on labour problems.

The trucking industry makes substantial use of outside consultants, the airlines somewhat less use of consultants, and the railways very little use of consultants or universities. The reason may be that our two major railways both have sizable in-house research staffs. Only about 5 per cent of transportation consultants' business in recent years has come from the transport industry.

The Status of Transportation Research in Canada

Many years ago, a Canadian university professor stated that "Canada is a problem in transportation." This may contain some element of dramatic overstatement, but no one with a knowledge of Canadian history can take serious issue with this statement. That it is still true today is obvious from even a casual glance at the maps in Figure 3, which compare populations and distances in Canada's most populated and heavily industrialized region with those in some other industrial nations.

In spite of the widely recognized importance of transportation to Canada, as shown by our enormous expenditures in moving people and goods, transportation remains a sadly neglected area for research and development. We have all too few people qualified to work in this area, and some of the best brains among them

Figure 3a–United States: Major Population Centres in Northeast Corridor

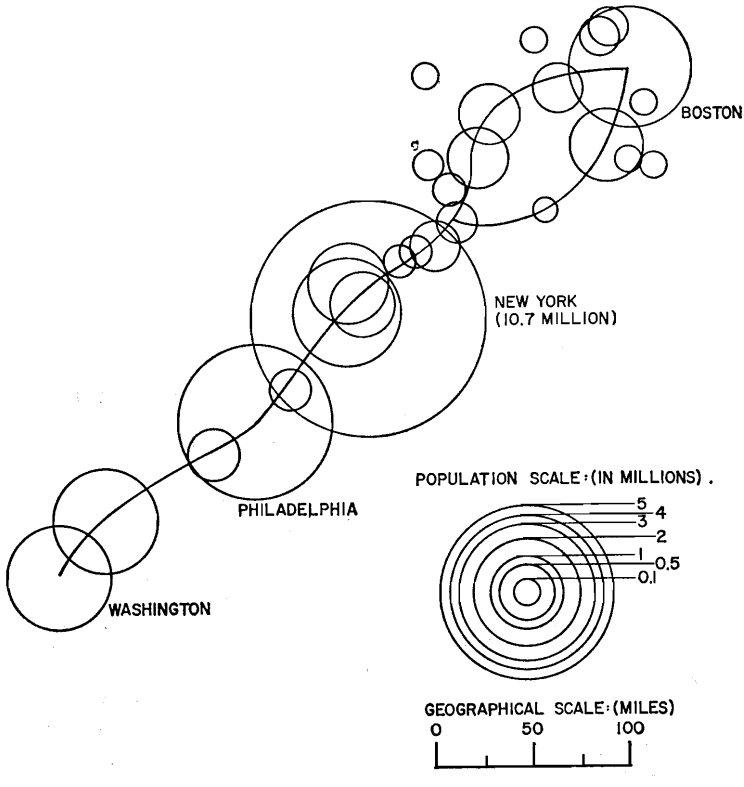


Figure 3b–England: Major Population Centres in Central Conurbation; and Japan: Major Population Centres along J.N.R. Tokaido Line

