Planning for Effective Technological Innovation: Recent Experience of Transport Canada

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ABSTRACT

A methodology for strategic planning of technological research and development (R&D) for transportation at the national level is presented. The methodology is based on recent Canadian experience with strategic planning in R&D. The methodology involves technology assessments, identification of issues, setting of R&D objectives, consultation with industry and provinces, and development of strategic options and strategy plans by sector. A successful application of the methodology to strategic planning of R&D for railroad transportation is outlined. The current application of the methodology to Canadian highway transportation is described with reference to achievements to date and future activities.

In this paper the strategic research and development (R&D) planning mechanism developed by Transport Canada for technological innovation is described, and two examples of its application are presented. The first example, rail freight, is a recent successful application of the methodology, and the second example, highway transportation, is currently in progress.

BACKGROUND

The department has designed its R&D efforts to support the attainment of transportation objectives, whether these be improved effectiveness of the department's ice-breaking services or related to the railways' concerns about improved productivity. This "demand-pull" orientation provides the justification for more than 85 percent of the department's R&D efforts. However, R&D programs also have to provide for the dynamism of technology. Flexibility must be provided in the department's R&D programs to accommodate longer term, higher risk efforts that cannot be justified solely on the basis of demand-pull. The department's support of exploratory research in such fields as materials technology, laser and fiber optics, combustion technology, magnetic levitation, and fifth-generation computers are examples of initiatives in this area, sometimes known as "technology-push."

The bulk of the department's R&D resources are, however, dedicated to objectives in the following areas:

- Policy decision making: R&D can provide the essential knowledge base on which informed decisions can be made. An obvious example is rail electrification. Most recently, a program was supported that, although it has real application to moving coal from Tumbler Ridge to the British Columbia Railway's main line, is also designed to collect data on the feasibility and performance of rail electrification technology under Canadian conditions.
- Support of safety regulation: This essential function of government affects both transportation safety and costs. For example, technological performance standards that can be set for the safe transportation of dangerous goods need to be known. Furthermore, in the Arctic and off the East Coast, technological standards that are required to permit safe and economic transportation in these hostile marine environments need to be known.
- Government transportation services: The federal government operates or supports the operation of major elements of Canada's marine and air transportation infrastructure. The provinces build and operate roads, sometimes with federal support, and the provinces and municipalities provide urban transportation services. R&D activities are key elements of the efforts required to improve the efficiency of these services and, of course, are also a key element of strategies to develop specifications for medium-term and longer term equipment procurements.
- Support of industry: Part of the role of Transport Canada is to act as a clearinghouse for information on transportation technology trends and related R&D programs. In many areas, Transport Canada has mounted, and will continue to mount, cooperative R&D programs with the transport industry to meet common objectives.

The resources available to achieve overall transportation R&D objectives are not limited to departmental or even federal sources. An important goal is to maximize the effectiveness of departmental R&D expenditures by complementary expenditures by other federal departments and external R&D participants. The distribution of transportation R&D expenditures (1) in Canada is given in Table 1.

At the federal level, policy development and planning for transportation R&D are coordinated and guided interdepartmentally through a panel led by Transport Canada. At the program level, departmental R&D mandates are limited, although there is good coverage across the technology innovation cycle. The steps in this cycle are given in Table 2 with the R&D participants listed under each step.

Some interesting issues arise from these patterns of expenditures and participation:

- The federal government as a whole spends a considerable sum of money on transportation R&D, but

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TABLE 1 Distribution of Transportation R&D Expenditures (*1*)

	Funding Source			
Mode	Federal	Provincial	Industry	University
Air	38	0	243	0.7
Marine	41	0	5	0.5
Rail	4	1	10	0.7
Road	16	10	6	0.3
Other	5	0	1	1.3
Subtotal	105	11	265	3.5
Total	384			

Transport Canada spends only $26 million or one-quarter of federal expenditures. More than 95 percent of this amount is contracted out either to private industry or to university research centers.

• Transport Canada is but one actor in stimulating technological innovation. To be successful across all modes, it must rely extensively on the efforts of others. To do so, it must engage in a process designed to build consensus on R&D objectives and priorities and on appropriate strategies.

These considerations have led to development of a logical and consistent process for planning and programming R&D. This process is designed to permit technology innovation to make its contribution to broader transportation and other sectoral needs and opportunities. It is also designed to be flexible to cope with the dynamics of both the environment and the technologies themselves. It addresses the need for focused R&D planning and for concerted programming, the lack of which was clearly identified in the assessments of Canadian transportation R&D activities carried out in the 1970s.