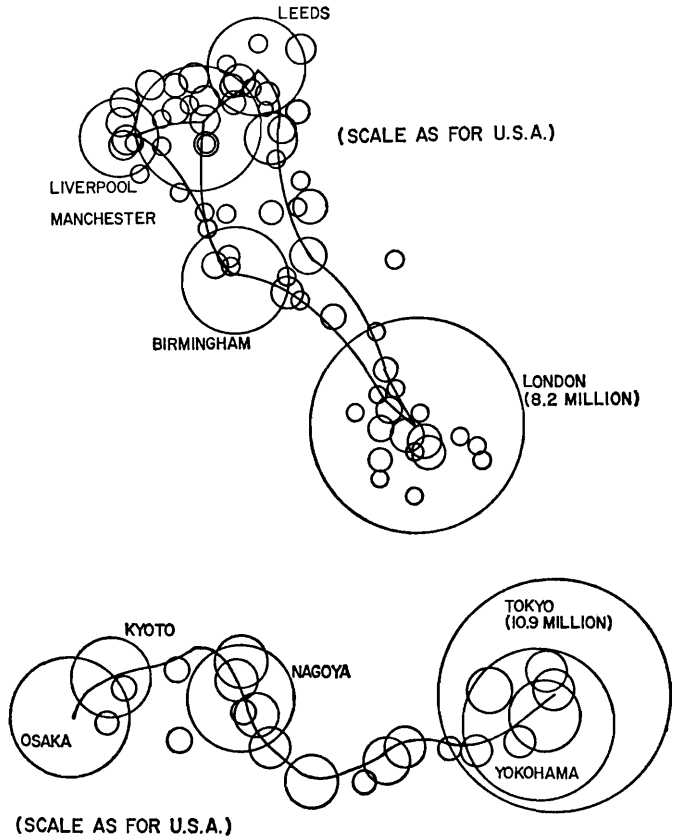
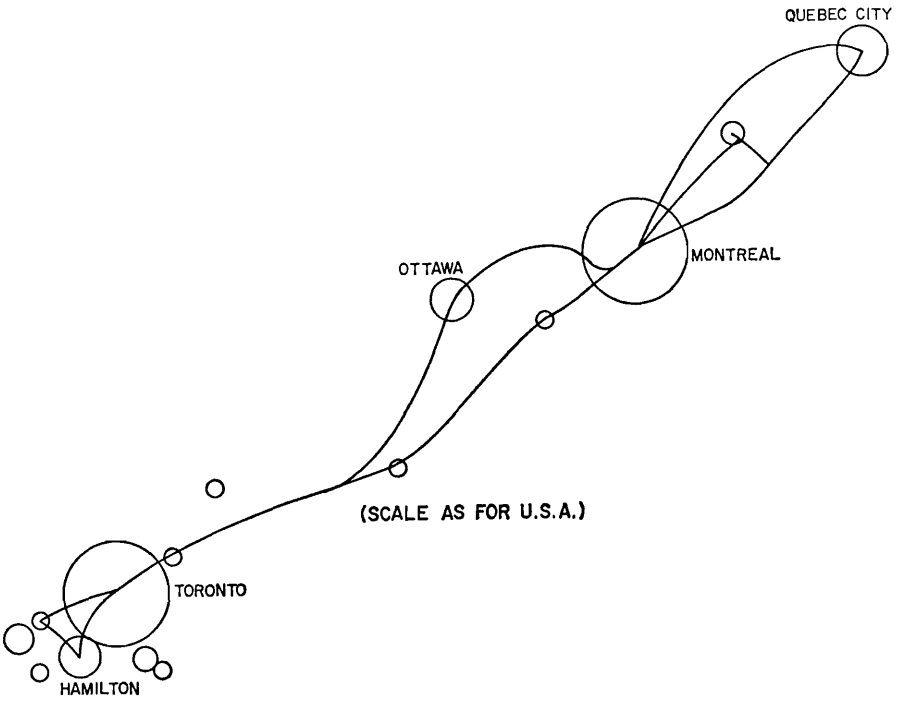


Figure 3c–Canada: Major Population Centres along (embryo) Southeast Corridor



are devoting their energies to the transportation problems to other countries.

The importance of transportation to the nation can be considered in political, economic and social terms. Only in the economic sector can its significance be measured at all quantitatively, and even here this is sometimes a most difficult exercise. Thus in attempting to assess the importance to the nation of a particular activity or group of activities, such as transportation, we tend to make the best possible assessment of the economic importance and then to make intuitive and comparative judgements regarding the importance of the political and social components of the activities concerned.

It can be misleading, and even wrong, to attempt to apportion R & D effort to the various fields of activity according to their economic importance at the national level. However, other techniques employed to assign R & D effort are often even less rational and this does at least provide some rough guidance in assigning R & D priorities and apportioning available effort.

In Canada, our current (i.e. non-capital) expenditures on R & D amount to something over 80 per cent of the total. Current expenditures in recent years on research and development have been equivalent to about 1.3 per cent of the Gross National Product. Many prominent and well-informed Canadians consider this fraction to be quite inadequate for our future well-being.

Only about 7 per cent of this current expenditure on R & D is the transportation sector, and by far the largest part of this is devoted to hardware development. Thus only 7 per cent of R & D funds are assigned to a sector on which we spend a sum equivalent to almost 20 per cent of the Gross National Product. About one-eighth of the Canadian labour force is employed directly in the transportation manufacturing and operating industries, and almost all Canadians spend some part of each day on wheels or wings.

Thus by the oversimple economic criterion referred to above, it would seem that transportation is not getting anything like its fair share of our present R & D expenditures.

Before accepting this judgement, however, we should perhaps attempt to examine more closely the nature of transportation research and development.

At the beginning of this study, it seemed logical to attempt a working definition of this term before starting the survey. We were, however, unable to formulate any better definition than that given earlier.

Very broadly, there seem to be three major areas of transportation research and development, namely:

1. What might be described, in the classical and broadest use of the term, as operations research. This research is concerned with improving existing systems within the bounds of the current technology in use. This includes most economic analyses, demand studies, intermodal comparisons, regional and area studies, labour relations, cybernetics, etc. It is usually inward looking, and its time frame is the present and immediate future.

2. Research on new concepts, which might be economic or technological or both. This is usually forward looking, and attempts to reshape our transport systems in the light of anticipated demands, social and economic changes, and the likely availability of new technology. It combines social, economic and technological forecasting with the synthesis of new and better systems, and should also be concerned with the problems of transition from "now" to "then".

3. Hardware-oriented research and development, which seeks to produce better hardware (and also the necessary software) to enhance or effect the improvements suggested as the result of (1) and (2) above. This can range from the prosaic problems of "hot boxes" through automated control of trains, improved baggage-handling at airports and better container equipment, to the more glamorous technology of hover-trains, capsule pipelines and hypersonic transport.

In Canada at the present time, it would seem that most of our limited resources

are being applied in category (1) above and at the more prosaic end of the spectrum in (3) above. There is all too little effort being made in category (2) above.

With the very limited effort available we are understandably devoting much of our effort to the oiling of squeaking wheels and have little or no perspective of the future. Thus, instead of being prepared for it by adequate planning, advancing technology continues to thrust its surprises upon us and we are all too often forced to adopt *ad hoc* and make-shift solutions. Examples of this have been the introduction of trans-atlantic jet aircraft and large deep-draft bulk carriers; in the present we are confronted with the jumbo jets and with competition from container ports to the south; in the future we may have to adapt to a revolution in urban transport, to competing land-bridge operations and to the advent of hypersonic air transport.

Technology transfer, or the lack of it, poses one of our major problems. Much technology is ripe for exploitation, but various economic, institutional and mental barriers delay its application to operating systems. In the field of technology it is not enough to know what is going on elsewhere. Passive monitoring of technological developments may acquire information, but it is also important to ensure that the information is put to work. We shall require extensive background knowledge, and rare skills in analysis, creative synthesis and sound judgement, if technological advances are to be recognized as relevant to Canadian requirements and exploited imaginatively and realistically. Canadian applications may differ quite radically from the applications for which the new technology was originally developed.

To date, there has been little indication that the need for adequate planning, and the trained personnel this will require, is recognized at any action level. We have failed either to recognize or organize the talents that we already have in this regard, or to train adequate numbers of professional people in the disciplines and skills that will be required in the future. As the Vice-President's Committee on Canadian Transportation Studies, of York University, has recently stated:

"Despite the great size and importance of the Canadian transport sector, there is as yet no real national emphasis in transport teaching and research. The universities carry out modest, mutually uncoordinated programs which emphasize technical (e.g. highway engineering), or regional (e.g. grain) transport problems. Nowhere in Canada at present does internationally respectable systems-oriented transport teaching and research take place.

"There is a severe current shortage of top transport personnel. Government and industry leaders feel that, in addition, existing staff will have to be upgraded substantially in order to keep pace with a rapidly changing technology and environment."