PLANNING FRAMEWORK

What follows is a straight-line description of a logical approach designed to produce consensus on what R&D is required to address transportation needs for technology innovation and to produce a strategic plan for transportation R&D (2). There are two stages the first of which is to develop a quantitative assessment of the technology innovations required to address transportation needs. The product of this stage is a set of objectives for innovation.

The second stage is designed to establish strategies for implementation, jointly or separately by members of the transportation community, of R&D programs that will meet these innovation objectives. The objectives are further ranked by priority in relation to the impact that transportation R&D has on other sectors of the economy.

There follows a brief outline of the framework used to establish technology innovation objectives and priorities, which, in turn, are used to develop strategic R&D plans to achieve these objectives and priorities. The flow of logic of the two-stage process is shown in Figure 1.

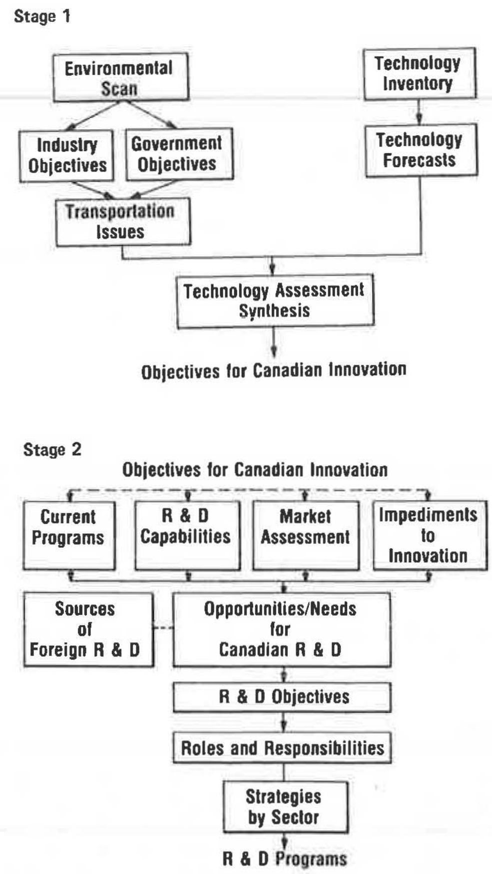

FIGURE 1 Transportation R&D strategic planning framework.

Stage 1

• To establish quantified targets for innovation in the short, medium, and long term: In analytical terms, this requires socioeconomic assessments of transportation systems to define the issues (for example, escalating highway maintenance costs) and the degree to which current technology constrains system safety and efficiency. In parallel, technology forecasts are developed to establish the improvements that can be achieved by innovation in vehicles, ways,

TABLE 2 Technology Innovation Cycle

Basic Research	Applied Research	Product Development	Demonstration	Deployment
National Research Council Universities	Transport Canada Carriers Provinces Other Federal Energy, mines, and resources Environment Fisheries Oceans U.S. and foreign (joint research)	Regional Industrial Expansion	Transport Canada Provinces	Transport Canada Provinces

and terminal technology and in related operating procedures.

Stage 2

• A review of existing R&D programs to define gaps and impediments to technology innovation: This review is extensive because it considers transportation R&D programs at all levels of government, in industry, and in the universities in Canada, the United States, and abroad. It requires assessment both of Canadian capability to work effectively in a particular field and of the degree to which such efforts can be justified, not only in transportation terms, but also in terms of the impact of R&D on objectives in related fields (such as energy, industrial and regional development, national defense, and environmental protection). This review results in the identification of strategic objectives for Canadian transportation R&D, which reflect both the need for technology innovation in a particular mode (or perhaps across modes) and the capability resident in Canada (or which could be developed in Canada) to meet the objectives.

• A review of the roles and responsibilities of federal and provincial governments, industry, and universities designed to define what part each of these could play in developing operational plans and programs to meet Canadian strategic transportation R&D objectives: This results in the identification of areas in which individual or joint R&D programs could be developed to meet the objectives.

This process, even in the simplified form described here, is time consuming. The pay-offs, however, in the rail freight case cited later in this paper, have proven to warrant the effort. It must be remembered that the process is designed to ensure not only that technology innovation needs are met but that they are achieved through integrated R&D planning and programming. Only in this way can success be achieved and the severe financial and human resource constraints that exist overcome.

RAIL FREIGHT R&D

In this section is outlined the application of the strategic planning approach to develop a rail freight R&D plan. This was one of seven areas of transportation R&D identified as high priority in a 1980 federal assessment. To leap forward to 1985, the results demonstrate how government and industry, through collective planning and individual and joint R&D programming, were able to maximize achievement of their R&D objectives through a commitment to work together (3). The results, aside from those directly related to transportation productivity and safety, have or will have significant impacts on such related concerns as energy and industrial development. It should also be noted that, although the initiative to develop this plan came from Transport Canada, its implementation and indeed its current shape would not have been possible without the efforts of all of the other participants.

Stage 1 Results

In 1981 the world economic outlook was still dominated by the energy crisis and slow economic growth. The railway industry in Canada was investing a minimal amount in R&D. There were concerns about medium- and long-term prospects for industrial growth based on a healthy and innovative rail sector. The strategic R&D objectives of the industry were

• To improve productivity and efficiency in order to recover profitability and

• To maintain and improve safety and reduce losses due to accidents.

The strategic R&D objectives of the government were

• To establish self-reliance in energy;

• To improve rail safety, in particular with respect to the transport of dangerous goods;

• To improve rail productivity and efficiency; and

• To reduce environmental impacts.

In 1981 four main rail freight sector issues, which provided targets for technological innovation, were defined:

1. Rail capacity: Rail investment in the 1980s was projected to be some $14 billion split almost equally between investments in locomotives and rolling stock and in infrastructure. In assessing this issue, it was found that capital investment economies could be attained by concentrating on the application of advanced technologies to improve the use of existing infrastructure as an alternative to traditional methods of expanding capacity, such as providing new sidings or double tracking. Among other things, this was the genesis of the Advanced Train Control R&D Program, which is currently being pursued jointly by the Railway Association of Canada and the American Association of Railroads.

2. Rail productivity: During the 1960s and the early 1970s the productivity of railway capital and labor increased annually at between 6.4 and 7.8 percent. During the remainder of the 1970s, and into the 1980s, this growth declined dramatically to between 0.7 and 2.0 percent annually. This resulted in an upward pressure on rail freight rates precisely at a time when increases in domestic inflation and the state of competitiveness of Canadian exports were emerging as major national issues.

3. Energy: Although to some extent the energy crisis appears to have abated, there remain continuing concerns about the price and availability of quality diesel fuel.

4. Safety: A time-series analysis of railway accidents shows that 31 percent resulted from track problems, 24 percent from employee mistakes, 18 percent from equipment failures, and the remainder from a combination of these or nonrailway concerns.

A sector profile was developed that identified the technologies relevant to railway system development. This consisted of an inventory of rail technologies with measures of their current effectiveness and forecasts of future technological developments.

The technological assessment process established five main thrust areas for innovation in rail freight: motive power, freight cars, intermodal systems, infrastructure and maintenance, and communication control and automation. This assessment was based on consideration of all possibilities for innovation not just those that might be developed in Canada. Within each thrust area, individual projects were assessed and rank ordered.

The relationship, in general terms, that was established between the top-down assessments of issues and the bottom-up forecasts of the ability of technology to resolve these issues is given in Table 3.

Stage 2 Results

In this section are summarized the main factors that led to the definition of a rail freight R&D program strategy.

TABLE 3 Relationship Between Assessments of Issues and Forecasts of Ability to Resolve Them

	Rail System Issues			
	Capacity	Productivity	Energy	Safety
Motive power				
Engine design	X	X	X	
Fuel alternatives			X	
Lower grade fuels		X	X	
Electrification	X	X	X	
Freight cars				
Materials	X		X	
Design	X	X	X	X
Smart cars		X	X	X
Track and train dynamics			X	X
Braking systems		X		X
Diagnostics				X
Displays				X
Hazardous commodities				X
Intermodal systems, infrastructure, and maintenance	X	X	X	
Equipment	X	X		
Procedures	X	X		
Roadbed	X	X		X
Wheel and rail wear	X	X	X	X
Grade crossings				X
Speed control			X	
Communication, control, and automation (location, routing, scheduling, and control)	X	X	X	

In 1981 federal and industry expenditures on rail freight R&D were on the order of $5.5 million annually. The objectives were technically feasible and desirable; the need was for new commitment to fill in the gaps and expand the total effort.