Some evidence in support of this latter statement may be derived from the recent experience of the Canadian Transport Commission in attempting to recruit senior staff for what is to be the first truly systems-oriented approach to the research problems of Canadian transportation. From the numerous applications received for eleven senior positions, to date only four have been filled by Canadians. There was a chronic shortage of Canadian transport economists with suitable experience, whereas the difficulty in recruiting technical staff was by no means as acute. This seems to reflect the ratio of eight engineers to one economist referred to above.

Within Canadian universities, the survey found only 40 faculty members who claimed to be transportation specialists. These specialists spend an average of about 30 per cent of their professional time on research projects. About a quarter of this research time is devoted to outside consulting and advising. This research effort is almost entirely random in its choice of subjects and it is almost

totally uncoordinated. Only 9 per cent of the respondents reported any significant collaboration with other universities on research projects, and the majority described such co-operation as "infrequent" or "non-existent to date".

It is obvious that a proper balance must be struck between the research and teaching activities of transportation specialists, expecially in view of their present small numbers. There is obviously considerable interest in transportation studies within several Canadian universities, and there is little doubt that a rapid expansion in this field would occur in response to outside stimuli by way of financial assistance and intellectual encouragement. The membership of the Minister of Transport's recently formed Advisory Council on Transportation Research includes seven university faculty members who are prominent in transportation teaching and research. Thus, this Council could well become a vehicle by which an appreciation of real-world transportation problems could be transmitted to the universities, and for informal co-operation between them. However, there is probably a need for a more permanent intellectual home for transportation researchers, wherein both broader and more detailed exchanges between "town and gown" could be encouraged, and a more rapid transfer of the fruits of research and development to operating systems could be effected.

Transportation research and development within the federal government has been, to date, extremely fragmented, *ad hoc*, and almost totally uncoordinated.

Broadly speaking, the federal government has three areas of responsibility in this regard:

1. Research in support of its own transportation responsibilities and programs.

2. Research in support of the transportation manufacturing and operating industries.

3. Research towards the planning of the nation-wide transportation facilities which will be required in the longer term in furthering national goals.

Far too many government departments and agencies seem to embark on transportation R & D projects of their own without reference to the work of other departments or to the needs of the public at large.

The National Research Council has devoted considerable sums of money to research and development projects in the field of transportation, and often this has been done without any conscious attempt to provide a balanced service to Canadian operating and manufacturing industry. There seems to be a need for basic cost-benefit analyses to aid the formulation of policy in this regard. To an outside observer it must often appear that effort is allocated disproportionately to such items as the development of a crash position indicator or research on gas turbine locomotives, without due regard to the technology transfer problems.

Occasionally programs are started in the right subject for the wrong reasons, or with the wrong people, and are quickly terminated when no longer expedient or when an inadequate capability to undertake them is revealed. Examples of these are the program on automotive safety of the National Research Council and the vehicle, mobility laboratory of the Defence Research Board.

Research within the Department of Transport often appears to be unduly fragmented. Research cells are seattered throughout the various branches of the Air and Marine Services. Research on railways and highways was the responsibility of the Railways and Highways Branch, which has now been absorbed into the Policy and Research Branch. The responsibility for intermodal coordination of research activities presumably rests with the latter.

In the Canadian Transport Commission, each of the major modal committees has its own research staff, but "matrix management" is applied to some extent in that the Vice-President, Research, is responsible for their technical performance. He is also responsible for the work

of the Research Division, which will be responsible for "macro-research" under the terms of reference provided by the National Transportation Act. When fully staffed, this new Research Division could become the focal point for all transportation research activities within the federal government, and will probably play a most important role in the co-ordination of transportation research on a national scale.

There is some small activity in transportation research and development in at least twelve other government departments and agencies, including the Atlantic Development Board, the Department of Agriculture, the Dominion Bureau of Statistics, the Department of Energy, Mines and Resources, the Department of Indian Affairs and Northern Development, the Department of Industry, Trade and Commerce, the Economic Council of Canada, the External Aid Office, the National Harbours Board, the National Energy Board and the St. Lawrence Seaway Authority.