It was generally found that Canadian rail research facilities could potentially perform almost all of the required R&D. Subject to market opportunity and foreign competition, they might be expected to produce competitive products in a number of areas. The analysis also showed the need for development of certain new facilities. This supported the Canadian National Research Council's recent investment in a controlled-climate testing facility for railway rolling stock.

Arising from this were assessments of the ability of Canadian products both to serve domestic markets and replace imports and to potentially penetrate North American and other foreign markets. For example, it was estimated that, as an outcome of enriched rail freight R&D, exports of Canadian products could grow from $150 million in 1976 to more than $500 million by the mid to late 1980s.

At the outset of the planning process, it was apparent that governments and industry had differing perceptions of needs and opportunities and of what needed to be done to meet them. It was also apparent that the relationship of Canadian railways and Canadian equipment manufacturers had resulted in short-term and discontinuous production. Both of these factors were at odds with maintenance of a viable manufacturing industry, let alone maintenance of a long-term commitment to R&D by that industry.

In view of the continental nature of North American rail systems, needs and opportunities for joint research with U.S. railroads and the Federal Railroad Administration were also identified.

An assessment of the roles of each level of government, industry, and academia, and of the options open to the federal government in relation to attainment of the strategic R&D opportunities, is reflected in the strategy outlined hereafter.

Canadian Rail Freight R&D Strategy

In light of government-industry awareness of strategic objectives and priorities, the following strategy was developed and subsequently implemented:

- The railways would conduct R&D to satisfy their operating strategies, system requirements, and needs for equipment specifications;
- The supply industry would conduct the R&D required for hardware and production systems to meet domestic and foreign market opportunities; and
- The federal government would work to overcome impediments to technological innovation and to create an environment for a viable rail freight R&D program in Canada.

In concrete terms, the federal government also augmented its contribution to rail freight R&D programs from some $1 million annually to between $3 million and $4 million annually. Despite the recession, industry, principally the railways, also augmented its commitment to research and development, and, by 1983-1984, total rail R&D expenditures had quadrupled to more than $20 million annually.

Summary

Much has resulted since this strategy was approved in 1981 and augmented resources for federal rail freight R&D programs were provided. Where federal technical regulation is involved, such as in the transportation of dangerous goods, the required R&D is funded by the department and work is carried out cooperatively with industry; for example, tank car explosion suppression technologies. To meet federal policy objectives, the potential for rail electrification is being thoroughly explored under Canadian conditions.

Where industry objectives for productivity dominate, the required R&D has been carried out on a shared-cost basis. Collaborative projects between Transport Canada and industry have resulted in new designs for a train location, identification, and control system; an end-of-train monitoring system; steerable trucks; a rail-reprofiling technique; a single-cylinder test engine; and a transponder for use in automatic rail car identification systems.

The most notable outcome of the rail freight R&D program is perhaps the current efforts of the Canadian railways not just to maintain but to expand on their commitment to R&D. Rail freight technological innovation is both making the railways safer and more productive and achieving some spin-off benefits for other sectors of the economy that reflect the significant role played by the railways in Canada. Finally, a new, augmented federal rail freight R&D program is in the planning stage.

HIGHWAY TRANSPORTATION R&D

Currently, some $34 billion is expended annually in Canada on highway transportation. In contrast, the combined expenditures on air and rail transportation are some $12 billion annually. However, R&D expenditures in air and rail amount to some $310 million annually, while those by all levels of government and industry for highway R&D amount to only $29 million. Some of the reasons for this are the high percentage of imported vehicles in use in the highway mode; a perceived lack of alternatives to current methods of building, operating, and maintaining highways; and attitudinal barriers that arise from an absence of thinking about what technology should and could be doing to resolve highway transportation problems. Certainly, the low level of expenditures on highway transportation R&D compared with other modes does not in itself justify increasing the level to conform to that of other modes. It does, however, signal the need to assess in hard terms what could and should be done in highway transportation R&D as has, for example, been initiated in the United States.

The Highway Advisory Board Plan of 1981 identified nine thrust areas for national highway transportation R&D planning. At that time R&D planning was dominated by the continuing world energy crisis, the urgent need to improve productivity of transportation, rising expectations for improved safety, and shrinking resource allocations for research activities. These concerns were common to all North American highway transportation jurisdictions. Needs for R&D were identified in the following areas:

- Highway data base,
- Traffic mix,
- Heavy vehicles,
- Infrastructure,
- Energy,
- Data-gathering devices,
- Special cold weather requirements,
- Urban highway-related needs, and
- Intermodal needs.

Stage 1 Results

Since early 1984, an analysis of highway transportation similar to that of Stage 1 outlined in the planning framework has been in progress within the federal government (4). By adopting the perspective of "highway transportation," the analysis sought to develop a global assessment that would encompass both infrastructure and vehicle systems. The results of this federal initiative were discussed with provinces, industry, and universities. One substantial outcome of these discussions has been to raise awareness of opportunities and needs for highway transportation R&D and to set in motion planning activities as a prelude to action.

The strategic objectives of Transport Canada for highway transportation relate first of all to its responsibility for regulation of motor vehicle construction standards under the Motor Vehicle Safety Act. Second, the department supports the national goal of a productive and safe highway transportation system. Third, the department is involved in financial assistance for selected elements of the national highway system and in these cases has an interest in improving efficiency and effectiveness through R&D.

The strategic objectives of the provincial governments relate directly to improving the efficiency and effectiveness of their expenditures on highway construction and maintenance and to reducing losses due to accidents. The strategic objectives of the highway transportation industry are defined collectively by vehicle operators, shippers and users, and firms involved in construction and maintenance of the system. These objectives are related to maintaining an economically viable transportation system that continues to provide employment and return on invested capital.

A short list of the seven main issues that impinge on highway transportation includes

- Productivity improvements;
- Safety, including transport of dangerous goods;
- Accessibility for elderly and handicapped persons;
- Energy, including conservation and alternative fuels;
- Human resources, training and development;
- Industrial and economic development; and
- Environmental protection.

The candidates for innovation activity were assessed on the basis of the following criteria. At the outset, the major potential impacts in the areas of productivity, safety, and accessibility were weighted uniformly in assessing research priorities. The remaining criteria (i.e., energy, human resources, industrial and economic development, and environmental impacts) were also assigned equal weights within their own category. Further assessments were based on a sensitivity test that involved ranking the issues in the order in which they have been enumerated.

After this analysis was completed, priority innovation targets were identified in three thrust areas: vehicles and systems, infrastructure, and management. A summary of the priority thrust areas and their component subgroups is given in Table 4. Because the process of consultation is incomplete, these thrusts are subject to modification before final acceptance by the highway transportation R&D community.

Stage 2 Results

The strategic planning activities related to Stage 2 of the planning framework for highway transportation R&D are now in progress. The largest single highway-related R&D project currently under way in Canada is the heavy vehicle weights and dimensions project. This is a cooperative project of the federal government, the provinces, and industry. Preliminary results are due in mid-1986.

In addition, federal responsibilities for road

TABLE 4 Priority Thrust Areas

Vehicles and Systems	Infrastructure	Management
Freight safety (including transport of dangerous goods), productivity, and efficiency (including energy efficiency)	Pavement performance, rehabilitation, maintenance, cold climate pavement technology	Physical distribution efficiency
Passenger safety (automobile, light panel truck, other vehicles) and efficiency (including fuel economy)	Protection from weather and salts Maintenance system efficiency and effectiveness	Technology and information to support regulations and/or regulatory reforms
Highway bus safety, productivity, and access for elderly and handicapped persons	Efficient use of existing facilities	
	Safety and energy efficiency of infrastructure: design, maintenance, operation	Expert systems technology to improve skilled labor productivity
	Access for elderly and handicapped persons at terminals	Technology transfer

safety have resulted in the preliminary identification of federal R&D program needs. These include occupant restraint and crash assistance research, statistical and behavioral research in such areas as the magnitude and nature of impaired driving, safety enhancements that could be obtained from improvements to driver communication systems, and improved vehicle safety standards. R&D is also being proposed to provide operators with improved problem-sensing devices, to provide safer containers for hazardous goods, and to minimize the risk of spills when transporting dangerous goods.

The provincial highway and transportation departments have well-established R&D programs, particularly in the areas of pavement performance and structures. The provincial research laboratories, together with the federal Motor Vehicle Test Centre, the National Research Council laboratories, and industry-operated laboratories form an effective network both to facilitate the transfer of new technology to Canada and to develop solutions to unique Canadian problems.