In the consulting industry, there exists a large pool of talent which could be more fully utilized in transportation research and development than it has been hitherto. However, this talent is distributed among some 40 or 50 companies, and the typical company has only about 6 professionals with experience in transportation. (See Volume II, Part 2, Section 5 for details.) Only two or three companies have large multidisciplinary teams of people who could be employed effectively in major transportation projects, although many other companies have a highly specialized expertise in the various aspects of transportation.

Work by consultants tends to be expensive, and is difficult to direct or monitor adequately unless very specific terms of reference and statements of work can be written. The latter is often extremely difficult in the case of research projects. The inherently competitive nature of the industry can also lead to difficulties. For example, the data acquisition process tends to be duplicated many times, and the exchange of information throughout the industry is inhibited.

In large sectors of the operating industry, we have a few competing but highly regulated companies who often share the same facilities and are increasingly modally integrated in their operations. Consequently, a fine balance must often be struck between competition and co-operation. The total spending of the Canadian industry on research and development is probably less than 0.2 per cent of its total revenues.

The Canadian transportation equipment manufacturing industry has some notable transportation "firsts" to its credit, such as the first diesel-electric locomotive, the first commercially feasible short take-off and landing (STOL) aircraft, the first small gas turbine power plant to find wide application, and the first surface-piercing fixed-foil ocean-going hydrofoil ship. It has had notable successes in developing new airborne equipment, and such Canadian "naturals" as off-road vehicles for the logging and exploration industries, over-snow vehicles and snow removal equipment.

On the other hand, it has developed little or no R & D capability in automotive engineering, shipbuilding, rapid transit or computers. It can be argued, of course, that these should be left to the big-league industrial nations since Canada cannot hope to compete effectively in these areas.

Towards a National Policy for Transportation R & D

National Goals and Research Planning

"It is presumptuous for scientists to try to formulate national goals since science is by no means the only important activity in the nation. But scientists have a duty to point out that most nations have neither explicit goals nor a mechanism for formulating them."
(Dr. O.M. Solandt, April, 1968)

Transportation is so much a part of Canadian life that it is indeed most diffi-

cult to formulate detailed policies for the development of our transportation systems, or for research oriented towards that end, in the absence of explicit national goals.

As we proceed beyond a minimal adequacy of our transport services, it will be increasingly important to obtain some national consensus on the priorities we should assign to transportation and other amenities such as education, welfare, health services, etc., which are competing for the tax dollar.

Econometrics is by now a fairly mature discipline and we have well-established techniques for optimizing physical systems, but we have only just started to think of means of quantifying, or even rating, our social valuations. We shall need to increase our efforts to systemize value judgements. The first step in this direction is surely to attempt a national scenario, leading to an explicit and detailed set of national goals, however iterative the process might be and however tentative the results.

In the meantime, there is much that can be done to develop policies in the area of transportation research which we can be fairly certain, albeit intuitively, will be in the direction of progress.

Certain planning objectives can be expected to maintain their relevance and validity in the foreseeable future and even beyond. Few will quarrel with the need for an "economic, efficient and adequate" transportation system, however elusive the definition of those terms within this context might prove to be. Our national wealth will continue to depend on the economic transportation of our resource materials and our manufactured goods to their markets. Our national well-being, on the other hand, will increasingly require criteria other than the purely economic to be applied to transportation planning. In the foreseeable future, for example, we may well have to modify our urban use of the automobile, or accept even less convenient access to our airports, if we wish to breathe acceptable air or to continue in "quiet enjoyment" of our homes.

In planning and implementing any major program of transportation research and development on a nationally coordinated scale, it will be necessary to establish realistic guidelines for determining which elements of the program should be undertaken by in-house government effort, which by universities, which by consultants and which by industry. Machinery will need to be established for data acquisition and the dissemination of information, for effective communication between the participants, and for adaptive control of the entire program.

In the foreseeable future there will be no shortage of research opportunities; there is, however, likely to be a very real shortage of research resources. The problem then is really one of selection of opportunities and allocation of effort. Criteria need to be developed for selecting and ranking research opportunities according to the effect that their successful pursuit is likely to have on the national well-being. The potential benefits to be derived from various alternative research programs must be weighed in relation to the relative tractability of the research problems, to the resources available and to the environmental constraints and impediments.

From such general assessments, policies can be formulated, and guidelines developed, which will help to ensure that resources are deployed in an effective and properly structured research program. This somewhat utopian plan will need to take into account the requirement that will always exist for a sizable fraction of research effort to be applied to *ad hoc* projects in an attempt to cope with the mistakes of the past and the surprises of the present.

The Role of the Universities

We should expect and encourage a major intellectual output from Canadian universities. This might range from contributions to economic and transportation

theory to the devising of new approaches to transportation planning and improved techniques for research.

Most important of all, perhaps, the universities should be encouraged to produce the trained researchers without whom any major program of research in this field will be impossible. If these are to become available in the numbers and of the quality which we believe will be required to raise our present efforts above the subminimal, we can hardly afford to let events follow the pattern of recent years.

From the results of our survey, two-thirds of the university respondents believed that some form of national transport institute was required. As may be seen from Volume II, Part 1, Sections 6.7 and 8.9, opinions as to the organization and functions of such institute(s) differed widely. Some faculty members believed that a single "centre of excellence" would attract experienced staff from other universities to the detriment of transportation teaching across the country. Others thought that a single centre might neglect regional transportation problems, and preferred a number of regional institutes, together with some central co-ordinating activity. On the other hand, some felt that only by establishing a strong central institution, and utilizing the best of the very limited talent available, could we hope to attract and to educate graduate students in anything like the numbers required.

Some embryo "centres of excellence" in transportation are already in existence on Canadian campuses. In most instances, however, their operations are currently subminimal, and none is likely to achieve an international reputation in transportation within the next decade unless the present level of support is greatly increased. Even if this were done, it is suggested that first priority at such regional centres should be given to the education of transportation researchers and managers, with next priority given to research on regional transportation problems. A central research institution, strategically located with respect to senior government, operating industry and manufacturing industry, could still play a vital role in undertaking impartial and full-time research on national transport problems, in stimulating and co-ordinating research activities by summer courses and seminars, in encouraging international co-operation in research, and in providing basic services for transportation research across Canada.

It is suggested that support of university teaching and research in transportation should be concentrated first on building a truly national, and eventually international, "centre of excellence", while at the same time encouraging an increasing activity at a small number of carefully selected regional centres.

Academic excellence in this or any other subject is not built up overnight, and any other approach is likely to dilute the quality of effort currently available to us in Canada to an unacceptable degree. Without a hub, there can be no centripetal action and we will not be able to attract either staff or students of the quality required.

It is frankly acknowledged that this proposal is likely to be unpopular in those universities already making a commendable contribution in this field. They may indeed suffer some dilution of staff initially, and lose some good potential students. However, more than two-thirds of the transportation teaching staff reported in the survey came from foreign universities, and it is unlikely that a fully fledged centre of excellence in transportation would be less successful in attracting talent from overseas, both to itself and to the regional universities. And the latter would be given the substantial and steadily increasing financial support which would permit them to employ additional staff.

Of those academics currently teaching transportation in Canadian universities, almost 60 per cent have no professional experience outside the universities. The median "outside" experience of the rest is less than six years. This, together with

some of the parochial attitudes and interests revealed, suggests that transportation teaching by Canadian universities would benefit greatly from a much greater exchange of appointments between universities, governments and operating industries. Such exchanges can be of great potential benefit to both parties in the exchange. The employees of federal and provincial governments and operating companies should be encouraged to lecture at their local universities whenever this is practical, for exposure to a student body can often have a salutary effect on professional attitudes and intellectual discipline. Similarly, faculty members should be encouraged to work within (and not just for) governments and industry during their summer months and sabbaticals. Probably all that is needed to effect this is better communication of opportunities coupled with more enlightened attitudes on the part of employers.

The Role of Industry

The Science Council of Canada in its Report No. 4, *Towards a National Science Policy for Canada*, has stated that "the largest proportion of the R & D part of a major program in transportation should be located in industry where it would be closest to the most direct and efficient mechanism of innovation. The producers of transportation hardware and the operators of transportation systems must be deeply committed to the realization of the aims of this major program."