An important influence on deliberations in Canada at this stage is the existence of a major highway research initiative in the United States. The American Association of State Highway and Transportation Officials is now in the process of developing a 5-year, $150 million R&D program entitled "Strategic Highway Research Program" (5). It is essential that any strategic R&D plans developed in Canada for highway transportation recognize the impact of this program. The program has identified the following six areas as having high payoffs:

- Asphaltic materials,
- Long-term pavement performance,
- Maintenance cost-effectiveness,
- Protection of concrete bridge components,
- Cement and concrete in highway pavements and structures, and
- Chemical control of snow and ice.

In each of these areas, a Canadian interest has been or can be defined. Although many of the issues faced by U.S. agencies are different, either in terms of the urgency for a solution or the nature of the problem, this U.S. effort, both in its definition of problem areas and in the proposed R&D solutions, provides guidance for targeting complementary Canadian efforts.

Roles and Responsibilities

It was realized early in the planning process that an appropriate national forum would be required for R&D program definition to proceed successfully. Recently such a forum came into existence with the merger of the Highway Advisory Board, mentioned earlier, and the Council on Cooperative Research of the Roads and Transportation Association of Canada. The outcome of this revised institutional framework is a Council on Highway Transportation Research and Development. This council combines the R&D policy advice function of the Highway Advisory Board and the R&D programming function of the Council on Cooperative Research. The organizations involved in the new council are shown in Figure 2.

Proposed Strategies

At present, a number of R&D program options are under active consideration. One proposal is to extend the vehicle weights and dimensions project. The Council on Highway Transportation R&D, which manages the current project, will develop a plan for further work in cooperation with Transport Canada.

Another proposal of the council is for the Roads and Transportation Association of Canada to develop a Canadian program complementary to the AASHTO Strategic Highway Research Program (6). This proposal, known as C-SHRP, would consist of three main thrusts:

- Integrated program elements in which Canadian agencies would be directly involved as integral elements of the U.S. program; for example, to contribute test sites to the long-range pavement performance evaluation program.
- Complementary Canadian research efforts in which Canadian R&D programs would be undertaken to cover problems complementary to but not being carried out under the U.S. program and unique Canadian problems.
- Monitoring SHRP to keep informed of what is happening in the program and to disseminate that information to appropriate agencies and individuals in Canada.

The effectiveness of a strategic planning process for R&D is measured by its success in achieving commitment to programs for action. By this measure, the

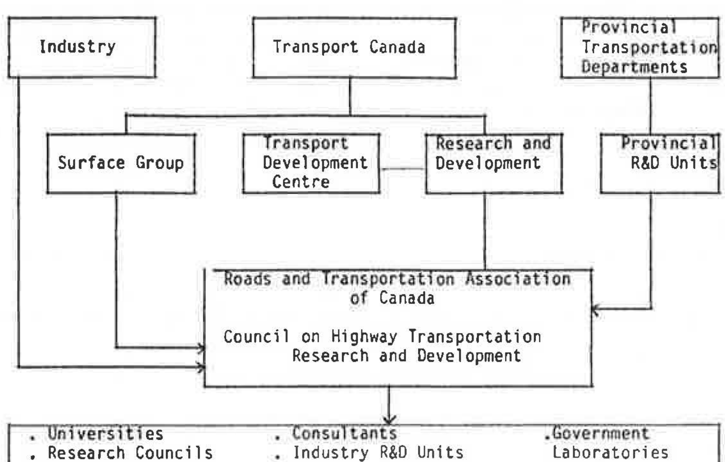

FIGURE 2 The national cooperative model.

strategic highway transportation R&D planning process pursued and supported by Transport Canada during the last 2 years is beginning to bear fruit. The department's role has been modest, but, through the catalytic action of its Highway Advisory Board, analysis of innovation needs, participation in institutional reform, and support for cooperative research with the United States, substantial and effective national highway transportation R&D plans are emerging to the collective credit of all concerned.

SUMMARY

Strategic planning for effective innovation in transportation is a lengthy and complicated task. When it has been completed the first time, subsequent rounds become easier, if only because the process builds a common understanding of problems and a common appreciation of how technology can be used to meet challenges. Its effectiveness, however, is only as good as the commitment those involved make to developing the plans, to committing resources to carry out R&D, and to following through to complete the innovation cycle. No one level of government, industry, or academia has the resources to carry out all of the required R&D or all of the steps of the innovation cycle. Success can be achieved provided that plans are flexible and modified to meet changing circumstances. If there is one lesson to be learned from the experience of the past 5 years in developing and implementing these plans, it is that no one has all the answers but that, by working together, the answers can be developed and R&D programs implemented to meet Canadian needs.

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