Let us consider for a moment the possible role of industrial research and development in such a program. In the field of transportation, any major research program must be essentially keyed to long-term objectives, and its short- and medium-term objectives should be rational steps in the progression from "now" to "then". In contrast to this, most industrial research is essentially short-term in its objectives; long-term planning in industry usually means 5 to 10 years. Quite understandably, industry seeks the quickest possible return on its investment in R & D. Also, in general, it ceases to be concerned with the performance of its products once the warranty period has expired, except insofar as this performance might affect its reputation and, hence, its repeat orders.

In transportation, the process of technology transfer starts with the identification of a need, proceeds through research on alternative concepts, design synthesis, applied research, detail design, development, demonstration, production design, production, introduction, maintenance and repair, to an eventual decision regarding obsolescence of the system or subsystems. This process can take anywhere between 10 and 50 years to complete, the shorter period being typical of highway equipment and the longer period not unknown in railway equipment.

Optimization of this process, in terms of total benefits to total costs, might conceivably result in doubling the capital expenditures on new equipment to recover an even greater amount from reduced maintenance costs and increased utilization throughout the life of the equipment. This is a concept which is generally quite foreign to private industry, and one for which it cannot be expected to invest its own R & D funds. This somewhat fanciful illustration is merely intended to demonstrate that the optimization processes of the system operator and the equipment supplier can differ greatly because their objectives are quite different. It is also fairly obvious that what might appear optimal to the transport system operator may not prove to be optimal for the user.

There must also be some doubt whether industry does in fact provide "the most direct and efficient mechanism of innovation." The record would have to be carefully examined to determine whether this is true even in the area of hardware research and development. The steam engine was not conceived by a contemporary industry, nor was the submarine, the airplane, the gas turbine engine, the nuclear power plant, or capsule pipe-

lining. Nor was the successful development of most of these achieved without massive technological and financial support from governments.

So far as non-hardware transportation R & D is concerned, Canadian manufacturing industry has very little capability, and the operating industry has, perhaps perforce, adopted unduly conservative attitudes in the past.

It is conceded that industry will have an important role to play in future transportation R & D, but its operations form only a part of the total process and will need to be financially stimulated and fully integrated into an overall program if the Canadian public is to get the "economic, efficient, and adequate" service that it probably deserves.

Government/Industry Co-operation

Federal government support of the R & D programs of Canadian transportation operating and manufacturing industries represents a sizable fraction of the total government expenditure on transportation R & D.

This support usually takes the form of either direct or indirect financial assistance to industry in performing its own R & D, or research undertaken by government laboratories to assist specific industrial research and development programs.

Examples of the former are transportation projects within the Department of Industry's Program for the Advancement of Industrial Technology, the Industrial Research and Development Incentives Act administered by the Department of Industry, the Industrial Research Assistance Program administered by the National Research Council, certain defence development projects in the transportation area which are supported by the Department of Defence Production, and certain defence research projects supported by the Defence Research Board.

Examples in the latter category are the research and development projects undertaken by the National Research Council in support of the transportation manufacturing industry, such as ship and airplane model testing, research on gas turbine powered locomotives, and research on fuels and lubricants for use in transportation. Most of this work is fully funded by the government, although charges are made for that work done on behalf of industry which is of a more routine nature and has little relevance to the research programs of the National Research Council. Occasionally, a project may be initiated by the National Research Council at the research stage and the subsequent development work may be undertaken by industry at its own expense. The weaning process can be a gradual one, with the National Research Council continuing to undertake supporting research at its own expense. The lack of clearly declared policy in such instances can lead to anomalous situations and dissatisfaction within industry.

With the exception of the Industrial Research and Development Incentives Act (IRDIA), financial assistance to industrial R & D projects is usually based on the merits of the project per se, without much consideration being given to its place in the wider context of government objectives on R & D. The government has no means at present of assisting industry in general studies of a specific area of technology aimed at identifying research and product development opportunities. Thus, any systems approach by industry to the development of improved transportation is largely excluded from government help. Nor is the government doing much research of this nature whereby Canadian industry could be guided in its decisions regarding entry into fields of new technology, or technology new to Canada.

There are many instances in which the government should be more active in pilot studies, and even in preliminary laboratory experiments designed to determine the feasibility of new concepts in transportation. These experiments could provide guidance to both government and industry in the future allocation of R & D resources.

The Role of the Federal Government

At the present time, intramural transportation research by the federal government is sadly lacking in cohesion, and there seems to be no structured approach to those transportation problems which are the concern of senior government. There is all too often an "on-again off-again" allocation of research effort in response to external pressures, as in the case of the recent programs in grain transportation and automotive safety. Virtually no machinery exists for the effective co-ordination of research activities by the numerous departments and agencies involved, and communication is inadequate even at the working levels within the same department.

No provision exists at the present for any continuing co-operation between the federal and provincial governments on transportation matters, or for periodic review of policies, plans and problems which might benefit from collaboration and co-ordination at the research level. Consultations do of course take place from time to time on specific proposals, projects and problems as they arise, and the Privy Council Office is responsible for arranging these.

If provincial, and even municipal, governments are to be full partners in planning improved national transportation systems, and if undue political pressures are to be counterbalanced by accurate information and a rational development plan for the nation's transportation services, it would seem that there is a need to examine the adequacy of the existing channels for communication and co-operation between governments on transportation matters in general, and research in particular.

In the view of the Science Council of Canada, "the role foreseen for the Federal Government is predominantly that of initiator, co-ordinator and provider of funds for much of the research and development, while the other sectors will be mainly performers of research and innovators." This is presumably intended to apply also to transportation research and development, since transportation is one of four areas selected by the Council for immediate planning.

It is hoped that the recently formed Research Division of the Canadian Transport Commission will fill an increasingly important need for a capability in "big picture" research to assist in policy development and for the co-ordination of transportation research activities throughout Canada. It will need to devote a continuing effort to the planning of research programs directed towards the implementation of national transportation policies, irrespective of whether the actual research is to be performed intramurally or by "the other sectors". It is the only existing agency of the federal government which is potentially capable of undertaking the tasks of any major program outlined earlier, and it has been given a clear mandate for this by the National Transportation Act.

Finally, the respective roles of the numerous other research groups involved in transportation within the federal government need to be more clearly defined if we are to avoid confusion and unnecessary duplication of effort.

International Co-operation

Transportation research, in the generally accepted sense of the term, is usually non-hardware "paper" research and hence comparatively cheap. However, the transfer of the fruits of this research into operating systems can be an extremely expensive process involving very large long-term capital investment.

For this reason, the preliminary stages of research, application study, system development and system demonstration on a pilot scale have to be extremely thorough in planning and execution to ensure economic viability and public acceptance.

If the technology transfer process in the field of transportation is not to be hopelessly prolonged because of the limited funds and effort available at the national level, the development and demonstration phases will, in many instances, have to be undertaken jointly

under bilateral or multilateral agreements between nations. This will require the closest international co-operation, even at the planning, research and development stages. Close and dynamic monitoring of foreign developments in transportation is probably essential if we are to avoid making expensive mistakes at home and are to accelerate the transfer process. We cannot afford technological chauvinism. What we fail to innovate, we must skillfully adapt.

There are already several examples of international co-operation in the development of improved transportation: the St. Lawrence Seaway, the Canadian National Railways turbo-train, the Concorde supersonic transport, etc. There seems to be little doubt that this trend will continue, for necessity is the mother of co-operation.

International co-operation is possible at many levels, ranging from "buying-in" to obtain information from research projects to contributing funds and manpower to joint development or demonstration projects.

Conclusions

This report has been confined mainly to the presentation of data on the current status of transportation research activity in Canada. It is believed that it has demonstrated the present inadequacy of this activity in relation to Canada's present and future needs.

Since this report represents the results of only some 20 man-months of professional effort, it cannot pretend to have done more than scratch the surface of its subject.

The work of this Study Group should therefore be regarded as a pilot effort only. It should be followed by a more comprehensive study in depth of the problems which beset transportation research in Canada and of the policies that need to be adopted if Canadian efforts in this field are to be more effective in the future.

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